MASS TRANSFER CORRELATION FOR DECOLORIZATION STUDIES IN IMMOBILIZED PACKED BED BIOREACTOR

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Abstract: The present study deals with microbial decolorization of the textile dye methyl violet using the microorganism, *Phanerochaete chrysosporium* in a packed bed bioreactor. The microorganism employed in the study was immobilized in calcium alginate acting as solid support. Studies were done at various initial concentrations of the dye, feed flow rates, different bed heights and different bead sizes. The mass transfer coefficient for dye transfer from bulk phase to the surface of the biofilm on the solid particle was calculated. The mass transfer coefficient was found to be in the range of 1.13×10^{-6} to 1.41×10^{-6} cm/sec. There was an increase in mass transfer with the increase in initial concentration of the dye, feed flow rate whereas it decreased with immobilized beads size and high flow rate. A dimensionless correlation was developed for the mass transfer coefficient in terms of dimensionless numbers viz., Sherwood, Reynolds and Schmidt numbers.

Keywords: Decolorization, Methyl violet, packed bed reactor, mass transfer coefficient.

Introduction: Textile dyeing processes exhibit highly colored wastewater in large amounts, which are let into the natural water streams. Around 10,000 different types of dyes and pigments are produced and an average of 10- 15% of these dyes are let into wastewater stream [1]. Several work involving chemical, physico-chemical, membrane treatment and biological treatment are on its way to purify the wastewater [2]-[3]. In the biological treatment processes, organisms such as *Phanerochaete chrysosporium*, *Coriolus versicolor*, *Pseudomonas* species, *Aspergillus* Sp., are involved in decolorization [4].

The organism best studied for treating dyes is *P. chrysosporium,* since the enzymes present in this organism that are involved in the process of decolorization is highly non-specific in nature and are able to degrade a variety of dyes [5]. The objectives are to develop a model to predict the mass transfer coefficient of the dye from the liquid phase to the solid phase, to investigate the relationship between the mass transfer coefficients and the reaction conditions and to examine the effect of the microorganism on the biodegradability of the dye under various conditions.

Experimental

2.1 Microbial culture

The white rot fungus *P.chrysosporium* MTCC 787 was obtained from the Culture Collection of Institute of Microbial Technology, Chandigarh, India.

2.2. Kinetic model

Model development for the prediction of mass transfer coefficient

The transfer of substrate from bulk liquid to the surface of bioparticle and the diffusion through the microorganism layer (biofilm) is given by the equation:

$$Q\left(S_f - S_b\right) = a_m V_{eff} K_f \left(S_b - S_s\right)$$

Where V_{eff} is the effective volume of the reactor, and a_m is the surface area for the mass transfer.

3. Results and discussion

3.1 Effect of initial dye concentration

The concentration of the dye methyl violet was varied in the range 0.02 g/l (v/v) to 0.09 g/l (v/v) (Fig.1).

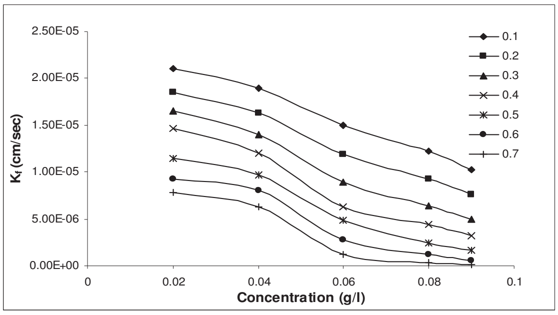

Fig.1. Effect of initial dye concentration on mass transfer Coefficient

As the concentration increased the percentage, decolorization lowered to a value of 57% from 99 %. The substrate diffusion mechanism involved in the substrate to the surface of the immobilized bead has been discussed at large [6]. Mass transfer coefficient decreased slightly at higher concentrations to that of lower concentrations (Fig 1). It seems to suggest that the mass transfer resistance is slightly prevalent at higher concentrations [7].

3.2 Effect on bed height

The dye concentration at the exiting stream was 99.5 % for a bed height of 10 cm and 50-71% for a bed height of 40 cm. When the concentration was increased from 10 to 40 % (v/v) of the original concentration of the dye, the decolorization percentage also increased with that of the bed height. There was no significant change in mass transfer coefficient due to the reason that mass transfer coefficients are not a function of bed height [8].

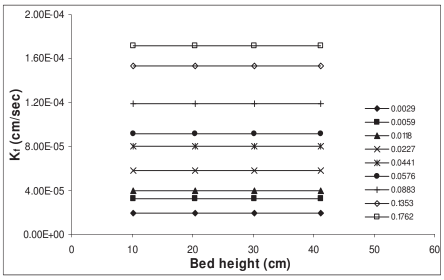

Fig.2. Effect of bed height on mass transfer coefficient

3.3. Effect on bead sizes

At an effluent mass flow rate of 0.0029 g cm^{-2} s^{-1}, various particle sizes (0.1, 0.2, 0.3, 0.4, 0.5, 0.6 and 0.7 cm) were used to investigate the effect of particle size. For a particle diameter of 0.1cm the percentage decolorization was observed to be 60% further as the particle diameter increased it was observed to be 46%.

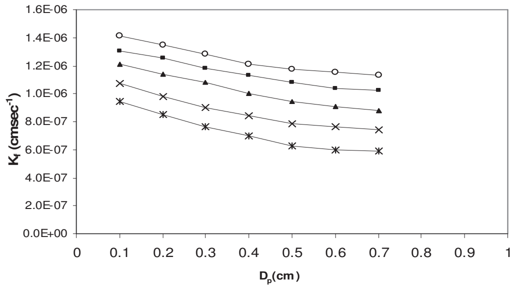

Fig.3 Effect of bead size on that of mass transfer coefficient

Studies on the mass transfer coefficient to that of the particle diameter were made (Fig. 3). It was observed a higher value of mass transfer coefficient at lower particle diameter and lower for higher particle diameter.

3.4. Mass Transfer Coefficient

The mass transfer coefficient K_f calculated using the equation 1 has been found to be in the range of 8.89 x10^{-6} to 1.72 x 10^{-4} cm/sec. The value of the Monod constant (1.462 x 10^{-3} g/l) for the microorganism is greater than the surface concentrations S_b, thereby justifying the assumption made in the modeling. Previous reports show that the biofilm thickness develops or increases with the length of the time and the biofilm development were based on the pore size [9]. Several correlations for mass transfer rates use the above equation but vary in the dependence of j_m on Re i.e.,

$$j_m = K * R_e^{-(1-n)}$$

It was found that as the flow rate increases, the Reynolds, Sherwood and the Biot number increases while Schmidt number decreases. The mass transfer coefficient was found to increase with the increase in the flow. The reason might be that there would be a reduction of the surface film, which is again proved by the biofilm results.

Conclusion : A new approach for determining the mass transfer coefficients was observed based on the characteristics of the immobilized cell beads. This was used to find out the kinetics of the reaction in a continuous mode. Biot number was calculated which gives the relationship between external and internal mass transfer diffusivities. It was found that there was a decrease in effectiveness with the increase in bead diameter concluding that the external mass transfer resistance is more significant in packed bed reactors involving immobilized beads. There was observed decrease in BOD and COD along with the reduction in color of the effluent taken in the present study.

References

[1] C.I.Pearce, J.R.Lioyd, J.T.Guthrie, The removal of color from textile wastewater using whole bacterial cell: a Review, Dyes Pigments. Vol.58, pp.179-196, 2003.

[2] N.Sangkil and G.T.Paul, Reduction of Azo dyes with Zero valent iron, Water Res.Vol.34, pp.1837-1845,2000.

[3] KV Radha, V Sridevi, K Kalaivani, M Raj,Electrochemical decolorization of the dye Acid orange 10, Desal. and water treatment, Vol.7, pp.1-3, 2009.

[4] J.S.Knapp, P.S. Newby and L.P. Reece, Decolorization of dyes by wood- rotting basidiomycete fungi, Enzyme Microb. Technol. Vol.17, pp.664 – 668, 1995.

[5] K.V.Radha, I. Regupathi, A.Arunagiri, T.Murugesan, Decolorization studies of synthetic dyes using *Phanerochaete chrysosporium* and their kinetics, Process Biochem. Vol.40, pp.3337-3345, 2005.

[6] Prachi koushik and Anushree Malik, Microbial decolorization of textile dyes through isolates obtained from contaminated sites, Jl of Scientific and Indl. Res. Vol.68, pp. 325-331, 2009.

[7] Asghar Mirzazadeh Ghanadi[a*], Amir Heydari Nasab[a], Dariush Bastani[b] & Ali Akbar Seife Kordi, The Effect of Nanoparticles on the Mass Transfer in Liquid–Liquid Extraction, Chem. Engg. Comm., Vol.202, issue 5, pp.600-605, 2015.

[8] Haribabu K and Sivasubramanian V, Determination of Mass Transfer Coefficient in an Inverse Fluidized Bed Reactor using Statistical and Dynamic Method for a Non-Newtonian Fluid, Jl. Sci. and Indl. Res. Vol.72, pp.485-490, 2013.

[9] J.C. Leyva-Diaz,A.Gonzalez-Martinez, J. Gonzalez Lopez, M.M.Munio, J.M. Poyatos, Kinetic modeling and microbiological study of two-step nitrification in a membrane bioreactor and hybrid moving bed biofilm reactor–membrane bioreactor for wastewater treatment, Chem.Engg.Jl., Vol.259,pp.692-702,2015.

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