International Journal of Chemical Sciences and Applications
ISSN 0976-2590, Online ISSN 2278 – 6015
Vol 3, Issue 2, 2012, pp 249-253
http://www.bipublication.com

STUDIES ON PHENOL BIODEGRADATION RATES IN WASTE WATER TREATMENT BY DRAFT TUBE FLUIDIZED BED BIOREACTOR

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[Received-13/04/2012, Accepted-17/05/2012]

ABSTRACT:

Biodegradation of phenol concentrated in bulk drug waste was performed experimentally using *Pseudomonas putida* immobilized on plastic beads in a draft tube Fluidized bed bioreactor (DTFBBR). Investigations have been carried out at different feed concentrations, feed and air flow rates. From the experimental data obtained, mass transfer coefficients of phenol (K_L) have been determined using conservation equations. The mass transfer coefficients for Phenol biodegradation in DTFBBR without recirculation were found to be in the range of 0.7063×10^{-6} to 1.7875×10^{-6} m/s. It was noticed that mass transfer coefficient was increasing with increase in feed flow rate, feed concentration and air flow rate. A model has also been developed for the biodegradation of phenol correlating its mass transfer coefficient with dimensionless numbers. The results obtained were compared with those available in literature and found to be reasonable.

Key words: Phenol biodegradation, *pseudomonas putida*, draft tube fluidized bed bioreactor, Mass transfer coefficient.

INTRODUCTION:

Most of the chemical and pharmaceutical industries generate highly toxic organic wastes such as phenol. Phenol is resistant to natural degradation and hence persists in environment. Phenol attributes carbolic odor to river water and can be toxic to living bodies and hence waste water treatment has become essential nowadays to meet the acceptable water quality standards. Physico-chemical methods of Phenol removal such as adsorption of industrial effluents by activated carbon leads to secondary effluent problems like disposal of activated carbon by incineration which generates harmful compounds viz., dioxins and furans [8]. Biodegradation of phenol in fluidized bed bioreactors (FBBRs) has been reported to be efficient owing to their effective performance and instinct merits such as very high concentration of immobilized cells on the solid particles, prevention of washout of the microbes, lack of clogging of the biomass, ease of separation of cells from product stream and elimination of limit on liquid flow rates due to decoupling of residence time of liquid phase and of microbial cells [1-6]. In phenol biodegradation processes, transfer rates of phenol, oxygen and other nutrients from bulk phase to bioparticle are the rate limiting steps. Therefore, the knowledge of phenol mass transfer coefficient is essential for the design and operation of FBRs. Sufficient literature for mass transfer correlations of phenol degradation in packed bed bioreactors, but scarce in FBBRs have been found. The present work addresses these gaps and reports the work carried out to develop mass transfer correlation for phenol biodegradation in FBBR in terms of air and feed flow rates and liquid properties. [4].

Developed a mathematical model to describe the biological phenol degradation in a three-phase fluidized bed reactor. A biofilm model was proposed that considers both the simultaneous diffusion and reaction of phenol and oxygen within the biofilm, and also the external mass transfer resistance between the liquid phase and the biofilm. The model assumes substrate-inhibited kinetics with respect to phenol and Monod kinetics with respect to oxygen. Experimental steady-state degradation data obtained in a three-phase fluidized bed bioreactor were used to calculate phenol and oxygen concentration profiles within the biofilm and to estimate the biofilm substrate diffusivities [10].

Experimental:

Draft tube fluidized bed bioreactor shown in fig.1 has been used in the present investigation. The DTFBBR made up of glass was provided with a glass sparger at the bottom of the reactor through which air can be sparged. The total volume of the reactor was about 2.67 l. The top of the glass reactor was closed with a plate through which all the probes and sensors were inserted into the reactor. An over flow line has been provided near the top for the reaction medium to flow out of the reactor in continuous operation. Two peristaltic pumps have been provided each for media and feed into the reactor. The reactor was provided with a glass jacket to maintain the temperature of the reactor system. A pH meter and a controller have been provided for maintaining the pH of the system by the addition of acid or base from the tanks provided at the top. Oxygen required for the microorganism has been supplied by a compressor. Fixed flow rate of broth containing the culture and growth medium of known inlet phenol concentration was introduced continuously into the reactor. The temperature was maintained at 30^0C with a heating or cooling circuit. P^H was maintained at 7.0 using 0.1N HCl and 0.1N NaOH. The concentration of phenol in the overflow was analyzed Idometrically after every one hour until steady state was reached. The experiment was repeated for feed flow rates of 300, 400, 500 and 600 ml/h, feed concentrations of 20, 30, 40, 50 and 60 ppm and air flow rates of 2, 3 and 4 lpm.

Results and Discussion:

The determination of mass transfer coefficient for phenol from the bulk of the liquid to the solid particle in the fluidized bed is based on the assumption that the phenol is diffusing from the bulk phase to the solid particle through a liquid film surrounding the solid particle. Under Steady state conditions, equating the rate of phenol degradation in the bioreactor to the total rate of mass transfer to the bio-particle in fluidized bed bio-reactor for feed flow rate of 396 ml/hr gives: $X_f V_b K S_s \eta = Q (S_f - S_b)$, for feed Flow rate of Q = 396 ml/hr = 0.11 x 10^{-6} m^3/sec, we get S_s = 0.00708 $(S_f - S_b)$, mass Balance over bio-particle gives, $N_p A_p K_L (S_b - S_s) = Q (S_f - S_b)$, we get K_L= 21.83257 x 10^{-8} $((S_f - S_b) / (S_b - S_s))$.

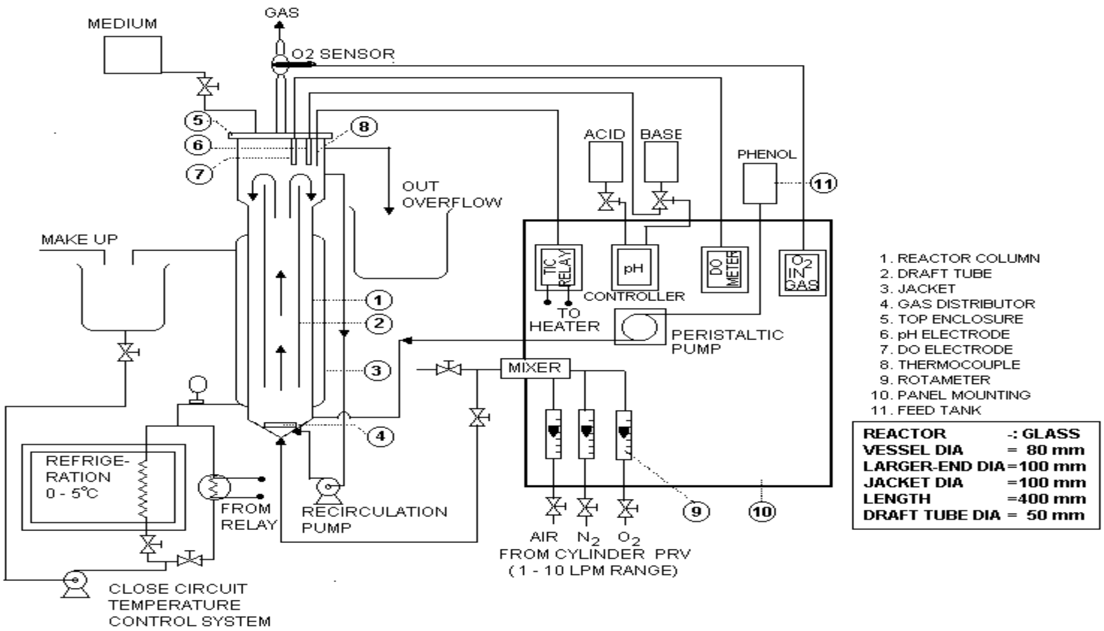

Fig.1 Fluidized Bed Bioreactor

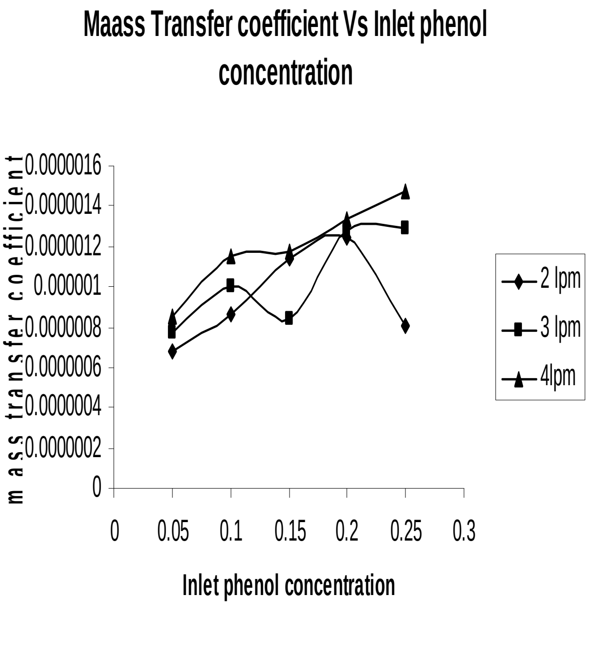

Fig. 2. Mass Transfer coefficients Inlet phenol concentration

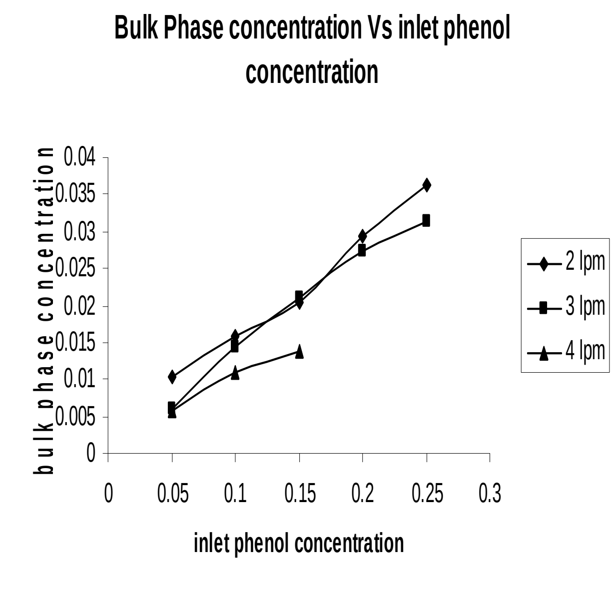

Fig 3: Bulk phase concentrations Inlet phenol concentration

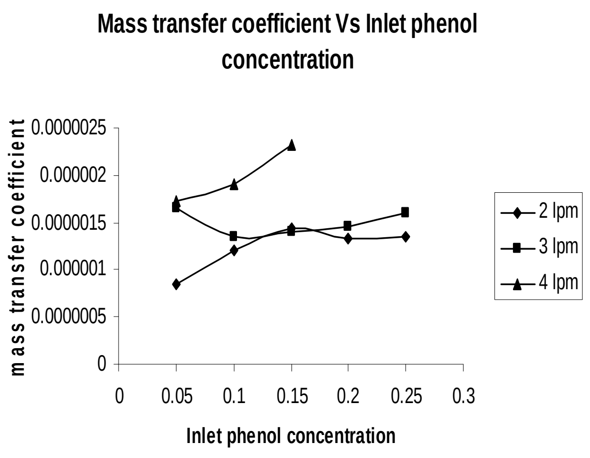

Fig. 4. Mass transfer coefficient VS inlet phenol concentration

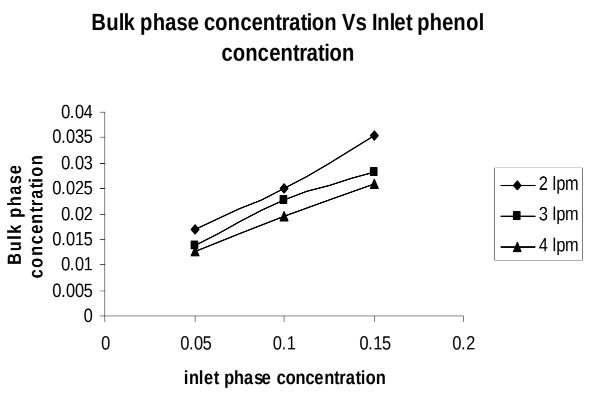

Fig: 5 Bulk Phase concentrations Inlet phenols

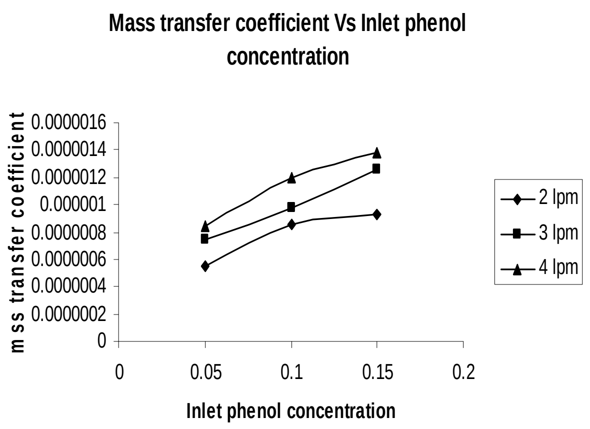

Fig. 6. Mass transfer coefficient VS inlet concentration

CONCLUSIONS:

The mass transfer coefficient for phenol in FBBRs was found to increase with increase in feed flow rate, concentration and air flow rate. Biodegradation of phenolic waste in fluidized bed bioreactor was observed follow first order rate kinetics. A correlation for mass transfer coefficient of phenol in terms of Sherwood, Reynolds and Schmidt numbers and ratio of fluid velocities has been developed. From the investigation, it is noticed that the effect of physical properties of fluids on biological processes is more than on chemical processes.

REFERENCES:

[1]. S. D. Kim and Y. Kang. Heat and mass transfer in three-phase fluidized-bed reactors – an over view. Chem. Engg. Sci.52 (1997) 3639-3660.

[2]. H. Miura and Y. Kawase. Hydrodynamic and mass transfer in three-phase fluidized-beds with non-Newtonian fluids. Chem. Engg. Sci. 52 (1997) 4095-4104.

[3]. W. Yang, Jinfu Wang, Tiefeng Wang, Yong Jin. Experimental study on gas-liquid interfacial area and mass tranafer coefficient in three-phase circulating fluidized beds. Chem. Engg. J. 84 (2001) 485-490.

[4]. S. S. Alves, C. I. Maia and J. M. T. Vasconcelos. Gas-liquid mass transfer coefficient in stirred tanks interpreted through bubble contamination kinetics. Chem. Engg. Proc. 43 (2004) 823-830.

[5]. C. O. Vandu and R. Krishna. Influence of scale on the volumetric mass transfer coefficient in bubble columns. Chem. Engg. Proc. 43 (2004) 575-579.

[6]. C. Akosman, R. Orhan and G. Dursun. Effects of liquid property on gas hold up and mass transfer in co-current downflow contacting column. Chem. Engg. Proc. 43 (2004) 503-509.

[7]. F. Garcia-Ochoa and E. Gomez. Theoretical predictions of gas-liquid mass transfer coefficient, specific area and hold-up in sparged stirred tanks. Chem. Engg. Sci. 59 (2004) 2489-2501.

[8]. M. S. N. Oliveira and Xiong-Wei Ni. Effect of hydrodynamics on mass transfer in a gas-liquid oscillatory baffled column. Chem. Engg. J. 99 (2004) 59-68.

[9]. Hirata, Y. Hosaka and H. Umezawa. Characteristics of simultaneous utilization of oxygen and substrate in a three-phase fluidized bed bioreactor. J. Chem. Engg. Of Japan 23 (1990) 303-307.

[10]. Y. Kang, L. T. Fan, B. T. Min and S. D. Kim. Promotion of oxygen transfer in a three-phase fluidized bioreactors by floating bubble breakers. Biotech. And Bioengg. 37 (1991) 580-586.
[11]. H. Beyenal and A. Tanyolac. The effect of biofilm characteristics on the external mass transfer coefficient in a differential fluidized bed biofilm reactor. Biochemical Engg. J. 1 (1998) 53-61.
[12]. W. T. Tang and L. S. Fan. Steady state phenol degradation in a draft-tube, gas-liquid-solid fluidized–bed bioreactor. AIChE Journal 33 (1987) 239-249.
[13]. G. Livingston and H. A. Chase. Modeling phenol degradation in a fluidized bed bioreactor. AIChE Journal 35 (1989) 1980-1991.
[14]. D. C. Arters, L.-S. Fan. Solid liquid mass transfer in a gas-liquid-solid fluidized bed. Chem. Engg. Sci. 41 (1986) 107-119.
[15]. P. Tournie, C. Laguerie, J. P. Couderc. Correlations for mass transfer between fluidized spheres and liquid. Chem. Engg. Sci. 34, (1979) 1247-1255.