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Kinetic Studies for an Aerobic Packed Bed Biofilm Reactor for Treatment of Organic Wastewater with and without Phenol

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Abstract

A laboratory scale aerobic fixed film bioreactor packed with glass beads for biofilm growth was used to evaluate the removal efficiencies of COD and phenol for a carbohydrate—phenol mixture in wastewater. It was done by an indigenous mixed culture inoculums developed after collecting sludge from a return line of an activated sludge plant. The test result on continuous flow in the above biofilm reactor indicated an optimum hydraulic loading range of 4-6.4 $m^3day^{-1}m^{-2}$ for attainment of reasonable amount of COD removal in case of carbohydrate substrate only. The COD removal efficiency, however, gradually depleted from 100% to 54% by gradual increase in organic loading (OLR) from 0.72-4.32 $kgday^{-1}m^{-3}$, beyond which removal was not significant. For the identical loading conditions, in presence of phenol in the substrate along with carbohydrate, the COD removal was observed varying from 100-40% in the above organic loading range. The COD removal kinetics in presence of phenol also shows a decreasing trend compared to data obtained without the presence of phenol in wastewater that reveals biological inhibition. The experimental data were fitted in a simple plug flow model for evaluating the zero order, first order and Monod form of rate equations to evaluate the kinetics. It was found that Monod type rate equations combining a zero and first order rate expression is the best fit for the above hydraulic and organic loading that gives a best fit half velocity constant value of 35 mgL^{-1} ($R^2 = 0.9612$).

Keywords: Packed Bed Reactor, Biofilm, Mixed Culture, COD Removal, Phenol, Kinetic Model

1. Introduction

Biofilm reactor is a popular method for biological treatment of wastewater to combat high organic strengths owing to enhanced mean cell residence time and economical oxygen supply [1-4]. However, adequate mixing in the biofilm reactor is important to ensure uniform distribution of substrate, sufficient contact between the microorganism and substrate and prevention of localized accumulation of toxic matter. In absence of recirculation, mixing can be achieved to some extent by uniform supply and distribution of oxygen in the reactor. Wastewater emanated from petrochemical, pharmaceutical, coke oven plant etc contains high phenolic compounds along with appreciable amount of COD. COD removal from wastewater can be obtained by either pure culture organism or by mixed culture system. As wastewater from industry contains mixed nature of organic matters and toxic compounds, and the maintenance of pure culture in industry for the treatment process of wastewater is difficult to achieve, so it is advisable to use mixed culture for treatment of wastewater having high COD and phenol concentration.

Phenol biodegradation by pure cultures of bacteria has been described by substrate inhibition models [4-7]. Otherwise, when mixed cultures are used there is no unique kinetic model for general agreement, but phenol is often considered as inhibitory at high concentrations [8-10]. At low substrate concentration, however, the inhibition is negligible; the model proposed by Monod may be used to describe the biodegradation process by either pure or mixed cultures. Furthermore, if the substrate concentration is much lower than the half-velocity constant (K), then a first-order kinetic model often applies.

