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Original Research Paper

Effect of Influent Concentration on Biodegradation of Phenol Using Packed Bed Reactor

P. S. Sagar, S. N. Dash and A. Prasad
Department of Chemical Engineering, GMR Institute of Technology, Rajam, Srikakulam Dist., A.P.

Key Words:
Phenol biodegradation
Packed bed reactor
Immobilized *Nocardia*
Biological fixed-films
Steady state

ABSTRACT

There is a general perception that the phenols being toxic are not amenable to biological degradation. Continuous biodegradation of phenol in synthetic wastewater is carried out in a packed bed bioreactor using immobilized *Nocardia hydrocarbonoxydans*. Glass beads were used as the carrier particles for cell immobilization. The effect of influent phenol concentration on packed bed bioreactor for phenol biodegradation during start up and at steady state were studied. Almost 99.6% degradation of 200 ppm phenol could be achieved. Percentage degradation of phenol decreased with the increase in influent concentration. The combined effect of higher phenol concentration and volumetric phenol loading might have resulted in lower degradation. Only 58.4% degradation of 1000 ppm phenol could be achieved with the packed bed bioreactor containing 6400 glass beads. Toxic effects of phenol were found to play a role at 1000 ppm influent concentration. With increase in dilution rate, the percentage degradation was decreased.

INTRODUCTION

The accumulation of organic carbon in many freshwater locations and the effluents from industrial plants joining the rivers and seas has great concern. It is becoming increasingly important to investigate how to degrade many troublesome contaminants and their biological oxidation in waste. The application of microbial system in the industrial end-of-pipe abatement plants is seen as cost effective method of removing pollutants from the environment by a process now known as biodegradation.

The origin of phenol in the environment is both anthropogenic as well as xenobiotic. Anthropogenic sources are from forest fires, natural run-offs from urban areas where asphalt is used as binding material and natural decay of lignocellulosic materials. Xenobiotic sources are industrial wastes from chemical manufacturing processes such as petrochemicals (Murugesan & Sheeja 2002), pharmaceutical industry, wood processing industry, pesticide manufacturing plants, coal gasification, polymeric resin production, oil refining industries, gas and coke industries, fibre glass units, plastic industry, paints and varnish industry, and textile industry which makes use of organic dyes. Phenol affects aquatic life causing ecological imbalance. It is lethal to fish even at relatively low concentration of 5-25 mg/L. Phenol imparts objectionable taste to municipal drinking water at far lower concentrations (< 0.01 ppm). When phenol-containing water is chlorinated toxic polychlorinated phenols can also result (Alemzadeh et al. 2000).

Different methods of treatment are available for reduction of phenol content in wastewater. The probable technologies are chlorination, ozonisation, adsorption, solvent extraction, membrane process, coagulation and flocculation. But these conventional physical and chemical methods have led to secondary effluent problems. Biological treatment is especially attractive because it has the potential

to almost completely degrade phenol while producing innocuous end products. In addition, it has the advantage of reduced capital and operating cost because of operation at ambient conditions. Thus, biological method of treatment has turned out to be a favourable alternative for phenol degradation. However, phenol is toxic (Scragg 2006) to most types of microorganisms at sufficiently high concentrations and can be a growth rate inhibitory to even those species, which have the metabolic capability of using it as a substrate for growth. So, for achieving satisfactory performance, phenol concentration needs to be maintained below toxic limits and acclimatization of organism to the wastewater environment is required.

Biological fixed films are commonly used in wastewater treatment as they provide several advantages over freely suspended cell systems. These include high biomass concentration, increased resistance to toxic shock loadings and higher volumetric throughputs due to independence of cell growth rate from reactor dilution rate (Tziotzios et al. 2005).

Nocardia hydrocarbonoxydans NCIM sp. 2386 has been chosen for the present study for phenol biodegradation. Biodegradation was conducted in a packed bed bioreactor (Murugesan & Sheeja 2005). Required number of glass beads on which *Nocardia hydrocarbonoxydans* is immobilized were placed. Immobilized *Nocardia hydrocarbonoxydans* over glass beads were placed in packed bed reactor. Experiments were conducted to analyse the performance of packed bed bioreactor for the biodegradation of phenol.

MATERIALS AND METHODS

The column was cleaned thoroughly with water and kept for drying. After drying, required number the immobilized glass beads were filled inside the column and phenol solution was filled up to the sampling port. Compressed air was sent from the bottom of the column for aeration at a constant rate to ensure oxygen concentration in the reactor liquid is more than 5 mg/L. Synthetic wastewater containing phenol and nutrient medium was sent with a constant flow rate using peristaltic pump through the inlet at the bottom of the column. The effluent was collected from the outlet port for different time intervals and analysed for the phenol concentration and free cell concentration until the system reached steady state. Steady state conditions were assumed when phenol concentration in the effluent reaches a constant value. Then the steady state biomass dry weight and bio-film thickness were determined.

To study the effect of influent concentration of phenol, continuous biodegradation of synthetic wastewater using 200 ppm, 300 ppm, 500 ppm, 800 ppm and 1000 ppm phenol was carried out in packed bed reactor with a dilution rate 0.0038547/hr and carrier loading of 6400 immobilized glass beads. Then continuously effluent phenol concentration and free cell concentration measured till the steady state was attained.

RESULTS AND DISCUSSION

Effect of influent concentration on effluent phenol during start up: Fig. 1 represents the results of time course variation of effluent phenol concentration from the bioreactor packed with 6400 glass beads immobilized with the cells and at the dilution rate of 0.0038547/hr (flow rate of 400mL/hr) with 200, 300, 500, 800 and 1000 ppm influent phenol concentration. The effluent concentrations were measured at constant time periods (4 hr) at the outlet port of the reactor (port at 8 cm from the bottom) during start-up till the steady state was achieved. The results showed that the effluent concentration of phenol initially dropped and attained steady state. It is observed from the start up

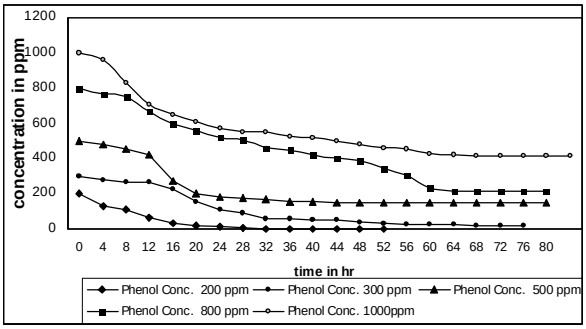

Fig. 1: Effect of influent concentration on effluent phenol concentration during start up and steady state.

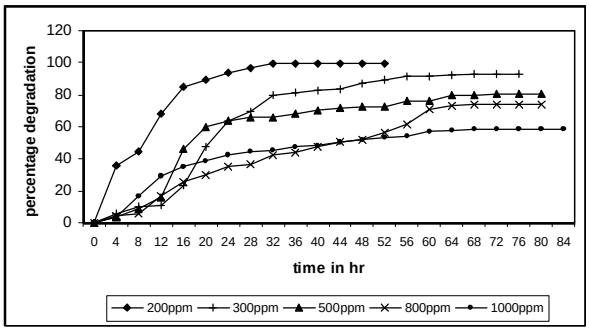

Fig. 2: Effect of influent concentration on effluent phenol concentration and percentage degradation at steady state.

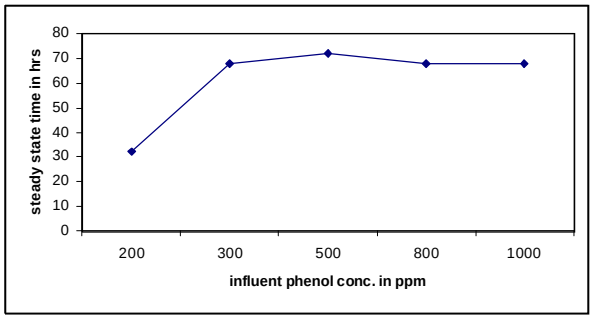

Fig. 3: Effect of influent concentration on effluent phenol concentration and percentage degradation at steady state.

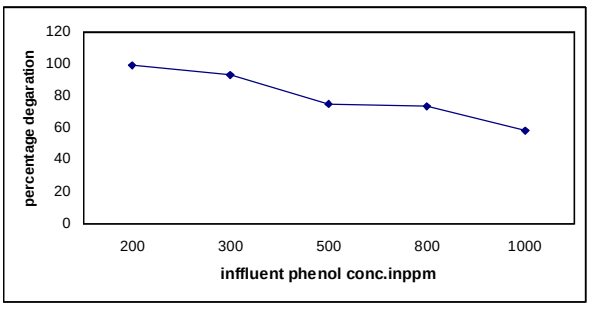

Fig: 4 Effect of influent concentration on effluent phenol concentration and percentage degradation at steady state.

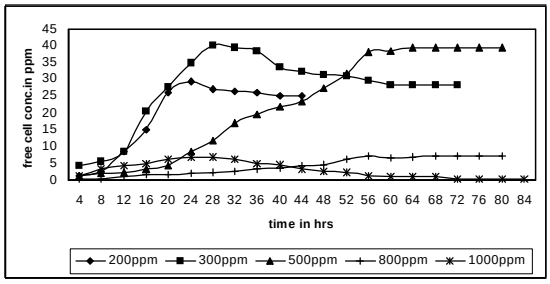

Fig. 5: Effect of influent concentration on free cell concentration during start up and steady state.

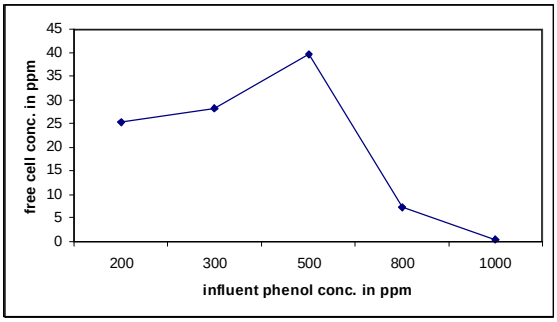

Fig. 6: Effect of influent concentration on free cell concentration during steady state.

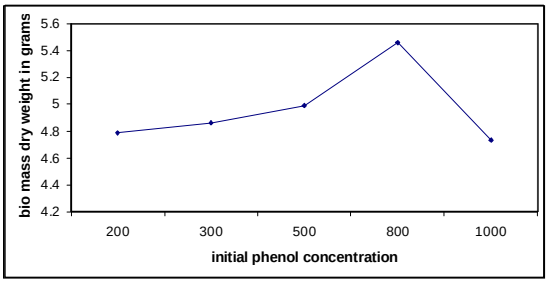

Fig. 7: Effect of influent concentration on steady state biomass dry weight.

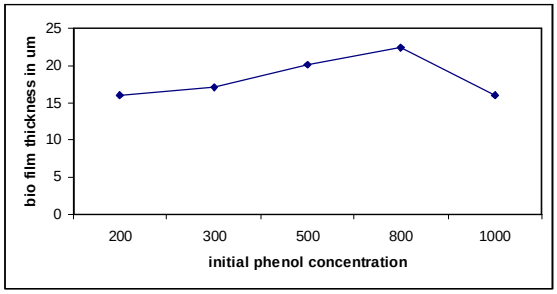

Fig. 8: Effect of influent concentration on steady state bio-film thickness.

results that the rate of degradation has decreased with the increase in influent phenol concentration.

Effect of influent concentration on effluent phenol concentration and percentage degradation at steady state: Fig. 2 shows that as the influent concentration is increased, the effluent concentration at steady state has also increased. Phenol effluent concentration for 200 ppm influent concentration is only 0.813 ppm. But for 1000 ppm influent phenol concentration, it is about 416 ppm. Fig. 4 represents the effect of influent concentration on steady state percentage degradation at the dilution rate of 0.0038547/hr with 6400 immobilized carrier particles. It is observed that the percentage degradation is reduced with increase in influent phenol concentration at the same dilution rate of 0.0038547/hr. When influent phenol concentration is 200 ppm percentage degradation is almost 99.6 %. For 1000 ppm it is decreased to 58.4 %. At low concentration of 200 ppm, the organisms can take up the available phenol almost completely.

Effect of influent concentration on free cell concentration during start up and steady state: Fig. 5 gives the effect of influent concentration on free cell concentration during the start up and at steady state at the dilution rate of 0.0038547/hr and with 6400 glass beads. The free cell concentration in the effluent during start up continuously changes due to continuous variation of growth rate and shear rate in the column. Detachment is not only a function of turbulence in the reactor, but it is a function of amount of attached biomass, bio-film thickness and biomass growth rate. Steady state is reached when the growth rate is balanced by the death and shear rate. Steady state free cell concentration has increased with increase in phenol concentration of up to 500 ppm. As it is seen from Fig. 6 and Fig. 7, the bio-film thickness and attached biomass dry weight has increased with increase in phenol concentration up to 800 ppm. Detachment is a function of bio-film thickness and the amount of attached biomass. So, as the phenol concentration is increased up to 500 ppm, the free cell concentration has increased. With further increase in influent phenol concentration to 800 ppm and 1000 ppm, the toxic effect of phenol may be playing a role, and hence, the free cell concentration decreases at higher influent phenol concentration.

Effect of influent concentration on steady state bio-film thickness: Fig. 8 shows the results of the variation of steady state bio-film thickness with the different influent phenol concentrations. The steady state bio-film thickness has increased up to 800 ppm concentration and then it is decreased as the concentration is increased to 1000 ppm. This may be due to the toxic effects of phenol on the microorganisms at higher concentrations.

Effect of influent concentration on time taken to reach the steady state: Fig. 3 shows the effect of influent phenol concentration on the time taken to reach the steady state. With the influent concentration of 200 ppm, the steady state was achieved in 32 hrs. But for the influent concentrations at and above 300 ppm, the steady states were achieved within around 68 to 72 hrs. Initial biomass present in the reactor itself may be sufficiently high to degrade 200 ppm phenol easily. So steady state has reached very fast. But when the influent concentration is high, the organisms cannot easily take up the higher phenol loading, and hence, more time is taken to reach the steady state.

Effect of influent concentration on the steady state biomass dry weight: Fig. 7 represents the effect of influent concentration on steady state biomass dry weight. It is observed that the steady state biomass dry weight has increased with increase in phenol concentration of up to 800 ppm. But with increase in phenol concentration to 1000 ppm, the steady state biomass dry weight has decreased. The effect is similar to the effect on bio-film thickness, reason being the toxic effect of phenol at high concentrations.

CONCLUSION

Continuous biodegradation of phenol was carried out in a packed bed reactor using immobilized cells of *Nocardia hydrocarbonoxydans* on glass beads. The effect of influent phenol concentration on phenol degradation by the performance of the bioreactor during start-up and steady state were studied. Almost 99.6 % degradation of 200 ppm phenol was achieved. The percentage degradation of phenol was found to be decreased with increase in influent concentration. The toxic effect of phenol was found to play a role at 1000 ppm influent concentration.

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