BIODEGRADATION OF HIGH CONCENTRATION OF PHENOL IN WASTEWATER TREATMENT BY BIOFILM DEVELOPED IN SAND SOIL MEDIA

Medhat Moustafa

Sanitary Engineering Department, Alexandria University,
21544 Alexandria, Egypt

ABSTRACT

The aim of this study is to evaluate the biodegradation performance of phenol in a fixed biofilm developed in sand soil media. The parameters which had been studied and may influence the biodegradation were: a) the grain size of sand, b) the rate of flow, and c) the initial phenol loading. Laboratory scale of two columns with inner diameter of 5 cm was used. The first column was packed with fine sand (0.8 mm) while the second column was packed with coarse sand (2.50 mm). Synthetic waste enriched with nuitrent was fed and recirculated to the top of columns. Phenol was introduced to the top of the sand layer. Daily samples were taken and analysed for: phenol, COD, pH, and suspended solids. The results indicated that grain size has no effect on phenol removal. The low rate of flow resulted better performance while the high loading of phenol slowed down the microbial activity.

Keywords:
Phenol - Biofilm in sand soil - Effective grain size - Rate of flow - Phenol concentration.

INTRODUCTION

Phenol (C_6H_5OH) is considered a hazardous compound in wastewater. Its impact implies the inhibition of biological activity of microorganism which is responsible for the stabilization of organic load in industrial and domestic effluents [1]. Phenol is used extensively in the synthesis of organic products, particularly phenolic-type resins.

It occurs as a natural component in industrial wastes from petrochemicals, coal-coking, petroleum refining, pharmaceutical plants and as well as in a side variety of industrial wastes from processes involving the use of phenol as a raw material [2].

Biofilms are microbial layers on the surfaces of solids or liquids. In nature, by far the greater percentage of bacteria live in biofilms e.g., on stones, in the soil and on the surface of the water. Biofilms are comprised of microorganisms, water, inclused particles, dissolved matter and gelatinous substances which are produced by the bacteria. Microorganisms living in biofilms are more protected than free bacteria suspended in water. Immobilization allows them to survive dry periods, toxic substances and longer phases in which there is a lack of nutrition. In biofilms, aerobic, anoxic and anaerobic zone develop in close proximity to each other. So that the different types of bacteria can live together in a very confined spaces. In addition, the advanced age of the sludge promotes the development of specialist and groups of bacteria that, e.g., interact in degrading the pollutants. Consequently, biofilm layers are particularly effective in the case of low substrate concentrations and substances which are difficult to degrade.

The concept of using biological treatment to remove phenol was first reported in 1920s [3]. Since then there have been many reports that discuss general design and operational guidelines for biological treatment of wastewater containing phenolic compounds. The existence of microbes capable of degrading phenolic compounds has been studied in laboratory experiments [4,5].

The main technique of the present study is based on recycling of synthetic wastewater to the top of the soil surface so that it could enable biological activity of biomass to remove the contaminate phenol until a final, maximal and best achievable stage [6]. The objectives of the present work were to study the influence of three different parameters on the performance of phenol biodegradation by biofilm. These three parameters were:

1- The effective grain size of sand.
2- The flow rate of recycled water.
3- The initial phenol loading on sand.

MATERIAL AND METHODS

1- Apparatus

To achieve the objectives of this work, two identical Perspex columns with internal diameter of 5 cm were used. The first column was packed with clean pre-washed fine sand of effective grain size 0.8 mm. The second column was packed with coarse sand of effective grain size 2.5 mm. In both columns the sand was under laid by 15 cm gravel to support the sand layer and to prevent the escape of the sand with the effluent. A-10 liter tank was placed in order to collect the effluent and recirculate it to the top of columns by the use of peristaltic pumps as shown in Figure (1). Phenol solution with initial known concentrations was introduced to the top of the sand layer. To create the microbial layers of biofilm, the system was seeded with activated sludge wastewater from nearby wastewater treatment plant [Kafer el-Dawar wastewater treatment plant] was pumped via peristaltic pump for three weeks before operating.

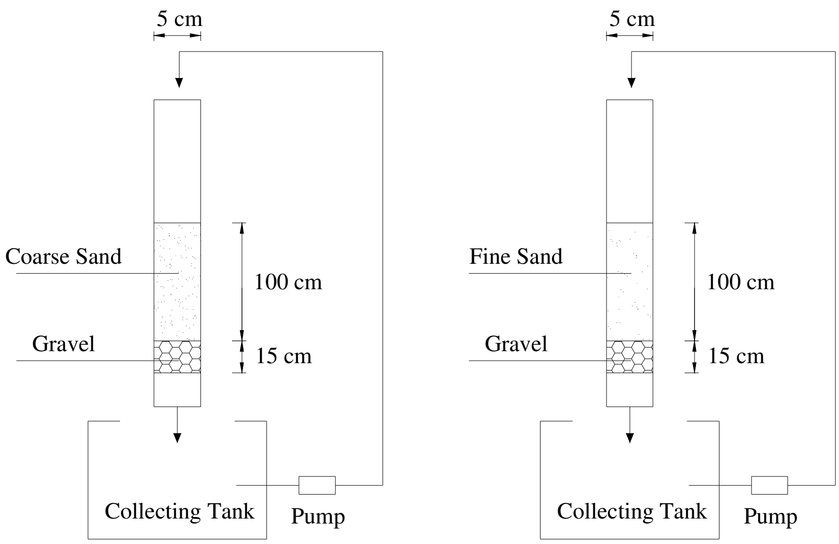

Figure (1). Schematic diagram of the experimental system

2- Operating Conditions

Three runs were carried out to observe the influence exerted by the three studied parameters. The first run was characterized by keeping constant flow rate and identical initial phenol loading to study the effect of the grain size. To study the effect of flow rates, three different flow rates operated in parallel on both sand columns keeping identical phenol loading. In the third run the rate of flow was kept constant at different phenol loading to observe the effect of the phenol concentration. All of the runs were carried out at the ambient temperature (25^{o}C).

3- Synthetic Waste and Sampling

To ensure adequate experimental control of the system a synthetic waste feed was used during the phases of the research. Between runs the columns were washed with tap water before the start of the next run. The tank for the recycling water contained 10liter of tap water enriched by 5 g/l glucose, 1.165 g/l $Na_3PO_412H_2O$ and 0.88 g/l $(NH_4)_2SO_4$ [7]. Samples were daily collected from the recycled liquid and analyzed of phenol, chemical oxygen demand (COD), pH and suspended solids. All the analytical work was done following the procedure mentioned in the 15$^{\underline{th}}$ edition of the Standard Methods for Examination of Water and Wastewater, 1995 [8].

RESULTS AND DISCUSSION

As described above the experimental work can be summarized in the exposures of phenol applied at the top of the columns which bioremediated by continuous recycling of aqueous solution enriched by nutrients. The results of the first group of runs are shown in Figures (2, 3). The results represent the effect of grain size distribution on the COD and phenol removal at identical phenol loading [100 mg/l] and flow rate [0.45 L/h]

As can be seen from the figures, there is no major difference could be observed as being influenced by the effective size of the sand grains. Although the fine sand enables higher and acclimated microbial densities as compared to coarse. The higher amounts of attached biomass mainly concentrated at the top of the columns. The relatively uniform biofilm distribution in the coarse sand could explain its better performance.

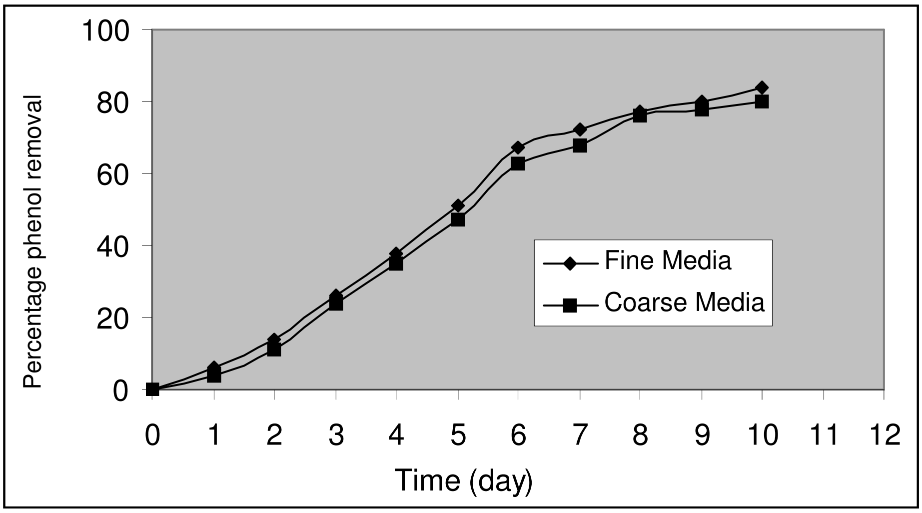

Figure (2). Effect of grain size on phenol removal

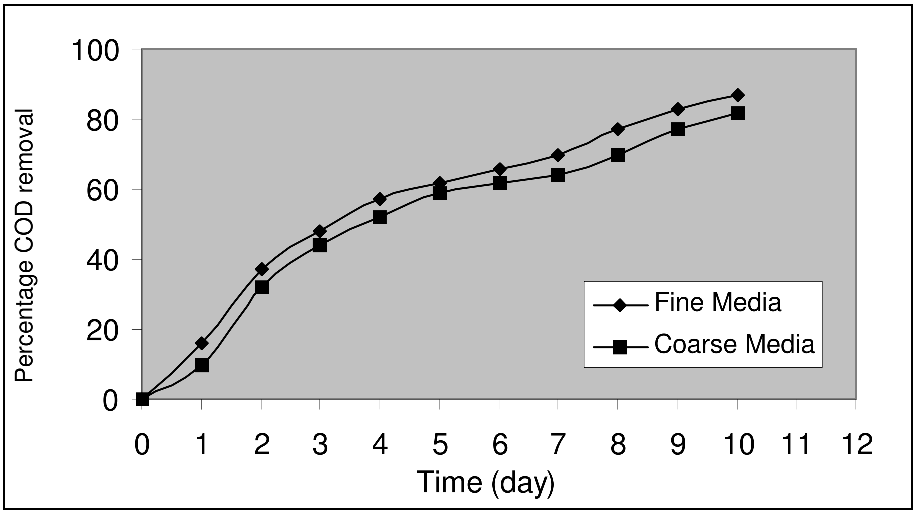

Figure (3). Effect of grain size on COD removal

The results of the second group of runs are shown in Figures (4, 5). These runs were based on different flow rates [0.36, 0.45 and 0.54 L/h] for both columns and identical phenol loading [100 mg/l]. Figures (4, 5) indicate that the lower flow rate enable better biodegradation of phenol and COD.

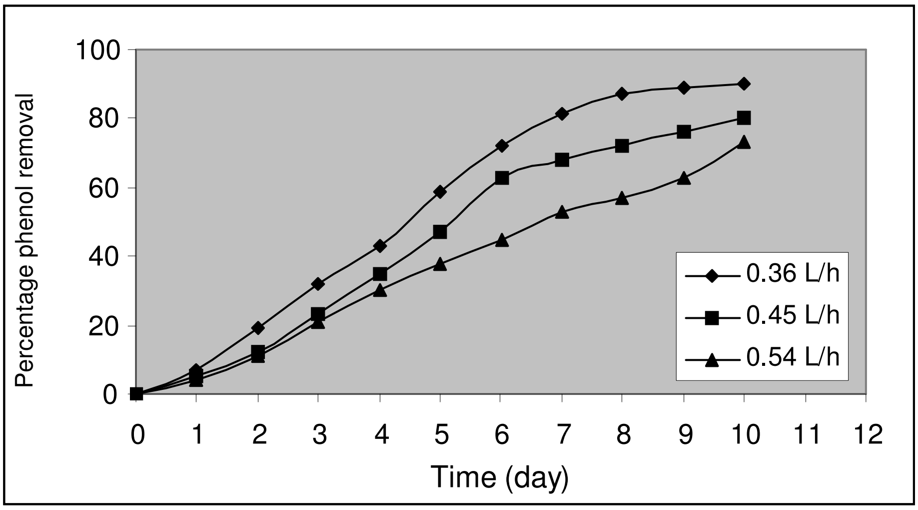

Figure (4). Effect of flow rate on phenol removal

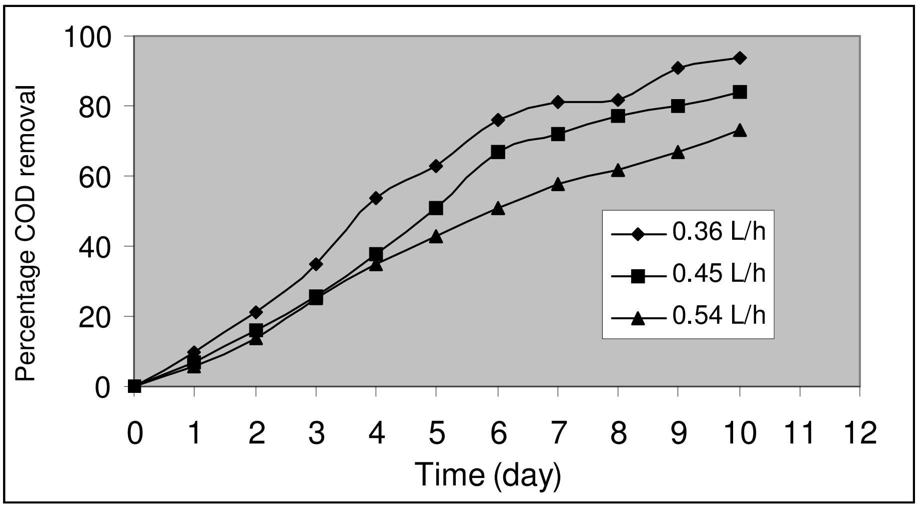

Figure (5). Effect of flow rate on COD removal

The achieved removal of phenol and COD was the results of the third group of runs are shown in Figures (6, 7). These runs were based on constant flow rate [0.45 L/h] and different phenol loading. The phenol loading applies on the top were 200 and 100 mg/L respectively. As shown in the figures, the high loading of phenol applied on the top of the columns slowed down the microbial activity.

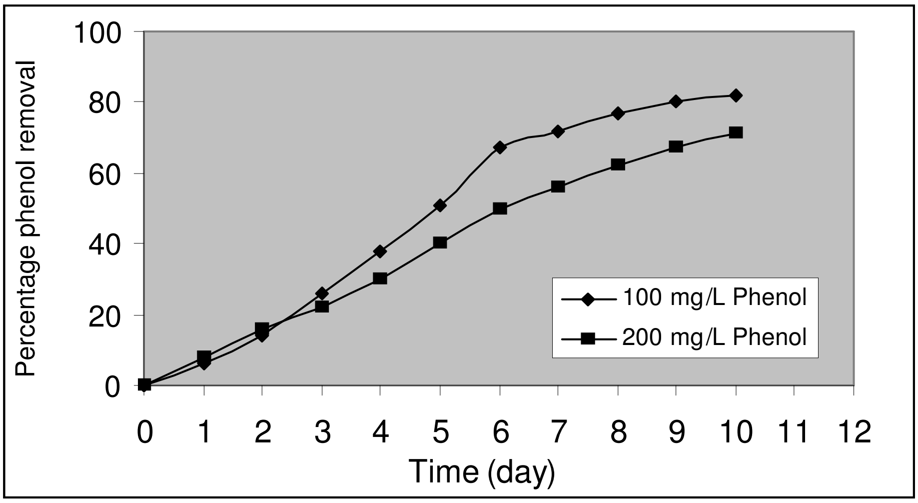

Figure (6). Effect of phenol loading on phenol removal

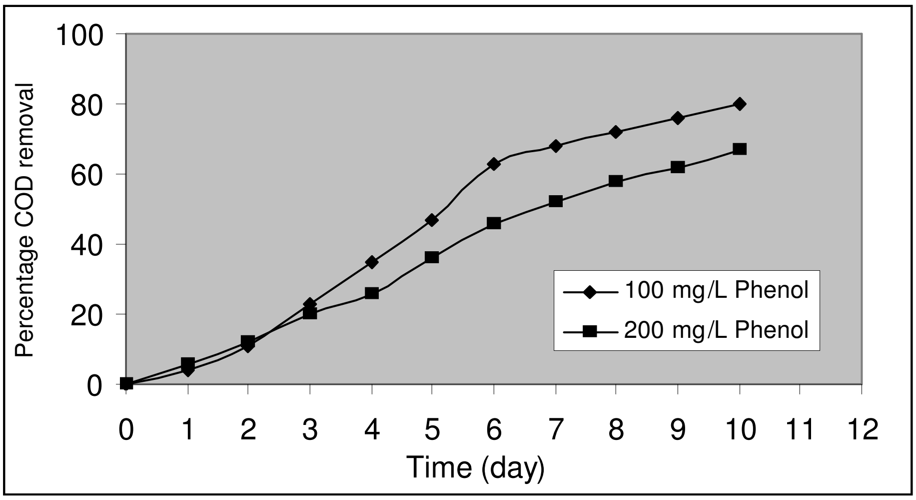

Figure (7). Effect of phenol loading on COD removal

The high removal percentage either in phenol or COD could be explained by the assumption that the amount of acclimated biomass in the column increased as more contaminant has been biodegraded. As a result the reduction of phenol and COD concentration in the recycled liquid occurred.

CONCLUSION

1. Phenol with high rate can be remediated by biofilm developed in sand soil media, the achieved removal of phenol and COD was about 90% and 87% respectively.
2. The grain size of sand has a little effect on phenol biodegradation since the relatively uniform biofilm distribution in the coarse sand compensates the high

acclimated microbial density. The rate of flow is very important factor in the process.

3. The flow rate is very important factor in the biological removal process of phenol and COD.
4. High load of phenol slowed down the microbial activity

REFERENCES

[1] Wesche, K.D. and Lotfy, H.R. "Biokinetic Parameters of Phenol Removal from Wastewater via BOD Test".

[2] Sawyer, C.N., McCarty, P.L., "Chemistry for Environmental Engineering 3rd Edition". McGraw-Hill Book Co., London (1978).

[3] Vipulanandan C., Wang S. and Krishnan S., "Biodegradation of phenol remediation of hazardous wastes contaminated soils", Marcel Dekker, New York, 1994.

[4] Yoong, E.T. and Lant, P.A. "Biodegradation of High Strength Phenolic Wastewater Using SBR". Wat. Sci. Tech. Vol. 43, No.3,pp 299-306.

[5] Essa, M., Farooq, S. and Nackla, G. "Effect of biofilm on the physical properties of sans contaminated with phenol", J. Environ. Sci. Health, A32 (4), pp 1109-1123, (1997)

[6] Antizarladislao, B., Katz, S. and Galil, N.I. "Phenol remediation by biofilm developed in sand soil media". Wat. Sci. Tech. Vol. 42, No. 1-2, pp. 99.

[7] El-Barki, W.A. "Treatment of Phenolic Wastewater". M.Sc. thesis in Civil Engineering, Alexandria University (2002).

[8] APHA (1995). Standard Methods for the Examination of Water and Wastewater 15th Edition. American Public Health Association, Washington D.C.