Influence of Varying Concentration of Toluene in a Soil Biofilter

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Abstract

Contaminant concentrations and their variability affect rate of removal of air contaminant in biofiltration. In this study with toluene as the air contaminant, extent of degradation rate at varying concentrations (from 50 to 700 ppm) in terms of elimination capacity (EC) was measured using a soil biofilter run for 215 days. It appears that no inhibition or oxygen limitation was observed at 700 ppm as EC went higher at this concentration reaching 58 g m-3 hr-1. Results show that at low toluene concentrations in the gas stream, toluene was degraded faster than it could diffuse into the biofilm while at high toluene concentrations, the whole biofilm was fully penetrated and there was no increase in EC due to biological activity limitation. Oxygen limitation may influence removal rates even if oxygen is not completely depleted in the biofilm with biofilm thickness as another factor in oxygen limitation. There was growth in the biofilm but it did not produce a biofilm thick enough to give rise to oxygen limitation. Though toluene inhibition and/or oxygen limitation could eventually become influencing factors, biofiltration may be used as an air pollution control technology at varying contaminant concentration.

Keywords: biofiltration, toluene, concentration, soil

1. Introduction

Contaminant concentrations and their variability affect rate of removal of air contaminant in biofiltration. (Tang *et al*, 1995). Degradation in biofiltration is limited when increased concentrations of pollutants reach toxic levels for the microorganisms (Delhomenie *et al*., 2005). In most studies on the influence of concentration on biofiltration performance, results involve varying concentrations at different parts of the reactor. The uniqueness of this study lies in the control of water content and the use of CO_2 production, in addition to the elimination capacity (EC), to measure extent of degradation rate where contaminants are distributed uniformly in a differential biofilter. Elimination capacity is the mass of contaminant degraded per unit volume of filter material per unit time. The objective of this study is to investigate the degradation rate of toluene at varied toluene inlet concentrations. This objective is attained by determining the EC at varying inlet concentrations and the corresponding CO_2 production.

2. Methods

In this study with toluene as the air contaminant, extent of degradation rate at varying concentrations in terms of elimination capacity (EC) was measured using a biofilter with soil as the bed medium. The biofilter used in this study is a differential reactor commonly used in catalysis research which allows rigorous control of environmental parameters in contrast to the traditional long column laboratory biofilter where most of the parameters change along the length of the reactor. (Beuger and Gostomski, 2009). It was run for 215 days. The sequential inlet toluene concentrations followed this order: 200, 400, 100, 150, 50, 700, 50 and 250 ppm and were grouped into three phases: phase A - before the increase to 700 ppm; phase B - during the increase to 700 ppm; and phase C - after the increase to 700 ppm. Table 1 shows the details on the actual average inlet concentrations in each period.

Table 1. Concentrations and the duration of operation at each period of the experiment

Phase	Period	Target inlet C (ppm)	Actual average inlet C (ppm)	Duration (days)
A	1	200	219.5 (±29.0)	14
	2	400	401.0 (±26.9)	24
	3	100	112.8 (±7.1)	12
	4	150	164.0 (±10.9)	12
	5	50	53.9 (±6.5)	16
B	6	700	665.8 (±64.1)	68
C	7	50	57.4 (±3.8)	28
	8	250	246.7 (±12.8)	41

3. Results and Discussion

Increasing the concentration to 700 ppm increased the EC to 135.3 g $m^{-3}h^{-1}$ from an EC of 11.7 g $m^{-3}h^{-1}$ at 50 ppm. Since no decrease in elimination capacity was exhibited at 700 ppm, it implied the complex and structured microbial ecosystem in the reactor was functioning well despite changes in concentration and air flow rates. The increased EC confirmed the increase in biomass.

In general, CO_2 production varies directly with the changes in the inlet concentrations. However, this result as shown in Fig. 1 is true only in Periods 1-6 but not in

Periods 7 and 8 where the CO_2 production continues to decrease at the steady inlet concentration.

Results of this study imply that at low toluene concentrations below the critical concentration of 350 ppm in the gas stream, toluene was degraded faster than it could diffuse into the biofilm and showed increasing EC with increasing concentration while at high toluene concentrations (above the critical concentration), the whole biofilm was fully penetrated and there was no increase in EC due to biological activity limitation. The difference in critical concentrations in Phase A and Phase C in this study may be an evidence of the difference in biomass thickness, biofilm area or growth which influences strongly the biofilter performance.

In this study, the carbon from degraded toluene was released as carbon in carbon dioxide due to bio-oxidation which implied complete degradation of toluene only at concentrations lower than 700 ppm. However, in the study of Seed and Corsi (1996), the carbon removal rates did not appear to be affected by combinations of BTX constituents at inlet concentrations exceeding 600 ppm. The difference in results may be attributed to the distribution of contaminants in the filter bed which was homogeneous in this study due to the design of the differential bioreactor.

In addition, toluene removal is affected by the presence of other gases as observed in the study of Rene et al. (2018). Smith *et al.* (2002), and Schroeder (2002) observed oxygen limitation at a toluene concentration of 593 ppm and 1000 ppm, respectively. In this study, it appears that no inhibition or oxygen limitation was observed at 700 ppm as EC went higher at this concentration. Oxygen limitation may influence removal rates even if oxygen is not completely depleted in the biofilm. Lower air permeability as a result of bed compaction, improper air distribution, or medium loading may lead to oxygen limitation (Devinny *et al*., 1999) and eventually reduced performance. Biofilm thickness is also a factor in oxygen limitation. Results of this study imply growth but it did not produce a biofilm thick enough to give rise to oxygen limitation.

4. Conclusion

Concentration affects degradation rate. In general, the degradation rate increased with increasing concentration. Higher EC was observed at higher toluene concentrations. High toluene concentrations may be advisable during start-up as it converts microorganisms that do not thrive on toluene into nutrients for desired degraders inducing growth and improved performance. The biomass formation induced by the high pollutant concentration improved the biofiltration performance. Though toluene inhibition and/or oxygen limitation could eventually become influencing factors, biofiltration may be used as an air pollution control technology at varying contaminant concentration.

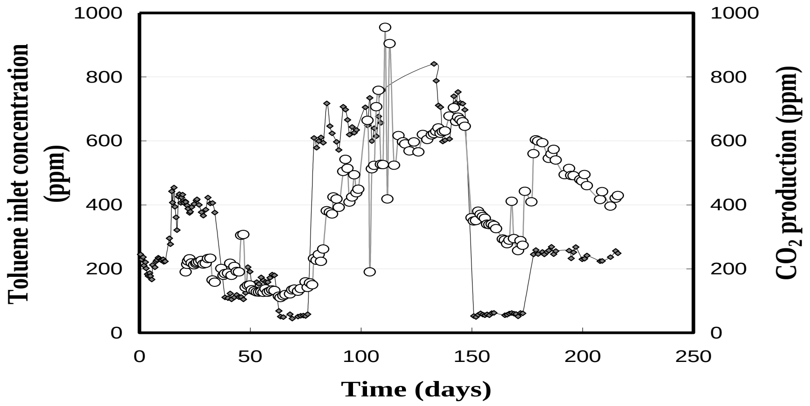

Figure 1. Changes in the toluene inlet concentration (diamond) and the CO_2 production (circle) through time

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