Characterization of a biotrickling filter treating methanol vapours

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ABSTRACT

The aim of this research is to characterize a biotrickling filter (BTF) treating methanol vapour emissions. The parameters studied were the nitrogen concentration in the nutrient solution and the empty bed residence time (EBRT). The effect of continuously recycling the nutrient solution was also analyzed. At nitrogen concentrations as low as 0.001 gN L^{-1}, the BTF presented removal efficiencies higher than 70 % for an inlet load of 110 g m^{-3} h^{-1}. A nitrogen concentration of 0.005 gN L^{-1} was used to study the effect of EBRT and the continuous recirculation of nutrient solution. At a constant methanol inlet concentration of 1500 ppmv, the BTF was operated in a range of EBRT from 20 to 265 s and the removal efficiencies respectively attained were 40 and 90 %. Methanol vapours were absorbed into the lixiviate and were taken into account in analysing the results.

1 INTRODUCTION

Methanol is a major pollutant emitted to the atmosphere in Canada. Methanol is toxic to human health and depending on exposure it causes headache, sleep disorders, gastrointestinal problems and optic nerve damage (OPPT, 2006). In the environment, methanol is related to problems like smog generation (Monod *et al.*, 1998). There are chemical, physical and biotechnological treatments which can be used for controlling methanol vapour emissions. Among them, the biotrickling filter is of considerable interest for effluents with low pollutant concentration and high volumetric flow rates (Cooper and Alley, 2002). The BTF advantageous characteristics are: no production of hazardous wastes, low energy consumption and low operation costs (Jorio and

Heitz, 1999, Delhoménie and Heitz, 2005). When the pollutant is water-soluble, *e. g.* ethanol and methanol, the BTF is able to operate in a wide range of inlet concentration (Avalos Ramírez *et al.*, 2007; Avalos Ramírez *et al.*, 2005). There are few studies which discuss methanol emissions control by using BTF (Avalos Ramírez *et al.*, 2005; Prado *et al.*, 2004). The aim of the present study is to determine the effect of nitrogen concentration in nutrient solution, the empty bed residence time (EBRT) and the role of the lixiviate on the performance of a BTF treating methanol vapour emissions.

2 MATERIALS AND METHODS

The experiments were performed using three identical biotrickling filters. The experimental setup is shown on Figure 1. The setup consisted of a bubbler containing methanol, a humidification column, a biotrickling filter with an empty bed volume of 0.018 m^3, a holding tank and a recycling pump. The nutrient liquid solution was fed into the BTF countercourant to the air flow. The concentrations of methanol were measured continuously with a total hydrocarbon analyzer (Horiba FIA-510, Horiba Instruments Inc., Irvine, CA, USA). The concentrations of carbon dioxide in air were measured continuously with a portable gas analyzer (Ultramat 22P, Siemens AG, Munich, GE).

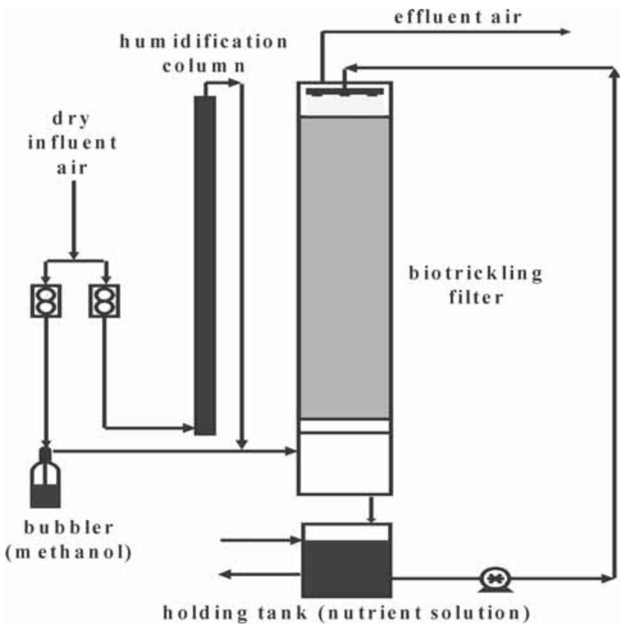

Figure 1. Schematic representation of biotrickling filter.

3 RESULTS AND DISCUSSION

3.1 Effect of nitrogen concentration on removal efficiency

Figure 2 shows the BTF removal efficiency as a function of the nitrogen concentration in the nutrient solution at a methanol inlet concentration of 1500 ppmv and an EBRT of 65 s. Urea was added to tap water in order to vary the nitrogen concentration in nutrient solution from 0.0 to 0.1 gN L^{-1}. Since tap water contains traces of nutrients, for example 0.0002 gN-NH_3 L^{-1}, the BTF still presented a removal efficiency of 70% without additional nutrients. Removal efficiency increased with nitrogen concentration passing from 70% at 0.0 gN L^{-1} to 90% at 0.1 gN L^{-1}. As shown in Figure 2, the removal efficiency increased from 70 to 80 % when nitrogen

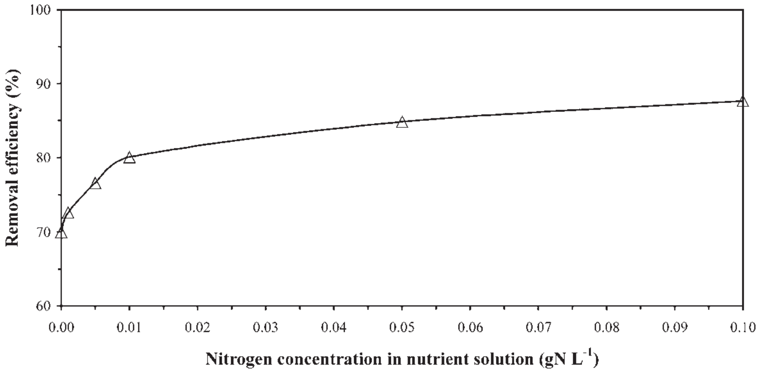

Figure 2. Variation of removal efficiency with nitrogen concentration in nutrient solution at an EBRT of 65 s and a methanol inlet concentration of 1500 ppmv.

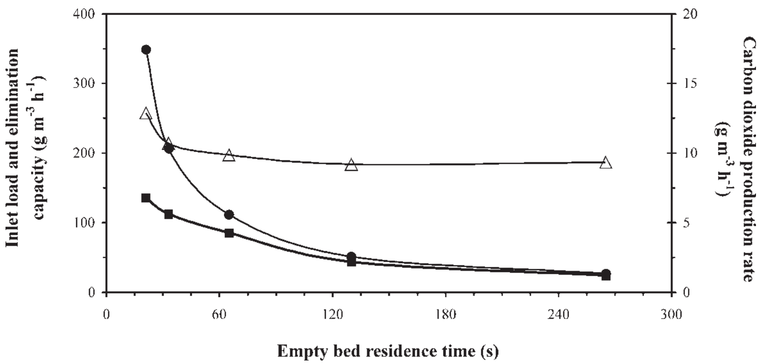

Figure 3. Variation of elimination capacity and carbon dioxide production rate with empty bed residence time, at a methanol inlet concentration of 1500 ppmv and nitrogen concentration in nutrient solution of 0.005 gN L^{-1}. (●) inlet load, (■) elimination capacity, (Δ) carbon dioxide production rate.

concentration passed from 0.0 to 0.01 gN L^{-1}. When nitrogen concentration increased 10 fold, from 0.01 to 0.1 gN L^{-1}, the removal efficiency only increased from 80 to 90%. BTF appears to be an appropriate treatment for controlling methanol vapour emissions at small concentrations of nitrogen.

3.2 Effect of empty bed residence time on carbon dioxide production rate and elimination capacity

In order to study the effect of EBRT and the role of the lixiviate in the performance of the BTF, a nitrogen concentration of 0.005 gN L^{-1} was chosen. The BTF was operated at five EBRTs: 20, 30, 65, 130 and 265 s. The methanol inlet concentration was maintained at 1500 ppmv for all experiments. Figure 3 shows the variation of elimination capacity with EBRT. Elimination capacity (EC) decreased with EBRT, from 135 g m^{-3} h^{-1} at 20 s to 25 g m^{-3} h^{-1} at 265 s. However, removal efficiency increased with EBRT, from 40 to 90%. This can be appreciated in Figure 3, as EBRT increased, the EC tended to the value of methanol inlet load (IL). The BTF presented a competitive performance at EBRT higher or equal to 65 s. Carbon dioxide production rate (PCO_2) decreased with EBRT from 13.0 to 9.5 g m^{-3} h^{-1}.

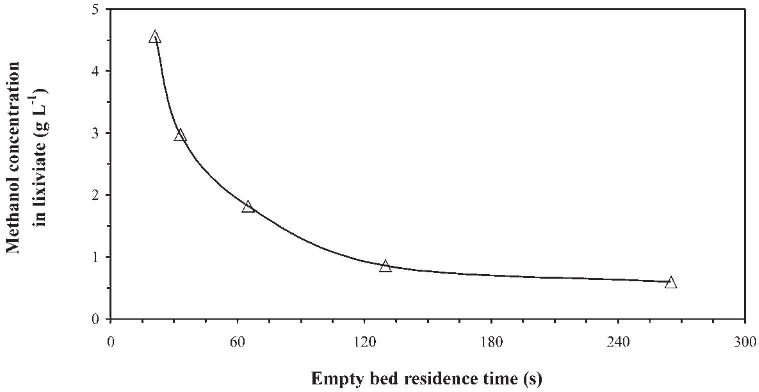

Figure 4. Variation of methanol concentration in lixiviate with empty bed residence time at a methanol inlet concentration of 1500 ppmv and nitrogen concentration in nutrient solution of 0.005 gN L^{-1}.

3.3 Role of lixiviate on methanol removal

Figure 4 shows that the methanol concentration in lixiviate decreased with EBRT. It passed from 4.5 g L^{-1} at 20 s to 0.5 g L^{-1} at 265 s. Since nutrient solution was renewed daily, absorption in the lixiviate was a mechanism for methanol removal. By comparing the curve of IL in Figure 3 with that of methanol concentration in lixiviate in Figure 4, it is evident that there is a direct relationship between the quantity of methanol in the inlet air flow rate to the methanol absorbed by the lixiviate. So that, the renewing of lixiviate is a way to remove methanol vapours from an air stream. The lixiviate in the present study contributed to obtain high removal efficiencies, especially at low nitrogen concentrations.

4 CONCLUSION

This study shows that the biotrickling filter is appropriate for controlling methanol vapour emissions at low nitrogen concentrations in nutrient solution. The BTF presents removal efficiencies of at least 70 % for concentrations as low as 0.0002 gN L^{-1} (tap water). The empty bed residence time greatly influences the BTF performance. BTF produces more carbon dioxide at small EBRTs. The lixiviate contributed to removal of methanol from the air stream.

5 ACKNOWLEDGEMENTS

The authors express their sincere acknowledgements to Natural Sciences and Engineering Research Council of Canada for the financial support.

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