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Methanol and ethanol treatment by biotrickling filtration: an experimental study

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ABSTRACT. The paper is related to the development of a high performance BTF to control methanol and ethanol emissions. Removal efficiency was studied in terms of various operational parameters such as inlet concentration of alcohol and empty bed residence time (EBRT). For an EBRT of 65 s, removal efficiency attained 75% in a range of ethanol inlet concentration of 1200 to 8000 ppmv, and in a range of methanol inlet concentration of 400 to 6500 ppmv. These results show that BTF removal efficiency was not affected by VOC concentration at constant EBRT. On the other hand, the EBRT has a direct effect on removal efficiency. When BTF operated at an ethanol inlet concentration of 400 ppmv the removal efficiency was nearly 100 % for an EBRT in the range of 65 s to 130 s, and it was 75 % for an EBRT of 30 s. Carbon dioxide generation was also analyzed and correlated with BTF performance.

1 INTRODUCTION

Methanol and ethanol are two volatile organic compounds (VOCs) which are among the most emitted pollutants in Canada. Both alcohols are toxic to human health, depending on exposure, and both of them are related to environmental problems, like smog and odour generation. There are several technologies for treating alcohol emissions: chemical, physical and biotechnological treatments. The biotrickling filter (BTF) is of considerable interest for 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). 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 *et al.*, 2005a; Avalos *et al.*, 2005b). There are few studies which discuss ethanol and methanol emissions control by using BTF (Cox *et al.*, 2001; Sologar *et al.*, 1997). The aim of this research is to develop a high performance BTF to control high inlet loads of ethanol and methanol emissions.

2 MATERIALS AND METHODS

The experiments were performed using two identical biotrickling filters. The experimental setup is shown on Figure 1. The setup consisted of a bubbler, a humidification column, a biotrickling filter, a holding tank and a recycling pump. The nutrient liquid solution was fed into the BTF in a countercourant flow with respect to air flow rate. The concentrations of alcohol were measured continuously with a total hydrocarbon analyzer. The concentrations of carbon dioxide in air were measured continuously with a portable gas analyzer. BTF performance was evaluated in terms of inlet load, elimination capacity and removal efficiency.

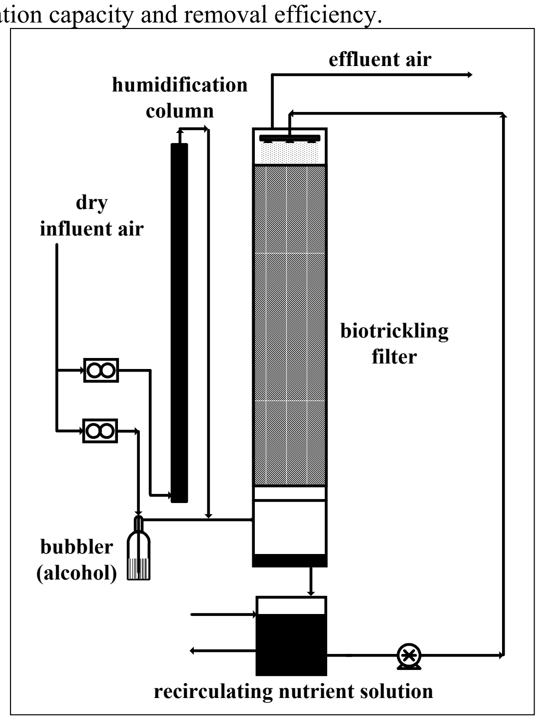

Figure 1. Schematic representation of biotrickling filter.

3 RESULTS AND DISCUSSION

3.1 Effect of ethanol and methanol inlet concentration on removal efficiency

Figure 2 shows removal efficiency as a function of ethanol and methanol inlet concentration at an air flow rate of 1.0 $m^3\ h^{-1}$. For ethanol inlet concentration from 100 to 1200 ppmv, the removal efficiency showed a sharp decrease from 100 % to 80 %. For inlet concentrations from 1200 to 8000 ppmv, the removal efficiency decreased slightly, from 80 % to 75 %. For methanol the removal efficiency varied as follows: a) from 200 to 400 ppmv, removal efficiency decreased from 95 % to 75 %; b) from 400 to 9600 ppmv, removal efficiency decreased slightly from 75 % to 65 %; and c) from 9600 to 15000 ppmv, removal efficiency was constant at 65 %. BTF appeared to be an appropriate bioprocess for controlling ethanol and methanol emissions in a wide range of inlet concentrations. BTF presented a competitive performance without being adversely affected at high alcohol inlet concentrations.

3.2 Effect of empty bed residence time (EBRT) on BTF performance

Figure 3 shows the variation of removal efficiency with EBRT. BTF was operated at two ethanol inlet concentrations, 400 and 1200 ppmv, and three residence times: 30, 65 and 130 s. For methanol experiments, BTF operated at 800 ppmv and two residence times: 30 and 65 s. For both alcohols, removal efficiency increased with residence time, specially in the range of 30 s to 65 s. In this range of EBRT and at an ethanol inlet concentration of 400 ppmv, removal efficiency increased from 75 to nearly 100 %. In the same range of EBRT and at a methanol inlet concentration of 800 ppmv, removal efficiency increased from 55 to 80 %. In the range of 65 s to 130 s, removal efficiency was constant at an ethanol inlet concentration of 400 ppmv and it increased slightly at an ethanol inlet concentration of 1200 ppmv. BTF presented a better performance in the case of ethanol, probably because of ethanol is less toxic than methanol.

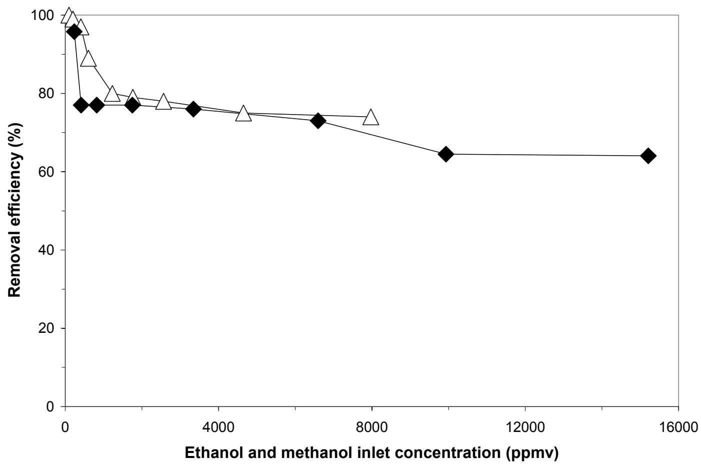

Figure 2. Variation of removal efficiency with (Δ) ethanol and (♦) methanol inlet concentration. The air flow rate was constant at 1.0 m^3 h^{-1}.

3.3 Effect of ethanol and methanol inlet concentration on carbon dioxide production

Figure 4 shows the variation of (C-CO_2 produced/C-alcohol removed) ratio with alcohol inlet concentration. The (C-CO_2 produced/C-alcohol removed) ratio presented a similar tendency for both alcohols. The ratio firstly increased and reached a maximum at 200 ppmv for both alcohols. Then, it decreased with increasing alcohol inlet concentration; by decreasing sharper the ratio for methanol than the ratio for ethanol. Finally, the ratio for methanol was constant in the range of 7000 ppmv to 15000 ppmv. This ratio represents the percentage of carbon mineralized from carbon removed. BTF mineralized a higher percentage of carbon from ethanol than from methanol. This could be interpreted as follows: a) ethanol is less toxic than methanol, so it is possible that there is more biomass present in the BTF treating ethanol, or b) a greater quantity of carbon compounds is transferred to nutrient solution in the BTF treating methanol.

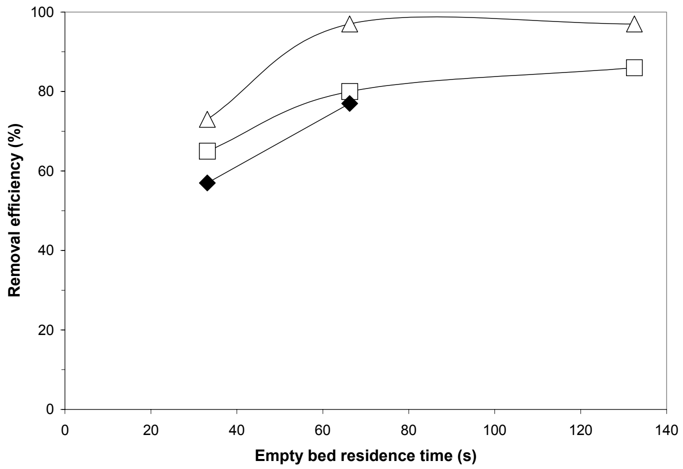

Figure 3. Variation of removal efficiency with empty bed residence time. (Δ) ethanol inlet concentration of 400 ppmv, (□) ethanol inlet concentration of 1200 ppmv, (♦) methanol inlet concentration of 800 ppmv.

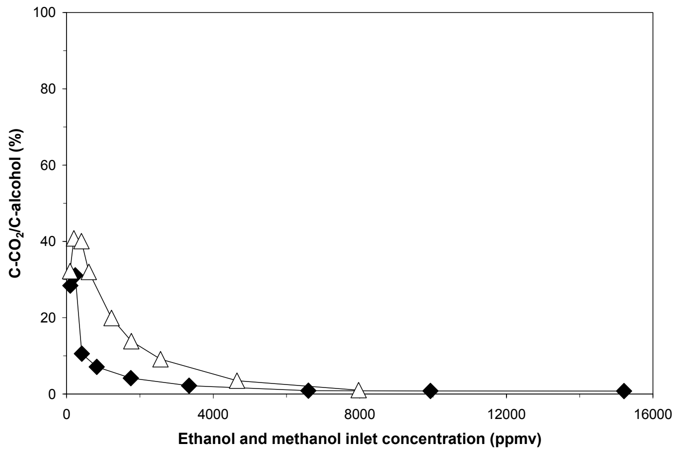

Figure 4. Variation of (C-CO_2/C-alcohol) ratio with (Δ) ethanol and (♦) methanol inlet concentration. The air flow rate was constant at 1.0 m^3 h^{-1}.

4 CONCLUSIONS

This study shows that the biotrickling filter is appropriate for controlling ethanol and methanol emissions at high inlet loads. The BTF presents removal efficiency of at least 75 % for ethanol inlet concentrations up to 8000 ppmv. In the case of BTF treating methanol, the removal efficiency is at least 65 % at inlet concentrations up to 15000 ppmv. The empty bed residence time has a great influence on BTF performance, specifically at residence times smaller than 65 s. BTF mineralizes a greater percentage of carbon from ethanol than from methanol. This is probably due to different toxicities of the alcohols and possibly to the different metabolites released by the microorganisms in the BTF.

5 ACKNOWLEDGEMENTS

The authors express their sincerely acknowledgements to Natural Sciences and Engineering Research Council of Canada for the financial support. We wish to thank the technical contribution of Louise Bibeau, research assistant, in the realization of this work.

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