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The Development of a Biofilter to Reduce Atmospheric Methane Emissions from MSW Landfills

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요 약 문

Biofilter performance to reduce CH_4 emissions from MSW landfills was tested under a variety of environmental and design conditions. The optimum soil moisture content for CH_4 oxidation in a loamy sand was 13% by weight. The addition of NO_3-N did not affect the CH_4 oxidation rate. Soil depths of 30 cm and 60 cm were equally efficient in CH_4 oxidation. When the CH_4 loading rate was decreased, the percentage of CH_4 oxidized increased. The maximum CH_4 oxidation rate was 27.2 mol $m^{-2}d^{-1}$ under optimum conditions (loamy sand soil, 13% moisture content, 30 cm soil depth, and an loading rate of 32.8 mol $m^{-2}d^{-1}$). Based on the above results, the installation of a properly sized and managed biofilter above a landfill cover should be capable of achieving a major reduction in atmospheric methane emissions from MSW landfills built with RCRA covers.

Key Words: Methane, oxidation, biofiltration, greenhouse gas, landfill gas.

1.Introduction

Methane is a very potent greenhouse gas, second only to CO_2 as an anthropogenic contributor to global warming (U.S. EPA, 1999). Its contribution to global warming is significant since it is approximately 20-35 times more effective at trapping heat than CO_2 (Boeckx et al., 1996; Parsons, 1995; U.S. EPA 1999; Yasushi et al., 1993).

Methane can be degraded in the presence of oxygen by methanotrophic bacteria. Microbiological CH_4 oxidation in aerated soil is an important sink for CH_4 emissions (Bender and Conrad, 1995). Methane from many modern municipal solid waste landfills with RCRA (Resource Conservation and Recovery Act) covers is vented directly to the atmosphere, except for some of the largest landfills at which it is collected and burned.

Proper application of microbiological oxidation of CH_4 in soil may provide the basis for designing biofilter systems through which landfill gas may be passed prior to its release to the atmosphere. Therefore, the objective of this study was to develop a lab-scale model biofilter system using soil as the filter bed medium and to evaluate the effect of environmental and design factors on the CH_4 oxidation capacity of the soil biofilter system.

2. Materials and Methods

A series of laboratory experiments were conducted using soil columns packed with loamy sand to evaluate the major factors controlling the CH_4 oxidation capacity of a soil biofilter (Fig.1).

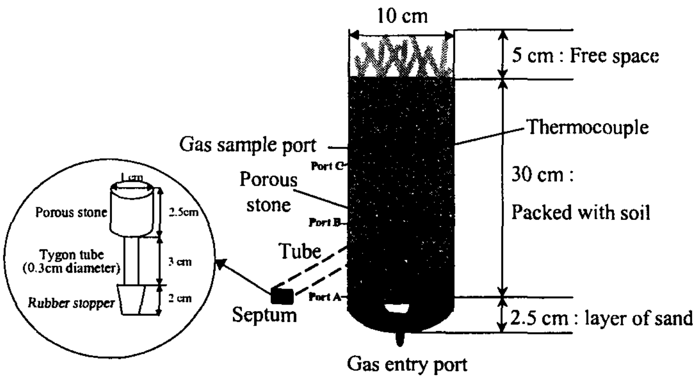

Fig. 1. Schematic diagram of a soil column and gas sampling device.

Before the columns were filled with soil, fertilizer was added to the soil to insure adequate plant nutrition. After the columns were filled with soil, they were planted with ryegrass, *Lolium perenne*, (1.45 g seed per column) and kept moist for periods of 30 or 90 days. After the 30 or 90 day incubation period was completed, CH_4 was introduced at a controlled rate to the gas entry port in the bottom of the columns using a cassette pump. The loading rates were 16.4, 24.6 and 32.8 mol CH_4 $m^{-2}d^{-1}$. Following a 48-hr equilibration period after the introduction of CH_4, gas samples were taken on 3 successive days from all sampling ports. Samples were analyzed for CH_4 and O_2 concentration using a gas chromatograph and an oxygen meter. CH_4 oxidation rate was calculated from the difference between inflow and outflow CH_4 concentrations and CH_4 loading rate.

3. Results and Discussion

Gas Concentration Profiles

The CH_4 concentration increased with depth and the O_2 concentration decreased with depth (Fig. 2). The depth of peak decrease in CH_4 concentration varied with treatments and CH_4 loading rates. The decrease in O_2 concentration with depth was due to O_2 consumption by methanotrophic activities and indicates the area at which the majority of CH_4 oxidation was occurring.

Effect of Soil Moisture

The loamy sand soil with 13% moisture content had higher oxidation rates, than the same soil with 5 or 20% moisture content (Table 1). The higher moisture content (20%) reduced methanotrophic activity by restricting O_2 diffusion in soil. Although gas diffusion in the drier soil is faster than in wetter soil, the lower moisture content (5%) reduced methanotrophic activity due to water stress. The optimum moisture content of

13% allowed both rapid gas diffusion and sufficient methanotrophic activity to oxidize CH_4.

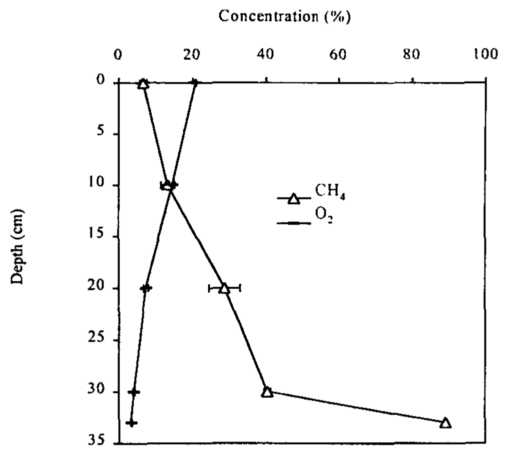

Fig. 2. Gas concentration profiles in 30cm deep soil columns with 13% moisture content, 25 mg kg^{-1} NO_3-N, 32.8 mol CH_4 $m^{-2}d^{-1}$ loading rate, and a 30 day incubation time. Data points are means ±SD (n=3).

Table 1. The influence of soil moisture content on CH_4 oxidation rate in 30 cm deep soil columns with 25 mg kg^{-1} NO_3-N, 32.8 mol CH_4 $m^{-2}d^{-1}$ loading rate and a 30 day incubation time. *All data are presented as the means ±SD (n=3). Means with same letter are not significantly different at the a= 0.05 level.

Moisture Content (%)	CH_4 oxidation rate* (mol CH_4 $m^{-2}d^{-1}$)±SD	Total CH_4 Oxidation (% of applied CH_4)
5	24.4 (±0.49) b	74
13	27.2 (±0.17) a	83
20	18.1 (±1.84) c	55

Effect of NO_3-N

The treatments of 10, 25 and 50 mg NO_3-N kg^{-1} soil had similar oxidation rates. This indicates that the amount of NO_3-N added to soil has no effect on the CH_4 oxidation rate. Periodic nitrogen additions to biofilter soils will be necessary to support a healthy vegetative cover, which prevent erosion and remove excess water. The results presented here indicate that NO_3-N can be used as a nitrogen source to support plant growth in a biofilter system without adversely influencing CH_4 oxidation

Effect of Soil Depth

No significant difference was found between CH_4 oxidation rates in 30 cm and 60 cm deep soil columns. Methane oxidation rates in both soil columns showed peak oxidation rates at approximately 30 cm depth. This indicates that 30 cm is depth in the biofilter at which the methanotrophic community will develop. The results of this experiment indicate that both 30 and 60 cm soil depth were equally efficient in CH_4

oxidation at a CH_4 loading rate of 32.8 mol CH_4 $m^{-2}d^{-1}$.

Effect of CH_4 Loading Rate

As CH_4 loading rate decreased, the total amount of CH_4 oxidized increased (Table 2). Methane loading rate is an important factor which determines biofilter efficiency. Too high a CH_4 loading rate will reduce the O_2 in the soil air, which may inhibit methanotrophic activity. Too low a CH_4 loading rate may not stimulate methanotrophic activity and thus CH_4 may not serve as suitable growth substrate.

Table 2. The influence of CH_4 loading rate on CH_4 oxidation rate in 30 cm deep soil columns with 13 % moisture content, 25 mg kg^{-1} NO_3-N and a 90 day incubation time. *All the data are presented as the means ±SD (n=3). **Means of total CH_4 oxidation followed by the same letter are not significantly different (α=.05).

CH_4 loading rate (mol CH_4 $m^{-2}d^{-1}$)	CH_4 oxidation rate* (mol CH_4 $m^{-2}d^{-1}$) ±SD	Total CH_4 Oxidation** (% of applied CH_4)
16.4	13.7 (±0.63)	83 a
24.6	18.9 (±0.23)	77 ab
32.8	23.4 (±3.81)	71 b

4.Conclusions

Biofilter performance was tested under a variety of environmental and design conditions. The optimum soil moisture content for CH_4 oxidation in the loamy sand was 13% by weight. The amount of NO_3-N added to soil had no effect on the CH_4 oxidation rate. At a CH_4 loading rate of 32.8 mol CH_4 $m^{-2}d^{-1}$, the 30 and 60 cm soil depths were equally efficient in their ability to oxidize CH_4. As the CH_4 loading rate decreased, the percentage of applied CH_4 that was oxidized increased. Based on the this study, the use of a properly sized and managed biofilter should be capable of achieving a major reduction in atmospheric CH_4 emissions from MSW landfills built with RCRA covers.

5.References

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