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Methane emissions from MSW landfill with sandy soil covers under leachate recirculation and subsurface irrigation

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A B S T R A C T

CH_4 emissions and leachate disposal are recognized as the two major concerns in municipal solid waste (MSW) landfills. Recently, leachate recirculation was attempted to accelerate land-filled waste biodegradation and thus enhanced landfill gas generation. Leachate irrigation was also conducted for volume reduction effectively. Nevertheless, the impacts of leachate recirculation and irrigation on landfill CH_4 emissions have not been previously reported. A field investigation of landfill CH_4 emissions was conducted on selected sandy soil cover with leachate recirculation and subsurface irrigation based on whole year around measurement. The average CH_4 fluxes were 311 ± 903, 207 ± 516, and 565 ± 1460 $CH_4\,m^{-2}\,h^{-1}$ from site A without leachate recirculation and subsurface irrigation, lift B2 with leachate subsurface irrigation, and lift B1 with both leachate recirculation and subsurface irrigation, respectively. Both gas recovery and cover soil oxidation minimized CH_4 emissions efficiently, while the later might be more pronounced when the location was more than 5 m away from gas recovery well. After covered by additional clay soil layer, CH_4 fluxes dropped by approximately 35 times in the following three seasons compared to the previous three seasons in lift B2. The diurnal peaks of CH_4 fluxes occurred mostly followed with air or soil temperature in the daytimes. The measured CH_4 fluxes were much lower than those of documented data from the landfills, indicating that the influences of leachate recirculation and subsurface irrigation on landfill CH_4 emissions might be minimized with the help of a well-designed sandy soil cover. Landfill cover composed of two soil layers (clay soil underneath and sandy soil above) is suggested as a low-cost and effective alternative to minimize CH_4 emissions.

1. Introduction

Methane (CH_4) is an important greenhouse gas because its global warming potential is 21 times more effective than that of CO_2 (IPCC, 2001). Atmospheric CH_4 concentration has more than doubled during the past several 100 years and continues to rise (IPCC, 2001). Of the global anthropogenic CH_4 emissions, more than 10% originate from municipal solid waste (MSW) landfills (IPCC, 2001). Landfill CH_4 is produced from anaerobic biodegradation of organic matter in the land-filled waste (Bogner et al., 1995; Kumar et al., 2004). CH_4 emissions vary significantly among the landfill sites and are affected by, e.g. gas recovery, microbial CH_4 oxidation, landfill age, the thickness of landfill cover, and meteorological conditions.

Gas recovery has been reported to control CH_4 emissions from the landfill sites effectively (Mosher et al., 1999; Lohila et al., 2007). Microbial oxidation of CH_4 in cover soils provides a complementary strategy for minimizing landfill CH_4 emissions (Barlaz et al., 2004; Berger et al., 2005; Abichou et al., 2006). Nevertheless,

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CH_4 oxidation rate varies significantly among soils. Kightley et al. (1995) documented that amendment with coarse sand enhanced CH_4 oxidation capacity by 26% compared with the unamended control soil. Berger et al. (2005) reported that 57–98% of CH_4 was oxidized within a simulated landfill cover; the maximum value was developed by porous coarse sandy soil. Generally, the topsoil of coarse texture shows a higher CH_4 oxidization rate than the fine one due to its well-aeration property (Boeckx et al., 1997; Berger et al., 2005; Watzinger et al., 2005). Apart from soil texture, increasing the thickness of cover soil elongates the retention time of transported CH_4 and results in a higher proportion oxidized accordingly (Abichou et al., 2006; Stern et al., 2007).

Besides greenhouse gas emissions, leachate treatment is another problematic issue attracting great concerns in landfill management. Bioreactor landfill is characterized by recirculating of liquid (e.g., leachate) to waste layer to accelerate waste biodegradation and increase landfill gas production (Chan et al., 2002; Sanphotia et al., 2006; Benson et al., 2007; He et al., 2007). Given that the landfill was operated under the same conditions of capping and gas extraction, the enhanced CH_4 production could raise the risk of higher CH_4 emissions from MSW landfill. On the other hand, leachate can be reduced effectively through soil irrigation by solar evaporation (Maurice et al., 1999; Lee et al., 2002; Watzinger et al., 2005; Dimitriou et al., 2006; Zalesny et al., 2007). Leachate irrigation to soils could decrease O_2 availability and thus inhibits microbial CH_4 oxidation (Haubrichs and Widmann, 2006). To this day, only Maurice et al. (1999) and Watzinger et al. (2005) reported the impact of leachate irrigation on microbial oxidation of CH_4 in soils. However, CH_4 emissions from landfill site under both leachate recirculation and irrigation have not been previously explored.

The study is to make a field investigation on diurnal and seasonal variations of CH_4 emissions from two landfill sites under different operations. The effects of leachate recirculation to waste layer, subsurface irrigation to cover soil, and soil thickness on CH_4 emissions were evaluated from landfill sites covered by the selected sandy soils.

2. Materials and methods

2.1. Experimental site

Tianziling MSW landfill was located at a valley in northern part of Hangzhou City (30°23′N, 120°12′E), eastern China. The land filling practice was operated in lift by lift under loading capacity of approximately 2000 t d^{-1} from 2001 to 2007 (Fig. 1). The compositions of the land-filled waste were listed in Table 1. The proportion of food waste accounted for approximately 60%, which indicated a high potential of CH_4 formation. Two landfill sites were designed for sampling: site A without leachate recirculation and subsurface irrigation and site B with leachate recirculation and subsurface irrigation.

Table 1
Compositions of the land-filled waste in Hangzhou tianziling landfill[a]

Compositions (%, wet weight)	Year		
	1999–2001	2002–2004	2005–2006
Food waste	52.0±0.99	60.1±8.11	59.3±15.5
Papers	12.6±0.24	9.97±1.49	7.50±3.86
Texture	1.21±0.37	1.84±0.80	2.19±1.85
Bamboo/woods	1.53±1.09	2.55±1.71	4.16±4.07
Plastics	12.6±2.29	14.3±1.44	21.9±11.6
Metals	0.84±0.06	1.12±0.34	0.77±0.21
Glass	0.87±0.31	1.96±0.38	1.05±0.52
Stone and others	18.4±1.98	8.35±5.04	3.09±0.80

[a] The data are shown as the mean (±SD) of the 3 waste samples.

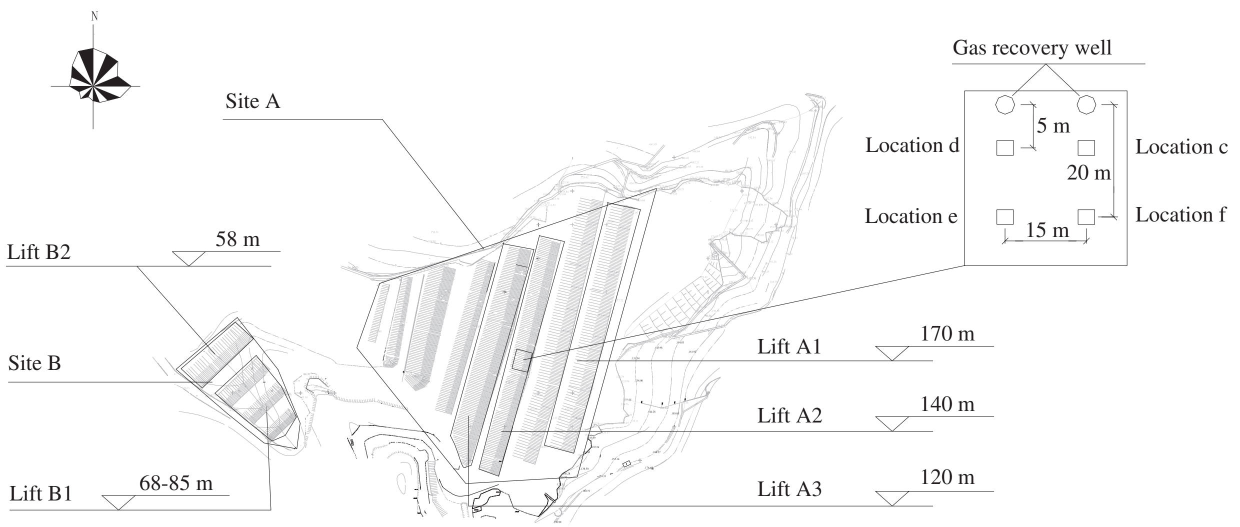

Fig. 1. Diagrammatic sketch of the sampling locations and lifts in Hangzhou tianziling landfill. Site A, without leachate recirculation and subsurface irrigation; lift B1, with leachate recirculation and subsurface irrigation; lift B2, with leachate subsurface irrigation.