Waste Management 34 (2014) 770–779

Contents lists available at ScienceDirect

Waste Management

journal homepage: www.elsevier.com/locate/wasman

Reduction of odours in pilot-scale landfill biocovers

M.A. Capanema [a,1], H. Cabana [b], A.R. Cabral [c,*]

[a] Laboratório de Pesquisas em Resíduos Sólidos, LARESO – Depto de Engenharia Sanitária e Ambiental, Universidade Federal de Santa Catarina, Campus Universitário, CEP 88040-970, Florianópolis, SC, Brazil

[b] Environmental Engineering Laboratory, Department of Civil Engineering, Université de Sherbrooke, Sherbrooke J1K 2R1, Canada

[c] Geoenvironmental Group, Department of Civil Engineering, Université de Sherbrooke, Sherbrooke, Quebec J1K 2R1, Canada

ARTICLE INFO

Article history:
Received 10 July 2013
Accepted 23 January 2014
Available online 17 February 2014

Keywords:
Odour abatement
Total reduced sulfur
Biocover
Landfill

ABSTRACT

Unpleasant odours generated from waste management facilities represent an environmental and societal concern. This multi-year study documented odour and total reduced sulfur (TRS) abatement in four experimental landfill biocovers installed on the final cover of the Saint-Nicéphore landfill (Canada). Performance was evaluated based on the reduction in odour and TRS concentrations between the raw biogas collected from a dedicated well and the emitted gases at the surface. Odour analyses were carried out by the sensorial technique of olfactometry, whereas TRS analyses followed the pulse fluorescence technique. The large difference of 2–5 orders of magnitude between raw biogas (average odour concentration = 2,100,000 OU m^{-3}) and emitted gases resulted in odour removal efficiencies of close to 100% for all observations. With respect to TRS concentrations, abatement efficiencies were all greater than 95%, with values averaging 21,000 ppb of eq. SO_2 in the raw biogas. The influence of water infiltration on odour concentrations was documented and showed that lower odour values were obtained when the 48-h accumulated precipitation prior to sampling was higher.

1. Introduction

The anaerobic decomposition of organic wastes within landfills generates a biogas composed of two important greenhouse gases, methane (CH_4, 50–60%), and carbon dioxide (CO_2, 40–50%). Biogas also includes trace concentrations (<1%) of hazardous and odour pollutants, such as volatile organic compounds (VOCs; e.g. benzene, toluene, ethylbenzene and xylene, or BTEX), halogenated hydrocarbons, mercury (gaseous elemental Hg) and some odorous gases, such as sulfur compounds (Ducom et al., 2009; IPCC, 2007; Kim et al., 2001; Scheutz et al., 2008; Zou et al., 2003).

Unpleasant odours generated from waste management facilities represent an environmental and societal concern because they negatively affect the quality of life of the surrounding population, particularly if the landfill is located relatively close to crowded areas, as is the case with several landfills in China (He et al., 2011). The main environmental and societal impacts of odour emissions are: reduction of quality of life, decreases in local property values; a population which becomes more sensitive to and less tolerant of odours, potentially leading to odour complaints, and risks to workers' health associated with the toxicity of some odorous and trace compounds. In addition, the public is concerned about the unknown effects of long-term exposure to landfill emissions (He et al., 2011; Scheutz et al., 2008; Sironi et al., 2005; USEPA, 2008).

Landfill odour emissions vary with meteorological conditions (e.g. atmospheric pressure and temperature) and within different sectors of the landfill. For example, odour concentrations of 120, 240 and 320 OU m^{-3} (odour units per cubic meter) have been measured on final covers, daily covers and in the air, respectively; whereas for raw landfill biogas, odour concentrations were quite high, with values between 250,000 and 1,200,000 OU m^{-3} (Capelli et al., 2008; Micone and Guy, 2007; Sironi et al., 2005).

Total reduced sulfur (TRS) are odorous compounds found in landfill biogas (Ducom et al., 2009; Sironi et al., 2005). The main sulfur compounds are: hydrogen sulfide (H_2S), methyl mercaptan (CH_3SH), dimethyl sulfide (DMS, $(CH_3)_2S$), carbonyl sulfide (COS), carbon disulfide (CS_2) and dimethyl disulfide (DMDS, $(CH_3)_2S_2$). H_2S has the characteristic smell of rotten eggs and is one of the main odorous compounds in landfill biogas. In addition, it is the most abundant (~80%) among sulfur compounds (Ducom et al., 2009; Hurst et al., 2005; Kim, 2006a; Lee et al., 2006).

* Corresponding author. Address: 2500, boul. de l'Université, Sherbrooke, Quebec J1K 2R1, Canada. Tel.: +1 819 821 7906; fax: +1 819 821 7974.

E-mail addresses: marlon.capanema@usherbrooke.ca (M.A. Capanema), hubert.cabana@usherbrooke.ca (H. Cabana), alexandre.cabral@usherbrooke.ca (A.R. Cabral).

[1] Geoenvironmental Group, Department of Civil Engineering, Université de Sherbrooke, Sherbrooke, Quebec J1K 2R1, Canada.

http://dx.doi.org/10.1016/j.wasman.2014.01.016
0956-053X/© 2014 Elsevier Ltd. All rights reserved.

Landfill sites have to comply with odour concentration and/or odour emission limits established by local regulations. The emissions can be controlled by gas recovery systems, daily covers, final covers, and masking and neutralizing techniques. However, it has been shown that gas recovery and final covers are not 100% efficient. In fact, gas recovery efficiencies can vary from 50% to 85% (Lombardi et al., 2006; Manfredi et al., 2009; Spokas et al., 2006). Final cover integrity can be compromised by erosion caused by intense rainfall and differential settlement of the waste mass, the results of which are localized cracks or hotspots that facilitate release of biogas directly to the atmosphere as fugitive emissions (Lee et al., 2006). In relation to masking and neutralizing techniques, some products consisting in a mix of water and essential oils (i.e. concentrated hydrophobic liquids extracted from plants) are used to mask or neutralize the odour of ambient air and provide a better olfactory comfort. It is rather a palliative approach that diminishes the odour nuisance, without necessarily eliminating it from the odour source. Several studies have been carried out to investigate the masking effects of odour compounds in gas mixtures (ADEME, 2008; Kim, 2010, 2011; MDDEP, 2006).

Management practices that could mitigate odour emissions are extremely important in connection with the social acceptance and environmental sustainability of waste management facilities. Thus, landfill biocovers constitute an effective alternative for odour abatement. A biocover, which is part of a landfill final cover, optimizes the development and activity of ubiquitous microorganisms that can oxidize CH_4 (into CO_2), and some VOCs and sulfur compounds in landfill biogas (IPCC, 2007; Iranpour et al., 2005). In addition, physical–chemical reactions, such as adsorption and absorption, can take place in the biocover soils, reducing their concentrations in the gas emitted to the atmosphere (Cooper and Alley, 2002; Ducom et al., 2009; He et al., 2011). The potential of odour abatement within landfill biocovers is high, with the reported removal efficiencies of 70–100% (Hurst et al., 2005; Iranpour et al., 2005). Solan et al. (2010) obtained odour abatement of 50% in a 0.20-m deep alternative daily cover constructed with demolition and construction wastes and woodchips.

A great number of studies about landfill biocovers have focused on the biotic oxidation of CH_4 (Capanema and Cabral, 2012; Huber-Humer et al., 2008; Scheutz et al., 2009; Stern et al., 2007). However, few studies have documented odour abatement and among those treating the subject, few have used the sensorial method of olfactometry. This study documented the odour removal in four experimental biocovers under actual field conditions by olfactometry and TRS analyses. The four biocovers were constructed at the Saint-Nicéphore landfill (Quebec, Canada) and monitored during four years (2009–2012). Biocover performances (or efficiencies) were calculated based on the reduction in odour and TRS concentrations between the raw biogas collected from a dedicated biogas well and the emitted gas at the surface of the field plots. Biogas loading, atmospheric pressure, temperature, precipitation and degree of water saturation (S_r) were the main parameters monitored during the study period.

2. Materials and methods

2.1. Field plots

This study is part of a multidisciplinary research project that started in 2006, with the initial goal of evaluating the microbial oxidation of the greenhouse gas CH_4 using biocovers in actual field conditions (details in Cabral et al., 2010b; Capanema and Cabral, 2012). Overall, eight field plots – namely biocovers 1B, 2, 3B and 4, and field columns (FC) 1, 2, 3 and 4 – were constructed and monitored at the Saint-Nicéphore landfill (Quebec, Canada). In 2009, odour and total reduced sulfur abatement started to be evaluated. The present study was carried out on four field plots (biocovers 1B and 2, and FC 2 and FC 4), the characteristics of which are presented in Table 1. Samples were collected during the 2009–2012 sampling campaigns.

Biocover 1B measured 2.45 m (W) × 9.45 m (L). Its configuration included, from the bottom up, a 1.90-m gas distribution layer (GDL) of 12.7-mm clean gravel, a 0.50-m transitional layer of 6.4-mm gravel and a 0.30-m substrate layer (Fig. 1). The latter consisted of one volume of a mixture of sand and compost (1:5 v/v) mixed with one volume of 6.4-mm gravel, with a resulting organic matter content of 7.2% $g_{o.m.}/g_{dry\ soil}$, a density (ρ_d) of 1500 kg m^{-3} and a total porosity of 48% (Table 1). Biocover 1B can also be considered as a biowindow, given that, for its construction, the final cover was excavated down to the waste mass, and it was constructed using higher permeability material to facilitate gas transport and promote CH_4 oxidation. As a consequence, the biogas loading could not be controlled (or monitored) for this particular field plot.

Biocover 2 measured 2.45 m (W) × 9.45 m (L). Its configuration included, from the bottom up, a 0.30-m gas distribution layer of 12.7-mm clean gravel, a 0.10-m transitional layer of 6.4-mm gravel and a 0.80-m substrate layer (Fig. 2). Its substrate consisted of the same mixture of sand and compost used in biocover 1B and had an organic matter content of 20% $g_{o.m.}/g_{dry\ soil}$, a density (ρ_d) of 700 kg m^{-3} and a total porosity of 64% (Table 1). Biocover 2 was fed with biogas from a dedicated well installed near the field plots. The amount of biogas provided to the plots was controlled by means of a valve (with the exception of biocover 1B), and the flow was measured using a flow meter (Cole Parmer Co). Biocovers 1B and 2 were insulated from the silty soil constituting the final cover by a 1.5-mm HDPE geomembrane (impermeabilization) and 0.15-m polystyrene panels. This insulation prevented lateral migration of moisture due to temperature gradients. In addition, the two biocovers were subdivided into four sections along their main axis. In each, temperature (TMC20-HD; coupled HOBO U12 data loggers from Onset) and water content (ECH2O EC-5; connected to Em50 loggers from Decagon) were continuously monitored at several depths (e.g. 0.10 m).

FC 2 and FC 4 measured 0.90 m × 0.90 m. Their configuration included, from the bottom up, a 0.10-m gas distribution layer of 12.7-mm clean gravel, a transitional layer of a fine wire mesh (to

Table 1
Characteristics of the field plot substrates.

Field plot	Substrate	Thickness (m)	Organic matter content (% $g_{o.m.}/g_{dry\ soil}$)	Density (kg m^{-3})	Total porosity (%)
Biocover 1B	Mixture of sand-compost and gravel	0.30	7.2	1500	48
Biocover 2	Mixture of sand-compost	0.80	20.0	700	64
Field column 2	Top soil	0.15	5.7	1209	52
	Sand	0.30	0.8	1611	41
Field column 4	Mixture of top soil and compost	0.05	9.4	n.d.[a]	n.d.[a]
	Top soil	0.10	6.0	1285	52
	Sand	0.30	0.7	1526	41

[a] n.d.: not determined.