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Research article

Methane hotspot localization and visualization at a large-scale Xi'an landfill in China: Effective tool for landfill gas management

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ABSTRACT

The variation characteristics and influence factors of methane emission at Jiangchungou landfill, one of the largest landfill in China, has been investigated by a one-year field monitoring campaign during 2015–2016. The methane concentration above the landfill surface varied widely from negligible to 33,975 ppm. At least 75% of the methane concentration values of the sampling points are lower than the allowed limit (500 ppm). More than 95% of the high concentration zones (> 500 ppm) were located in the temporary cover area (TA). Several environmental factors were found to be related to the variation of the concentration values. A clear correlation was observed between barometric pressure and exceeding-standard areas with a correlation coefficient of −0.743 ($p < 0.1$). The concentration values in the final cover area (FA) were about one order of magnitude lower than those observed in the TA due to the fact that rapid methane production rate happened in the first 180 days after the high kitchen content wastes were landfilled. The percentages of the measured concentration values exceeding 500 ppm near the gas collection wells in TA zone were 71.5% in November, 2015 and 55.7% in January, 2016 due to the leakage from the sides of gas collection wells. The average methane concentration values on the HDPE geomembrane was higher than those observed on the loess cover due to the fact that the geomembrane was relatively thin (0.5 mm) and can be easily damaged by the operation vehicles. Thicker geomembranes (> 1.5 mm) with a good construction quality control are expected to provide better performance at this site.

1. Introduction

Municipal solid waste (MSW) landfills contain large amounts of organic materials. They will degrade in anaerobic conditions to produce large amounts of landfill gas (LFG), which is mostly represented by methane and carbon dioxide (Huber-Humer et al., 2008). MSW landfills have been identified as one of the major anthropogenic sources of methane emissions (Ishigaki et al., 2005; Aronica et al., 2009; Lou and Nair, 2009). Methane is considered to be one of the major causes of global warming. Methane has a radioactive efficiency of 3.7×10^{-4} w/m^2 ppm compared to 1.4×10^{-5} w/m^2 ppm of CO_2. The greenhouse potential of methane is 25 times greater than that of CO_2 over a 100-year time horizon (IPCC, 2007; El-Fadel et al., 2012).

The variability of methane emissions from landfill surfaces can be attributed to the biological and physical processes that occur within the landfill waste body and cover soils (Nolasco et al., 2008; Tecle et al., 2009). The gas production rate of MSW is dependent on its fill age and tends to drop exponentially when it reaches its peak value. Under stable degradation conditions, the fill age of MSW will be one of the key factors affecting biogas production. Proper design and maintenance of cover systems are also very important in controlling gas emissions. Meteorological factors can also affect gas migration. Heroux et al. (2010) conducted a series of experiments on a Montreal landfill and pointed out that atmospheric temperature, rainfall, and atmospheric pressure have statistically significant effects on methane emissions. Bogner et al. (2011) monitored the variation of methane emission rates with the changes of space and seasons for 2 years at two California landfills. They found that methane emission rate at the operational surface was not dependent on seasonal changes. However, the variations in methane emission rate from temporary cover surface were found to be 4 orders of magnitudes greater than that from the final cover surface. The methane emission rates for the cases with a high density polyethylene (HDPE) geomembrane and without the geomembrane were compared by Trapani et al. (2013). Their results showed

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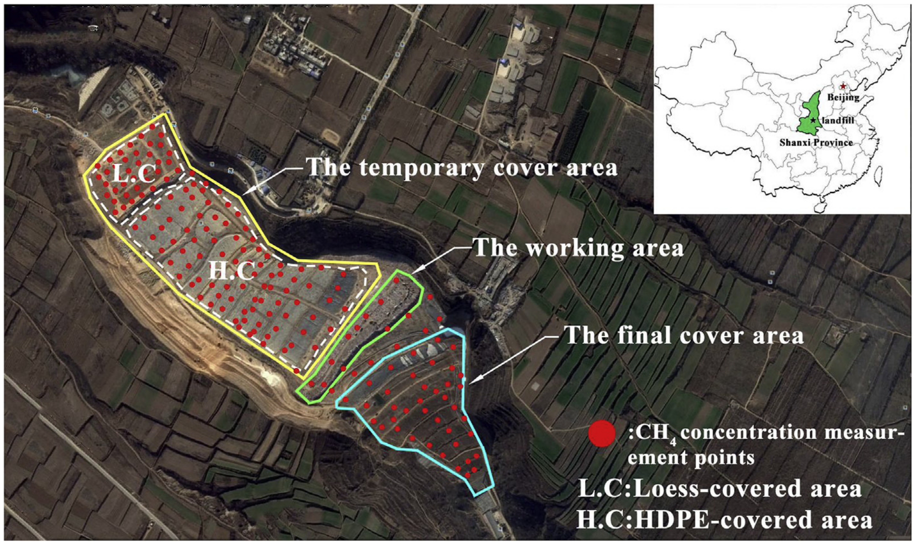

Fig. 1. Location of Xi'an Jiangcungou landfill.

that HDPE geomembrane played an important role in mitigating methane emissions.

Municipal solid waste in China contains large amounts of kitchen waste with an amount varying from 40% to 85% on wet basis (Chen et al., 2014). Kitchen waste is defined as food scraps and the waste produced by families, catering services, restaurants and other sources. The kitchen waste consists of rapidly degradable components such as sugar, protein and fat (75% by dry basis %) and cellulose (15% by dry basis %) (Gao et al., 2015; Jiang et al., 2018). The relatively lower content of cellulose results in lower methane generation capacity. These are the reasons for the faster methane generation rate and lower potential generation capacity of MSW in China compared to western countries (Chen et al., 2010). The existing whole-site methane monitoring campaigns were mainly conducted in landfills in developed countries with low-kitchen waste content (Capaccioni et al., 2011; Röwer et al., 2011; Trapani et al., 2013). However, very limited work has been carried out on field monitoring of gas emission from the high kitchen waste content landfills in China. Zhang et al. (2012) analyzed methane released from a clay-covered surface in a closed Chinese landfill and found that the methane concentration reached 87.22 mg/L (nearly 12% by volume). This concentration is much higher than that specified in the regulation (5% by volume) (GB50869-2013) and will last for a long time after the landfill was closed. It is thus of great importance to carry out full scale regular LFG emission monitoring investigations in China for active landfills. Periodical LFG emission monitoring is also necessary in response to specific requirements of current legislation and regulations on landfill management (Capaccioni et al., 2011). The long-term methane concentration data are very important for the landfill owners to understand the efficiency of the landfill cover system and the gas collection system. For the proper management of a landfill site in terms of economic costs and environmental issues, it is also necessary to propose an affordable method to check the real impact of landfill gas emission and the collecting systems.

There are some limitations for different existing gas monitoring methods including the most widely used static chamber method. For the whole landfill site monitoring, a large number of points are needed to quantify representative flux of the whole site (Gonzalez-Valencia et al., 2016). In this case, the chamber method is time and labor intensive (Scheutz et al., 2011). The methods including the mass balance and trace plume are also difficult to be adopted due to the needs for specialized and expensive instrumentation, infrequent measurements due to the intensive labor required to set up instruments, atmospheric stability and wind direction dependence, and the challenge of obtaining gas concentration distributions along the two planes. The portable laser measurement detector is an effective monitoring method for the determination of CH_4 concentration at the ground surface and hotspot identification, which would be undetected using static chambers.

The aim of this paper was to highlight the importance and the effectiveness of direct measurement to evaluate the overall methane emission from a high kitchen waste content landfill surface. The results can be used to improve landfill operations and management. A one-year methane concentration monitoring program using the portable laser measurement detector was carried out on a high kitchen waste content landfill located in Western China for the first time. The visualization of the seasonal variation of methane spatial distribution is depicted and the processes to screen and localize methane hot spots on the landfill cover are presented together with the factors affecting gas emission. The findings would be of great value for landfill cover design and LFG emission control in the high kitchen waste landfills. The data can also be used to check the validity of numerical models developed for assessment of methane emission from the landfill covers. This monitoring method also provides a good tool to optimize the efficiency of LFG recovery system.

2. Materials and methods

2.1. Experimental site description

Jiangcungou landfill site is located in the city of Xi'an in Northwest China. The landfill is the only waste disposal facility of the city (Zhan et al., 2016). It is a valley type landfill (34°14′55″N, 109°5′53″E) and occupies an area of 730,000 m^2. It was designed to contain 49 million m^3 of MSW and received about 6700 t of waste per day in January, 2016. The fraction of kitchen waste contained in the fresh MSW on site was 51.4% in wet mass. The fractions of other components, i.e., paper, wood, textile, plastic and ash are 12%, 2%, 4.4%, 14.8% and 12.3%, respectively (Guo, 2017).

As shown in Fig. 1, the total surface area of the landfill is 330,000 m^2. The whole site can be divided into 3 parts based on the ages of the waste landfilled: the final cover area (FA) (more than 2 years), the working area (fresh) and the temporary cover area (TA) (less than 1 year). The capping system in FA was constituted by 1 m compacted loess underlain by a 0.35 m gravel-geotextile layer. Temporary cover in the TA (L.C region) consisted of a 0.8 m thick layer of compacted loess. A 0.5 mm thick HDPE geomembrane was additionally

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