Environmental Pollution 234 (2018) 174–180

Contents lists available at ScienceDirect

Environmental Pollution

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

Methane emissions from a landfill in north-east India: Performance of various landfill gas emission models☆

Muralidhar Gollapalli, Sri Harsha Kota*

Department of Civil Engineering, Indian Institute of Technology, Guwahati, India

ARTICLE INFO

Article history:
Received 30 March 2017
Received in revised form
4 September 2017
Accepted 19 November 2017

Keywords:
Municipal solid waste
Chamber method
LandGEM
IPCC model

ABSTRACT

Rapid urbanization and economic growth has led to significant increase in municipal solid waste generation in India during the last few decades and its management has become a major issue because of poor waste management practices. Solid waste generated is deposited into open dumping sites with hardly any segregation and processing. Carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) are the major greenhouse gases that are released from the landfill sites due to the biodegradation of organic matter. In this present study, CH_4 and CO_2 emissions from a landfill in north-east India are estimated using a flux chamber during September, 2015 to August, 2016. The average emission rates of CH_4 and CO_2 are 68 and 92 mg/min/m^2, respectively. The emissions are highest in the summer whilst being lowest in winter. The diurnal variation of emissions indicated that the emissions follow a trend similar to temperature in all the seasons. Correlation coefficients of CH_4 and temperature in summer, monsoon and winter are 0.99, 0.87 and 0.97, respectively. The measured CH_4 in this study is in the range of other studies around the world. Modified Triangular Method (MTM), IPCC model and the USEPA Landfill gas emissions model (LandGEM) were used to predict the CH_4 emissions during the study year. The consequent simulation results indicate that the MTM, LandGEM-Clean Air Act, LandGEM-Inventory and IPCC models predict 1.9, 3.3, 1.6 and 1.4 times of the measured CH_4 emission flux in this study. Assuming that this higher prediction of CH_4 levels observed in this study holds well for other landfills in this region, a new CH_4 emission inventory (Units: Tonnes/year), with a resolution of $0.1^0 \times 0.1^0$ has been developed. This study stresses the importance of biodegradable composition of waste and meteorology, and also points out the drawbacks of the widely used landfill emission models.

1. Introduction

The urban population in India has increased by 31.8% up to 91 million in the last decade (India, 2011). This rapid increase in urbanization translated to large amounts of solid waste production in the country. Even though the municipal solid waste (MSW) generation rate is increasing, waste management practices are not up to the current best practices. MSW comprises of degradable, partially degradable and non-degradable fractions like food, vegetables, paper, wood, leather, plastics, glass, metals, dust and other inert materials from domestic, agricultural, and commercial sources. MSW management includes operations like collection, storage, transportation, processing and disposal of solid waste in cities and rural areas. In India, MSW generated varies from 0.1 to 0.5 kg/capita depending upon the location, activities and life style of the residents (Akolkar et al., 2008). The disposal of MSW into landfills is the most popular and economic method of disposal. About 75% of the MSW generated from urban India is collected and disposed in non-scientifically managed dumping grounds. About 70–90% of landfills in India are open dumpsites (Chakraborty and Kumar, 2016; Jha et al., 2008). This practice not only effects health of humans living in the immediate vicinity of the area, but also results in land, water, and air pollution.

The solid waste disposed in landfills is subjected to biodegradation. The methanogenic bacteria converts acetic acid and hydrogen gas into methane (CH_4) and carbon dioxide (CO_2), two

☆ This paper has been recommended for acceptance by Charles Wong.

* Corresponding author.
E-mail address: harshakota@gmail.com (S.H. Kota).

https://doi.org/10.1016/j.envpol.2017.11.064
0269-7491/

Table 1
Yearly change in population, waste generated and disposed in landfill.

Year	Population	Waste generated (Gg/year)
2008	919059	200
2009	933766	204
2010	948556	206
2011	963429	210

major greenhouse gases. Even though CH_4 has lower concentrations, it can entrap radiation more effectively than CO_2. Enteric fermentation, rice cultivation, waste water handling, solid waste disposal and fugitive emissions from solid fuels are the five major sources of CH_4 in India (http://edgar.jrc.ec.europa.eu/). In addition to the population, CH_4 generated from a landfill also depends on other variables such as composition of biodegradable waste, moisture content, pH, and meteorological conditions like temperature, relative humidity and solar radiation. Compared to the developed countries, MSW in India has more moisture and organic content (Visvanathan et al., 2005).

Previous studies either use in-situ methods like flux chamber technique (Chakraborty et al., 2011), tracer gas correlation, micrometeorological (Lohila et al., 2007), differential absorption LiDAR (Robinson et al., 2011), vertical radial plume mapping methods (Goldsmith et al., 2012) or zero or first order decomposition models developed by the Intergovernmental Panel on Climate Change (IPCC) or the United States Environmental Protection Agency (USEPA) to estimate emissions of land fill gases (Rao et al., 2016). Previous studies (Chakraborty et al., 2011; Jha et al., 2008) observed over prediction of the models due to lack of field specific waste characteristics and meteorological data. For example, a recently developed landfill gas model by Kumar et al. (2016), which includes temperature as one of the input parameters, showed good performance.

The objective of this study is to estimate the diurnal variation in emission rates of CH_4 and CO_2 using flux chamber technique from the landfill site in the largest city in north-east India, Guwahati. The performance of IPCC, Modified Triangular Method (MTM) and the USEPA's Landfill gas emissions model (LandGEM) models, will be evaluated using the in-situ estimated fluxes. This is the first study carried out in India which carried seasonal variation of diurnal change in CH_4 and CO_2 emissions, and first in north-east India to estimate LFG emissions.

2. Methodology

2.1. Site description

Guwahati, commercial capital of Assam state in India is located at 26.18° N and 91.73° E on the banks of river Brahmaputra. It covers an area of 216 km^2 with a population of 0.963 millions (India, 2011), and is one of the rapidly growing cities in the country. This location has moist and wet tropical climate (Mahanta et al., 2013). The city is divided into 20 zones, comprising 60 wards. The average per capita generation rate of MSW is 0.6 kg/day in the city (Chakraborty, 2014; Pradhan et al., 2012). Table 1 shows the population and the corresponding waste generated. The waste composition is 29%, 36%, 10% and 18% of food, garden, paper, wood and straw, respectively (Pradhan et al., 2012). The landfill site is spread over an area about 24.12 ha, of which a significant area of 15.12 ha has been suggested for the development of a sanitary landfill, with the remaining 9 ha being reserved for a composting plant. The gas samples were collected in a part of the landfill, which was operational from 2008 to 2011. The data were collected from September of 2015 to August of 2016. The data were divided into three seasons-winter (November to February), summer (March to June) and monsoon (July to October) (Chakraborty et al., 2011).

2.2. Flux chamber method

The flux or static chamber method is a widely used, simple and economical method to measure the emission fluxes of LFGs. This technique involves the trapping of the LFG in an enclosure, while it leaves the soil surface for a reasonable period of time, to enable quantifiable sample collection for laboratory analysis. In this study, a stainless steel circular chamber of dimensions 35 cm height and 40 cm diameter with one end closed and equipped with two holes, as shown in Fig. 1, was used. While one hole was used to collect LFG, another was used to measure the temperature inside the chamber. All the sampling sites were selected to cover the central and peripheral region of the dumping area and the feasibility of sampling. The entire closed landfill area was divided into four equal segments with a sampling site in each. The chamber was placed with 10 cm inserted into the top layer to avoid lateral emissions. The gas

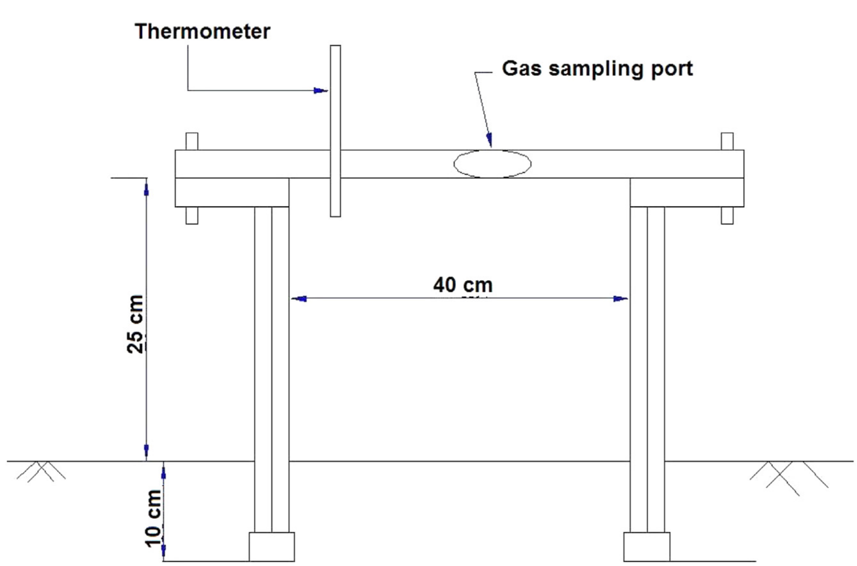

Fig. 1. Schematic of the flux chamber used in this study.