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QUANTIFICATION OF THE METHANE EMISSIONS FROM MASONS LANDFILL, UK

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SUMMARY: The methane emission from Masons landfill, UK during a six day measurement campaign was successfully quantified using the tracer dispersion method. Tracer gas (acetylene) was released from three to four points at the landfill, and plume traverses were performed at different distances (up to 6.7 km) and directions to the landfill. In total, more than 140 plume traverses were conducted. The average measured methane emission rates were higher on the first three days (333 ± 27, 371 ± 42 and 410 ± 18 kg h^{-1}) compared to the last three days (217 ± 14, 249 ± 20 and 263 ± 22 kg h^{-1}) - most likely a result of changes in barometric pressure. The gas collection efficiency was approximately 69%.

1. INTRODUCTION

Methane is a potent greenhouse gas and the anthropogenic emission of methane to the atmosphere contributes to global warming. The methane emission from the waste sector is a significant part of the global anthropogenic methane emission, and landfills are responsible for the majority of the greenhouse gas emission from this sector (Bogner et al., 2008). Several initiatives have been taken to minimize the methane emission from landfills, e.g. by methane recovery followed by flaring or utilization, or by constructing mitigation installations such as a cover material with enhanced methane oxidizing capability. Due to a series of factors, methane emissions from landfills are very heterogeneous in both time and space, which, combined with the large size and an often challenging topography of a landfill, make methane emission quantification a challenging task.

The Technical University of Denmark has implemented a novel analytical setup enabling mobile measurement of small changes (ppb level) in atmospheric methane concentration. This enables detection and quantification of methane sources by performing measurements downwind from the source in combination with release and measurement of a tracer gas. The analytical setup and the dynamic tracer dispersion method have been tested at more than 40 Danish landfills since November 2011 (e.g. Mønster et al., 2014; Mønster et al., 2015), building up a sound knowledge on quantification of the total fugitive methane emission from landfills. However, Danish landfills are, on an average, relatively small compared to UK landfills, and the possibility for testing the methodology on larger emission areas with potentially higher emissions, led to collaboration between the Technical University of Denmark and University of Southampton performing two measuring campaigns (June and August 2014) at the Masons

landfill near Ipswich, UK.

The main objective of this study was to quantify the total methane emission from the Masons landfill site, and to investigate temporal variations over the course of the monitoring. A secondary objective was to determine the gas recovery efficiency and finally, an attempt to identify emissions arising specifically from non-combusted methane emitted from on-site gas engines was conducted.

2. MATERIAL AND METHODS

2.1 Masons Landfill

Masons Landfill is located in Great Blakenham in the county of Suffolk, approximately 5 miles north of the town of Ipswich, UK. The site has been in operation since 1992 and is licensed to receive a mixture of waste including domestic, commercial and industrial wastes, oil contaminated wastes, contaminated soils and asbestos. On average, the landfill has received between 200,000 to 500,000 tonnes of waste annually, mainly domestic, construction and industrial wastes, and soils. Since opening, the site has taken 6.3 Mt waste to the end of 2013.

The site is comprised of 11 cells, covering an area of approximately 330,000 m^2. The cells were constructed with an engineered base of 225 - 300 mm bentonite enriched soil and a 2 mm high-density polyethylene (HDPE) synthetic liner. The majority of the landfill cells are filled to final levels and has been restored, with just a small operational area remaining in the centre of the site. The northern parts of the site are capped and fully restored with a 1 mm LDPE liner overlain by restoration soils, and to the east, the waste has been capped with a 1 mm LDPE liner, but currently has no restoration material.

An active gas management system is in operation at the landfill, comprising of a network of gas extraction wells, connected to a system of gas mains and spurs. The gas collection system directs collected gas to the gas utilisation plant, which has four landfill gas engines and a flare. During the course of the tracer release experiments, either two or three of the four engines were in operation. When only two engines were operating, a flare was used to burn excess landfill gas. Flow through the plant during the trials, averaged 1900 m^3 h^{-1}, with an average mass of 660 kg methane h^{-1}.

2.2 Measuring method

The methane emission was measured using a tracer technique that combines controlled tracer gas release from the landfill with time-resolved concentration measurements downwind of the landfill (Mønster et al., 2014; 2015). The tracer technique in general is based on the assumption that a tracer released at an emission source will disperse in the atmosphere in the same way as the gas emitted from the source. Assuming that the wind direction is defined and conditions in the air above the landfill area is well mixed, the gas emission rate (E_{gas}) can be calculated as a function of the ratio of the integrated cross-plume concentration of gas emitted to integrated cross-plume concentration of tracer, as follows:

$$E_{gas} = Q_{tracer} \cdot \frac{\int_{Plume\ end\ 1}^{Plume\ end\ 2} C_{gas}\, dx}{\int_{Plume\ end\ 1}^{Plume\ end\ 2} C_{tracer}\, dx} \cdot \frac{MW_{gas}}{MW_{tracer}} \qquad \text{(Eq. 1)}$$

Where E_{gas} is the methane emission rate (kg h^{-1}), Q_{tracer} is the release rate of the tracer gas (kg h^{-1}), C_{gas} and C_{tracer} denote cross-plume concentrations (ppbv) above the background concentration, MW denotes molecular weights and x corresponds to distance across the plume.

Measurements were performed with a cavity ring-down spectroscopy, methane/acetylene analyser (G2203, Picarro Inc., USA). Atmospheric air was sampled from the roof of the monitoring vehicle and brought to the analyser via an external pump, enabling a fast response time while driving. The atmospheric concentrations of methane, acetylene and water were measured with a frequency of 2 Hz and logged together with the GPS position. The precision of methane and acetylene measurements was 0.48 ppb and 0.40 ppb respectively, making it possible to detect small changes in atmospheric concentrations whilst driving. A GPS (model R330 GNSS Receiver and A101 Smart Antenna, Hemisphere, Canada) was used to log the position of the monitoring vehicle, measured within 0.20 m precision.

Tracer gas bottles (15.9 litres) filled with ~2.35 kg dissolved acetylene (98.5 % purity) were used to release the tracer gas at the landfills. The rate of release was controlled manually with valves against calibrated flow meters, with periodic checks during a release to maintain stable flow rates. The accuracy of the flow meters was previously demonstrated in the laboratory to be better than 3%. The tracer gas bottles were placed in areas of the landfill with the highest methane emissions in order to simulate emissions in the best possible way.

2.3 Measuring campaign

Before the emission quantifications commenced off-site screening of the methane concentrations in the area surrounding the landfill was carried out to establish background concentrations of methane and acetylene and to identify other methane sources in the area, which potentially could interfere with the quantification of the methane plume from the Masons landfill.

Downwind measurements are carried out along public highways around the landfill, with monitoring distances and location varying depending on the wind direction, the degree of dispersion, the accessibility of roads, and possible interference with other methane sources.

In total, six tracer gas release (TGR) experiments were performed, each consisting of one to three hours of acetylene release. For a given test, measurements were performed at up to three different distances to the landfill and in different directions from the landfill, depending on the wind direction and intensity at the time of the measurement. Table 1 provides an overview of each test, including information on measuring dates, weather conditions (average wind speed and direction and atmospheric pressure), tracer gas release (number of tracer gas release points and total release rates), and measurement transects (measuring distance and number of transects performed). Tracer gas was released from three to four points at the landfill, and plume traverses were conducted at different distances (up to 6.7 km) and directions to the landfill. In total, more than 140 plume traverses were conducted.

Table 1. Overview of the measurement campaign showing measuring dates, weather conditions, tracer release rates, measuring distances, and number of performed plume transects.

Test no. / Date	Measuring time interval	Measuring distance to the landfill (m) and total number of plume transects (*n*)	Weather conditions			Tracer gas release points	Total tracer gas release rate (kg h^{-1})
			Avg. temp. (°C)	Avg. wind speed (m s^{-1}) and dominant direction	Avg. atmos. pressure (mbar)		
TGR 1 06.08.2014	17:20-19:00	1700-2000 (*18*)	25.0	8.0 W	1005.1	1,3,4,5	3.35
TGR 2 07.08.2014	18:00-22:20	2000 (*9*) 3500-4000 (*12*) 6700 (*8*)	19.1	4.9 E	1010.5	1,2,3,5	3.48
TGR 3 08.08.2014	16:30-19:15	1600-2000 (9) 3000-3800 (2) 4500-5000 (6)	20.1	5.1 SE	999.2	1,3,5	2.55
TGR 4 11.08.2014	16:30-18:15	1700-2000 (15)	17.6	9.3 SW	1001.8	1,3,4,5	2.6
TGR 5 12.08.2014	16:30-18:30	1700-3000 (14) 2500-4200 (2) 4800-6000 (6)	18.5	9.7 WSW	1000.0	1,4,5,6	2.58
TGR 6 13.08.2014	08:15-09:15	1700-2000 (13)	16.9	7.8 W	998.7	1,3,5,6	2.59

3. RESULTS AND DISCUSSION

Table 2 summarises the average methane emission rates determined for each TGR. Figure 1 shows examples of methane and tracer gas plumes measured in three distances from the landfill, all measured the same day (Aug. 7th, 2014). The fair weather conditions made it necessary to perform measurements in the late afternoon and in the evening when the lower solar flux resulted in a more stable troposphere with a lower inversion layer. This caused a slower mixing of the gasses, but allowed plume measurements up to 6.7 km downwind from the landfill.

The average methane emission varied between 217±14 and 410±18 kg h^{-1} within the individual measurement days, but the measured emission rates were higher on the first three days (333±27, 371±42 and 410±18 kg h^{-1}) compared to the last three days (217±14, 249±20 and 263±22 kg h^{-1}). This was not due to measuring artefacts, such as wind/measurement direction and measurement distance, but was more likely due to an actual change in the fugitive emission. Such a change is known to happen with changes in the atmospheric pressure. The higher emissions measured during the first three days of the campaign was measured during a period with an overall decrease in atmospheric pressure (from approximately 1014 mbar Aug. 5th to 987 mbar Aug. 10th). The lower emissions measured during the last three days of the campaign were carried out during a period with an initial pressure increase followed by a period of stable pressure.

The average daily gas recovery flow varied between 1780 and 1948 m^3 h^{-1}, with a methane

content of between 48.9% and 50.8%. With a methane recovery of between 633 and 679 kg h^{-1} (at STP; 1 atm, 0 °C), the gas collection efficiency was approximately 69%, assuming that the methane generated is the sum of the methane recovered and the methane emitted to the atmosphere, thus not including a potential methane oxidation in the landfill cover soil.

The gas engines sited in the gas utilisation plant may emit non-combusted methane, either from leakages or from inefficient combustion. The location of the gas utilisation plant, close to the landfill and close to the site boundary made it difficult to differentiate between any potential emissions from the gas utilisation plant and emissions from the rest of the landfill. However, on one occasion (Aug. 11th) it was possible to distinguish the individual plumes from the gas utilisation plant and the remaining landfill. By integrating the plumes on an individual basis, the emission from the gas engine area was estimated to be between 14 and 22 kg h^{-1}, which represents a slippage rate (un-combusted methane) of between 2.1 and 3.3% based on a gas engine flow rate of 663 kg h^{-1}.

Figure 1. Relative atmospheric methane (red) and acetylene (yellow) concentrations above background measured at three different distances to the landfill on road W1, 2 and 3 on Aug. 7th, 2014. Maximum methane concentrations above background were 2620, 1290, and 590 ppb at the three measuring distances 2000m, 3500-4000m and 6700m, respectively. Maximum acetylene concentrations above background were 15.2, 9.0, and 4.6 ppb at the three measuring distances 2000m, 3500-4000m and 6700m, respectively. Yellow triangles mark the approximate placement of the tracer gas bottles). Map data: Google, Infoterra Ltd & Bluesky.

Table 2. The calculated methane emission rates (kg h^{-1}) on the six measurement days in August 2014.

Test no. / Date	Measuring time interval	Measuring distance to the landfill (m) and number of plume transects (n)	Total number of usable transects for emission quantification	Methane emission rate[a] (kg h^{-1}) ± Standard error[c]	Overall average methane emission rate[b] (kg h^{-1}) ± Standard error[c]
TGR 1 06.08.2014	17.20-19.00	1700-2000 (18)	18	333±27	333±27
TGR 2 07.08.2014	18.00-22.20	2000 (9) 3500-4000 (6) 6700 (5)	20	389±77 357±69 295±27	371±42
TGR 3 08.08.2014	16.30-19.15	1600-2000 (9) 4500-5000 (6)	15	390±19 441±16	410±18
TGR 4 11.08.2014	16.30-18.15	1700-2000 (15)	15	217±14	217±14
TGR 5 12.08.2014	16.30-18.30	1700-3000 (15) 2500-4200 (1) 4800-6000 (5)	21	274±47 293 225±21	249±20
TGR 6 13.08.2014	08.15-09.15	1700-2000 (13)	13	263±22	263±22

[a] The average methane emission rate based on the measurements performed at each measuring distance,
[b] The overall average methane emission rate based on *all* the measurements performed at each measuring time interval.
[c] The uncertainty is given as ± the standard error of mean on a 95% confidence interval.

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