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Quantification of the methane emission from Masons landfill - Part I

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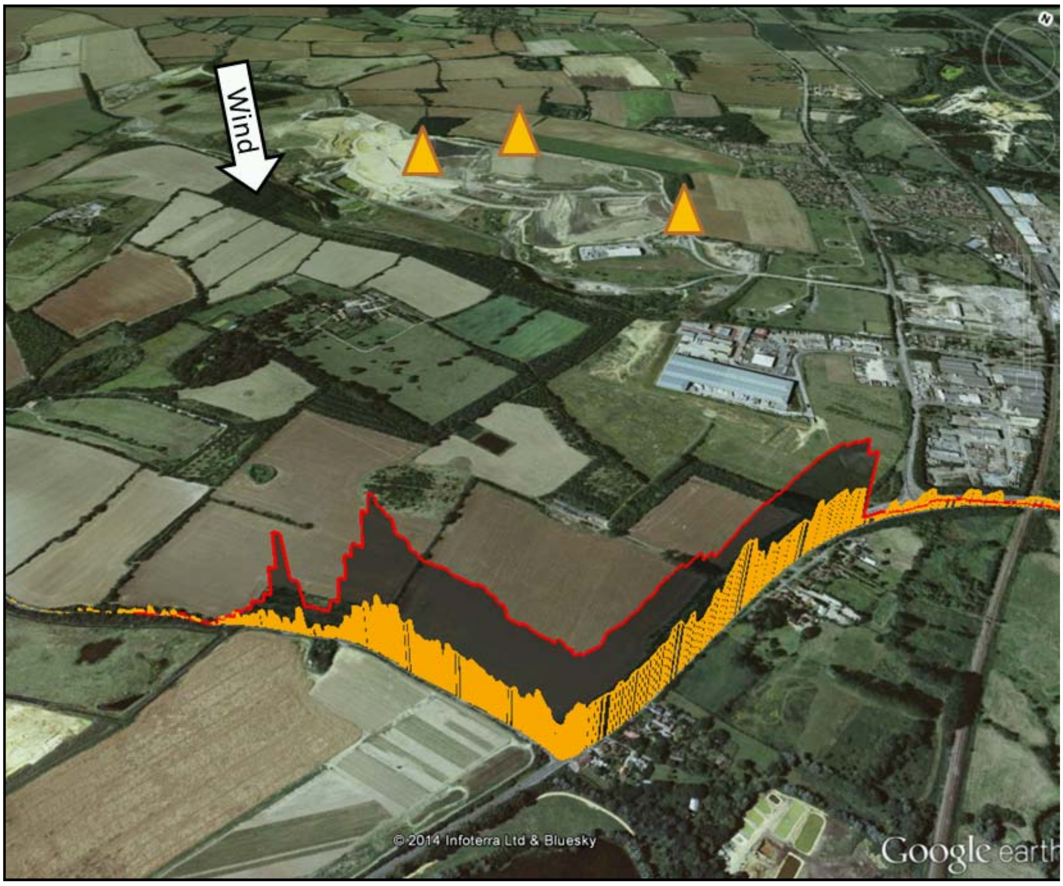

The relative atmospheric concentration of CH_4 and C_2H_2 approximate 1500 meter downwind from Masons landfill on June 12th 2014. Triangles mark the C_2H_2 release points on the landfill. The atmospheric background concentration is subtracted.

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1. Introduction and purpose

The Technical University of Denmark has recently implemented a novel analytical setup enabling mobile measurements of small (ppb level) changes in atmospheric methane concentrations. This enables detection and quantification of methane sources, by performing measurements downwind from the source in combination with the release and measurement of a tracer gas. The analytical setup and the dynamic tracer dispersion method have been tested at approximately 20 Danish landfills since November 2011 (Mønster et al., 2014a; Mønster et al., 2014b), building up a sound knowledge of quantitative fugitive methane emission from landfills. However, Danish landfills are, on average, relatively small compared to UK landfills, and the possibility for testing the methodology on larger emission areas with potentially larger emissions led to a collaboration between the Technical University of Denmark and the University of Southampton performing a trial measurement campaign at Masons landfill near Ipswich, UK.

2. Description of the method

The method used for quantifying the total emission of methane from the Masons landfill is called the dynamic tracer dispersion method (Mønster et al., 2014a; Hiroko et al., 2014; Scheutz et al., 2011; Galle et al., 2001). The theory behind this method is that gases with long atmospheric lifetimes will behave in the same way regarding mixing and transportation in the atmosphere. Therefore, it is possible to release a known amount of a tracer gas close to an emission source and measure the atmospheric concentrations of tracer gas and methane at a suitable distance downwind from the emission source. The atmospheric concentration ratio between methane and the tracer gas at the measurement point will be the same as the ratio between the release of the tracer gas and the methane emission. The principle is shown in Figure 1.

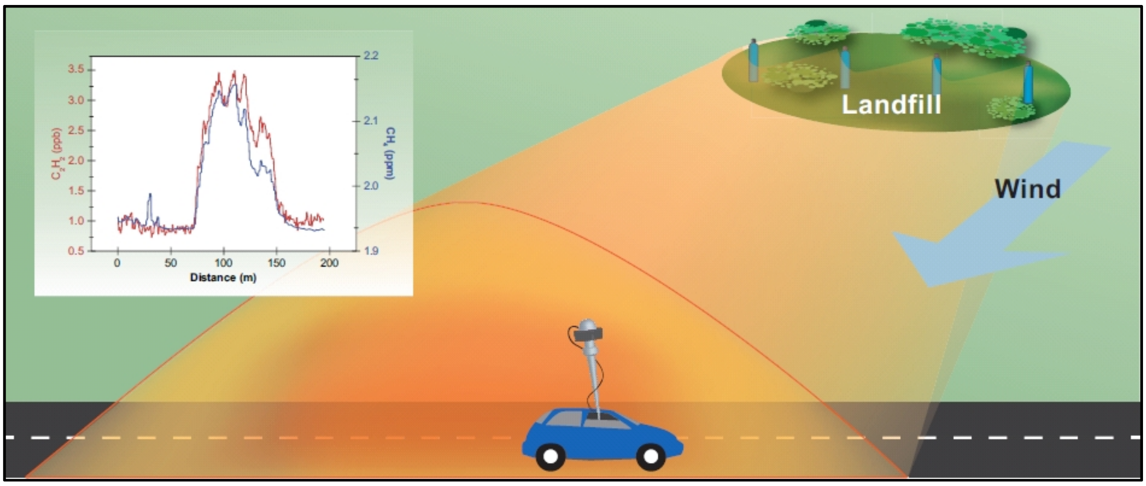

Figure 1. The principle of the dynamic plume method for quantifying greenhouse gas emissions from fugitive sources.

The measurements were performed with a methane/acetylene analyser (Picarro model G2203) which can measure very small changes in the atmospheric concentration (Mønster et al., 2014a). A GPS was connected to both instruments for logging the measured concentrations to its geographical location. To obtain the best possible simulation of the source area, tracer gas was released at the parts of the landfill where elevated methane concentrations were measured during an initial background screening. Initial measurements on and around the landfill were conducted for locating these emission areas.

3. Masons Landfill Site

Masons Landfill is located in Great Blakenham in the county of Suffolk, approximately 5 miles north of the town of Ipswich. The site has been in operation since 1992, and is licensed to receive a mixture of waste including domestic, commercial and industrial wastes, and oil contaminated wastes and contaminated soils as well as stable, non-reactive hazardous wastes (contaminated soils and asbestos waste only). On average, the landfill has received between 200,000 to 500,000 t.p.a., mainly domestic, construction and industrial wastes, and soils.

The site has 4 phases (11 cells), covering an area of approximately 330,000 m^2. All cells were constructed with an engineered base consisting of 225 - 300 mm bentonite enriched soil and a 2 mm high density polyethylene (HDPE) synthetic liner.

The current operational area is in the southern part of Phase 3 (see Figure 2). Phase 2 and the northern parts of Phase 3 are capped and fully restored with a 1 mm LDPE liner overlain by restoration soils. Phase 1 has been capped with a 1 mm LDPE liner, but currently has no restoration material. There has been no tipping in Phase 4 and the cell is in the process of being dismantled.

An active gas management system is in operation at the landfill, comprising of a network of vertical and horizontal gas extraction wells, connected to a system of gas mains and spurs. The gas collection system directs collected gas to a Gas Utilisation Plant (GUP), which has four landfill gas engines and a flare. The GUP currently generates around 3 MW. During the course of the tracer release experiments, three of the four engines were in operation.

4. Description of measurement campaign.

Measurements were performed between June 10th and June 12th 2014. On June 10th, only screenings of atmospheric methane concentrations in the area were made, while tracer release and methane emission quantifications were carried out on both June 11th and 12th. Different tracer gas release rates were tried, to ensure sufficient tracer gas for quantification in the downwind plume, but also to have tracer gas release for enough time to perform several plume traverses. Successful quantifications were made in the afternoon on June 11th with a total tracer gas release of 1.1 kg h^{-1} from three tracer gas bottles (0.37 kg h^{-1} per bottle) and in the morning on June 12th with a total tracer gas release of 2.6 kg h^{-1} from four tracer gas bottles (0.65 kg h^{-1} per bottle). Figure 2 and 3 show the placement and securing of a trace gas bottle on the ridge of the landfill between the covered (liner and soil) part and the active part of the landfill.

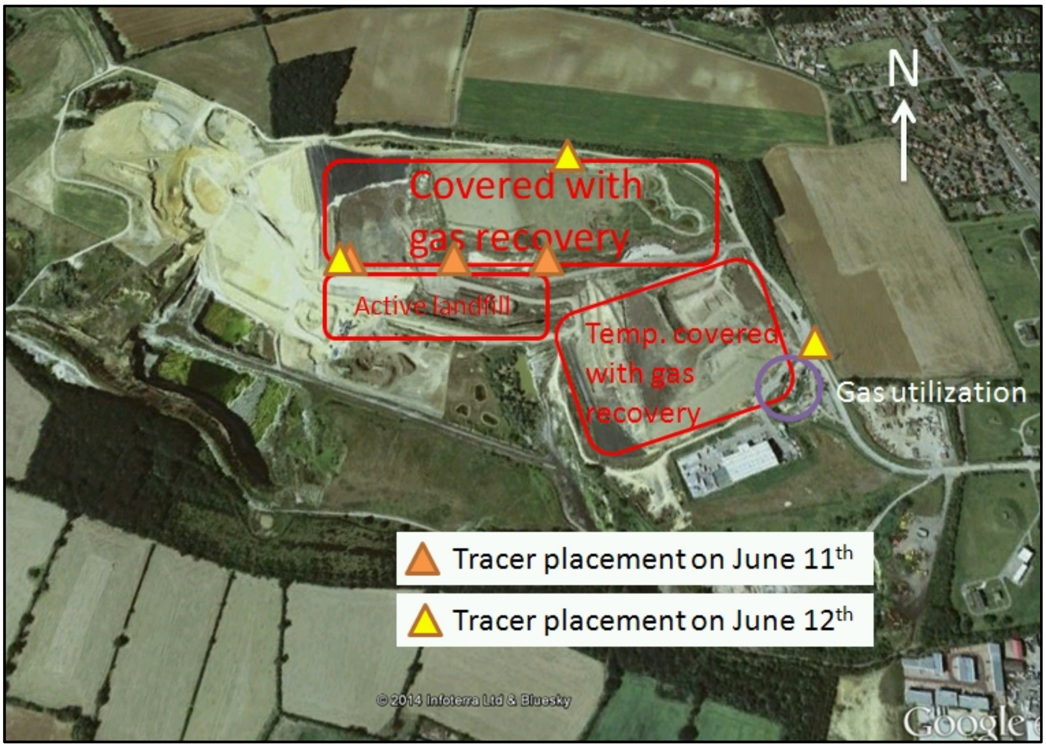

Figure 2. Overview of Masons landfill and the tracer gas placement on the two measurement days.

Figure 3. Tracer gas placement and securing at the ridge between the old, coved and the new, active part of the landfill.

The measurements were carried out during a period of calm, sunny and warm weather, resulting in a fast rising plume, making it difficult to measure the downwind plumes at ground level when moving away from the landfill. The weather conditions (atmospheric pressure and wind speed) in the week around the measurement days are shown in Figure 4 and 5. On June 11th, in the afternoon the measurements were made during an increase in atmospheric pressure (from 1014 to 1016 mbar) with winds from west (5-8 mph) and an air temperature of 20-22 °C. On June 12th in the morning, the measurements were made during a period with a stable, but relatively high pressure (1024 mbar) with little wind (2-3 mph) from north and northwest and an air temperature of 17-19 °C.

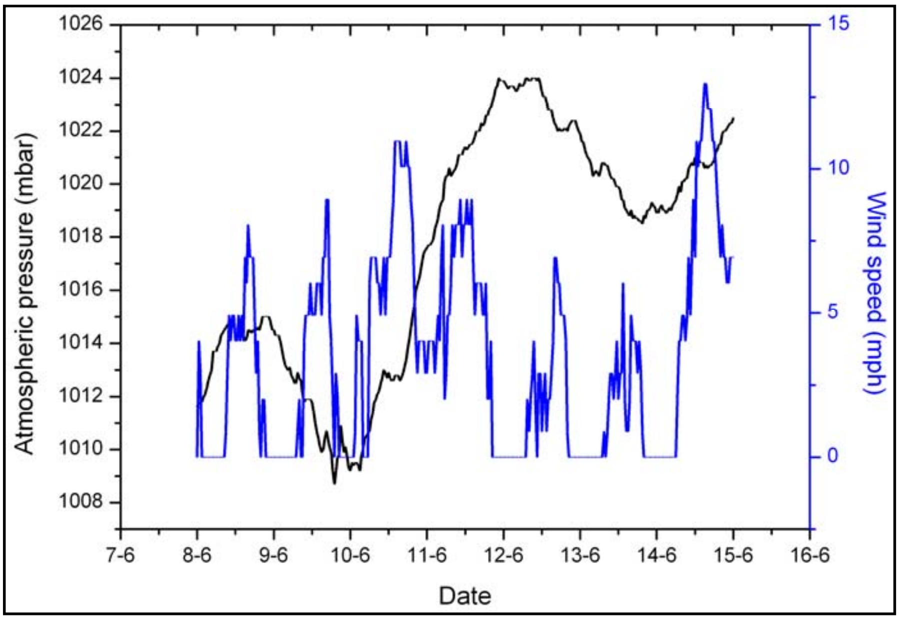

Figure 4. Atmospheric pressure and local wind speed during the week around the two days of measurements.

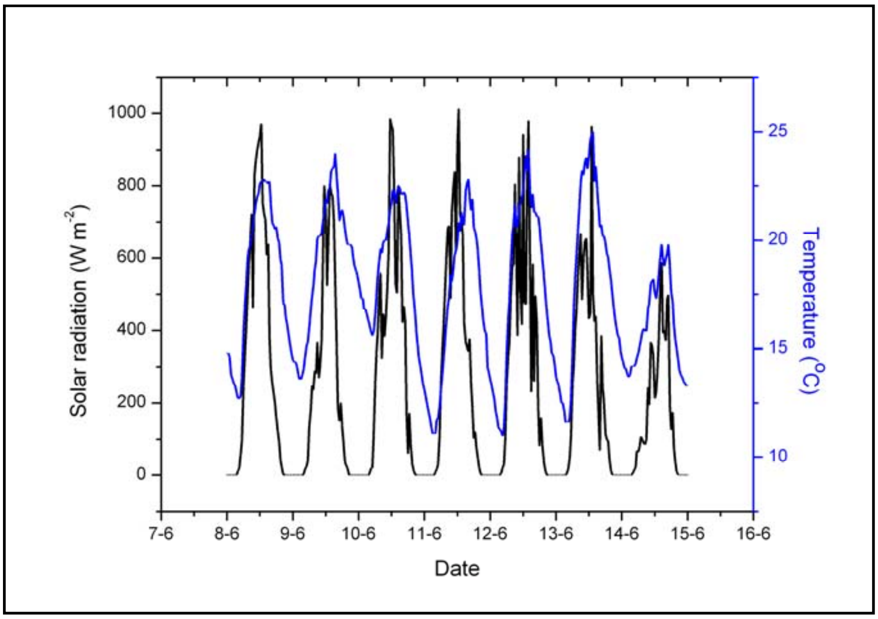

Figure 5. Incoming solar radiation and temperature in the week around the two days of measurements.

5. Results & Discussion

Masons landfill consists of three main areas (see Figure 2): An active area where waste is being deposited, an area of temporary cover with a plastic liner, and an area covered with a plastic liner and restoration soil (Figure 5). The landfill gas recovery from the two covered areas is routed to the GUP, where the total flow and quality of the recovered gas is monitored.

Figure 5. Active landfill part (front) and part covered with plastic liner (back).

5.1 Methane screening of the area

Initial screenings for methane in the area around Masons landfill were carried out in the afternoon on June 10th. Besides Masons landfill, sources of methane were found at a landfill south of Masons (Blood Hill) and at a farm northwest of Masons (see Figure 6). Although the relative methane concentrations shown in Figure 6 show higher concentrations near the two other sources, this does not mean that there is more methane coming from these sources than from Masons. It is simply that the measurements were taken closer to the sources.

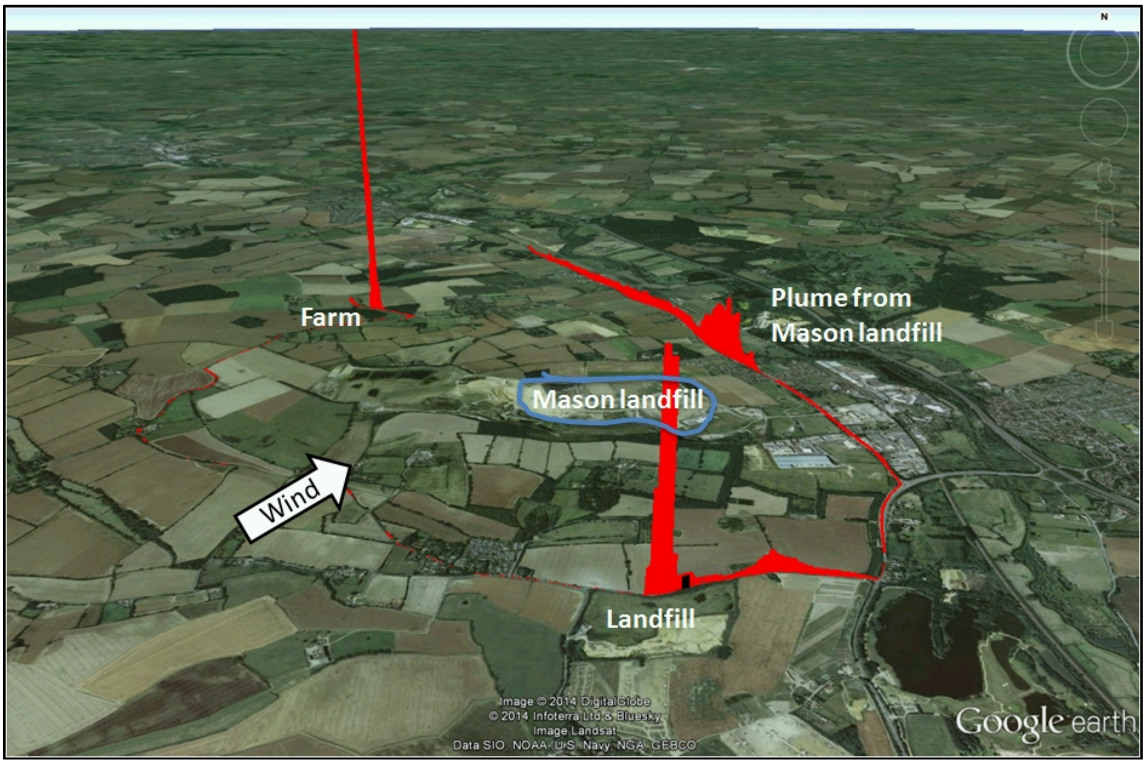

Figure 6. Relative methane concentrations above background up- and downwind from Masons landfill.

5.2 Initial methane screening of Masons landfill

An initial screening for methane on Masons Landfill site was carried out on June 10th prior to placing the tracer gas bottles for quantifying the whole site methane emission. Access was not permitted to the active part of the landfill, but atmospheric methane concentrations were measured along all other accessible roads on site. Figure 7 shows the relative methane concentrations above background. Note, that in order to visualise better the results from all measured roads, north is orientated downwards in Figure 7. Highest concentrations were measured near the ridge between the active part of the landfill and the older, covered part with gas extraction wells, as well as downwind from there. Elevated concentrations were also measured downwind from the gas utilization unit.

5.3 Whole landfill emission

With the wind generally from the south or south-west, the highest methane concentrations were monitored on the ridge directly downwind of the active operational area which, together with the temporary capped slope between the ridge and the active area, was assumed to be the main methane emitting parts of the site. Consequently, the ridge was considered to be a good location for releasing tracer. On June 11th, three tracer gas bottles were distributed on the ridge and the plume of methane and tracer gas was measured downwind about 1600-1700 m southeast of the landfill (see Figure 8).

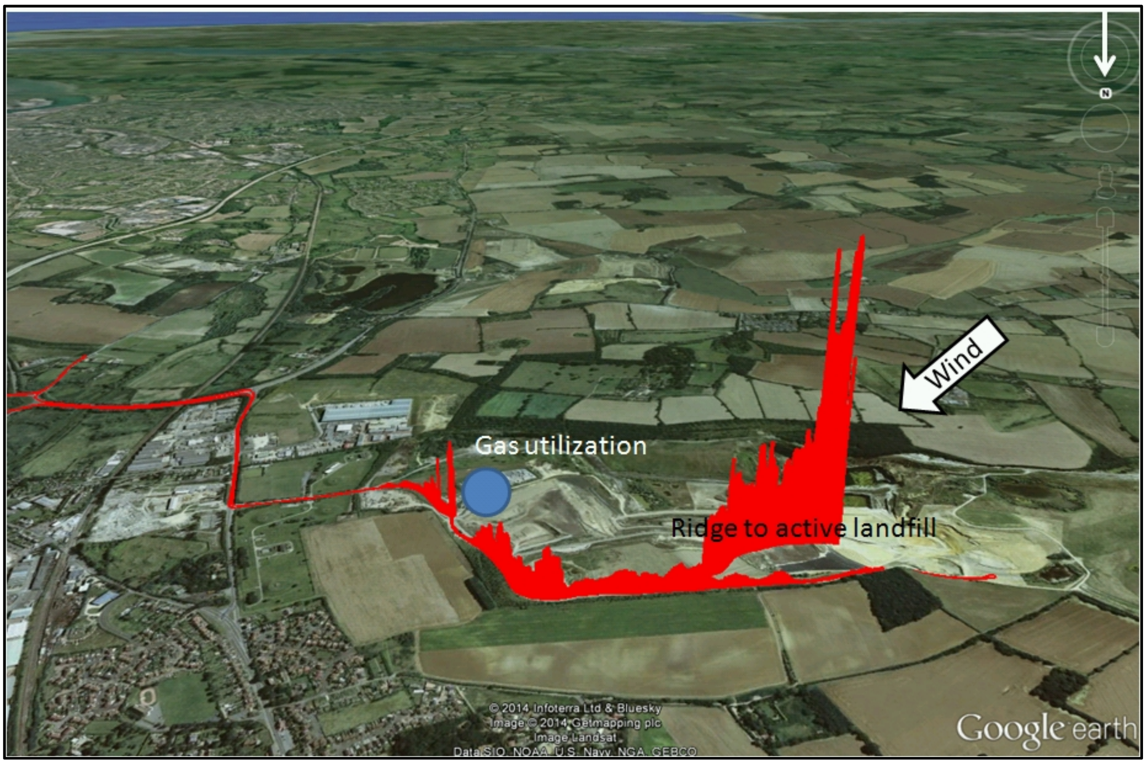

Figure 7. Relative methane concentrations above background concentrations during screening on Masons landfill site and along the ridge, downwind from the landfill. Measurements were performed on June 10th, 2014.

Figure 8. Three tracer gas bottles on Masons landfill (yellow triangles) and the downwind plume of methane (red) and tracer gas (yellow) 1600-1700 m away. Measurements were made on June 11th, 2014. Maximum methane and tracer gas concentrations were approximately 400 and 2.2 ppb above background, respectively.

Five successful traverses were completed on June 11th and the individual calculated emission rates are listed in Table 1. The measured average methane emission was 286 kg CH_4 h^{-1}.

Table 1. Calculated emissions obtained from traverses completed on June 11th

Time	Emission (kg CH_4 h^{-1})
18.46	293
18.48	235
18.50	315
18.52	308
18.55	280
Average	**286**
Std dev	**32**
Std err	**14**

Within a dataset, approximately 68% of values assuming ”a normal distribution” are within one standard deviation (Std dev) away from the mean, and 95% of values lie within two standard deviations.

The standard error (Std err) is a measure of the error of the true average of the readings i.e. there is a 68% propability that the data represented in Table 1 has an average emission rate of 286 ± 14 kg CH_4 h^{-1}.

There was very little wind in the morning on June 12th, and what there was changed direction constantly. This resulted in a very broad and well mixed plume south of the landfill. The tracer gas bottles were distributed slightly different from the day before, with one bottle on the ridge like on June 11th, one bottle on the landfill boundary to the north and one bottle by the gas utilization unit. The tracer gas placement and the corresponding downwind plume 1500-1700 m south of the landfill is shown in Figure 9.

Eleven successful traverses were performed and the individual methane emission rates are listed in Table 2 together with the average, the standard deviation and the standard error on the mean value. The average methane emission measured within approximately one hour was 331 kg CH_4 h^{-1}.

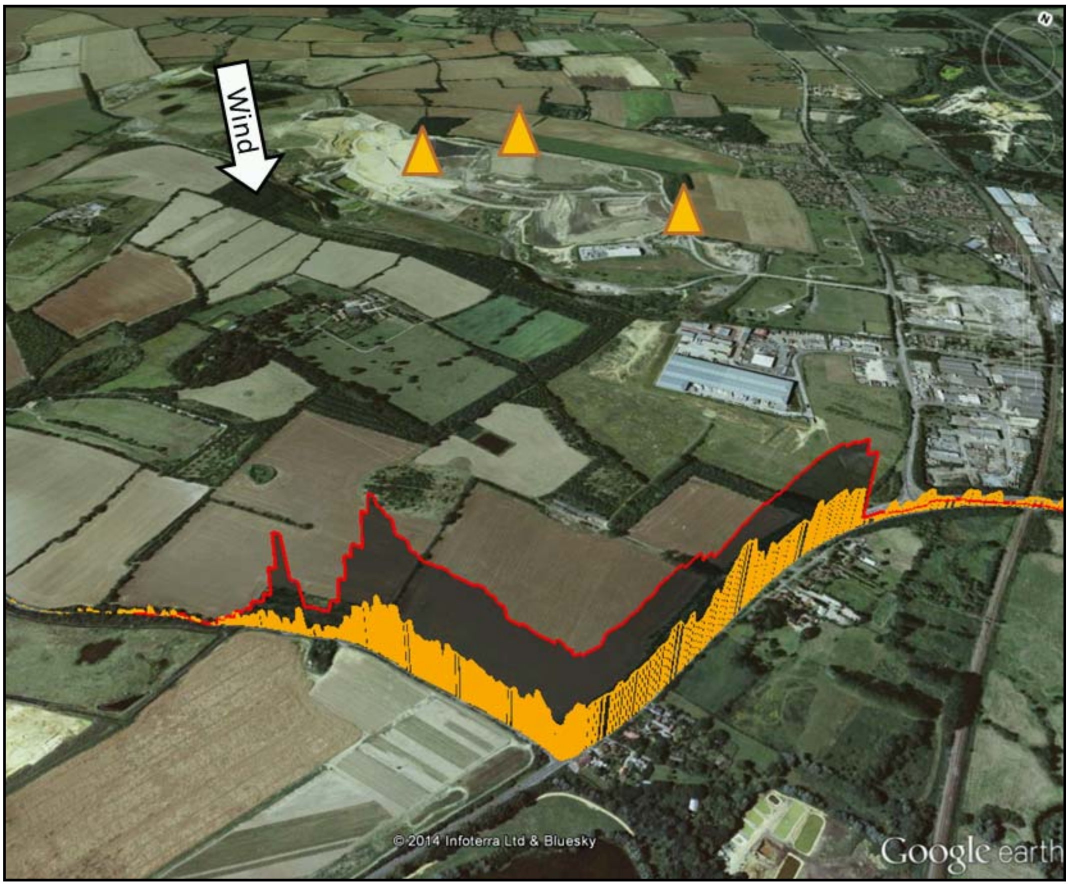

Figure 9. The relative atmospheric concentration of methane (red) and tracer gas (yellow) approximate 1500 meter downwind from Masons landfill on June 12th, 2014. Triangles mark the tracer gas release points on the landfill. Maximum methane and tracer gas concentrations were approximately 350 and 1.5 ppb above background, respectively.

Table 2. Calculated emissions obtained from traverses carried out on June 12th.

Time	Emission (kg CH_4/hour)
8.05	323
8.10	415
8.15	396
8.21	447
8.25	365
8.29	268
8.32	323
8.38	191
8.42	221
8.44	279
8.47	331
Average	**323**
Std dev	**80**
Std err	**24**

5.4 Whole landfill gas capture rates

In the morning of 11th June, the gas recovery flow, measured at the GUP, was 2094 $m^3 h^{-1}$ with a methane content of 50.5 %, giving a utilization of 754 kg methane/hour at STP. By the afternoon, gas recovery flow had decreased marginally to 2068 $m^3 h^{-1}$ with a methane content of 47.4 %, corresponding to 700 kg methane/hour at STP.

On the second day of monitoring, daily averages of gas recovery flow and methane concentration were 2098 $m^3 h^{-1}$ and 50.1 % respectively, corresponding to 750 kg methane /hour at STP.

Data from the GUP is given in Table 3.

Table 3. LFG utilisation data

	June 11th (am only)	**June 12th (Daily average)**
CH_4 (%)	50.5	50.1
CO_2 (%)	37.0	36.6
O_2 (%)	0.65	0.65
Suction (mb)	-78	-78
Engine 1 (kW)	1084	1087
Engine 2 (kW)	867	876
Engine 3 (kW)	1000	994
Total kW	2951	2957
Flare Flow ($m^3 h^{-1}$)	155	159
Total site flow($m^3 h^{-1}$)	**2094**	**2098**
Total Methane measured (kg h^{-1})	**754**	**750**

6. Conclusions

The methane emissions from Masons landfill, during the afternoon on June 11th and morning June 12th were successfully quantified using the tracer dispersion method. The emission rates measured over the two days were 286±14 and 323±24 kg CH_4 h^{-1}, respectively. With a methane recovery between 700 and 754 kg CH_4 h^{-1}, the methane emitted to the atmosphere accounts for approximately 30% of the total methane generated, 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 measurements were made somewhat more difficult to obtain due to calm, warm, dry weather, with high solar radiation leading to a rapid vertical mixing and/or plume rising. This made it more difficult to measure downwind plumes at ground level. On June 11th, the measurements were carried out during an increase in barometric pressure, whereas on June 12th the atmospheric pressure was stable and relatively high. Typically, whole site LFG emissions during periods of increasing atmospheric pressure are likely to be lower than the expected "average emission rate".

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