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Fredenslund, Anders Michael; Scheutz, Charlotte

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Remote sensing quantification of methane emissions from 10 biogas plants in Denmark and Germany

Fredenslund, A.M.[*] & Scheutz[*], C.

[*] Department of Environmental Engineering, Technical University of Denmark, Bygningstorvet, Building 115, 2800 Kongens Lyngby

1. INTRODUCTION

The production of biogas may provide several benefits concerning mitigation of greenhouse gas (GHG) emissions. These benefits include fossil fuel substitution and reduction of GHG emissions from manure storage. Biogas is also a fuel that can be utilised for a variety of energy purposes, and can improve energy security. Due to the high global warming potential of methane (CH_4), emission of this gas from biogas production facilities may significantly reduce the GHG mitigation effect [1], and CH_4 loss should be minimised.

Accurate measurement methods are needed to quantify CH_4 emission from biogas plants and thus assess the need for taking actions to reduce leakage. Also, quantification of CH_4 loss from biogas production is needed to accurately assess biogas production with regards to environmental impacts in life cycle assessment studies. Recent developments in analytical instrumentation have provided new opportunities with regards to measurements of fugitive emissions. Remote sensing methods are useful to measure emissions from sources where emissions occurs on relatively large areas, and where locating and quantifying each individual point of emission is not feasible.

We have used a remote sensing method to measure total methane loss from 10 biogas plants in Denmark and Germany. The overall purposes of this work were to test this measurement methods' applicability to quantify CH_4 emission from biogas plants and to perform measurements on a number of different plants to assess methane loss from the production of biogas. In this paper, preliminary results of this work are presented. Due to the difficulty of establishing fugitive CH_4 losses by measurements, quantitative studies are few. This work also aims at providing a better understanding of the magnitude of this potential problem for the biogas industry.

2. TRACER GAS DISPERSION METHOD

We used a remote sensing method often referred to as the tracer gas dispersion method (TGD) to measure CH_4 emissions from the biogas plants in this study. TGD relies on the continuous release of a gaseous tracer combined with downwind measurements of atmospheric concentrations of target gas (CH_4 in this case) and tracer gas. These measurements are performed with a mobile analytical platform, which is used to traverse the downwind plume several times per measurement campaign – typically at a distance of app. 1 km to ensure mixing of CH_4 and tracer gas. The method is now used to measure total methane emissions from landfills in Denmark in relation to the biocover initiative to minimise such discharges [2]. The method has also been used to study fugitive emissions from other facilities, such as waste water treatment plants [3] and composting facilities [4].

The basic principle behind TGD is the assumption that a tracer gas released from an emission source will disperse into the atmosphere in the same way as CH_4 emitted from the source. The emission rate (E_{gas}) can be calculated as a function of the ratio of the integrated cross-plume concentration of CH_4 emitted to the integrated cross-plume concentration of the tracer gas, according to Eq. 1 [5]:

$$E_{gas} = Q_{tracer} \cdot \frac{\int_{Plume\ end\ 1}^{Plume\ end\ 2} C_{gas} dx}{\int_{Plume\ end\ 1}^{Plume\ end\ 2} C_{tracer} dx} \cdot \frac{MW_{gas}}{MW_{tracer}} \quad (1)$$

where Q_{tracer} is the release rate of the tracer gas (kg h^{-1}), C_{gas} and C_{tracer} are concentrations of CH_4 and the tracer (ppbv) above background level, MW_{gas} and MW_{tracer} are the molecular weights of CH_4 and the tracer gas and x is the distance across the plume.

Concentrations of methane were measured using a cavity ring down spectrometer (G2203, Picarro Inc., USA) installed in a car. Atmospheric gas was pumped into the analyser from an intake placed on the roof of the car. The measurement frequency of the instrument was approximately 2 Hz, and the precision levels of the methane and acetylene measurements were 0.48 ppb and 0.40 ppb, respectively, which enabled the detection of small variations in atmospheric concentrations.

A GNSS system was used to log the position of the measurements (R330 GNSS receiver and A43 antenna, Hemisphere, Canada). The gas tracer used for the measurements in this study was acetylene (C_2H_2). The release flows from acetylene gas bottles were controlled using calibrated flow meters and regulators (Sho-Rate, Brooks Instruments, Holland). The points of release of tracers varied in each campaign from a single location up to three. The locations of racer release were determined by performing a screening of ambient CH_4 concentrations at each biogas plant which provided information on the spatial distribution of CH_4 emissions from the sites.

3. BIOGAS PLANTS AND MEASUREMENT CAMPAIGNS

TGD measurements to measure total CH_4 emissions from 10 biogas plants were performed in the period October, 2015 to June, 2017. The biogas plants varied in size, gas utilisation (combined heat and power (CHP), biogas upgrade or off site utilisation) and main substrate(s) for biogas production. Table 1 lists key characteristics of the plants. Plant 1-8 were located in Denmark. At these biogas plants, two separate measurement campaigns were performed on different dates. Plants 9 and 10 were located in Germany. At both of these plants, a five days measurement campaign was performed.

4. PRELIMINARY RESULTS

Table 1 lists preliminary results of the TGD measurement campaigns. The values of gas production were reported by the plant operators for the measurement day in each case.

Measured CH_4 emission rates varied between 1.3 and 25.5 kg CH_4 h^{-1} (Table 1). The average CH_4 loss (defined here as measured emission/gas production) was 2.0%, where the loss calculated for the individual measurement campaigns on the various plants ranged from 0.3% to 21.0%. There was a general tendency that the calculated CH_4 losses were higher for the smaller biogas plants. Also, some variation in losses was observed when comparing measurement campaigns for the same biogas plants. The highest loss was observed at biogas plant 6, where the emission equalled 21.0% of the production in the last of the two campaigns, which was much higher than what was observed at the first campaign (5.1%). The cause of this was not found – no irregularities were reported by the biogas plant. However, the longer measurement campaigns performed at biogas plants 9 and 10 showed that emission rates can vary significantly over time, and may spike at certain operational events such as stirring open tanks and pumping digestate into tank trucks.

The TGD method was found applicable to measure total CH_4 emission rates at biogas plants. Compared to landfills, where we have used the same methodology and instrumentation, biogas plants are more localised sources of fugitive emissions, and the downwind plumes were easily detectable. However – to reduce

emissions from facilities, it may be feasible to apply on site methods, which can pinpoint leaks and thus areas and leakages were emission can be reduced.

Table 1. Characteristics of the biogas plants in this study, biogas production (at each campaign) and measured CH_4 emission (at each campaign).

Biogas plant #	Main substrate(s)	Gas utilisation[1]	Gas production (kg CH_4 h^{-1})	Measured CH_4 emission (kg CH_4 h^{-1})	CH_4 emission / gas production
1	Manure, org. waste	Off site	416	1.3	0.3%
			451	5.5	1.2%
2	Manure, org. waste	CHP	404	3.3	0.8%
			404	9.5	2.4%
3	Manure, energy crops	BU	406	13.4	3.3%
			415	7.9	1.9%
4[2]	Manure, org. waste	BU	525	12.6	2.4%
			1491	25.5	1.7%
5	Manure, org. waste	Off site	64	4.1	6.4%
			84	8.7	10.4%
6	Wastewater sludge	CHP & BU	99	5.0	5.1%
			93	19.5	21.0%
7	Wastewater sludge	CHP	97	10.1	10.4%
			97	6.0	6.2%
8	Manure, org. waste	Off site	880	4.9	0.6%
			885	7.1	0.8%
9	Maize silage	CHP & BU	400	2.1	0.5%
10	Maize silage	CHP	127	2.6	2.1%
		AVERAGE	408	8.3	2.0%

[1] CHP = Combined heat and power (on site), BU = Biogas upgrade (on site)

[2] The production capacity of biogas plant 4 was expanded in the period between the two measurement campaigns

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