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Characterization and Quantification of Methane Emissions from Waste in the UK

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MEthane goes MObile
MEasurements and MOdelling

1. Background

Globally, human activities produce over 60% of total CH_4 emissions, with 22% of emissions from the energy sector and 10% from the waste sector [1]. In the UK, the waste sector contributed 36% of total methane emission in 2017[2]. Fugitive emissions from major sources are not yet well quantified. As seen in **Fig. 1**, methane emission from landfill sites has decreased, but anaerobic digestion emission and composting has increased in recent years.

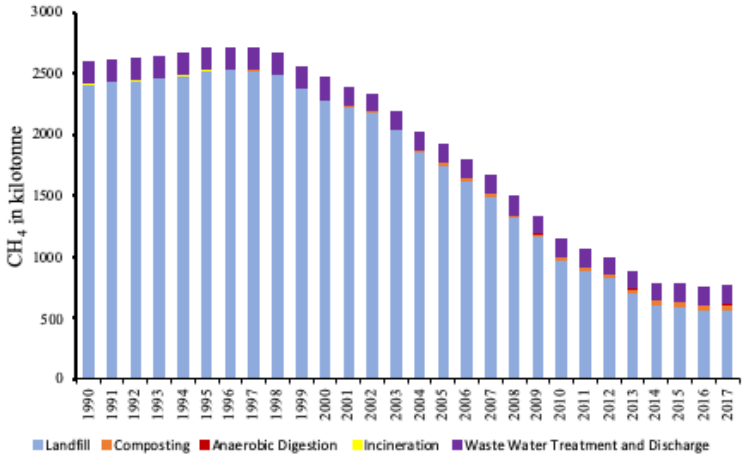


Fig. 1 UK national inventory of methane emissions by source sector[2]

Most of the biogas plants have started operation in the last few years and a significant number of them have not been included in emissions inventories. Recent studies suggested that biogas plants have considerable methane emissions. Also, stable isotopic signature analysis is widely used to characterize the sources, as different source types have clearly distinct $\delta^{13}C$ signatures.

The **objective of this study** was to evaluate the seasonal impact on landfill methane isotopic signature changes and quantify biogas plant emission rates in the UK.

1.Dlugokencky, E.J., Nisbet, E.G., Fisher, R., Lowry, D., 2011. Global atmospheric methane: budget, changes and dangers. Philos. Trans. R. Soc. A Math. Phys. Eng. Sci. 369, 2058e2072

2.NAEI (2019) UK National atmospheric emissions inventory, http://naei.beis.gov.uk/overview/pollutants?view=summary-data&pollutant_id=

2. Methodology

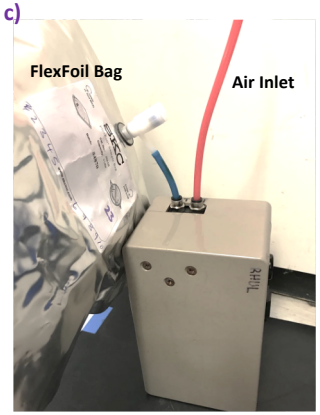
A mobile Picarro G2301 Cavity Ring-Down Spectrometer equipped with a battery power supply and **LGR UMEA** seen in **Fig. 2.a)**, coupled with the Climatronics sonic anemometer and hemisphere GPS receiver **Fig. 2.b).** Air sample is collected in a Flexfoil bag **Fig. 2.c)** and carbon isotopic ratios can be analysed by **high precision CF GC-IRMS Fig. 2.d)** to characterize sources of methane emission.

a)

b)

Fig. 2 a) The Picarro G2301 and A0941 mobile module were in a Dacia Duster. A set of 4 x 110 Ah marine batteries provided 9+ hours of continuous instrument **(b)**Hemisphere GPS receiver

c)



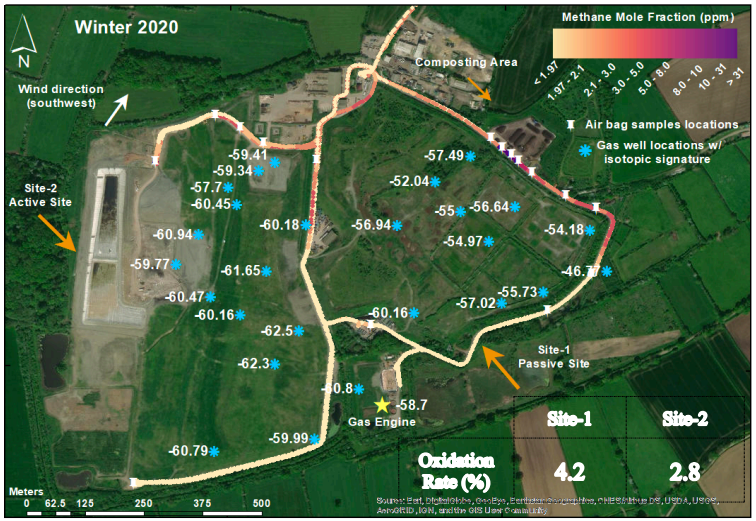
d)

Fig. 2 c) Air sample collection. **d)** Once identified the plumes have been sampled by filling Flexfoil bags for later carbon isotopic analysis by high precision GC-IRMS at the RHUL lab.

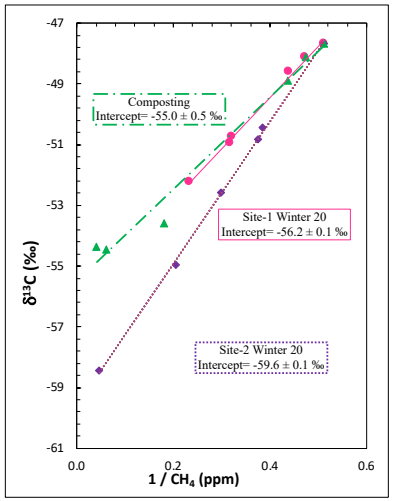
3) Results and Conclusion

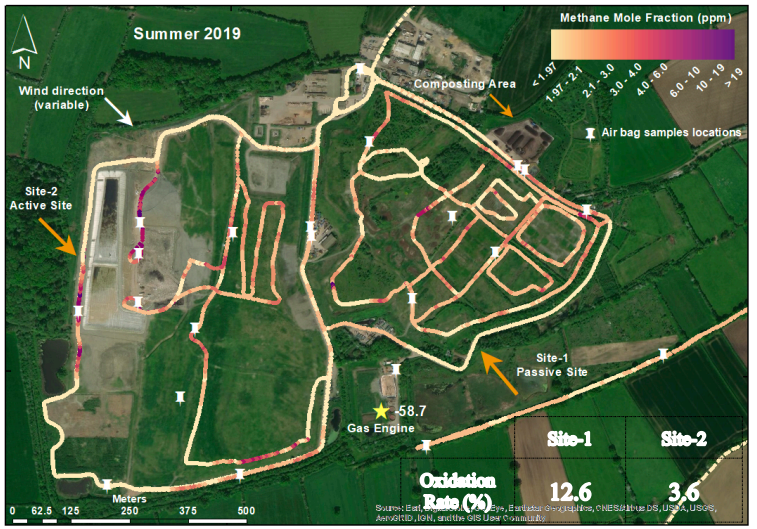
3.a) Landfill Result – Isotopic Signature and Oxidation

Seasonal oxidation rate study: Winter – Summer



b)





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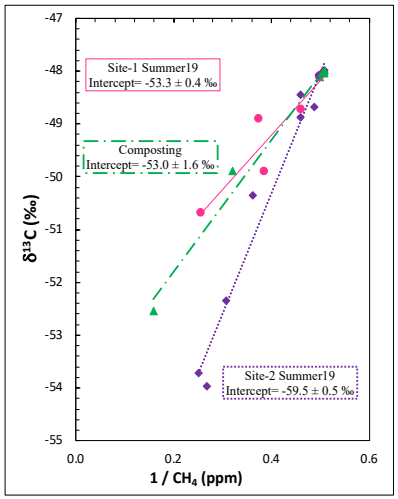

Fig. 3 a) Methane plume map of Landfill site on 12th February 2020] **b)** Keeling plot for sampling of different areas of the site on 12th February of 2020 **c)** Methane plume map of Landfill site on 9th July 2019 **d)** Keeling plot for sampling of different areas of the site on 9th and 10th July 2019

- During **winter survey**, methane mole fractions were higher on the east side of the site, in the area downwind of active site and a leaking gas well.

- The mean $\delta^{13}C$–CH_4 of methane emitted to the atmosphere from the -59.6‰ **active part of the site** and for -54.8 ‰ from the **closed part** of the landfill.

- Methane emissions from older, closed sites are characteristically **more enriched** in δ13C than emissions from active sites. At this site the oxidation rate was **higher** in the closed part of the site compared with the active part for both winter and summer surveys

- During **winter season**, a higher methane mole fraction, more depleted isotopic signature and a lower oxidation rate were observed from this landfill site.

- The difference between **summer and winter** isotopic signatures was between 0 to 2.9 per mil.

- Summer, fall and winter landfill surveys have been completed and the details will be discussed in our paper. Unfortunately, a planned spring survey was cancelled due to the Covid-19 pandemic

3) Results and Conclusion

3.b) Biogas Plant – Methane Emission Rate Result

Food Waste Biogas Plant - Gaussian Plume Modelling Approach

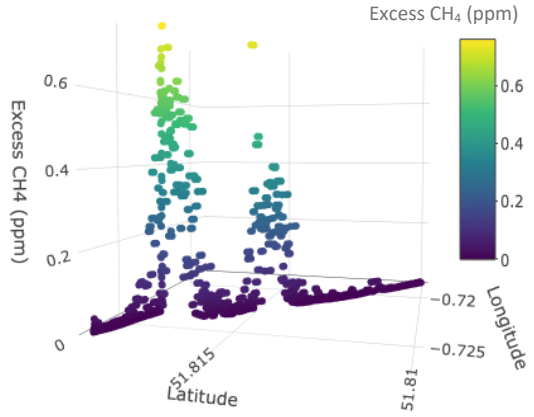

Fig. 4 Excess methane mole fraction changes based on latitude and longitude

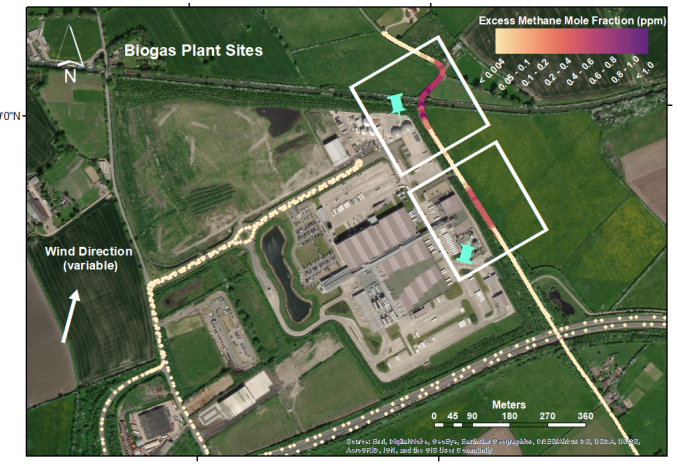

Fig. 5 Excess methane plume map of biogas plant

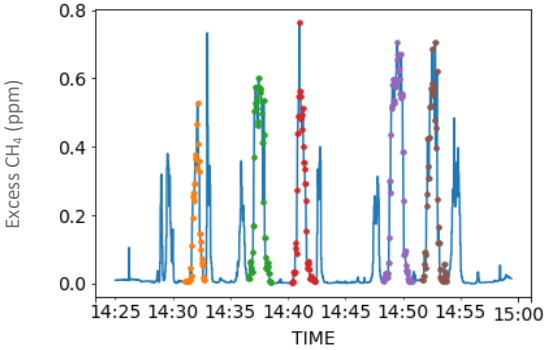

Fig. 6 Biogas Plume (Excess mole fraction vs time) with selected peaks for emission rate calculation of **upper** biogas plant

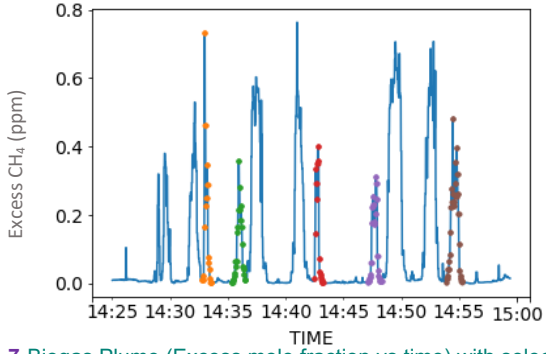

Fig.7 Biogas Plume (Excess mole fraction vs time) with selected peaks for emission rate calculation of the **bottom** biogas plant

- This facility is the largest dairy company in the UK. Annually, 50,000 tonnes food waste are digested in the biogas plant.
- There were two methane sources at the site. One was from a dairy residual anaerobic digester, and the other was from a food waste anaerobic digester. In total 990 Nm^3/h biomethane is produced in the facility [3].
- Emission rate was calculated 1.5 to 5.3 kg CH_4/hr combining these two sources by Gaussian plume modelling approach using the Python programme.

- **0.3 - 0.6%** of the total amount of produced methane was emitted from this biogas facility assuming that it was operating to full capacity during the period of investigation. This methane loss percentage appears to be highly variable across biogas facilities.

- Together with the 8 other investigated biogas plants, the total emission rates estimated **47.9 to 198 kg CH_4/ hr.**

- CH_4 losses varied between **0 – 22%** of the total amount of calculated produced gas for 9 biogas plants in the UK.

- Emission rate calculation included the **uncertainties** from from the unknown height of the source, variability in wind speed, direction, and stability class, and variation in each transect.

- Detailed analysis of the biogas plant CH_4 emission rates will further be discussed in our paper.

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3. The official information portal on Anaerobic Digestion, web page http://www.biogas-info.co.uk

Oxidation Rate Calculation

Equation 1. $f_o = \frac{\delta E - \delta A}{(\alpha_{ox} - 1) * 1000}$

Equation 2. $\alpha = 1.0251 - 0.000313 * T$

If $\boldsymbol{\delta}^{13}C$ of methane emitted from a landfill ($\boldsymbol{\delta}$ E) and methane in the anoxic zone($\boldsymbol{\delta}$ A) are known, the fraction of methane oxidised (f_o) can be calculated using Equation 1[4]. This equation assumes purely advective transport of methane through the cover soil. α_{ox} is a fractionation factor resulting from the preference of the bacteria within the cover soil to oxidise ^{12}C rather than ^{13}C. This fractionation factor is dependent on temperature and soil type. The selection of the constant α in Equation 1 was calculated from the equation 2 derived by Börjesson et al. (2009) following measurements at a Swedish landfill site [5].

4. Liptay K. et al., Use of stable isotopes to determine methane oxidation in landfill cover soils, JGR Atm, 103, D7, 8243-8250 (1998) 5.Börjesson G. et al., A national landfill methane budget for Sweden based in field measurements, and an evaluation of IPCC models, Tellus, 61B, 424-435 (2009).