Beyond the flux box - a simple method for measuring whole site LFG emissions

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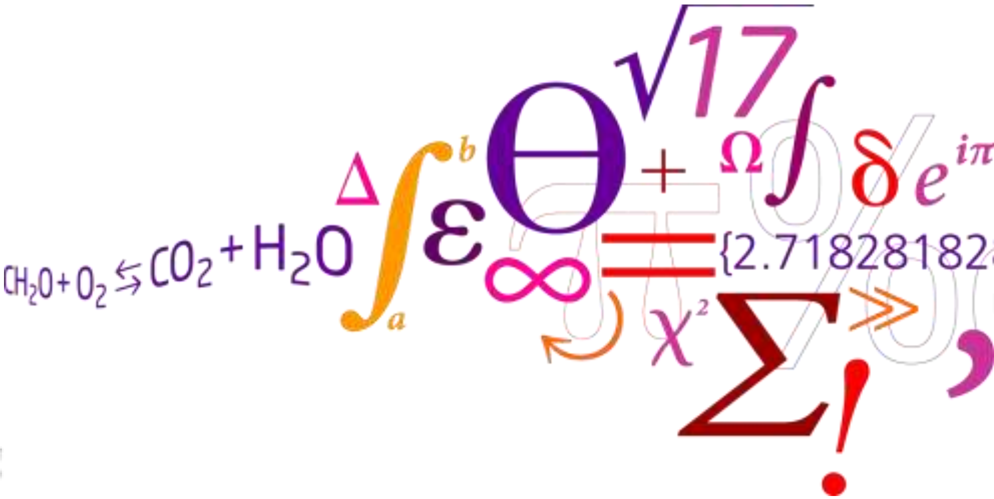

DTU Environment
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Content

- Introduction
- The dynamic tracer dispersion method
- Control test and learnings
- Methane emission data from 15 Danish landfills
    - Old closed landfills and landfills still in operation
    - Landfills with gas extraction and landfills with on-site composting activities
- Methane emission measurement activities in the UK
- Conclusions

Introduction – why do we need emission measurements?

- Methane emissions from landfills are in most cases based on gas generation models using default values for most input parameters
- Modelling results of methane emissions are rather uncertain
- We need robust methodologies for whole landfill gas emission measurement:
  - to validate models and obtain better prediction tools
  - to report emissions for regulatory purposes
  - to document emission reductions based on implementation of new mitigation technologies
  - to provide inventory data for environmental assessment

Introduction – what are the challenges?

- High spatial variability
  - Methane emission rates can vary up to seven orders of magnitude within a few meters distance
  - 50-70% of the total emission comes from a minor area (<5%) of the landfill
- High temporal variability
  - Highly dependent on changes in barometric pressure (within a few hours)
  - Dependent on temperature, precipitation etc. as these factors influence methane oxidation (seasonal variation) and gas transportation
- Large area
  - 5-20 ha
- Complex topography
  - Large differences in elevation

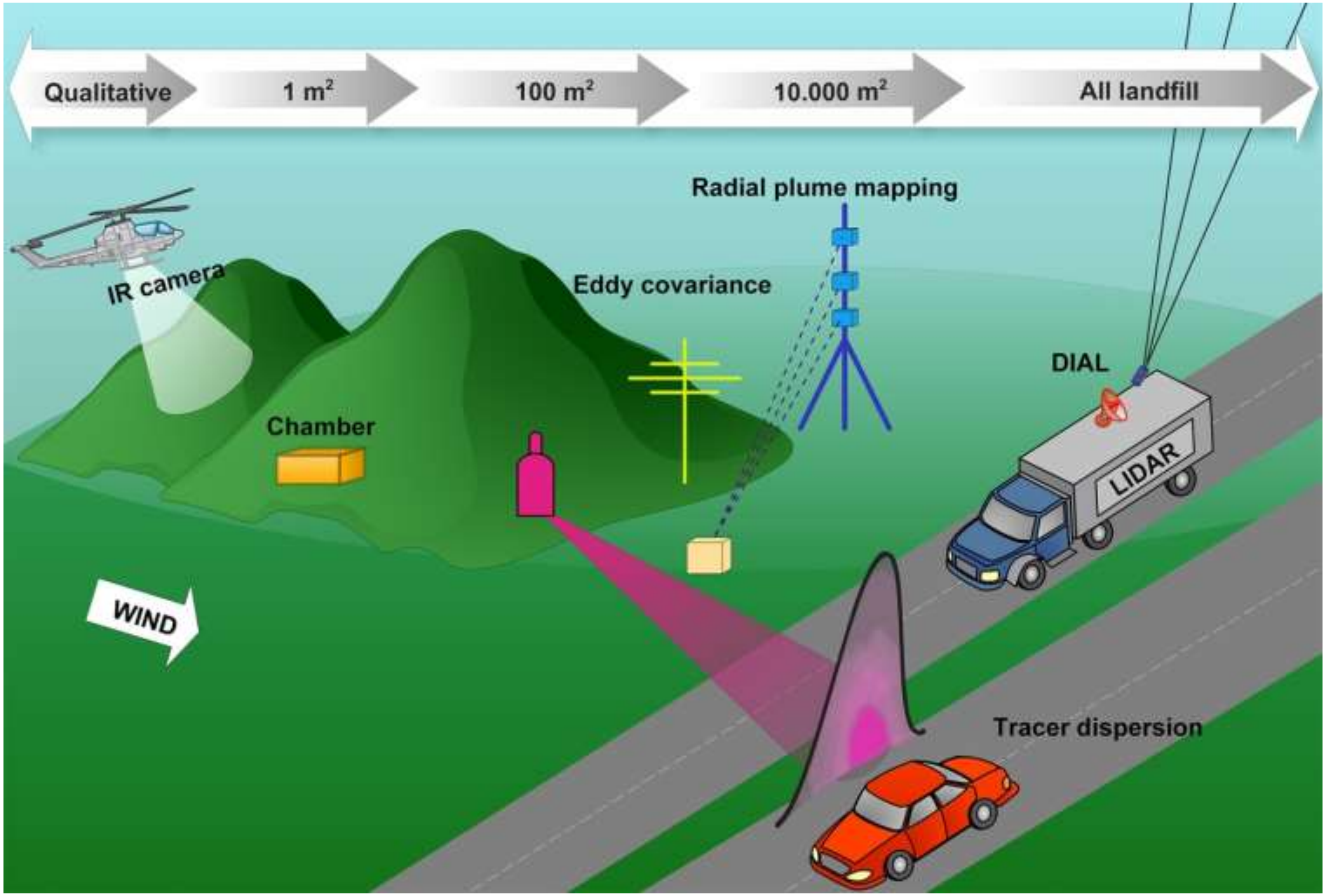


Introduction – many methods are available

- A number of new methods have been developed in the last few decades
- There is not one specific method that has been recognized as an international reference method to measure annual methane emissions from landfills
- Also few are commercially available and only in a handful of countries
- Few comparison studies have been conducted to assess the best methodology




Introduction – overview of methods



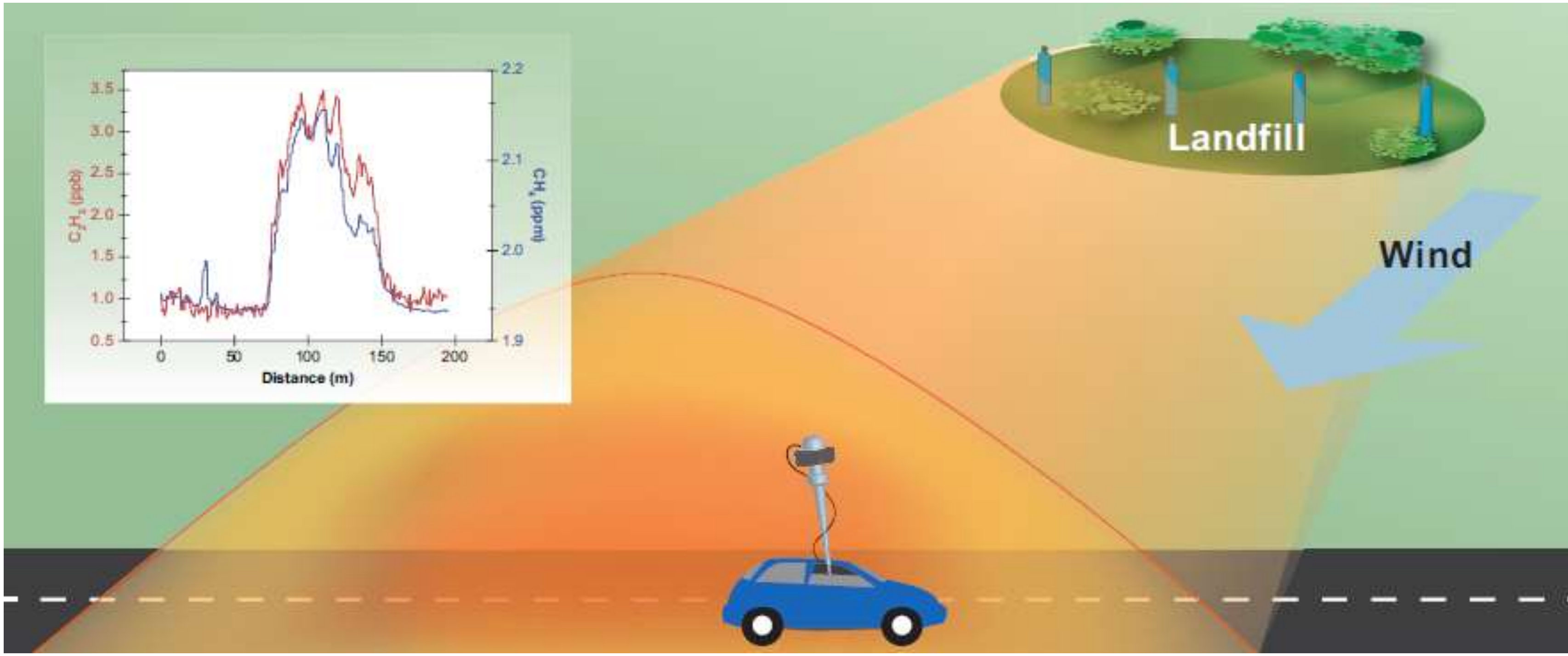
Introduction - The flux chamber method

- Surface fluxes are nearly always extremely heterogeneous distributed
- The majority of the emission might be emitted through a small area of the site
- Measurements in grid or randomly chosen points will lead to underestimation
- Measurement affects emission – especially while pressure-driven
- Measurements are usually carried out over a short time period (5 minutes) – covering a whole site is very time consuming (days)

HOWEVER:

- Chambers together with gas probes can increase process understanding

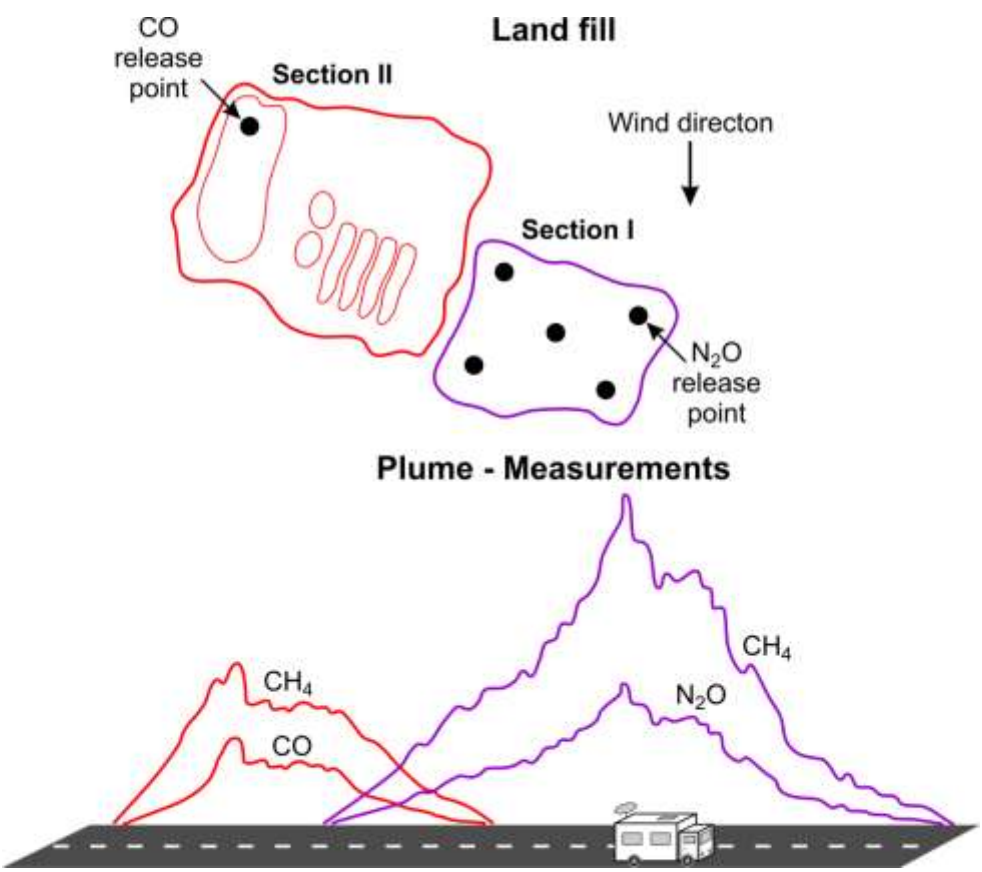
Dynamic plume tracer dispersion method – single tracer approach



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

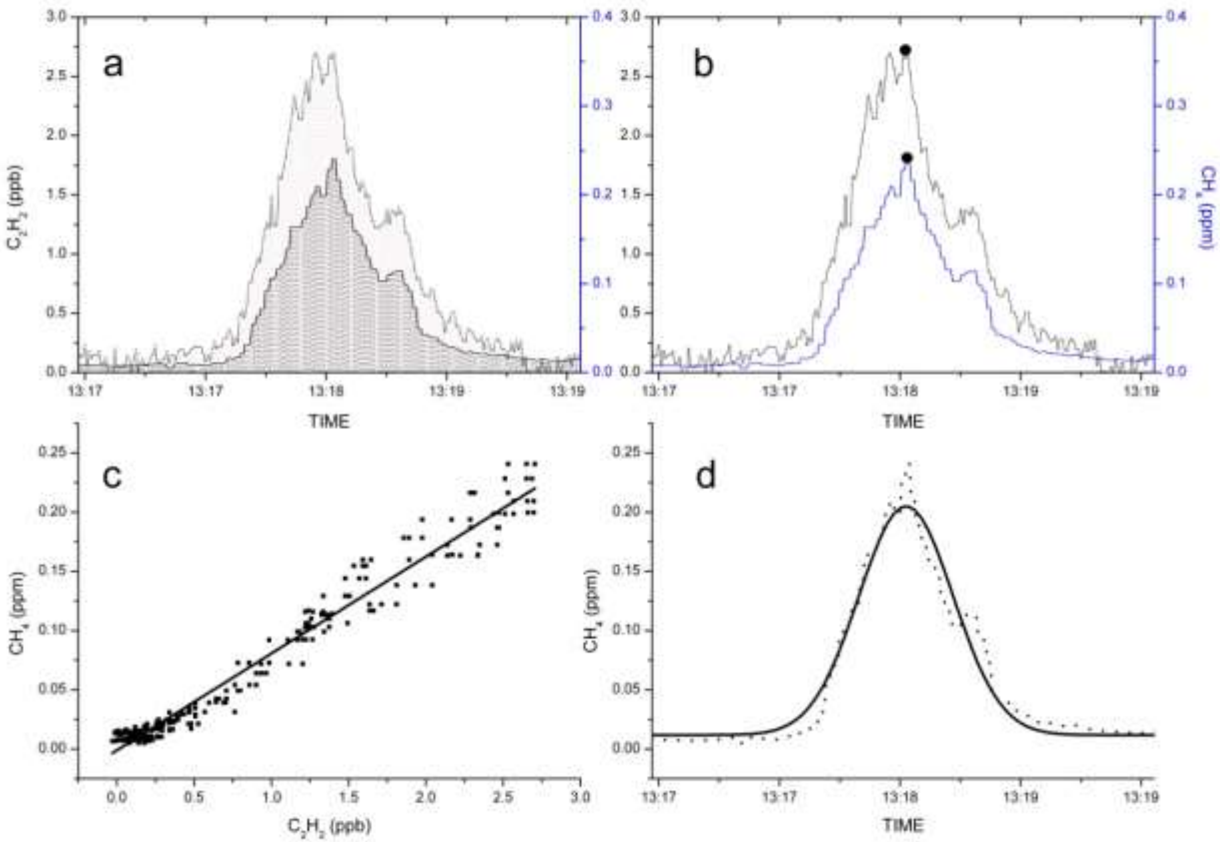
- Tracer gas with long atmospheric lifetime
- Stable wind conditions (speed, direction, vertical mixing)
- Drivable roads nearby and oriented
- Sensitive analytical instrument (high resolution) and fast responding

Dynamic plume tracer dispersion method – double tracer approach



Scheutz et al. 2011, WM Special issue

Methods for obtaining the methane to trace gas ratio



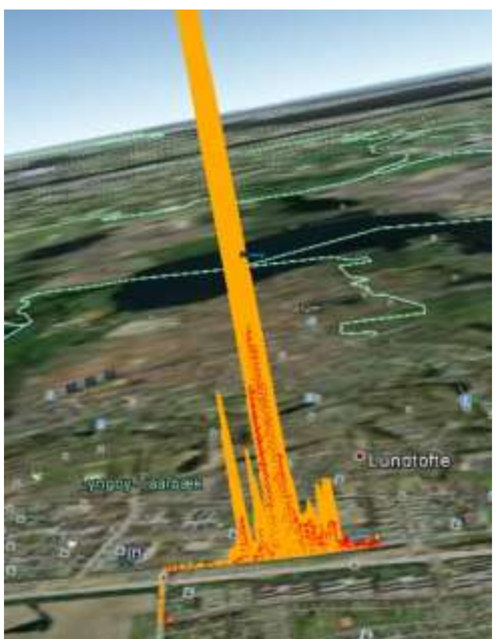
a) Total plume integration, b) Peak height, c) Single point scatter plot, and d) Gaussian plume modelling

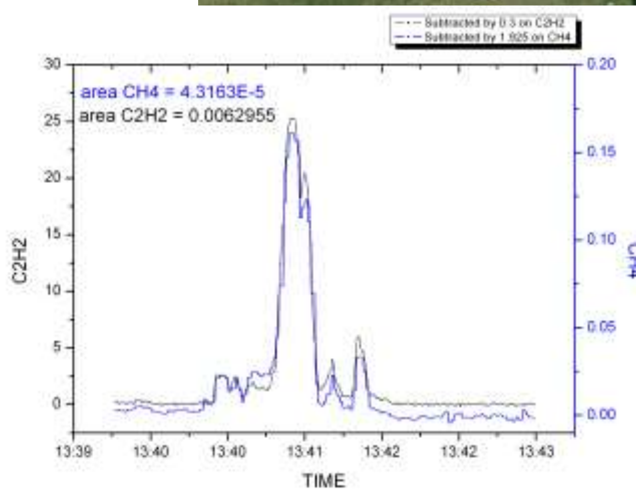
Controlled tracer and methane release test

- Measurement distances
- Tracer gas configurations
- Determination of methane/tracer ratios

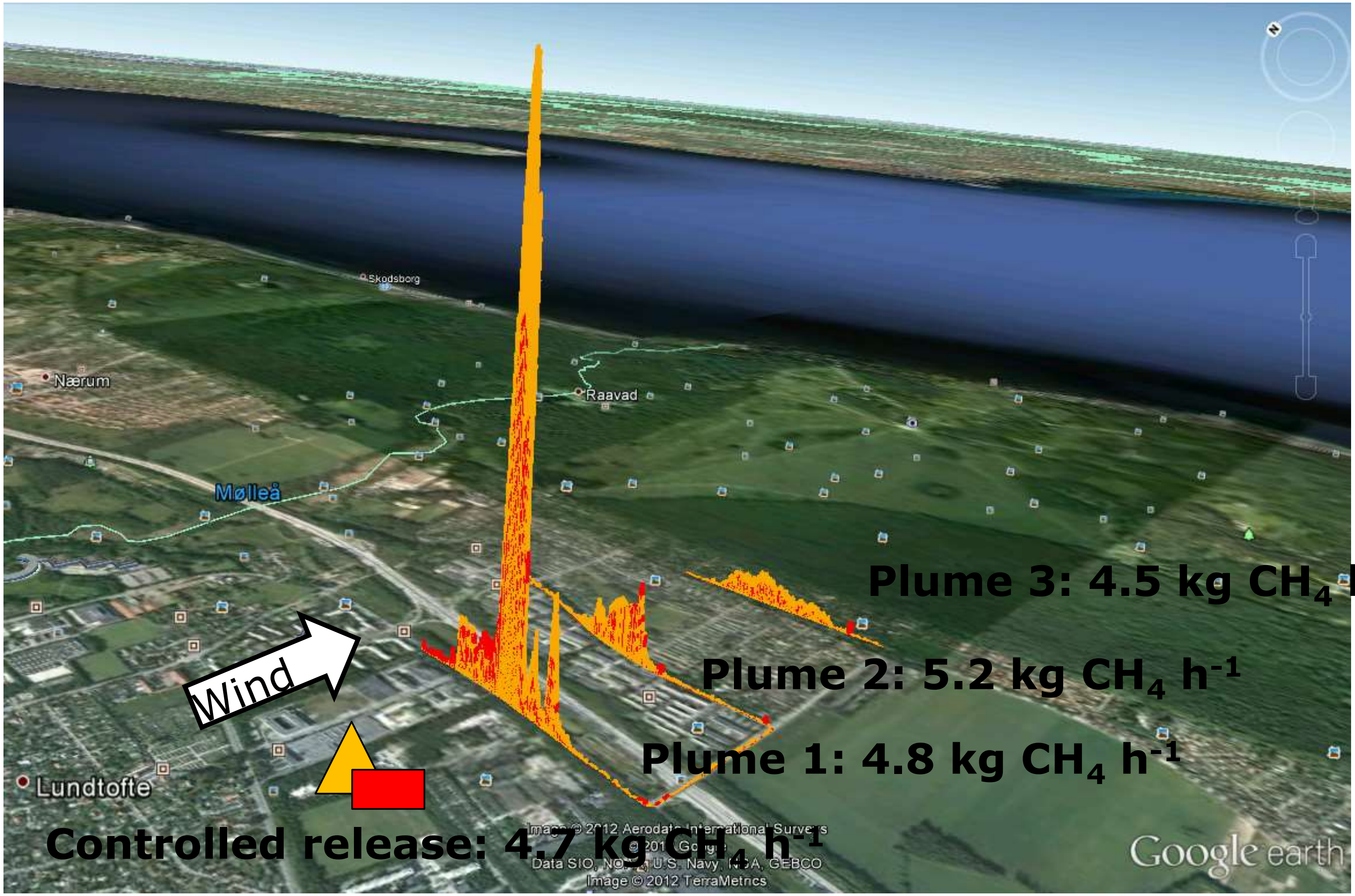
Release of CH_4 and C_2H_2

Plumes 350 m downwind





Controlled tracer and methane release test
Plumes: 350, 700 and 1200 m downwind

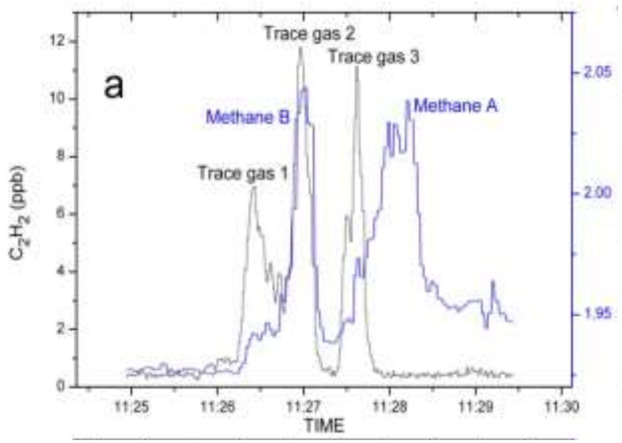


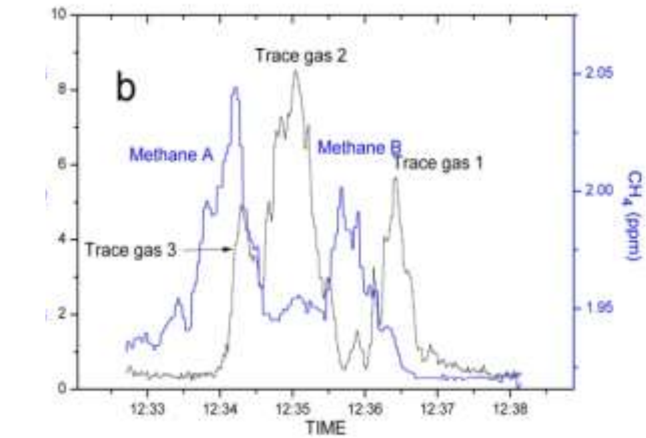
CH_4 (red) and C_2H_2 (yellow) concentration above background

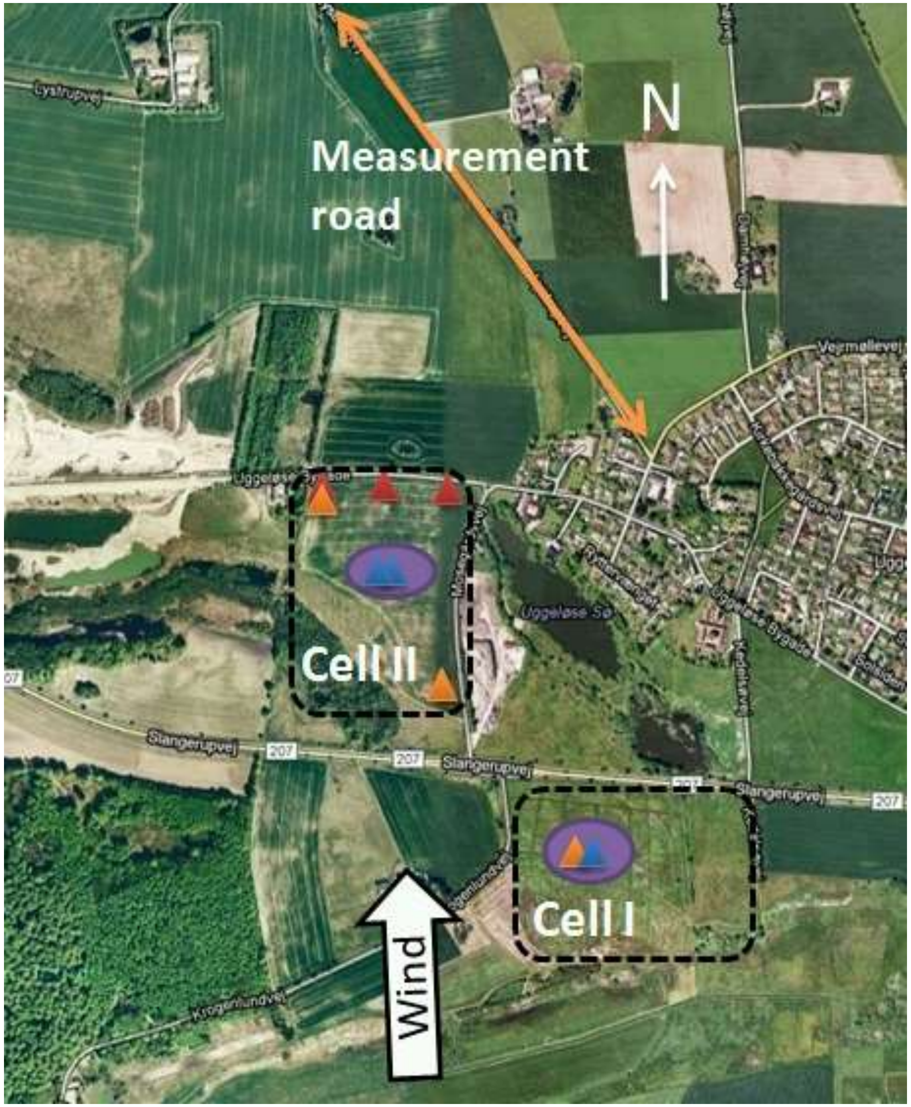
Learnings from the controlled release testing

- The plume integration approach gave more accurate results (-2 - 6%) than using the peak height (3 - 24%) and scatter plot approach (-6 - -15%)
- The tracer dispersion method was more sensitive to misplacement of the tracer in upwind than sideways direction
- Placing the tracer bottles upwind or downwind to the source led to an overestimation or underestimation of the methane emission rates, respectively
- Increasing measurement distances minimize the error from misplacement of tracer release
- Gaussian model without trace gas gave the most uncertain emission rates

Quantification at Uggeløse landfill

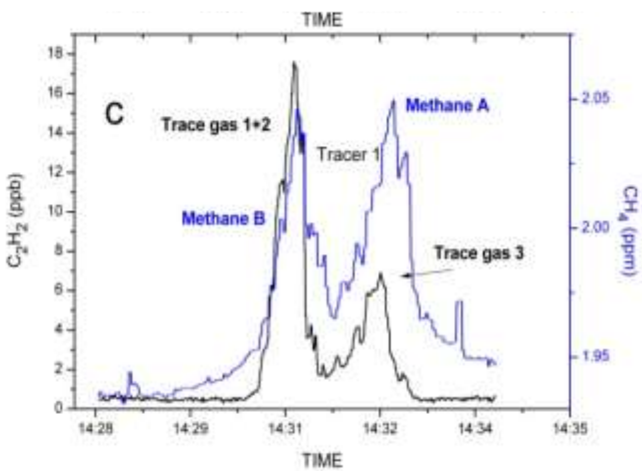


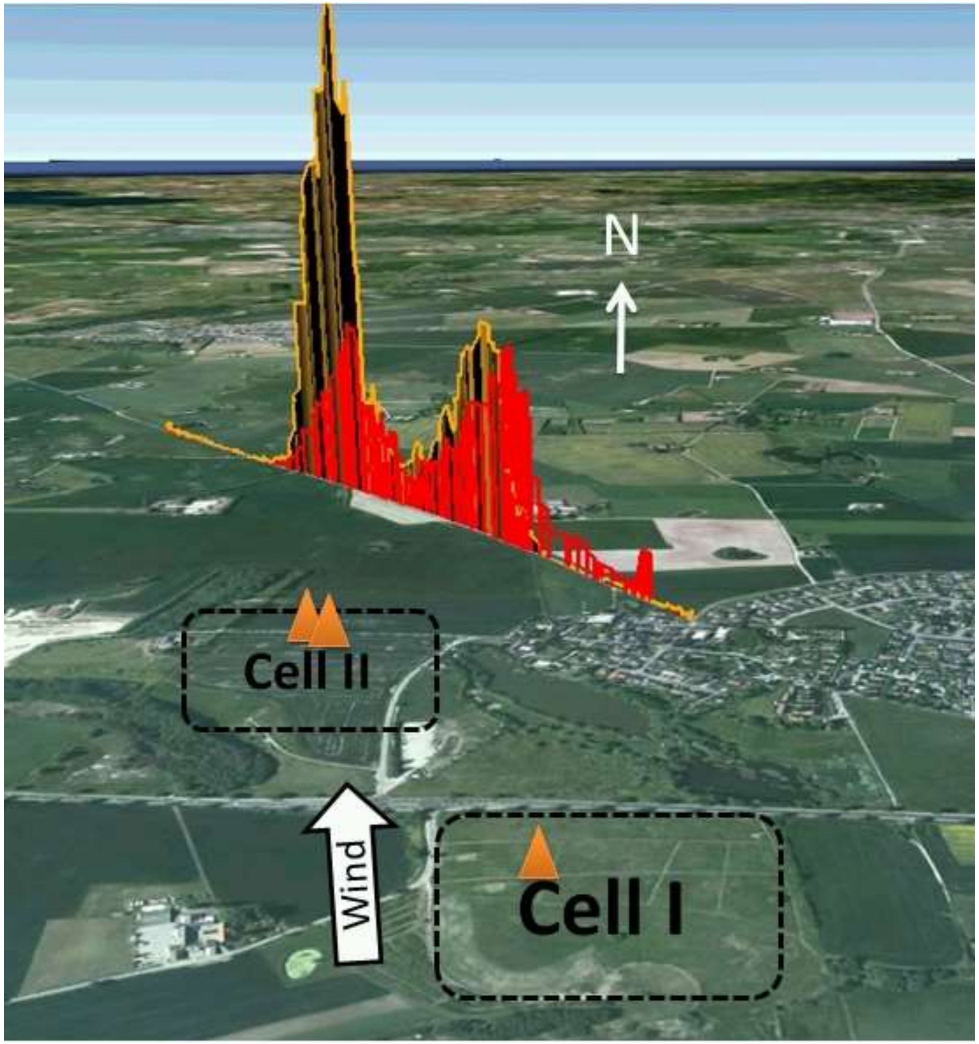




Quantification at Uggeløse landfill

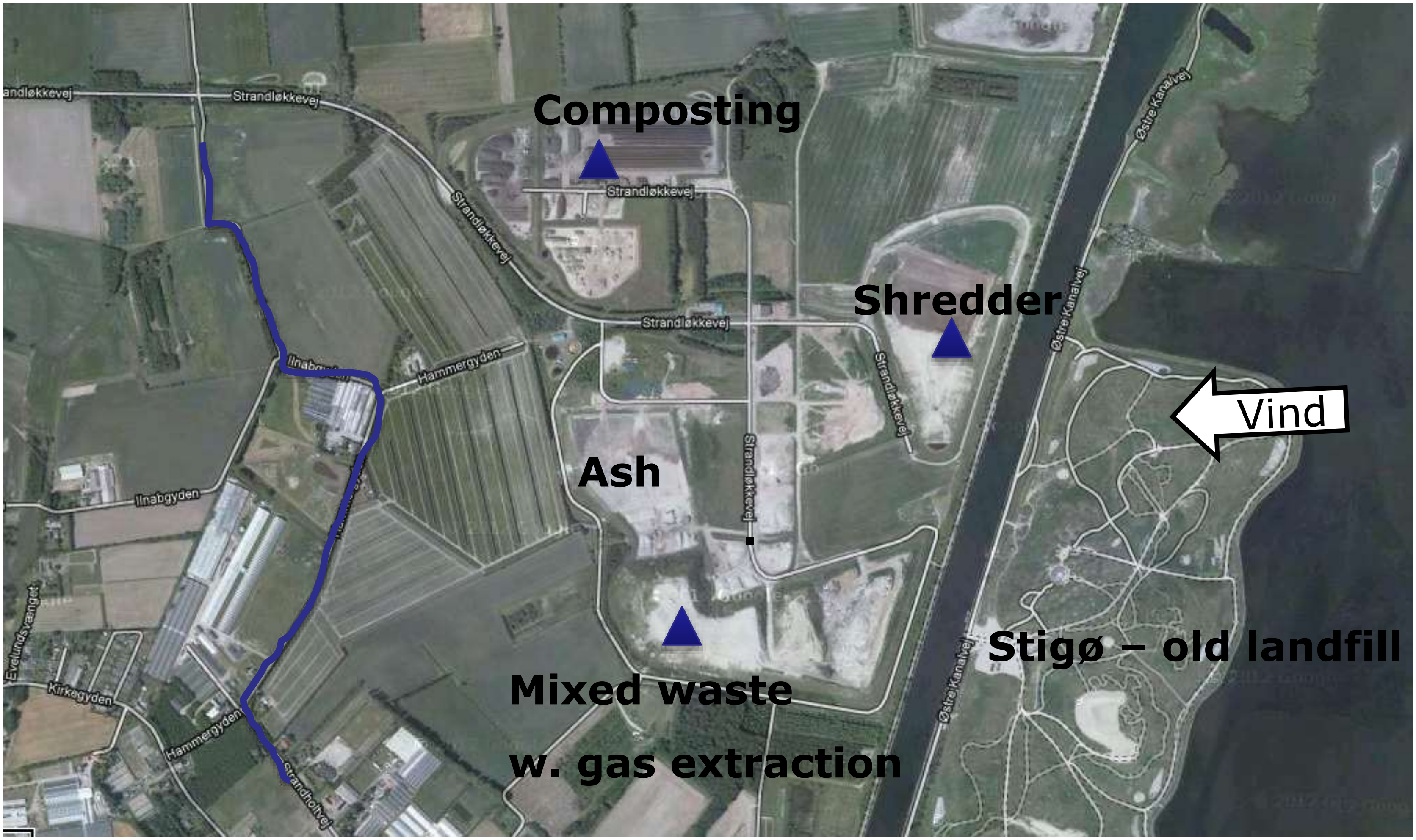
- Good match of tracer and methane plume
- Methane emission of 5.3 kg/h (Cell I) and 4.1 kg/h (Cell II)





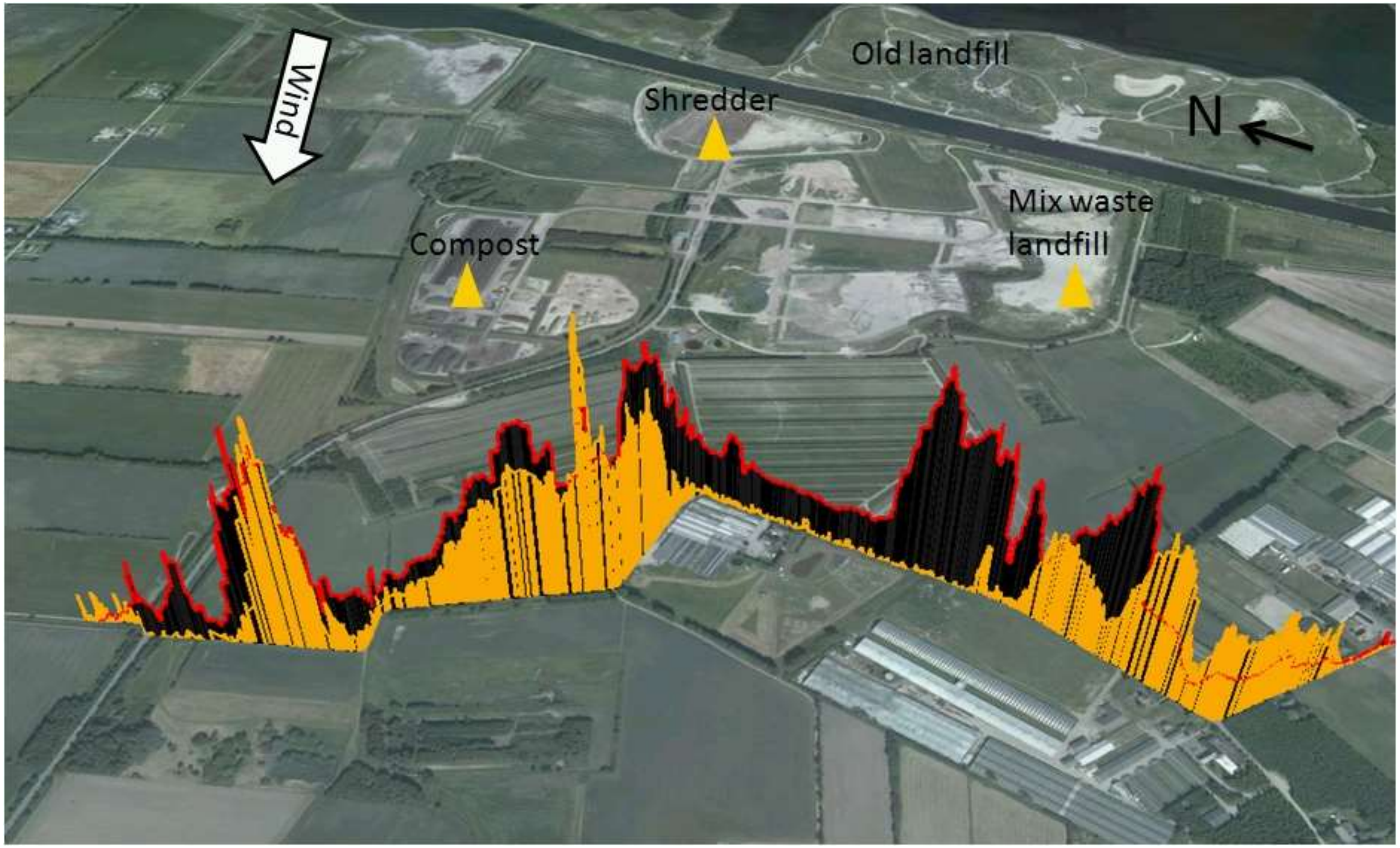
CH_4 (red) and C_2H_2 (yellow) concentration above background

Quantification at Odense Landfill



▲ = tracer placement

Quantification at Odense Landfill



Quantification at Odense Landfill

- At this specific site four methane plumes were recorded showing emissions from a composting facility, a shredder cell, an old landfill, and a mixed waste landfill
  - shredder cell: 19.7 kg CH_4 h^{-1}
  - mixed waste landfill: 13.3 kg CH_4 h^{-1}
  - composting facility: 16.8 kg CH_4 h^{-1}
  - old landfill: (n.a. but > 20 kg CH_4 h^{-1})
- At Odense where the gas collection system collected 38 kg CH_4 h^{-1} in comparison to a total landfill emission of 33.1 kg CH_4 h^{-1}

Landfill methane emissions (kg h^{-1})

Landfill	Disposal period	Area (ha)	Emission from disposal units (kg CH_4 h^{-1})		Total landfill emission (kg CH_4 h^{-1})	Emission from on-site activities (kg CH_4 h^{-1})
Audebo (2)	1990 →	4.7			16.0±6.0	39.1±9.6 (Biological treatment and composting)
AV Miljoe (4)	1989 →	30			32.4±7.6	
Eskelund (1)	1950-1980	15.0			6.1±0.6	
Fakse (3)	1981-1997	13	32.6±7.4	10.3±5.3	42.2±7.2	2.9±0.7 (Composting + sludge storage)
Feltengård (1)	1983 →	10.3			3.8±0.7	
Frederiksværk (1)	1950-2009	7.5			8.9±1.2	4.0±0.7 (Composting)
Glatved (2)	1981 →	14.0			60.8±10.9	
Hedeland (1)	1978-2009	10.0			3.1±0.7	
Klintholm (2)[a]	1978 →	6.5	5.4±0.9	9.6±1.7	15.0±2.6	5.1±2.4 (Composting)
Odense (2)	1994 →	6.0	19.7±2.6		33.1±9.0	16.8±7.8 (Composting)
Uggeløse (1)	1970-1989	11.0	5.3±1.1	4.1±1.1	9.5±1.6	
Viborg (1)	1989-2009	3.5			11.1±2.9	7.4±2.2 (Composting)
Skovsted (1)	1987 →	4.0			2.6±0.9	
Skårup (1)	1980 →	8.9			11.9±1.2	Composting (included in the emission)
Ærø (1)	1985-2005	5.0			6.9±1.6	

Measurements on UK landfills

Three tracer gas bottles at UK landfill (yellow triangles) and the downwind plume of methane (red) and tracer gas (yellow) 1600-1700 m away.

UK site: 7 days, tree measuring distances, >100 plume traverses

3 additional UK sites — Last two weeks

Conclusion – methodological aspects

- We have a reliable and robust method that can be used for quantifying gas emissions from landfills
- The detection limit is around 1 kg methane per hour
- Precision is around 10% or lower when measuring conditions are good
- Using wind conditions we can often quantify individual plumes from different sources
- One campaign takes about 3-6 hours
- Accessibility to the sites and topography have not at any of the visited sites prevented quantification – so far….

Conclusions – methane emissions

- Methane emissions from the 13 Danish landfills varied between 3 and 61 kg CH_4 h^{-1}
- Gas collections systems had an extraction efficiency of 40-50%
- Landfills with shredder waste emit significant amounts of methane
- On-site waste treatment activities including composting and biological treatment emits methane in amounts comparable to the landfill site

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National outlook

- All sites have gas emissions (2-20 $g/m^2/d$), which potentially could be mitigated by using biocovers
- In comparison with the Danish Inventory Reporting the measured emissions are lower - about 60%

Conclusions – international

- The tracer dispersion method has been applied for methane emission quantification at four UK landfills
- The method was included in an method comparison study (UK and in Sweden)

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Thank you for your attention

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