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Using stable isotopes as an indicator for the
remaining gas generation potential in
decommissioned municipal waste landfills – a
concept study

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Presentation overview

01 **Background**

02 Objectives and strategy

03 Planned work

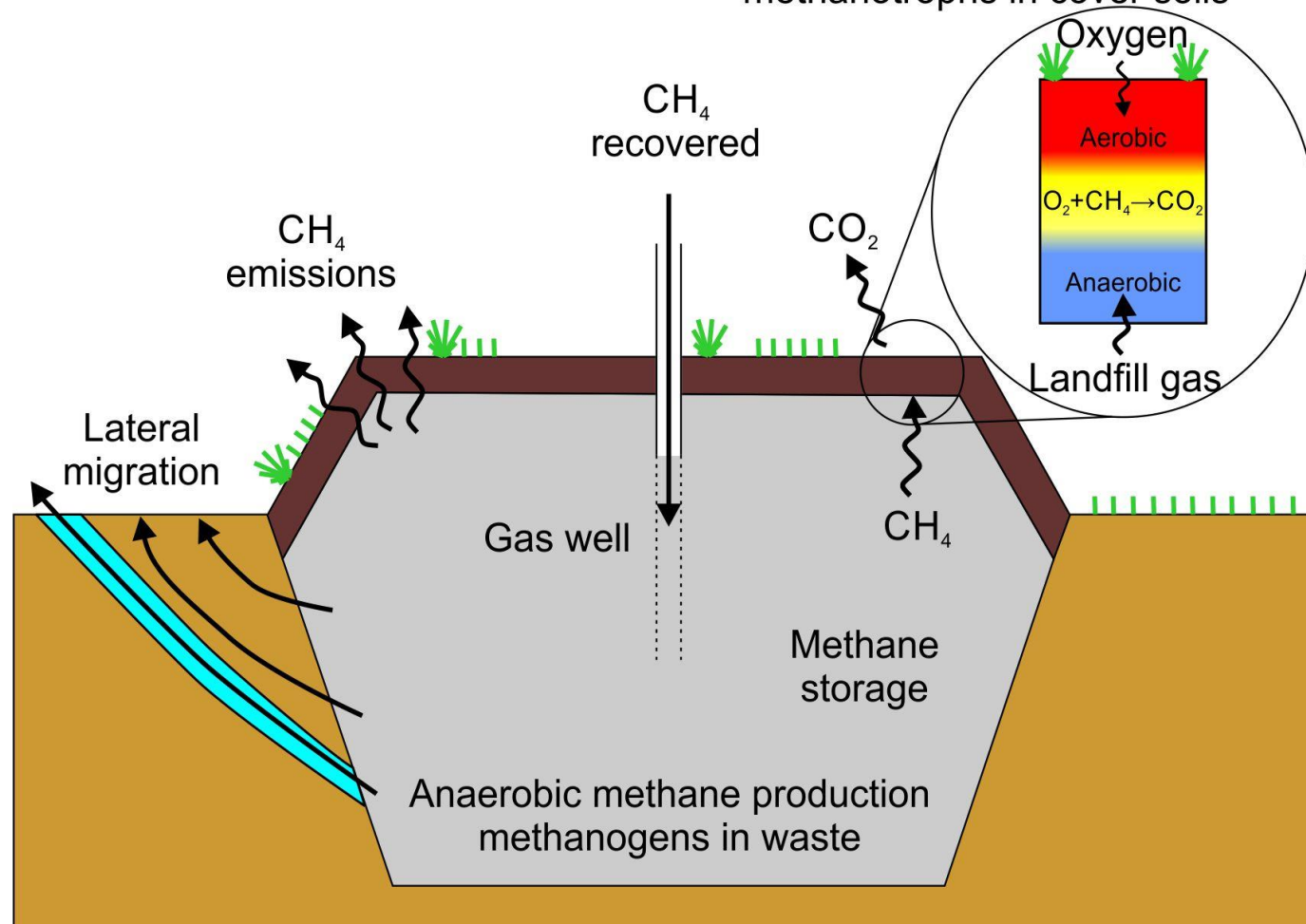
Background

- Understanding and quantifying landfill emissions is both legally required (e.g., national greenhouse gas inventory reporting) and important to reduce potential negative health impacts on persons living nearby to or on top of active or decommissioned landfills.
- Currently, this is done through 1st-order decay modelling together with estimates of input material and organic matter content. At best, annual or bi-annual surface emissions measurements are performed.
- The PhD Project “Do landfills ever die? Developing advanced stable isotope approaches to trace the fate of carbon in landfills,” a collaboration between The Norwegian University of Life Sciences (NMBU) and the Institute for Energy Technology (IFE), aims to improve understanding of landfill emissions through increased process understanding within landfills.

Methane in Landfills

$$\text{CH}_4 \text{ emitted} = \text{CH}_4 \text{ generated} - \text{CH}_4 \text{ recovered} - \text{CH}_4 \text{ oxidized} - \text{CH}_4 \text{ migrated} - \Delta \text{CH}_4 \text{ stored}$$

Aerobic methane oxidation
methanotrophs in cover soils



Methane production – many pathways

Hydrolysis – acidogenesis – acetogenesis –
methanogenesis

Fate of methane

Stored / oxidized / emitted

CH₄ mass balance depends on site-specific conditions – often unknown

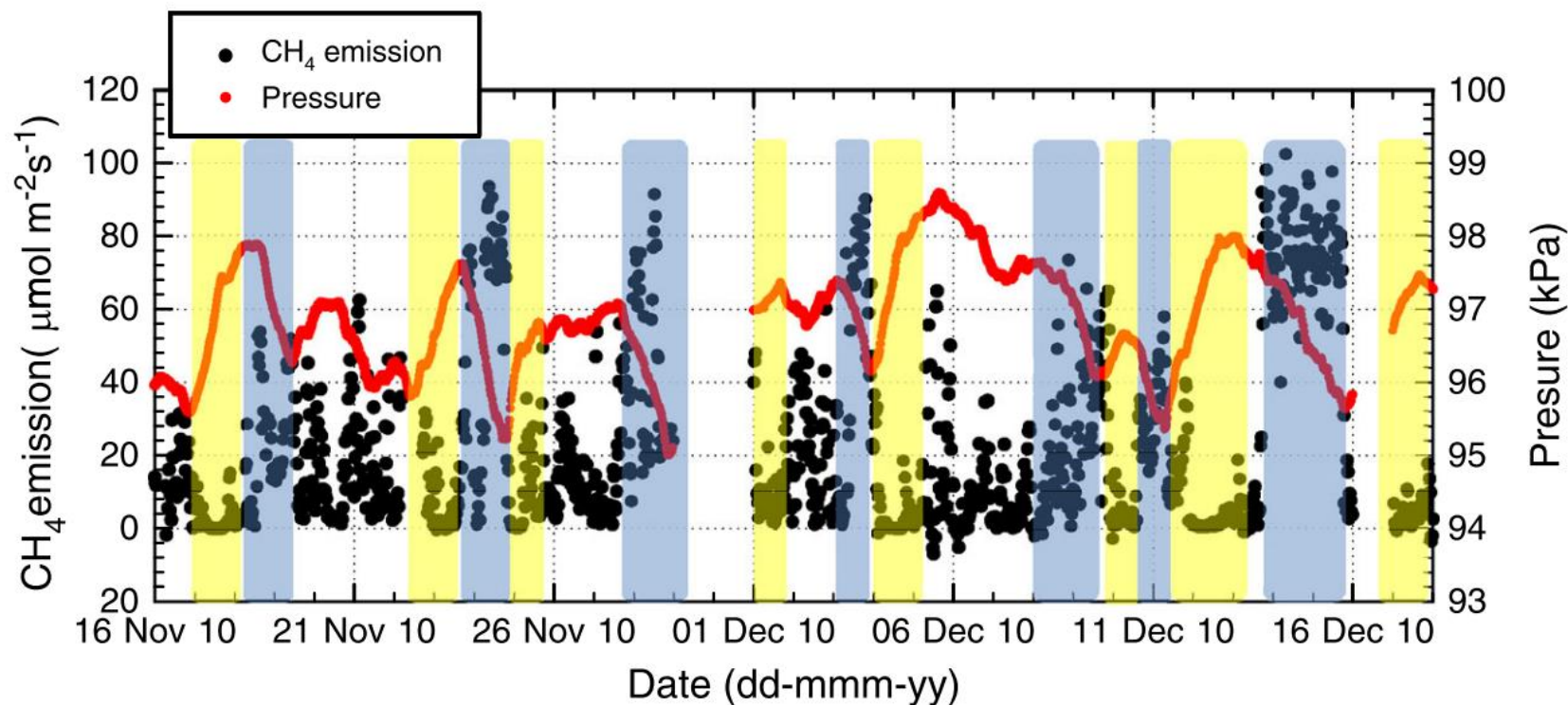
- Waste composition
- Local geomorphology
- Local climate
- Presence/efficiency of oxidation cover
- Presence/efficiency of side and bottom liners
- Water saturation

Many unknowns!

Microbial methane oxidation processes and technologies for mitigation of landfill gas emissions (Scheutz et al.;2009)

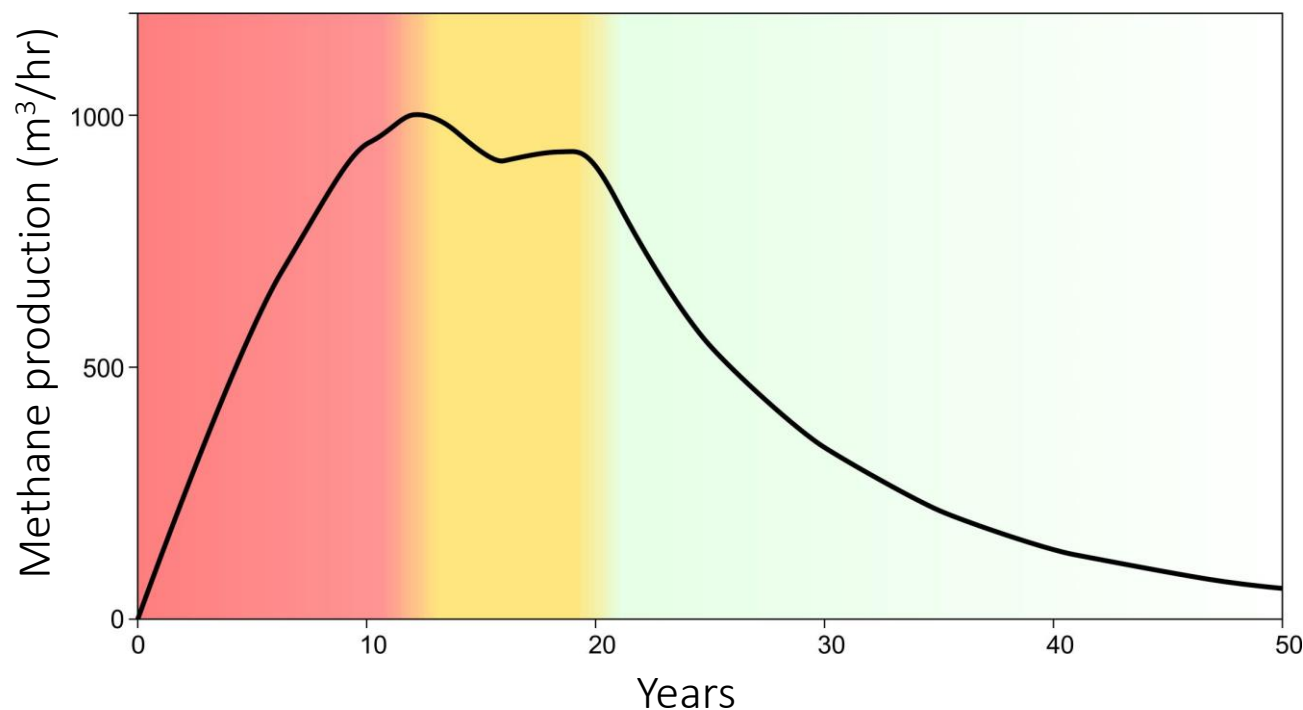
Limitations of current methods

- High uncertainty in estimation of diffuse emission, esp. in older landfills
- Large spatial and temporal variability of instantaneous emission rates
- Techniques with highest spatial resolution are very time-consuming and difficult to apply at whole-site scale, and challenging with high temporal resolution
- Techniques integrating flux over large areas are challenged by variable topography and interfering CH₄ sources, and require accurate micrometeorological models



Impact of changes in barometric pressure on landfill methane emission (Xu et al. 2014)

When will gas production end?



In a closed system with known inputs and constant temperature/pressure/moisture etc. (for example in the lab), techniques exist to accurately describe gas production behavior.

In an open system with unknown inputs and outputs, and variable parameters, this is more challenging.

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Objective

Improve estimation of landfill gas production rate and remaining production potential in landfills

Strategy

- Improve accuracy of whole-site CH₄ flux estimates at landfills by combining recent developments in field measuring techniques with stable isotope techniques
- The specific objectives are:
 - Develop a methodology for rapidly quantifying landfill emissions at landfill scale
 - Establish stable isotope markers in leachate and efflux product/substrate pairs as proxies for estimating remaining degradation potential
 - Integrate rate data from within landfills with surface flux measurements for improved estimation of production rate and estimated future production
- Developing the above methods will also lead to novel insights into the seasonal effects of freeze/thaw and drying/rewetting cycles on landfill CH₄ emissions and CH₄ oxidation efficiency in Nordic climates

Example – methane oxidation

- Most landfill processes result in isotopic mass fractionation:
 - Methanogenesis
 - Carbonate production
 - Landfill gas transportation
 - Methane oxidation
- Example: methane oxidation
 - Bacteria oxidize CH_4 with ^{12}C faster than CH_4 with ^{13}C
 - The degree of oxidation is directly correlated to the absolute value of change in the isotope ratio on each side of the oxic zone.

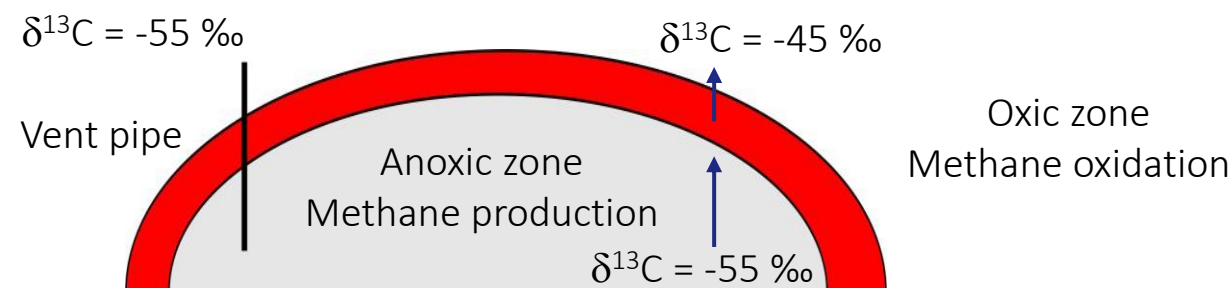
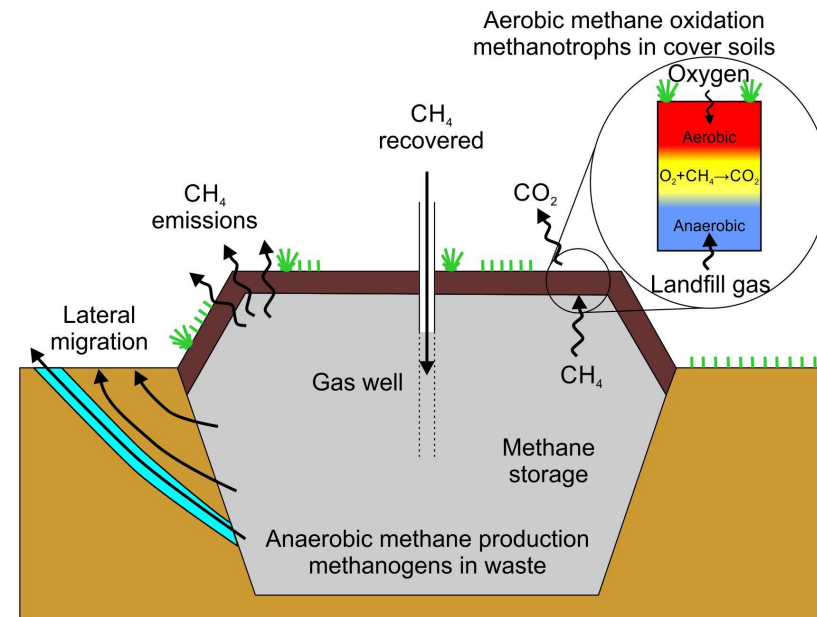


Image source: **Above** Scheutz et al. (2009) Microbial methane oxidation processes and technologies for mitigation of landfill gas emissions
Below Liptay et al. (1998) Use of stable isotopes to determine methane oxidation in landfill cover soils

Stable isotopes to estimate the remaining degradation potential

- Stable isotopes alone do not say anything – they give information about kinetics and how far processes have come between reactants and products
- This work will aim to establish new reactant/product pairs that are possible to measure and that provide new information about the remaining methane degradation potential and where a landfill is in its life cycle.
- Hypothesis: the biodegradability of remaining organic matter is reflected by the stable isotope ratios of product/substrate pairs in landfills

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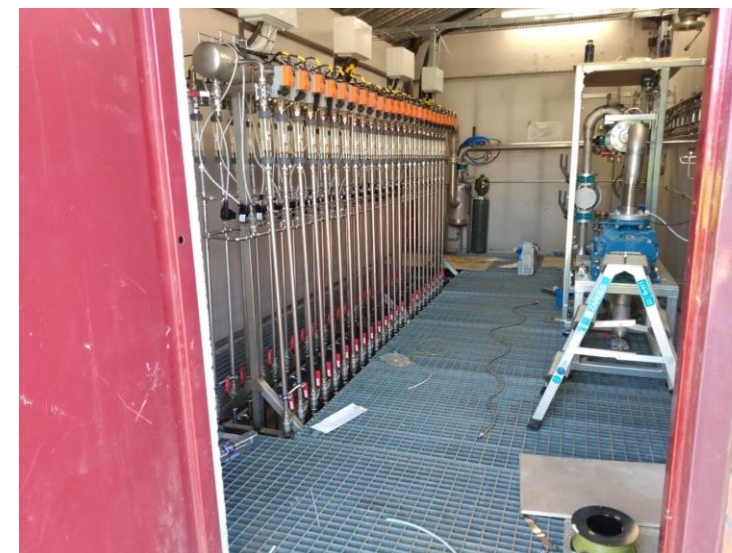
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Landfill fieldwork

- 3 landfills – waste of contrasting qualities/ages
 - Slettebakken deponi (Bergen) – 1941-1960 (*fieldwork started*)
 - Brånåsdalen nedlagt avfallsdeponi (Lillestrøm) – 1970-1990
 - Landfill #3 (to be determined) – 1955-1975?
- Sample collection
 - Excavated waste
 - Surface gas emissions
 - Leachate
 - Collected landfill gas from within the waste layers (where available)



Method development - rapid surface flux measurements (CO₂ + CH₄)

- Combine optical instrumentation with modern “smart chamber” sampling techniques – lower measurement times leading to higher spatial resolution
- In situ flux and stable isotope measurements



Integration of emissions data with stable isotope fractionation data

Combine improvements in methodology and with new understanding of isotopic changes in substrate/product pairs at a test site

- Emissions measurements to calibrate the isotopic systems in terms of landfill-scale gas production

Outcomes

- Accurate estimations of total emissions
- Prediction of remaining degradation potential and productive life
- Improved estimate of oxidation efficiency of the cover layer, with increased spatial resolution compared to current methods

PhD Project

- PhD student: Christian Schöpke
- Project title: “Do Landfills Ever Die?” Developing advanced stable isotope approaches to trace the fate of carbon in landfills
- Main supervisor: Peter Dörsch, NMBU
- Co-supervisors: Stephane Polteau, IFE
Viktoriya Yarushina, IFE
Pål Tore Mørkved, UiB
Ingar Johansen, IFE
- Duration: 4 years (September 2020-August 2024), 75%
- Concurrent/related projects: EarthresQue SFI
(Centre for rescue of earth materials and waste in the circular economy, hosted by NMBU)



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