Pressure effects on methane emissions from landfills

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Aim of the research

- Field studies report short-term variation of several orders of magnitude in measured CH₄ fluxes from landfills.

- This variation makes discontinuous measurements uncertain, without understanding the influence of meteorological conditions and most importantly barometric pressure.

- This presentation aims at illustrating CH₄ emission dynamics under the influence of barometric pressure changes and develop a concept model that can explain these dynamics.

Figure 1. Processes affecting the fate of methane generated in a landfill.

Methods

- **Investigated site**: The study was performed at Skellingsted landfill, located in Western Zealand, Denmark.

- **Quantification technique**: The eddy-covariance method is used, a micrometeorological method able to measure continuously over long periods.

- **Advantage**: Cope with temporal variability

- **Disadvantage**: Partially representative emissions of the whole landfill due to spatial heterogeneity

*Figure 2. Setup of the eddy covariance instrumentation at Skellingsted landfill. Instruments shown include an open-path CH₄ analyzer, a 3-D sonic anemometer, and an open-path CO₂/H₂O analyzer.*
Results and Discussion

Representation of heterogeneity of the landfill.

Figure 3. Wind direction measurements plotted against average CH$_4$ emission fluxes binned by wind direction.

Figure 4. A Google Earth image showing the locations of EC station and the area of elevated CH$_4$ emission fluxes.
Results and Discussion

- Under increasing barometric pressure CH$_4$ fluxes suppressed almost to 0.
- Under decreasing barometric pressure the emission rate was greatly increased.
- A delay period was observed in the response of CH$_4$ fluxes to pressure changes.

Figure 5. (a) Methane emissions (open circles) time-series from Skellingsted landfill from 4th December 2019 to 19th January 2020 and barometric pressure (red line).
(b) Methane emissions time-series during the 3rd week of 2020. Emission data points represent 15-min averaged CH$_4$ emission fluxes.
Results and Discussion

Conceptual model and hypotheses

- Landfill gas (LFG) advects from the core through the cover layer of the landfill driven by small vertical pressure ($p$) gradients.
- **Phase 1a:** Suppressed CH$_4$ fluxes ($\frac{dP}{dt} > 0$)
  - Ambient air (blue bars) is pushed into the landfill. (advection and $\frac{dP}{dz} > 0$)
  - LFG-ambient air interface (green/bluish area) increases. (diffusion)
- **Phase 1b:** Suppressed CH$_4$ fluxes ($\frac{dP}{dt} < 0$)
  - Top layer of air inside the landfill is flushed out. (advection)
  - LFG-ambient air interface increases. (diffusion)
- **Phase 2:** Linear increase of CH$_4$ fluxes ($\frac{dP}{dt} < 0$)
  - LFG-ambient air interface is flushed out.
- **Phase 3:** Maximum CH$_4$ fluxes ($\frac{dP}{dt} \leq 0$)
  - a) High fluxes that compensate the built up of LFG under suppressed transport.
  - b) Stationary fluxes that represent the LFG generation rate.

Figure 6. Methane emissions (open circles) time-series and barometric pressure (dark red line). Bars illustrate 1-D landfill columns and the main LFG transport mechanisms.
Conclusions

- Eddy-covariance method can adequately illustrate that methane emissions depend strongly on changes in barometric pressure.

- The high-resolution CH$_4$ fluxes allow us the observation of the underlying LFG transport processes (advection and diffusion) through landfill soil.

- The spatial variability of the landfill should be taken into consideration during the model-based interpretation of methane emission pattern.
Thank you!

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