Simulation model for gas diffusion and methane oxidation in landfill cover soils

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Outline

- Introduction
- Model development
- Results & discussion
- Conclusions

Introduction

- Cover soils can reduce the CH_4 emission by landfills.

  $\Rightarrow$ Models can help optimize CH_4 oxidation.

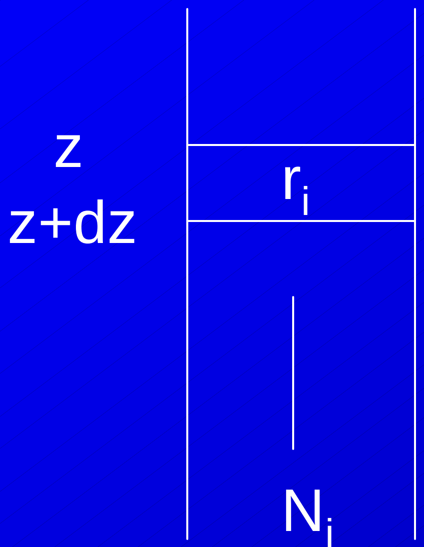
- CH_4 oxidation in landfill cover soils is poorly quantified.

  $\Rightarrow$ Models can improve inventories.

Model development

- Basic assumptions:
  - Gross LFG flux is log-normally distributed.
  - For each gross flux a 1-D model of diffusion and CH_4 oxidation applies.
  - Integration of the obtained oxidation rates leads to total CH_4 oxidation.

1-D model: Mass transport



Transient mass balance:

$$e\frac{\partial y_i}{\partial t}\frac{P}{RT} = r_{\mathrm{DB}} r_i - \frac{\partial N_i}{\partial z}$$

Nonfickian diffusion:

$$-\frac{P}{RT}\frac{\partial y_i}{\partial z} = \sum_{\substack{j=1\\ j\neq i}}^{n} \frac{N_i y_j - N_j y_i}{D_{\mathrm{soil},ij}}$$

1-D model: CH_4 oxidation

CH_4 oxidation rate: $$r_{CH_4} = -\frac{V_{max}[CH_4]}{K_m + [CH_4]} \cdot \frac{[O_2]}{K_{O_2} + [O_2]}$$

Stoichiometry: $$CH_4 + 1{,}5\ O_2 \rightarrow 0{,}5\ CO_2$$

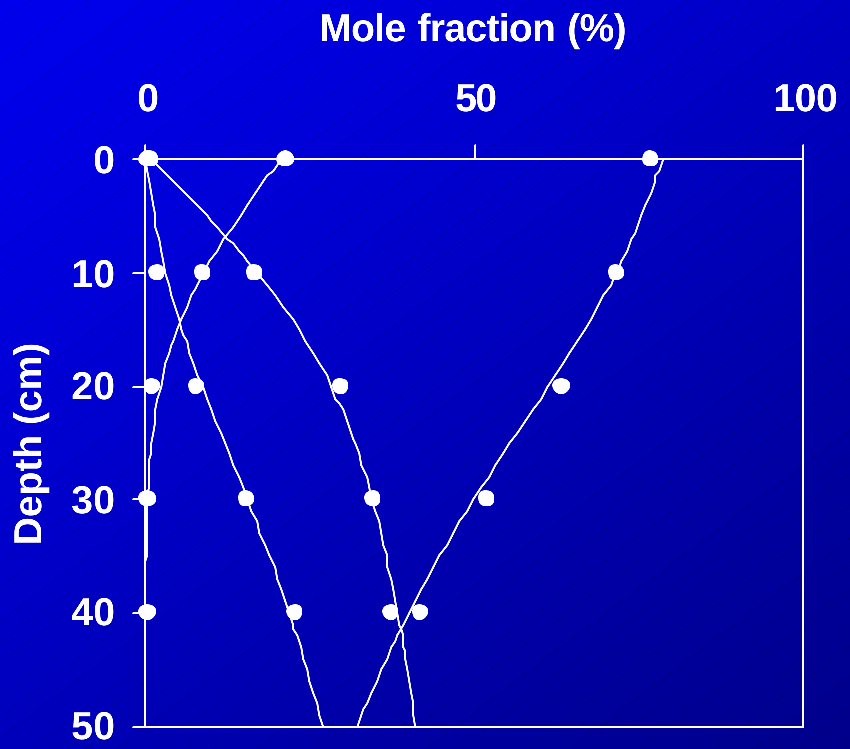
Microbial growth: $$\frac{dV_{max}}{dt} = m\ V_{max}$$

with: $$m = \frac{m'_{max}\left(1 - \frac{V_{max}}{V_{max,max}}\right)[CH_4]}{K_m + [CH_4]} - a$$

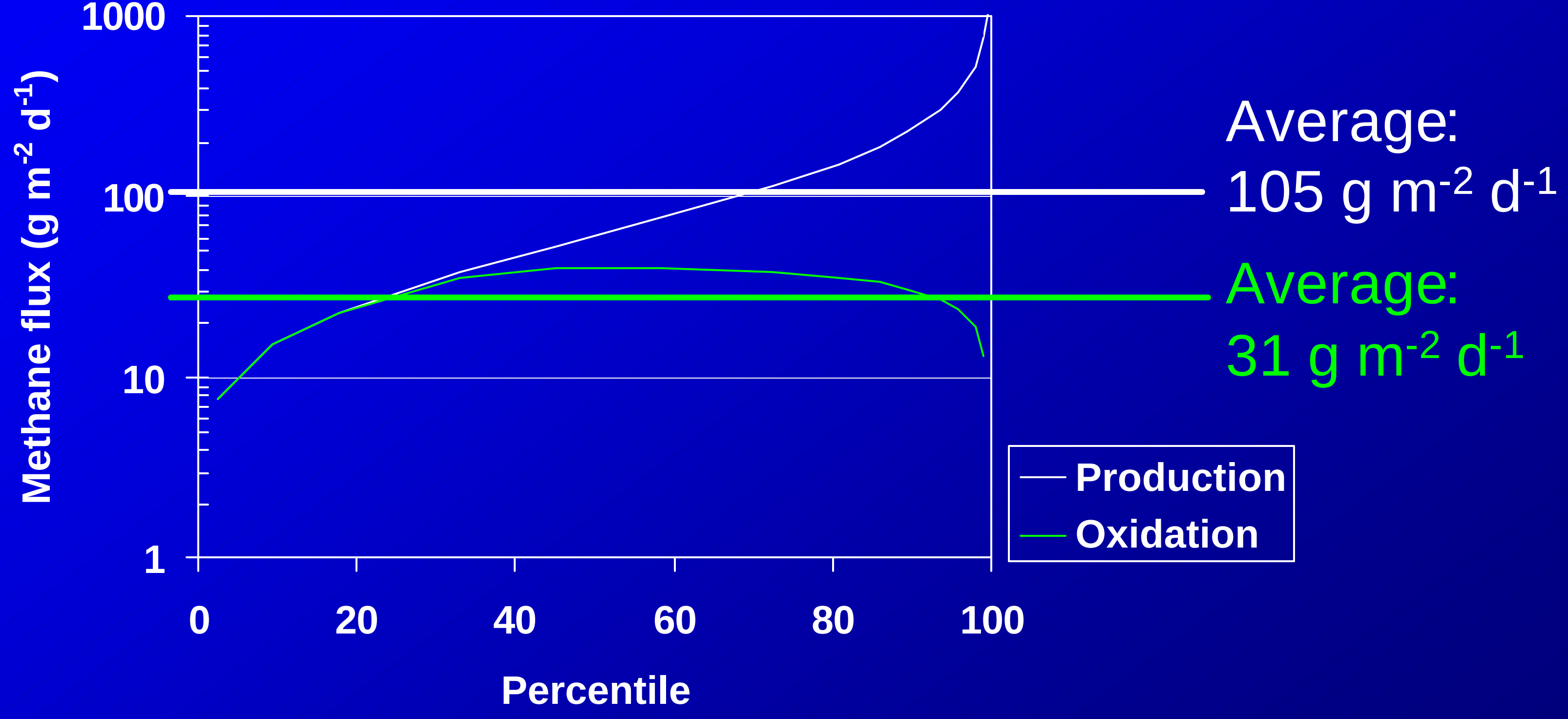
Parameter values

- At room temperature:
  - $V_{max,max}$ = 750 nmol CH_4 kg^{-1} s^{-1}
  - K_m = 6600 ppm CH_4 in the gas phase
  - μ'_{max} = 2,2 d^{-1}
  - a = 0,1 d^{-1}
- Temperature correction:
  - Correction factor for V_{max}, μ'_{max} and a: Q_{10} = 2.8
  - K_m increases linearly with temperature

Result: concentration profile



Extrapolation to field conditions



Conclusions

- The model correctly predicts concentration profiles in a laboratory set-up.
- Extrapolation to real landfill cover soils leads to a year-round average methane oxidation efficiency of 30%.
- Decreasing the heterogeneity of the gross LFG flux can improve the methane oxidation efficiency.