Evaluating Landfill Gas Collection Efficiency Uncertainty

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Presentation Overview

- Objectives
- Methane flow balance and sources of uncertainty in each component
- Compare of modeled and measured gas collection efficiency and emissions
- Conclusions

Objectives

- To estimate and compare methane collection efficiency and fugitive emissions from field measurements and mathematical modeling, and quantify the uncertainties in these estimates

Volumetric Methane Flow Balance

With the assumption of an equal mass density (ρ) for the mass balance components, the methane flow balance could be presented as:

$$Q_g = Q_c + Q_{ox} + Q_{em}$$

where:

- Q_g = Annual generated methane (m^3yr^{-1})
- Q_c = Annual collected methane (m^3yr^{-1})
- Q_{ox} = Annual oxidized methane (m^3yr^{-1})
- Q_{em} = Annual emitted methane (m^3yr^{-1})

Methane Generation – Sources of Uncertainty

- Cannot be directly measured
- Determined from mathematical models (e.g. EPA's LandGEM model)
- Uncertainty is largely associated with model parameters

Methane Generation – Sources of Uncertainty

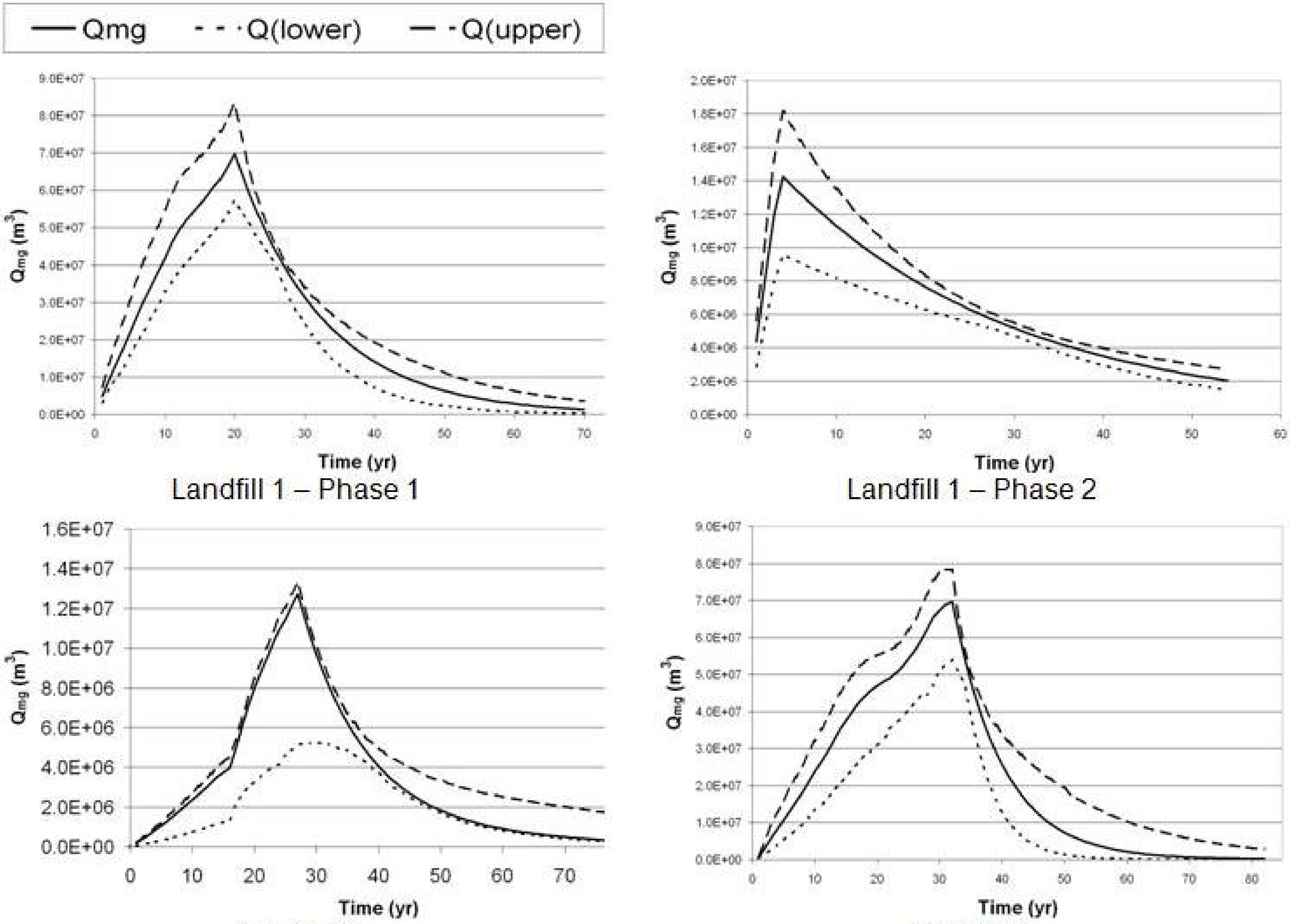
$$Q_g = \sum_{i=1}^{n} \sum_{j=0.1}^{1} k \left(\frac{M_i}{10}\right) L_{0_i} e^{-kT_{zj}}$$

where:

i	=	Time period of waste disposal, yr
j	=	1/10 time increments, yr
n	=	(Last calendar year of waste disposal) – (Calendar year of initial waste disposal)+1, yr
z	=	Time period of LFG generation from waste disposed in year i, yr
k	=	Methane generation rate constant, yr^{-1}
M_i	=	Tonnage of waste disposed in year i, Mg
L_{0i}	=	Methane generation potential of waste disposed in year i, $m^3 Mg^{-1}$
T_{zj}	=	Age of j^{th} section of waste M_i in year z, yr

Case Study Landfill Results

Landfill	k, yr^{-1}			L_0, m^3Mg^{-1} (1)		
	Likliest	Minimum	Maximum	Mean	Minimum	Maximum
A – Cell 1	0.08	0.05	0.13	62	54	72
A – Cell 2	0.04	0.02	0.05	56	49	61
B – traditional	0.04	0.01	0.05	70	59	81
B – wet	0.10	0.01	0.11			
C	0.13	0.04	0.25	63	55	70.8
D	0.13	0.06	0.13	61	51	72
E	0.06	0.05	0.09	140	111	163
F	0.09	0.07	0.23	74	64	83
G	0.04	0.03	0.04	93	82	103



Qmg
Q(lower)
Q(upper)
Q_{mg} (m^3)
Time (yr)
Landfill 1 – Phase 1
Landfill 1 – Phase 2
Landfill 3
Landfill 4

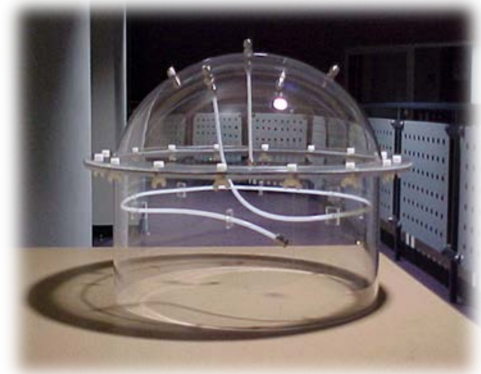
Methane Oxidation – Sources of Uncertainty

- A fraction of the uncollected methane is oxidized due to bacterial activity in soil covers
- Extent is a function of methane loading rate, cover materials, cover thickness, quality/condition of the cover, and ambient temperature
- US EPA and IPCC recommend a default oxidation fraction of 0.1 (includes effects of preferential pathways).
- Literature review: for mixed soils, range 0.07 – 0.68, average 0.32 $\pm$ 19%

Methane Emissions – Sources of Uncertainty

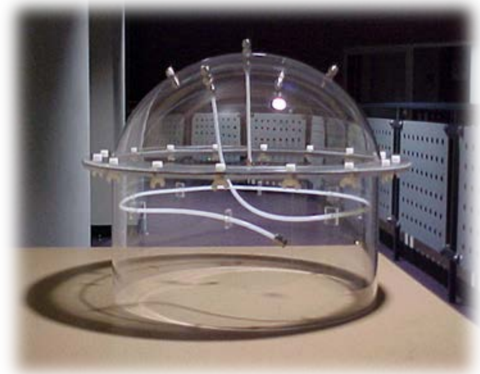
- Methane not collected or oxidized is emitted
- Function of pressure and concentration difference across cover as well as cover condition (e.g. presence of cracks, permeability)
- Primary sources of uncertainty are variations in barometric pressure, precipitation, temperature, wind conditions, and gas generation rates.

Measurement of Methane Emissions



- Flux chamber
- Tracer gas
- Horizontal radial plume mapping optical remote sensing
- Vertical radial plume mapping optical remote sensing
- Inverse modeling
- Differential absorption light detection and ranging
- Micrometeorological eddy covariance
- Helicopter-borne spectroscopy

Measurement of Methane Emissions



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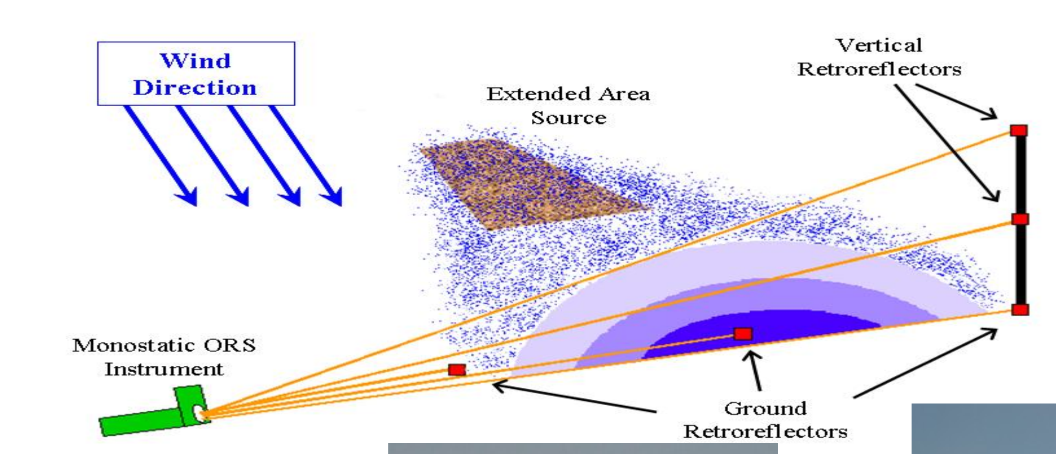
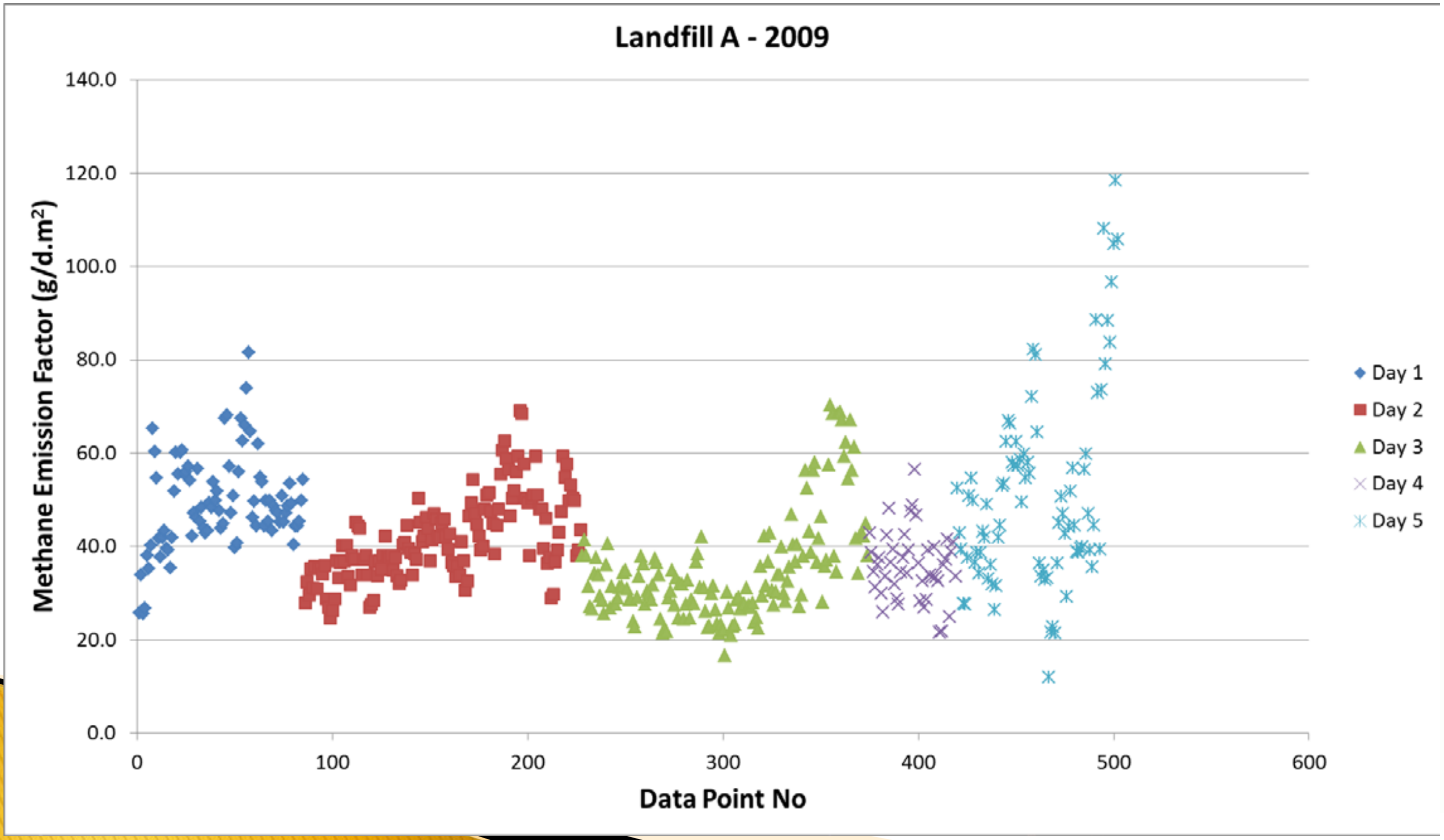
Case-Study Landfills



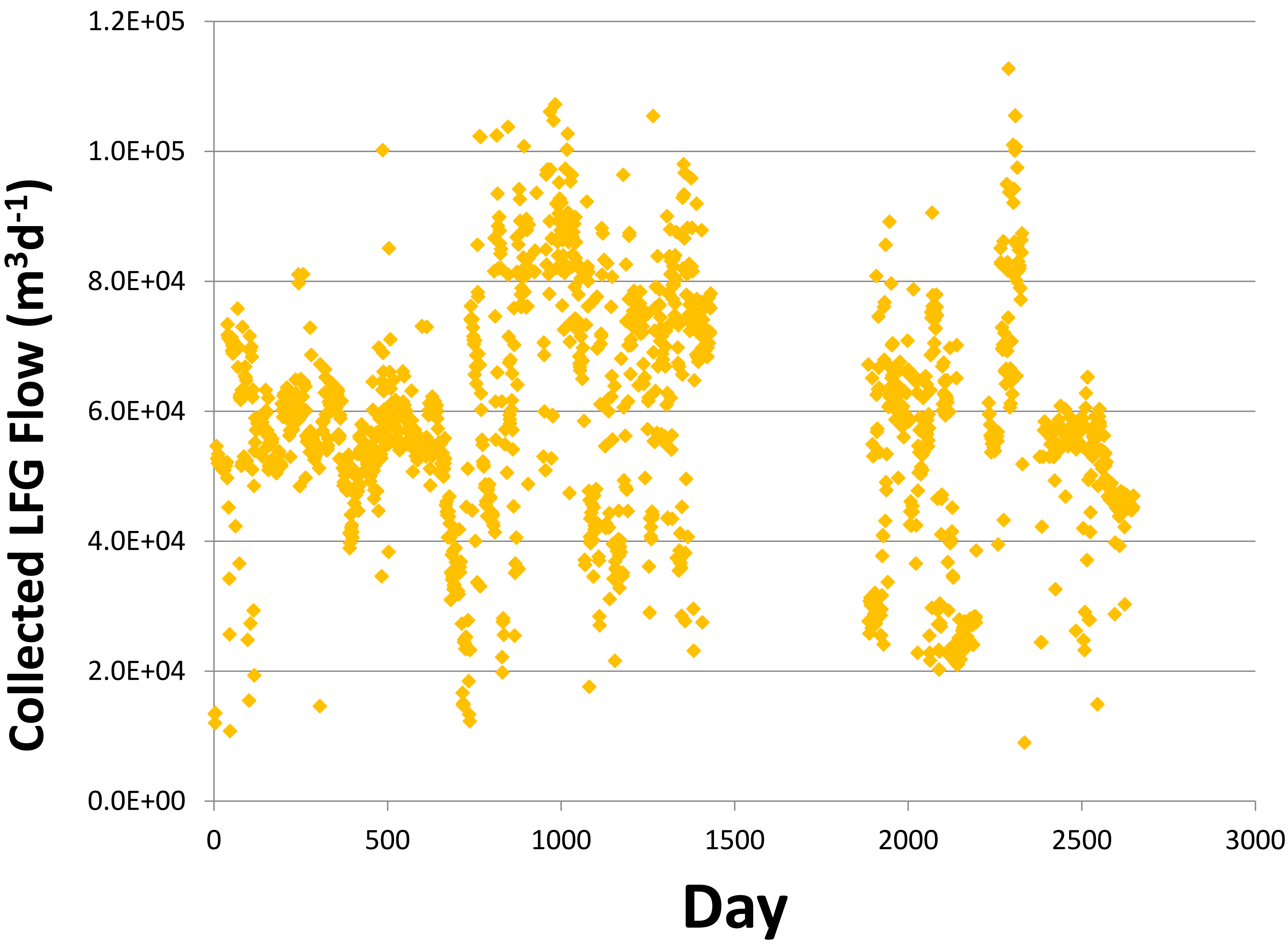
Case-Study Landfills

- Each landfill was modeled and emissions/collection measured over 1-week period (total five measurement sets)



Methane Collection – Sources of Uncertainty

- In our model, collection efficiency is a function of cover type
- Uncertainty is a function of variability in gas generation and emission rates
- Assumptions for collection efficiency:
  - Daily cover only – 67%
  - Intermediate cover – 75 %
  - Engineered final soil – 87%
  - Geomembrane – 90%


Collected LFG Flow (m³d⁻¹)
1.2E+05
1.0E+05
8.0E+04
6.0E+04
4.0E+04
2.0E+04
0.0E+00
0
500
1000
1500
2000
2500
3000
Day

Model/Measured Comparison of Flow Components at time t

Model

- Use LandGEM to calculate Q_g
- Calculate Q_c assuming collection efficiency as function of cover
- Calculate Q_{ox} from literature values
- Determine Q_{em} from flow balance
- Determine uncertainty from Monte Carlo analysis and parameter statistical information

Measured

- Use VRPM OPS to measure Q_{em}
- Measure Q_c (LFG flow rate and methane concentration)
- Calculate Q_{ox} from literature values
- Determine Q_g by flow balance
- Determine uncertainty from Monte Carlo analysis and field measurements statistical information

Model/Measured Comparison of Flow Components

Model

- As above and use equation:

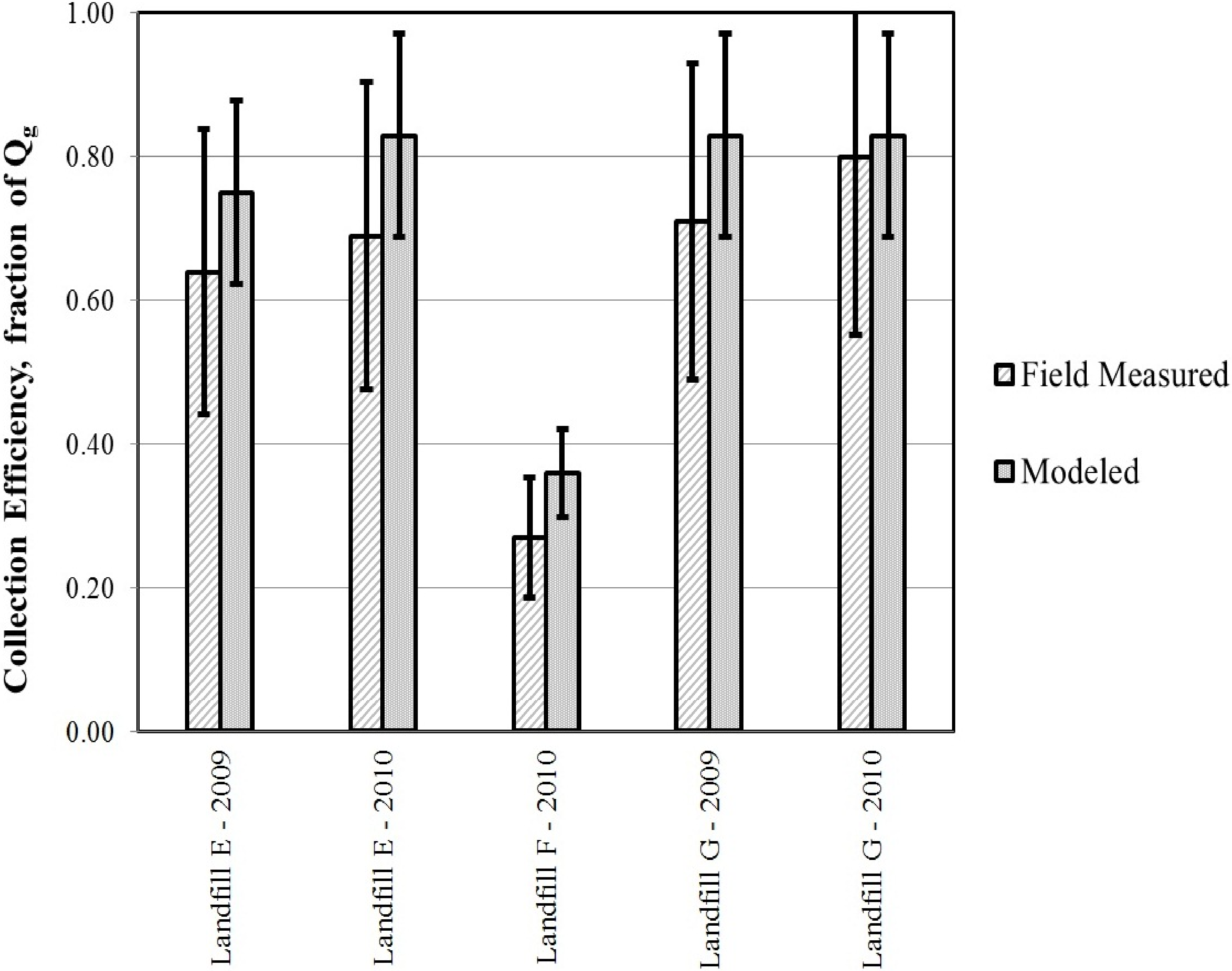
$$\eta_t = \frac{Q_{c_t}}{Q_{g_t}}$$

Measure

- As above and use equation:

$$\eta_t = \frac{Q_{c_t}}{Q_{c_t} + Q_{em_t} + Q_{ox_t}}$$

Landfill	Year	Field Measurements, fraction of Q_g (CV, %)			Modeled, fraction of Q_g (CV, %)		
		Collected	Emitted	Oxidized	Collected	Emitted	Oxidized
E	2009	0.61 (16)	0.26 (30)	0.12 (101)	0.75 (22)	0.21 (64)	0.03 (106)
	2010	0.69 (42)	0.21 (45)	0.10 (103)	0.83 (16)	0.15 (71)	0.02 (117)
F	2010	0.30 (42)	0.48 (28)	0.23 (80)	0.36 (20)	0.60 (11)	0.04 (105)
G	2009	0.65 (40)	0.24 (50)	0.11 (108)	0.83 (13)	0.14 (65)	0.03 (99)
	2010	0.83 (17)	0.12 (35)	0.05 (119)	0.83 (13)	0.14 (65)	0.03 (99)



Collection Efficiency, fraction of Q_g
1.00
0.80
0.60
0.40
0.20
0.00
Landfill E - 2009
Landfill E - 2010
Landfill F - 2010
Landfill G - 2009
Landfill G - 2010
Field Measured
Modeled

Conclusions

- Measured methane flow balance components were found to have relatively large coefficients of variation, *i.e.* 11 to 44% for collected, 16 to 49% for emitted, and 80 to 116% for oxidized LFG
- Modeled flow component uncertainty ranged from 13 to 22% for collected, 11 to 71% for emitted, and 99 to 117% for oxidized
- Sources of uncertainty include challenges in large-scale field measurement of emissions and spatial/temporal fluctuations in flow balance components
- Modeled collection efficiencies were consistently higher than those calculated from field measurements (by 20% on average); values reported in literature may be high

Acknowledgement

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