Greenhouse Gas and Criteria Air Pollutant Emissions and Gas Collection System Efficiencies at California Landfills

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A CARB presentation based on the work of Jim Hanson, Nazli Yesiller, and Derek Manheim; Cal Poly San Luis Obispo. CalRecycle Contract: DRR16109 and CARB Contract: 16ISD006

Full Report and 2021 Webinar Presentation:
https://ww2.arb.ca.gov/resources/documents/landfill-gas-research

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Research Overview

Detailed assessment of California landfill gas emissions

- California landfill characterization and site selection
  - Representative landfill sizes, waste compositions, climatic regions, range of operational conditions (e.g., gas collection, 31 cover types)
- Field analysis and lab testing
  - Aerial measurements at 16 selected landfills
  - Ground-based static flux chamber measurements at a subset of 5 landfills
  - 82 landfill gas (LFG) species investigated, including methane (CH4), nitrous oxide (N2O), and volatile organic compounds (VOC)

Data Analysis

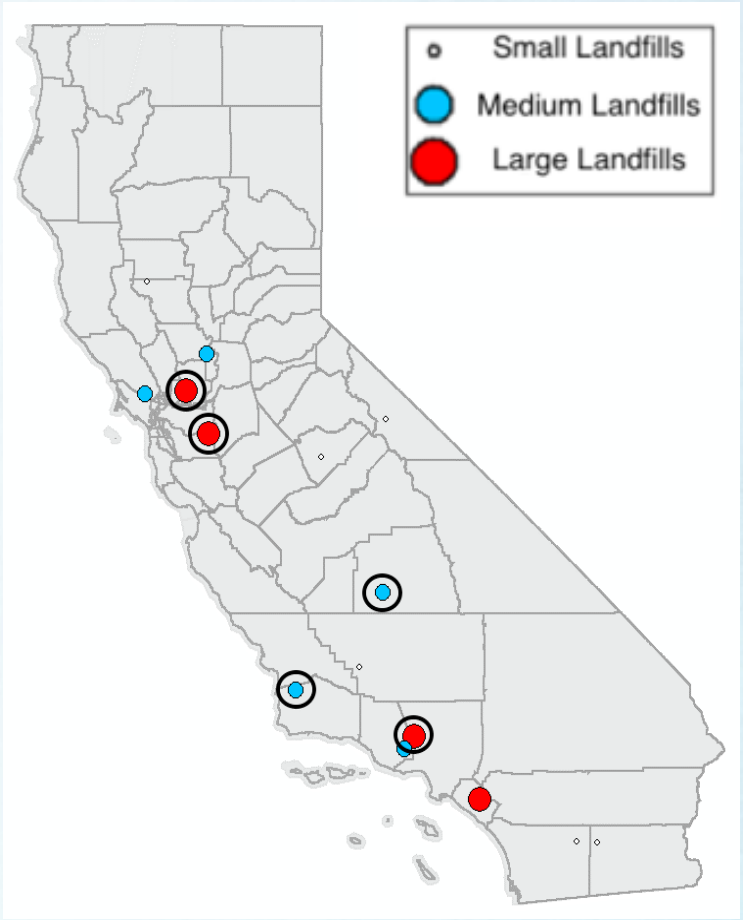
- Explored correlations between emissions and a wide array of factors to understand the effects of operational, environmental, and climatic conditions on surface flux
- Intra- and inter-landfill emissions variations. For example,
  - Cover types and properties including thickness and clay content;
  - Size characteristics including waste column height and waste age;
  - Collection system vacuum pressure;
  - Distance from a gas extraction well; and
  - Seasonal and diurnal variation
- Compared multiple approaches to estimating gas collection efficiency
  - Aerial measurements, ground measurements, LandGEM (USEPA model)

Landfills Selected for Research

Name	Size	Waste (million tonnes)	Active Face (m^3)	% Final Cover	Gas Collection	Climate Zone
Stonyford	Small	0.1	65	2%	No	Csb
Salton City	Small	0.2	-	-	No	BWh
Borrego	Small	0.3	-	-	No	BSk
Pumice Valley	Small	0.3	1,200	0%	No	Csb
Mariposa County	Small	0.6	200	0%	No	Csa
Taft	Medium	3	-	-	Yes	BWk
Teapot Dome	Medium	5	1,200	0%	Yes	BSk
Santa Maria Regional	Medium	8	700	31%	Yes	Csb
Redwood	Medium	18	2,000	0%	Yes	Csb
Simi Valley	Medium	28	12,100	0%	Yes	Csb
Sunshine Canyon	Medium	34	-	-	Yes	Csb
Yolo County Central	Medium	37	11,800	41%	Yes	Csa
Chiquita Canyon	Large	42	5,600	28%	Yes	Csb
Site A	Large	45	6,100	10%	Yes	Csb
Frank R. Bowerman	Large	47	-	-	Yes	Csb
Potrero Hills	Large	53	3,000	6%	Yes	Csa

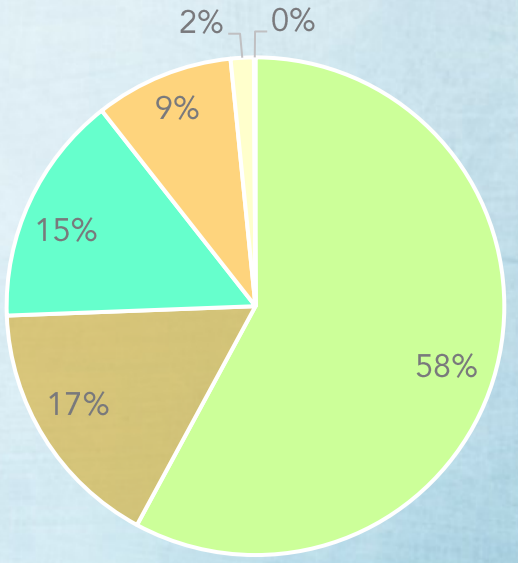
Ground & Aerial Measurements

Aerial Measurements



Climate Zones

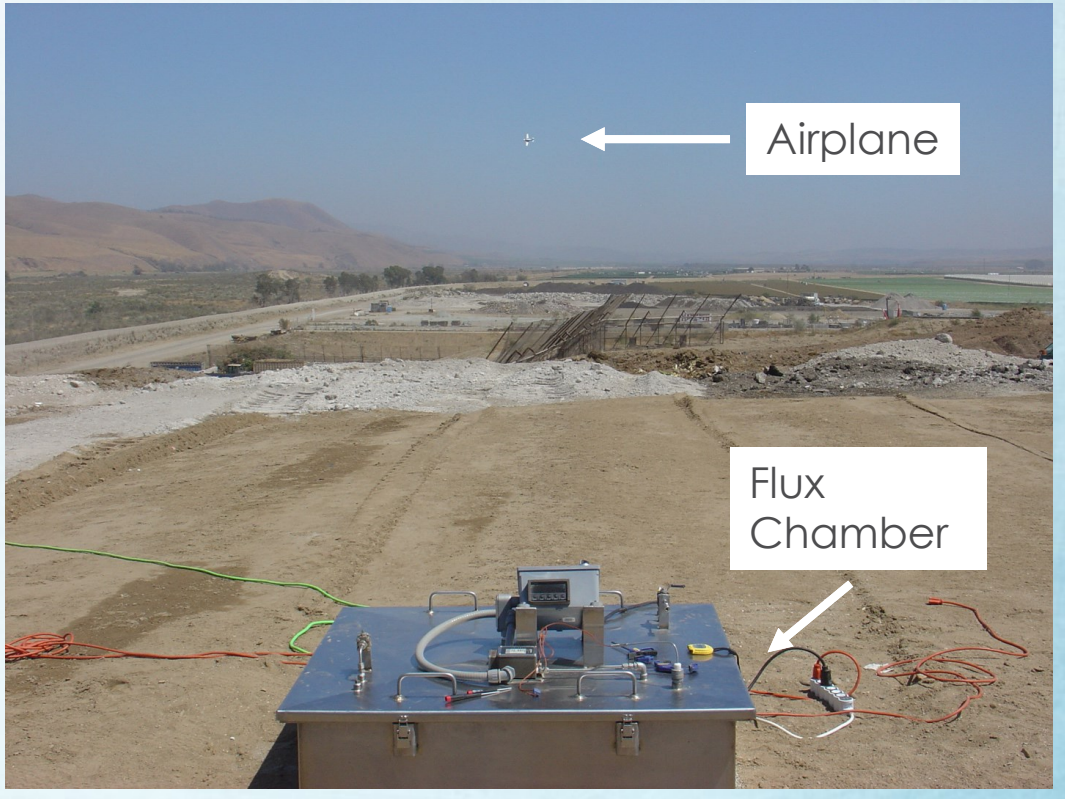
Distribution of Total Statewide Waste-in-Place by Climate Zone



- BWh: arid, desert, hot
- BWk: arid, desert, cold
- BSk: arid, steppe, cold
- Csa: temperate, dry summer, hot summer
- Csb: temperate, dry summer, warm summer
- Dsc: cold, dry summer, cold summer

Measurement Methods and Limitations

- Ground measurements using 1m^2 static flux chambers
- Aerial measurements using cavity ring down spectroscopy



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Correlations Between Site-Specific Operational Conditions and Methane Emissions - Ground

High emissions with larger areas of daily & intermediate cover

Low emissions at older sites with more final cover

Landfill Parameter	Correlation Coefficient for Methane [Ground, 5 sites]
% Interim Cover	0.8
Waste Column Height (m)	0.7
Areal Coverage (m^2)	0.6
% Daily Cover	0.5
Average Measured Waste Age (years)	0.5
Waste Throughput (tonnes/day)	0.3
Average Daily Temperature (°C)	0.3
Waste Depth (m)	0.2
Active Face (m^2)	0.2
Net Precipitation (mm)	0.1
LFG Flow Rate (m^3/min)	-0.1
LFG Collected (m^3)	-0.2
Fraction biodegradable waste (%)	-0.6
Site Age (years)	-0.9
% Final Cover	-0.9

Weak correlations with size and climate factors

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Correlations Between Site-Specific Operational Conditions and Methane Emissions – Aerial

Landfill Parameter	Correlation Coefficient for Methane [Aerial, 15 sites]
Average Measured Waste Column Height (m)	1
Waste Throughput (tonnes/day)	0.8
Areal Coverage (m2)	0.8
Waste Depth (m)	0.7
LFG Collected (m3)	0.7
Active Face (m2)	0.7
LFG Flow Rate (m3/min)	0.4
Average Measured Waste Age (years)	0.3
% Interim Cover	0.3
Average Daily Temperature (°C)	0.2
Net Precipitation (mm)	-0.01
% Daily Cover	-0.1
Fraction biodegradable waste (%)	-0.1
Site Age (years)	-0.2
% Final Cover	-0.4

Larger landfills → Higher emission rates

Large active face correlated to higher emission rates

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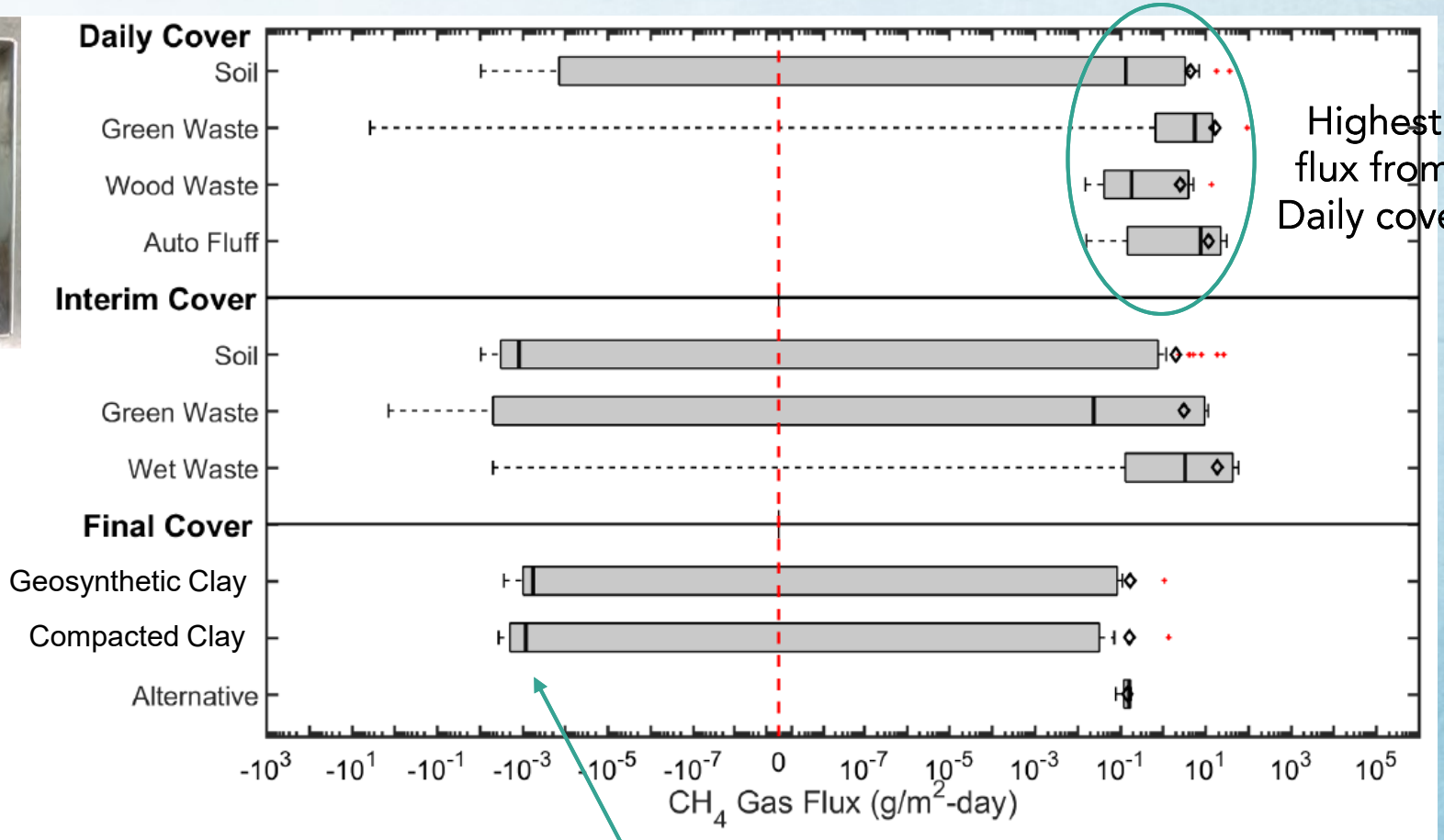
Greenhouse Gas Flux by Cover Type

- 31 distinct cover types
- Soil covers are generally more effective than non-soil covers
- Coarse, highly porous materials such as autofluff and C&D waste were least effective

Methane Fluxes in Daily, Intermediate, and Final Cover Categories



Negative flux from areas with Final cover

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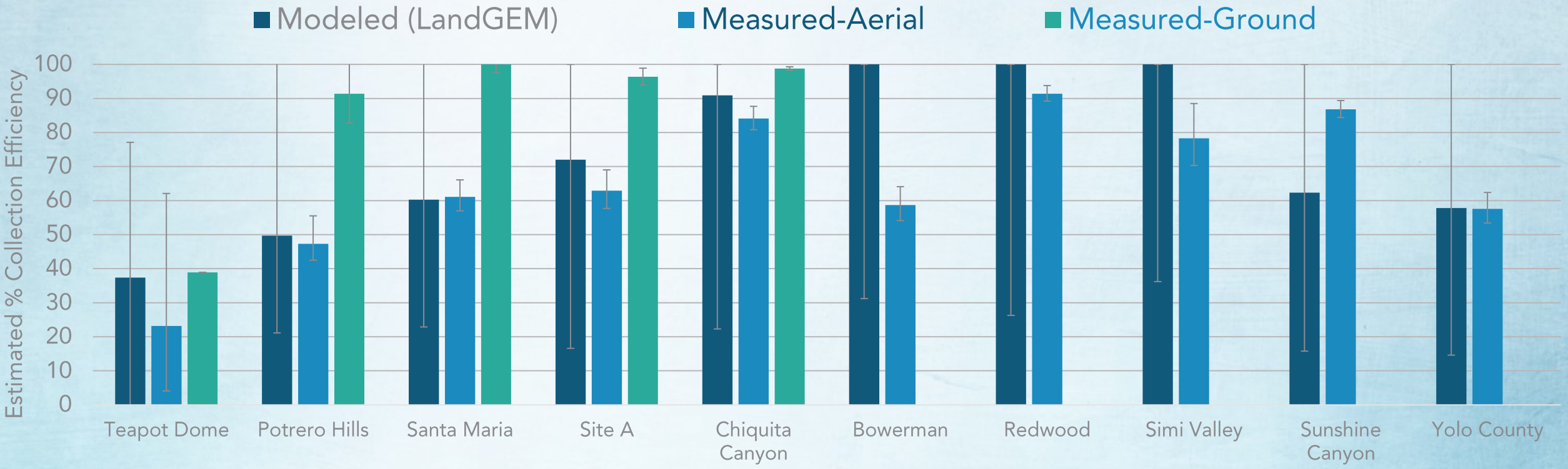
Conclusions for Emissions Control Measures

- Limit the area of active waste placement (working face)
- Avoid concentrated areas of organic sludges and other wet waste
- Daily covers:
  - Minimize area and duration of coverage: install Intermediate cover within days—not weeks —of waste placement
- Intermediate covers:
  - Increase thickness up to 1 meter, fines content >30%; minimize area
- Final covers:
  - Specific Thresholds Recommended:
    Thickness >150 cm, Fines >60%, Clay >12%, Plasticity >20%

Landfill Gas Collection Efficiency Estimates

$$\text{Modeled \% CE} = \frac{[Collection]}{[Modeled\ Generation]}$$

$$\text{Measured \% CE} = \frac{[Collection]}{[Emissions + Collection]}$$



- Different approaches to estimating collection efficiency (CE) led to a range in efficiency estimates
- Estimates across landfills and approaches ranged from 25 to 100 percent

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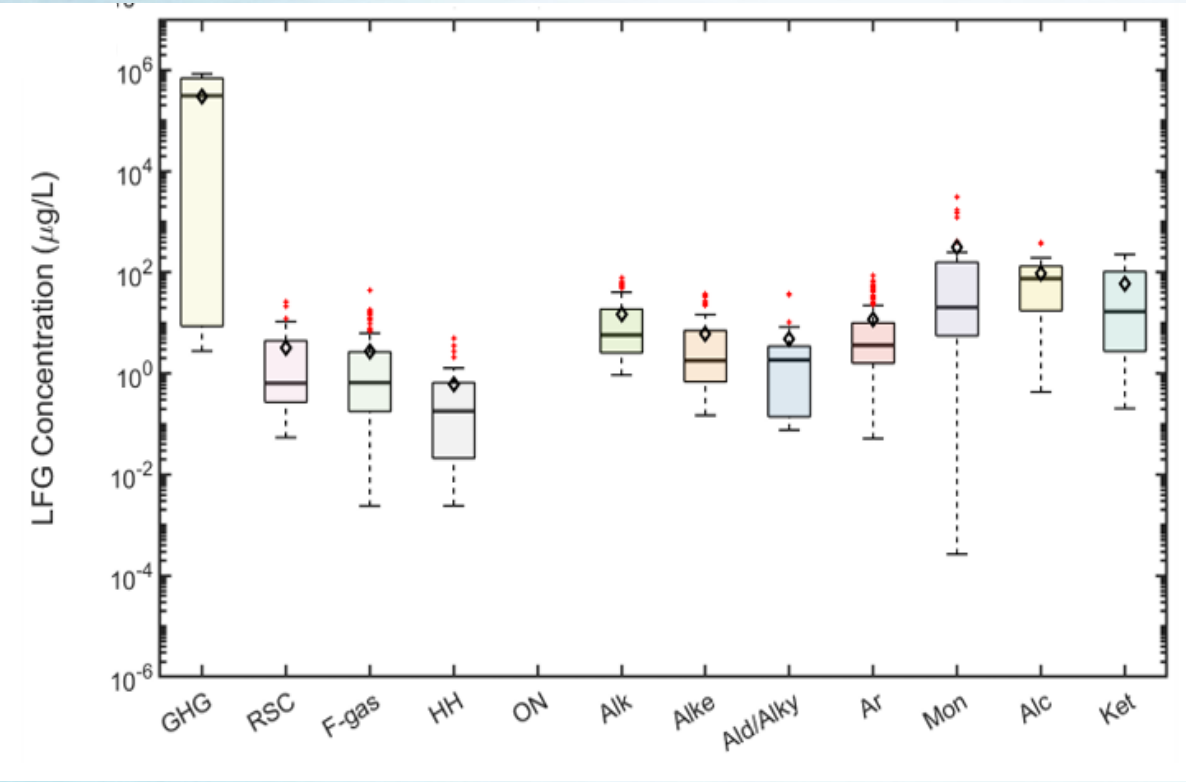
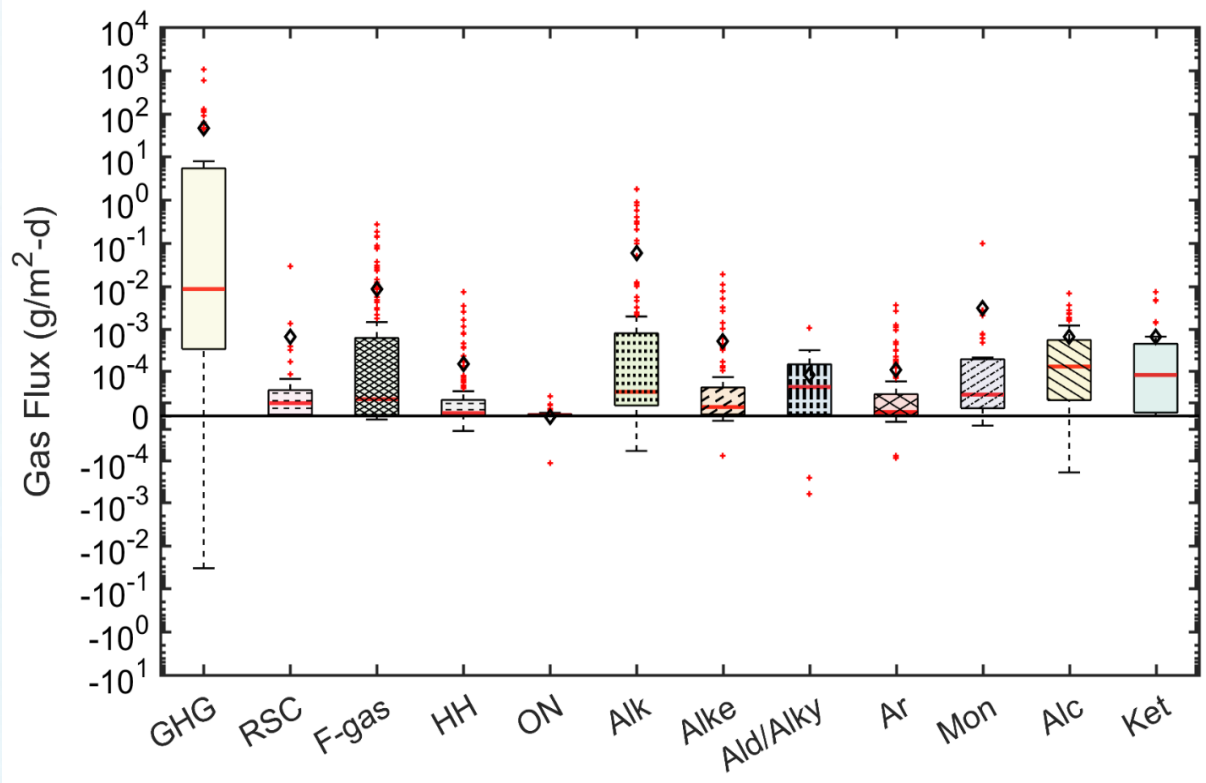
Non-Methane VOC Emissions

- Concentrations in collected landfill gas are not a reliable indicator of surface flux
- A given chemical should not be used as a surrogate for other chemicals



Concentrations in Collected Landfill Gas by Chemical Family



Measured Surface Fluxes by Chemical Family

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THANK YOU!

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