Quantification of methane emissions from the natural gas gathering system using distributed sensors

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Project objectives

- Demonstrate the ability of a distributed, low-cost sensor network to quantify temporally varying methane emissions from natural gas gathering infrastructure
- Apply this approach to measure emissions from gathering pipelines and pig launchers
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• Demonstrate the ability of a distributed, low-cost sensor network to quantify temporally varying methane emissions from natural gas gathering infrastructure

• Apply this approach to measure emissions from gathering pipelines and pig launchers
  • Our NETL partners did not find any gathering pipelines with large enough leaks to target
Characterization of inexpensive metal oxide sensor performance for trace methane detection

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We tested sensors using different operating principles:

**Metal oxide semiconductor**
- MQ-4
- Sensirion SVM30
- SGX IR12GJ, VQ549ZD
- TGS 2600, 2602, 2611
- Alphasense MOX

**Photo ionization**
- Alphasense PID (10.6 & 9.6eV)

Furuta et al, *AMT*, 2022
We conducted laboratory tests to identify candidate sensors.
Some sensors performed well
Others did not
We tested sensors using different operating principles.

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Sensors displayed inter-unit precision, but inter-unit variability suggests that individual calibrations are needed.

**TGS2600**

- $R = 1.00$
- $\beta = 1.11$

**MQ4**

- $R = 0.97$
- $\beta = 0.67$

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“Good” sensors showed humidity and T dependence
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We built calibration models that worked well under laboratory conditions.
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\[ CH_4 = \alpha + \beta_1 (\text{sensor resistance}) + \beta_2 (H_2O) + \beta_3 (H_2O)(\text{sensor resistance}) + \epsilon. \]

Carnegie Mellon University

Furuta et al, AMT, 2022
We tested multiple models for calibration
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\[ \text{CH}_4 = 1.425 + 0.12 S_c + 0.375/S_c - 0.0065 T_a + 
   +53.3 \rho_v + 0.0022 S_c \cdot T_a - 0.0017 T_a/S_c + 
   +4.9 S_c \cdot \rho_v - 67.4 \rho_v/S_c - 0.39 S_c \cdot T_a \cdot \rho_v 
   +1.15 T_a \cdot \rho_v/S_c , \]
We tested multiple models for calibration.

Models that incorporate multiple sensor responses might be better equipped to handle T, RH.
We tested the sensors outdoors
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There was almost no variability in methane concentrations at our ambient location
We tested the sensors outdoors in an environment doped with methane
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The calibration model could not account for rapid changes in ambient T and RH.
Stratifying by RH yields good correlation between CH\textsubscript{4} and sensor signal, with best performance at low RH.
Sub-selecting periods of constant RH yields better results
We deployed sensors near a pig launcher on multiple locations
We deployed sensors near a pig launcher on multiple locations. CH$_4$ was elevated at the pig launcher, but we never encountered any CH$_4$ plumes that would allow for emission estimation.
Next steps and lessons learned

• The RH and T interferences are difficult to correct in real time
• Sensors perform best at low RH
  • This suggests that drying the sample flow will lead to better performance
• Limit of detection is 0.3 ppm for a 5-minute sample under dry conditions. This should be sufficient to quantify leaks in the near field