Jui-Hsiang (Rayson) Lo

Ph.D. Candidate in the Department of Civil and Environmental Engineering

Project Overview

1. InSeNSE – Improving Pipeline Safety During Gas Leakage Events Using Near Real-Time Data Networks and Optimal Decision-Making Tools

To address the challenges associated with monitoring and evaluating underground gas leaks from pipelines, particularly in cases where immediate resolution is not feasible or long-term monitoring is required, there is a need for data-driven, real-time control. This is crucial for enhancing safety and preventing catastrophic incidents related to gas leaks. The project aims to (1) develop an innovative real-time data network and decision-making algorithm for methane detection and quantification of belowground leaks and (2) establish a recommended practice for deploying gas sensing protocols that are widely applicable and accessible.

The main objectives of this project are:

1. Develops a low-cost, near real-time, wireless natural gas monitoring detector network to provide operators with decision-making information related to gas leakage incidents.
2. Develops a method to process data collected in a network, resulting in a gas-sensing protocol.
3. Provides a recommended practice to deploy the gas sensing protocol.
4. Advances the science of leak detection and measurement methods for underground pipelines.

2. R-PLUME – Response Protocol for Large Underground Methane Emissions

This project is to better understand gas migration from moderate-to-large underground leaks, validating models to understand those leaks, and developing methods to assess and respond to these leaks. The project aims to address underground natural gas (NG) leaks characterized by moderate to high flow rates (>100 scfh), which can result in potentially explosive concentrations in the vicinity. The proposed work will contribute to a deeper understanding of gas migration behavior and offer decision guidance for stakeholders through the following objectives:

1. Conducting direct measurements of gas migration speed and extent, both at the surface and in the subsurface, across various environmental conditions.
2. Integrating measurements with models to enhance knowledge and extrapolate insights beyond measurable scenarios.
3. Establishing connections between gas concentration measurements and environmental conditions to estimate the extent of gas migration.

3. NYSEARCH – Optimal design and operation of soil aeration systems for belowground natural gas leak mitigation

The main objective of this proposal is to develop a practical approach to the design, operation, and monitoring of natural gas soil aeration systems that incorporates site-specific yet easily attainable information. We will address questions from the beginning of the design, such as whether specific bar hole spacing and configurations can produce flow conditions that will yield acceptable removal rates. Can aeration rates be achieved under the proposed bar hole spacing and soil conditions? Moreover, can the flow rates yield acceptable gas removal rates/concentrations within the time frames of interest to operators?

This work also:

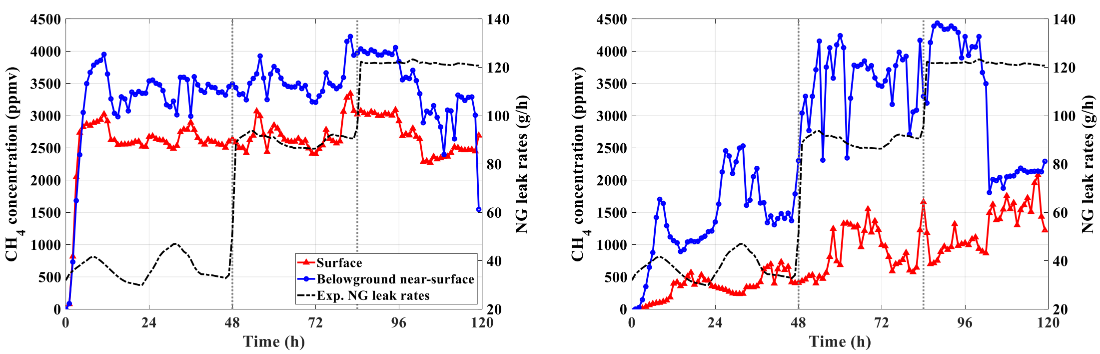
1. Provide a structured, technically based approach to the design and operation of soil aeration operations.
2. Provide scenario examples of the design of aeration systems that practitioners can use to make contingency field decisions on aeration system design and operation.
3. Deliver empirical understanding of soil aeration operations through ‘proof of concept’ controlled aeration experiments.
4. Advance aeration methods for leaking/repairing underground pipelines, especially for complex leak scenarios.

Research Progress

InSeNSE

The project was divided into five main tasks: 1) Establish a collaborative study structure with InSeNSE advisors; 2) Develop the low-cost near real-time CH_4 detector network and simulation-approach; 3) Conduct controlled NG release experiments; 4) Conduct field validation of the approach with a local utility company; and 5) Provide a recommended practice of proposed CH_4 detector network and the approach. All tasks were completed in August 2023. More detailed results can be found in Lo et al (2023).

The project developed a low-cost, near-real-time, wired/wireless natural gas detector network for monitoring surface and belowground near-surface gas migration, particularly focusing on elevated gas leak rates. Field-scale controlled NG experiments with leakage rates ranging from 37 to 121 g/h indicate that elevated belowground near-surface (BNS) gas concentrations persist long before elevated surface concentrations are observed. On average, BNS CH4 concentrations were 20% to 486% higher than surface CH4 concentrations within the monitoring radius of 4 meters from the leak location. An increase in the BNS CH4 concentration was observed within 3 hours as the leak rate increased from 37 to 89 g/h. However, due to the atmospheric fluctuations, any changes in surface CH4 concentrations could not be confirmed within this period. The plume area of the BNS CH4 extended approximately two times farther than that of the surface CH4 as the gas leak rate increased from 37 to 121 g/h.



(a) (b)

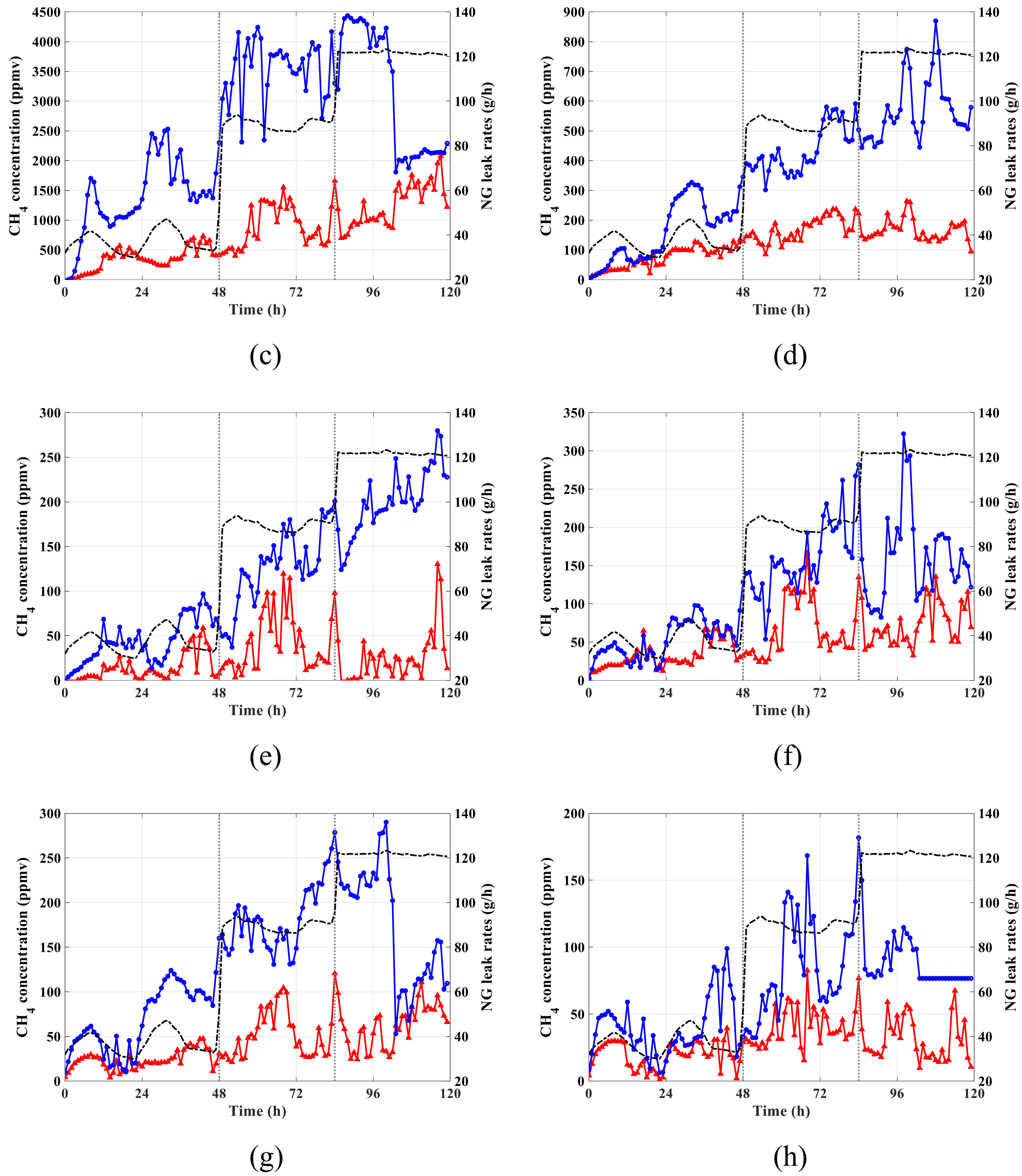


Fig. 1 – Measurements of maximum surface and BNS CH_4 concentrations at (a) 0, (b) 1, (c) 1.5, (d) 1.8, (e) 2.5, (f) 2.9, (g) 3, and (h) 4 m from the leak point. The red line presents surface methane concentration, while the blue line indicates BNS CH_4 concentrations. The BNS CH_4 concentration in (h) shows a constant value from hour 104 due to the detection issue of the sensor. The dashed line presents the controlled NG leak rates (g/h). The gray dotted lines present the time when the released gas increased to the next level.

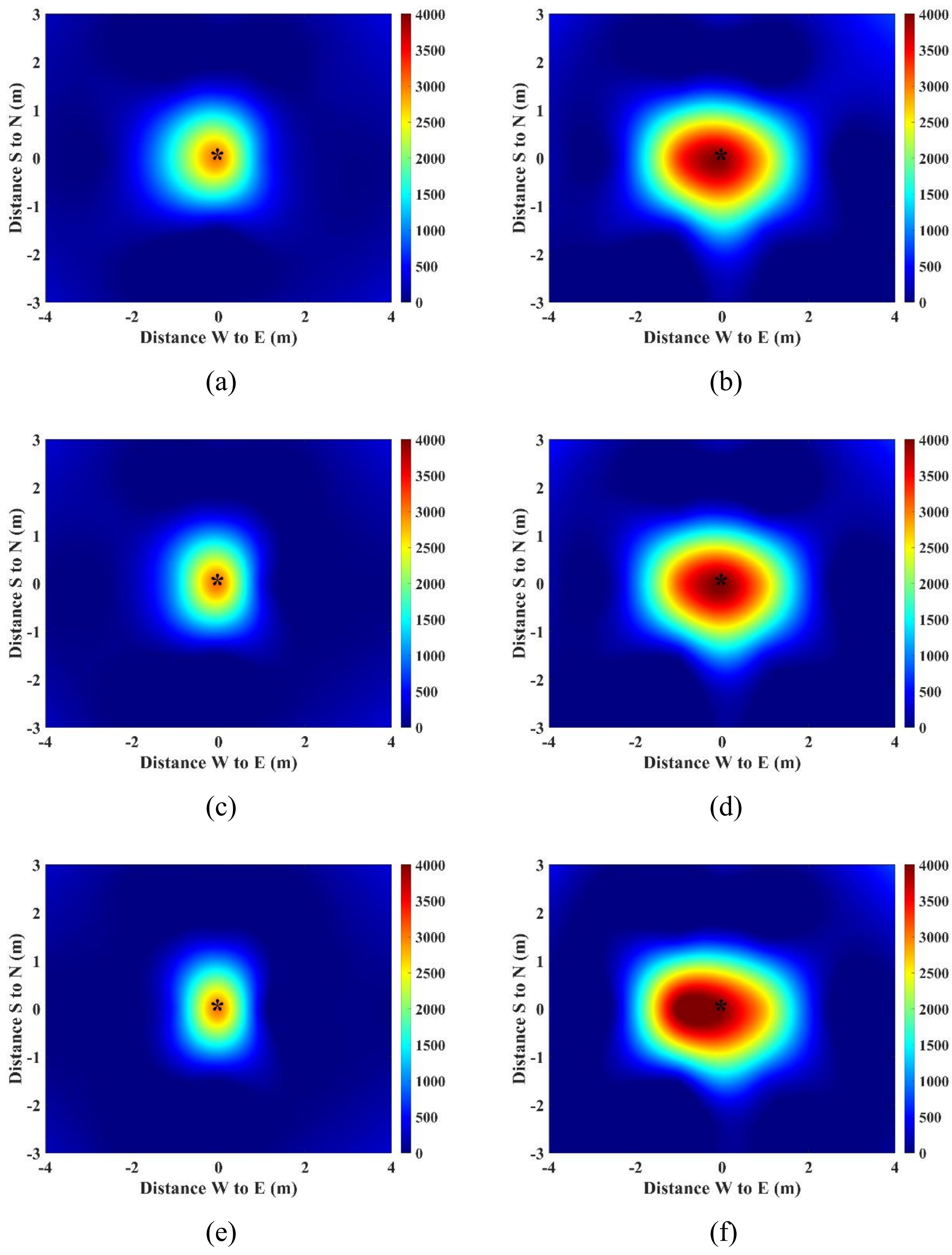


Fig. 2 – Top view of observed surface (a, c, and e) and BNS (b, d, and f) CH_4 expression (ppmv) from hour 84 to hour 86. The controlled gas leak rate increased from 89 g/h to 121 g/h during this period. The star maker (*) in the contour presents the location of the leak point.

In addition, the developed inverse gas migration model, a modified version of the ESCAPE model, demonstrated strong capabilities in estimating non-steady underground natural gas leak rates, using surface/belowground near-surface methane concentrations, meteorological conditions, and soil properties. The estimated NG leak rates by the modified ESCAPE model agree well with the experimental NG leak rates (m=0.99 and R^2=0.77), demonstrating that including soil characteristics and BNS CH4 measurements can advance estimations of non-steady NG leak rates in low and moderate NG leak rate scenarios.

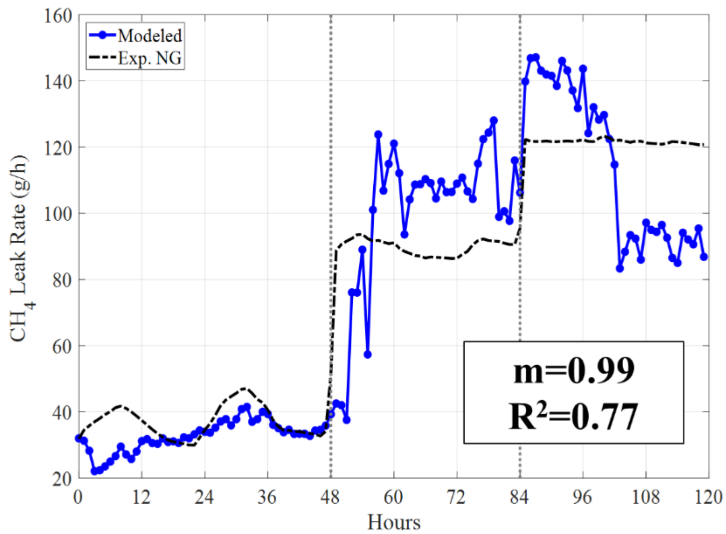


Fig. 3 – The comparison between the estimated transient NG leak rates (blue circle line) and the controlled NG leak rate (black dash line).

R-PLUME – Response Protocol for Large Underground Methane Emissions

In this project, I was engaged in the development of a soil aeration model. The primary goal is to explore the factors influencing the optimization of the design, operation, and monitoring of soil aeration. Numerical experiments are being conducted, encompassing diverse soil properties and venting strategies.

Research Plans

Soil aeration Modeling

1. Conduct numerical experiments with more complicated environmental conditions (e.g., precipitation and surface covers)
2. Conduct field-scale experiments to evaluate the performance of soil aeration model.

NYSEARCH – Optimal design and operation of soil aeration systems for belowground natural gas leak mitigation

In this project, I am presently engaged in developing a two-phase transport model and designing and operating field-scale soil aeration testing under different soil conditions and soil aeration strategies at METEC. The primary modeling work is to numerically investigate the gas migration behavior below the ground surface during the active/passive soil aeration. The experimental measurements are used to explore the factors influencing the design, operation, and monitoring of soil aeration to optimize the soil aeration strategies.

Research Plans

Soil aeration modeling and experiment

1. Conducted numerical experiments with near-surface water cap and dry surface.
2. Validate the soil aeration model based on the experimental data.

Publications

- Lo, J. H., Smits, K. M., Cho, Y., Duggan, G. P., & Riddick, S. N. (2024). Quantifying non-steady state natural gas leakage from the pipelines using an innovative sensor network and model for subsurface emissions-InSENSE. Environmental Pollution, 341, 122810.