PTAC Biocovers Project Update Meeting

May 2024

MEMS Research Project: Ian Hers, Aaron Cahill and others

A need for alternative approaches for managing minor integrity failure and marginal well leakage

AGU ADVANCING EARTH AND SPACE SCIENCES

Geophysical Research Letters

RESEARCH LETTER
10.1029/2023GL106496

Key Points:

- First evaluation of leakage of methane from nine decommissioned unconventional gas wells
- At least five wells (56% of those examined) potentially suffering integrity loss resulting in minimal emissions
- Methane emissions observed are considerably mitigated through natural soils-based oxidation

Supporting Information:

Supporting Information may be found in the online version of this article.

Correspondence to:

A. G. Cahill,
a.cahill@hw.ac.uk

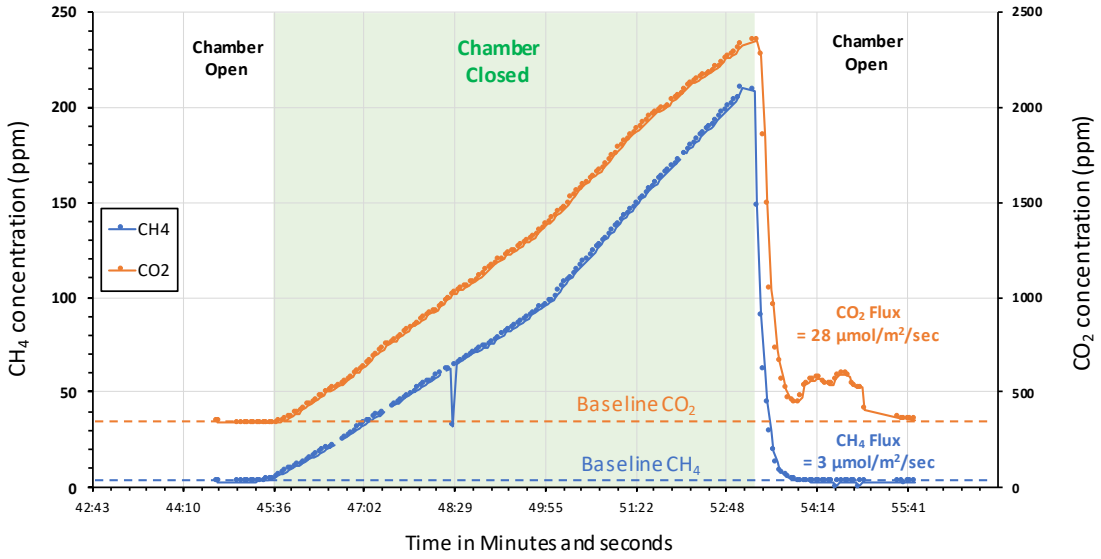
Evaluating Methane Emissions From Decommissioned Unconventional Petroleum Wells in British Columbia, Canada

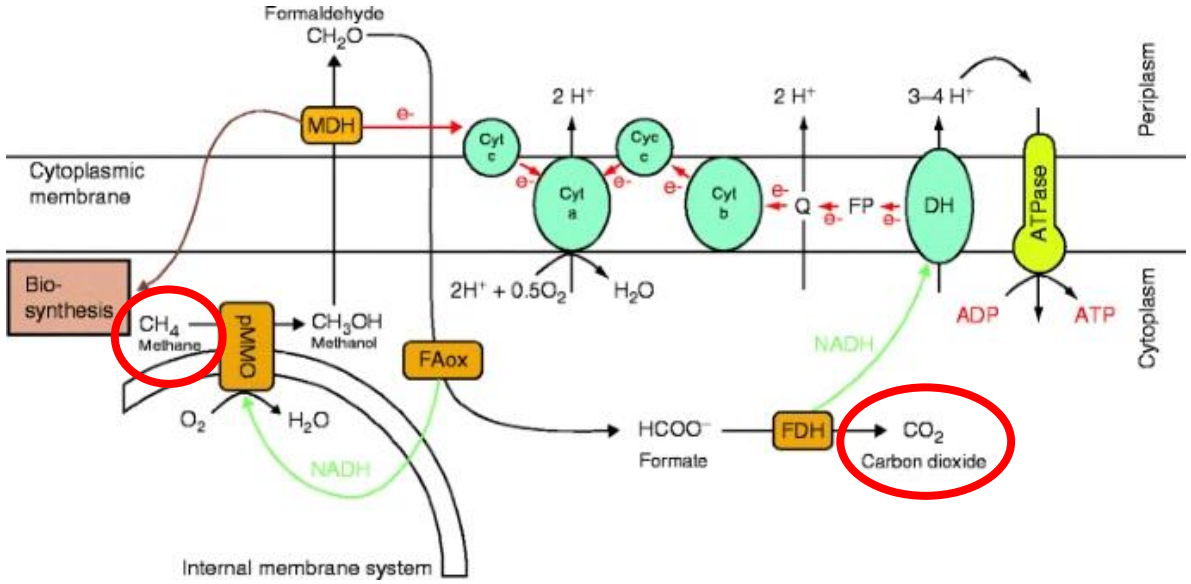
Aaron G. Cahill[1], Mohammad Joukar[1], Morteza Sefat[2], and Chelton van Geloven[3]

[1]The Lyell Centre, Heriot-Watt University, Research Avenue South, Edinburgh, UK, [2]Institute of Geoenergy Engineering, Heriot-Watt University, Research Avenue South, Edinburgh, UK, [3]Ministry of Forests, Lands, Natural Resource Operations and Rural Development, Government of British Columbia, Prince George, BC, Canada

Abstract Hundreds of thousands of unconventional natural gas wells recently constructed across North America have transformed the global energy landscape and generated widespread concern relating to fugitive methane leakage. To date, no studies have evaluated the integrity of unconventional wells post-abandonment. Here, we evaluated emissions at nine decommissioned unconventional wells within the Montney region of British Columbia, Canada and found two exhibited co-emission of CH_4 and CO_2 from surrounding soils indicating integrity failure, releasing up to ~2,000 kg of CO_2-eq/yr into the atmosphere. A further three wells exhibited statistically significant anomalous CO_2 fluxes of ~500 kg/year from surficial soils around the well, likely associated with minor integrity failure and derived from near total soil-based aerobic oxidation of fugitive CH_4. These findings suggest that more than half of decommissioned unconventional wells may generate emissions, however only relatively small contributions to GHG emissions result that are significantly mitigated through natural soils-based CH_4 oxidation.

Porous Media CH_4 oxidation has great potential to aid management and mitigation of well leakage

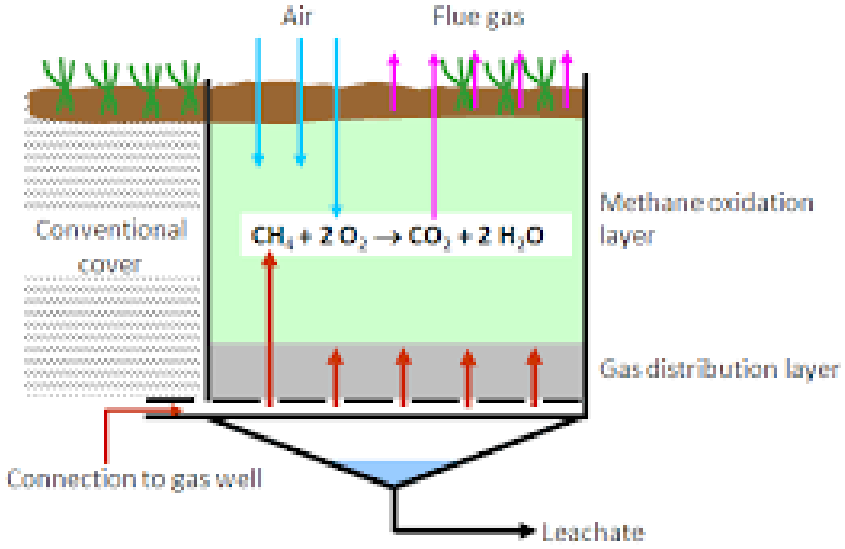




- Potential reduction in GHG emissions of up to 97% (over 20 years) if full conversion from CH_4 to CO_2 is achieved.
- BUT: it's not magic – a fairly complicated, multi step process…
- Lots of controlling parameters and factors affect rates and extents…
- A need for enhanced understanding of the process…

Project Structure

- **Literature Review**
- Biocover Demonstration
  - **Site attainment**
  - **Site and gas delivery system design/plan**
  - **Biocover design development (including preliminary modelling)**
  - **Site set up and installation of instrumentation**
  - **Biocover baseline monitoring – has been essential**
    - **Temperature and moisture**
    - **Soil gases**
    - **Surface fluxes**
    - **Isotopes and radiocarbon**
    - **Microbial testing**
    - **Weather**
  - Biocover operation – injection to start in May 2024
  - Data evaluation and interpretation (including additional modelling)
  - Technical reporting and dissemination of findings
    - Key suggestions/proposals on potential for roll out at scale in “live” environments

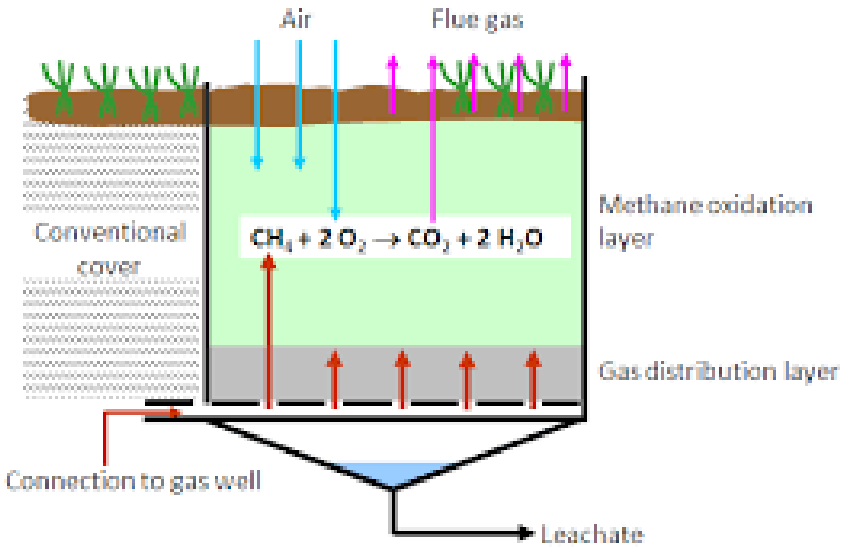


Site Set-up and Background Monitoring

Baseline Soil Gas Monitoring

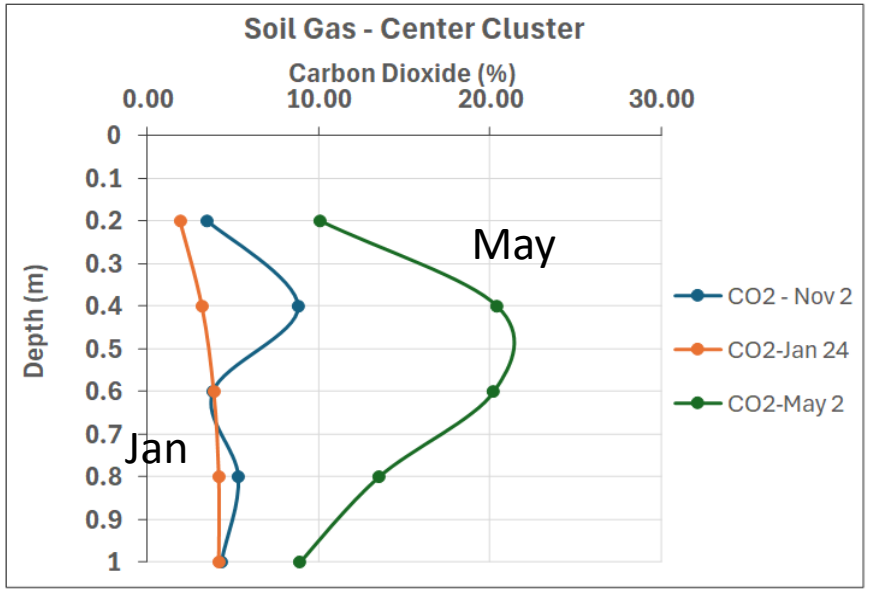
- Monitoring events Nov 2/3, 2023, January 24, 2024, May 2, 2024

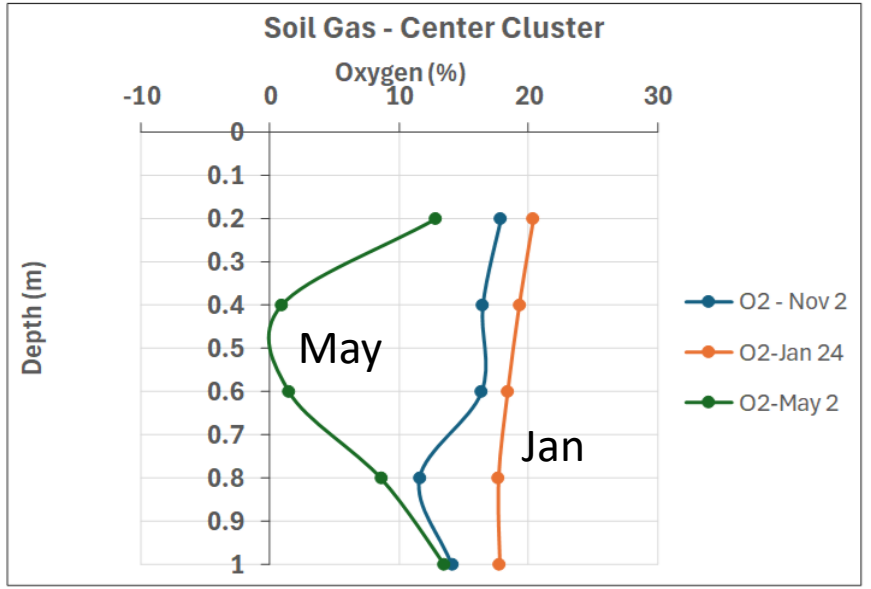
- O_2: 0.1 - 21.8 %
- CO_2: 0.1 - 22.3 %
- CH_4: 2.1 - 5.9 ppm
- H_2S: 0 - 119 ppm (max at probe where O_2=0.1 %)
- CO: 0 – 18 ppm

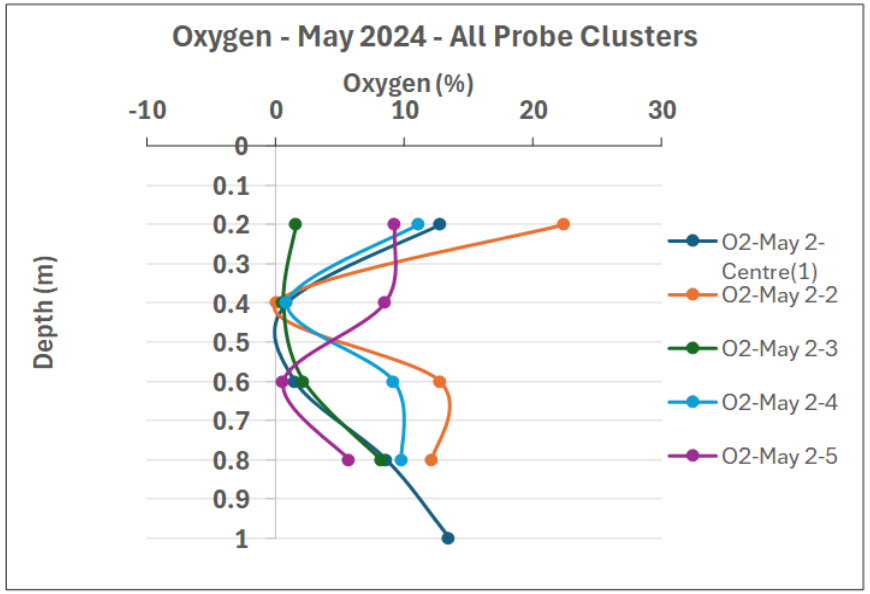


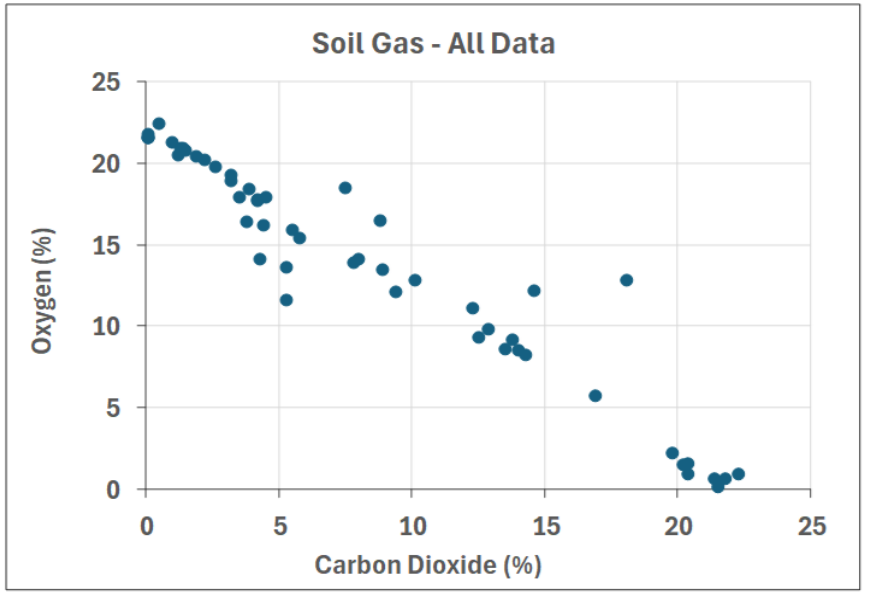
- Soil gas regime reflects primarily aerobic compost respiration with localized anaerobic conditions and sulphate reduction, but negligible methane generation (this could change with time)

Baseline Soil Gas Monitoring









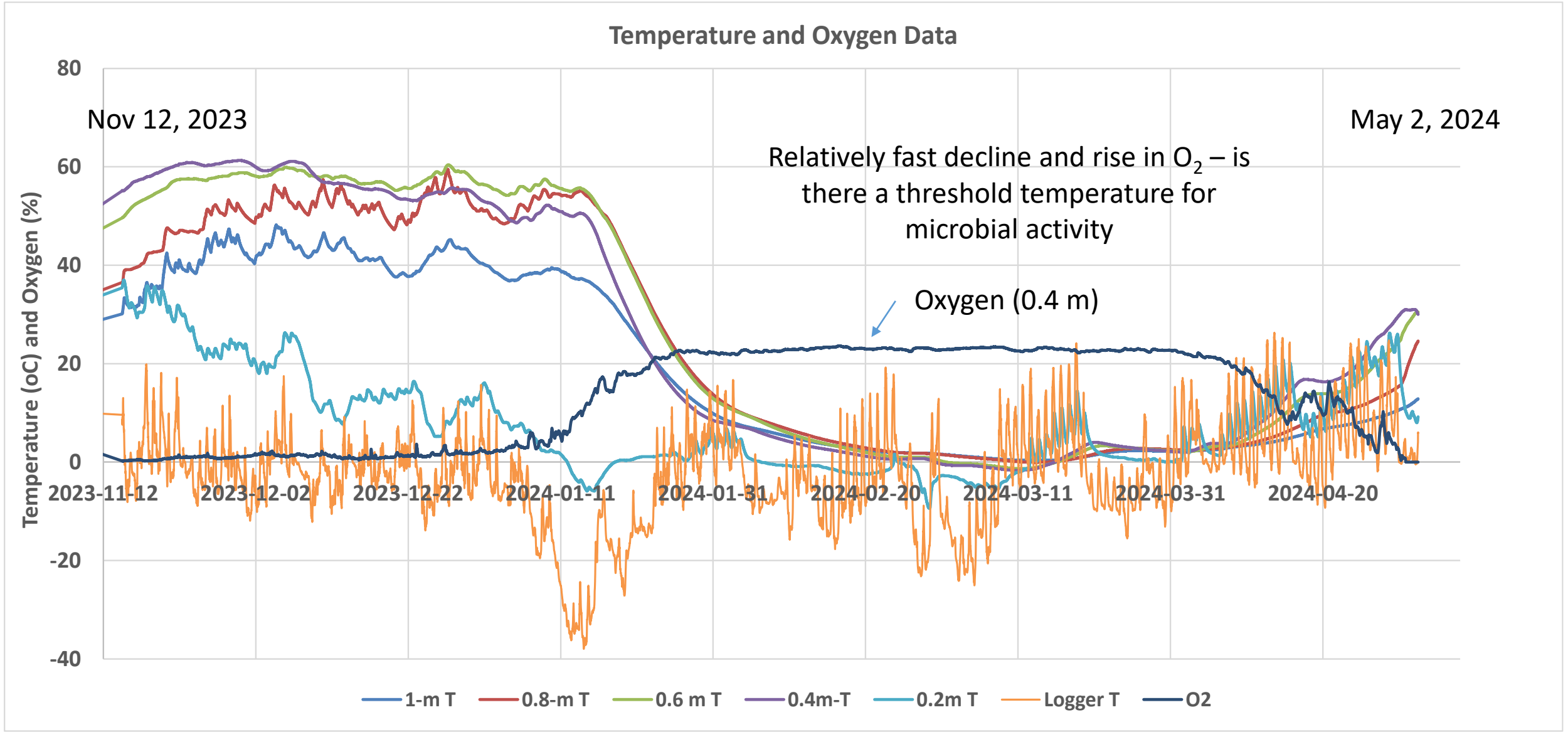
CO_2 and O_2 inversely correlated in May

CO_2 and O_2 from respiration should fall on a straight line – can be used as a QC check

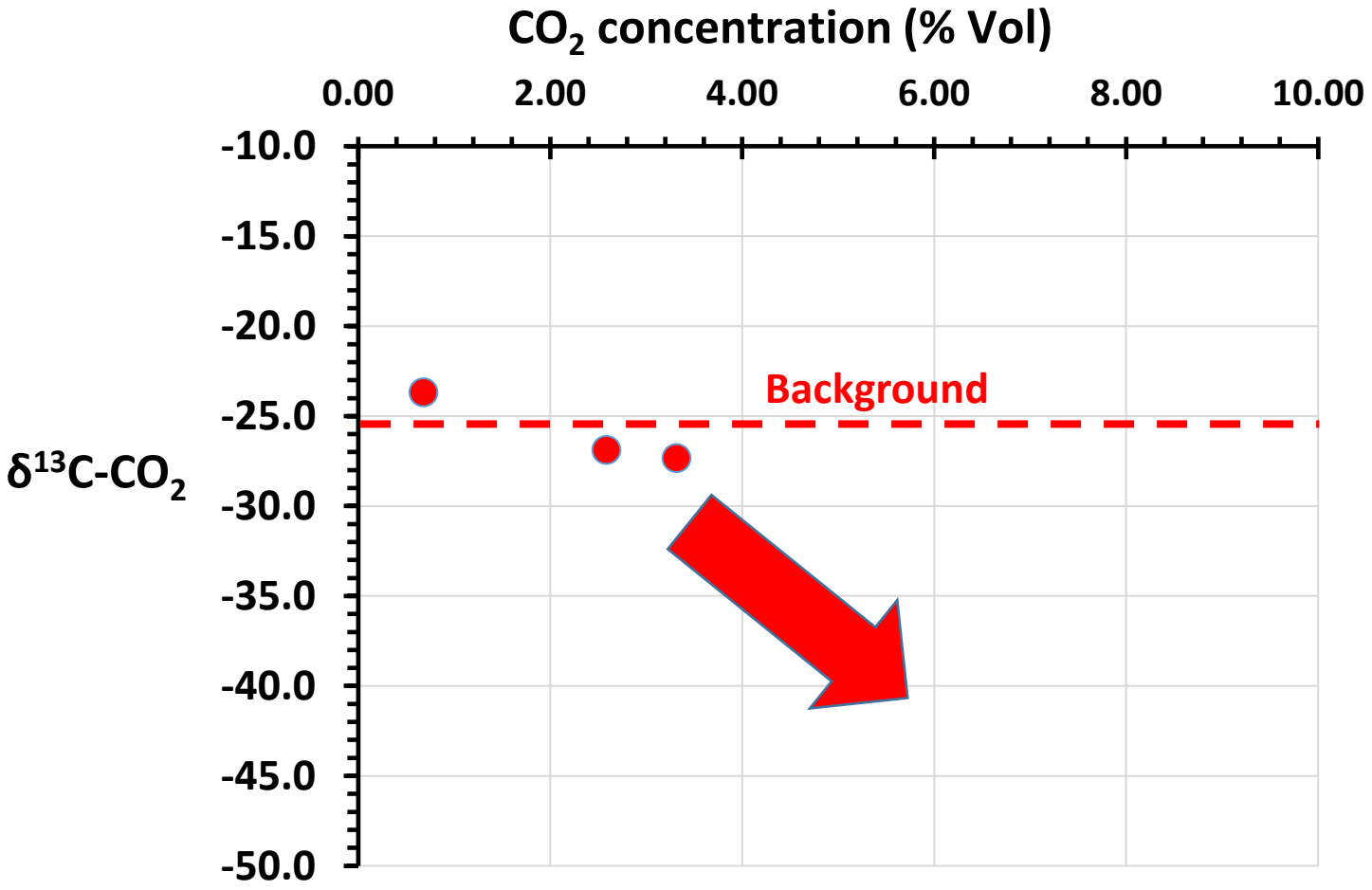
Baseline Soil Gas Monitoring

- Nov 2, 2023, data was collected shortly (1-2 days) after filling of cell, consequently the somewhat elevated O2 could have been from mixing
- Jan 24, 2024 O_2 was near atmospheric indicating decline in respiration
- May 2, 2024 O_2 was highly variable, most depleted at 0.4 m depth, indicating increase in respiration
- May be entry of air (O2) into cell through uncapped injection pipe at base and through other cracks/openings
- Possible small convection cell with air rising in cell?

Baseline Temperature / Oxygen Monitoring



Stable Carbon Isotope Baseline Delineated



Can now look to quantify the increase in concentration and shift negative in $\delta^{13}C\text{-}CO_2$ (i.e. depleted in ^{13}C) during injection to evaluate CH_4 oxidation…

Need to understand “who” is eating the methane…

(Literature Search and evaluation of potential methods of Microbial Analysis)

JMB Journal of Microbiology and Biotechnology

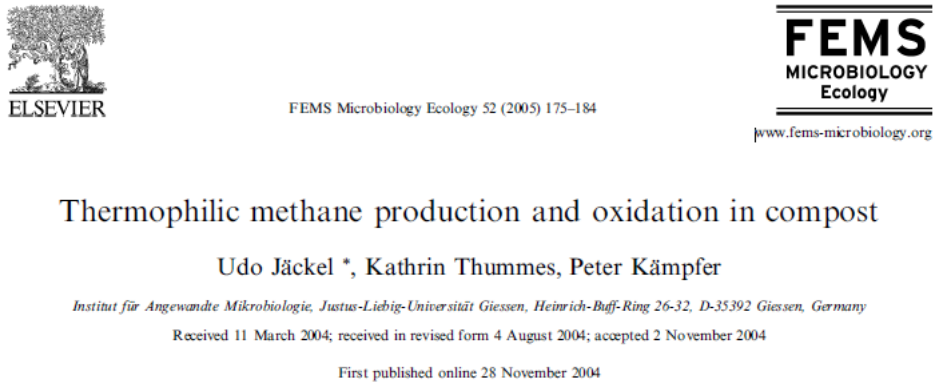
J. Microbiol. Biotechnol. 2021. 31(6): 803–814
https://doi.org/10.4014/jmb.2103.03005

Characterization of the Bacterial Community Associated with Methane and Odor in a Pilot-Scale Landfill Biocover under Moderately Thermophilic Conditions

Hyoju Yang[1], Hyekyeng Jung[1], Kyungcheol Oh[2], Jun-Min Jeon[2], and Kyung-Suk Cho[1]*

[1]Department of Environmental Science and Engineering, Ewha Womans University, Seoul 03760, Republic of Korea
[2]Green Environmental Complex Center, Suncheon 57992, Republic of Korea

- Bacterial genera (DNA) were identified using qPCR testing under temperatures ranging from moderately thermophilic (40-50oC) to mesophilic (30oC) conditions
- Major methane oxidizing species were Methylocaldum spp. during t-philic and Methylobacter spp. during m-philic conditions.
- Diversity of bacterial community in the biocover during t-philic did not decrease significantly compared to m-philic (Halet et al. 2010 found diversity was less during thermophilic phase)



ELSEVIER

FEMS Microbiology Ecology 52 (2005) 175–184

FEMS MICROBIOLOGY Ecology

www.fems-microbiology.org

Thermophilic methane production and oxidation in compost

Udo Jäckel *, Kathrin Thummes, Peter Kämpfer

Institut für Angewandte Mikrobiologie, Justus-Liebig-Universität Giessen, Heinrich-Buff-Ring 26-32, D-35392 Giessen, Germany

Received 11 March 2004; received in revised form 4 August 2004; accepted 2 November 2004

First published online 28 November 2004

- Methane oxidation demonstrated under thermophilic conditions; optimal temperatures were 45-55oC
- Methylocaldum main strain isolated
- Short lag times of about a day

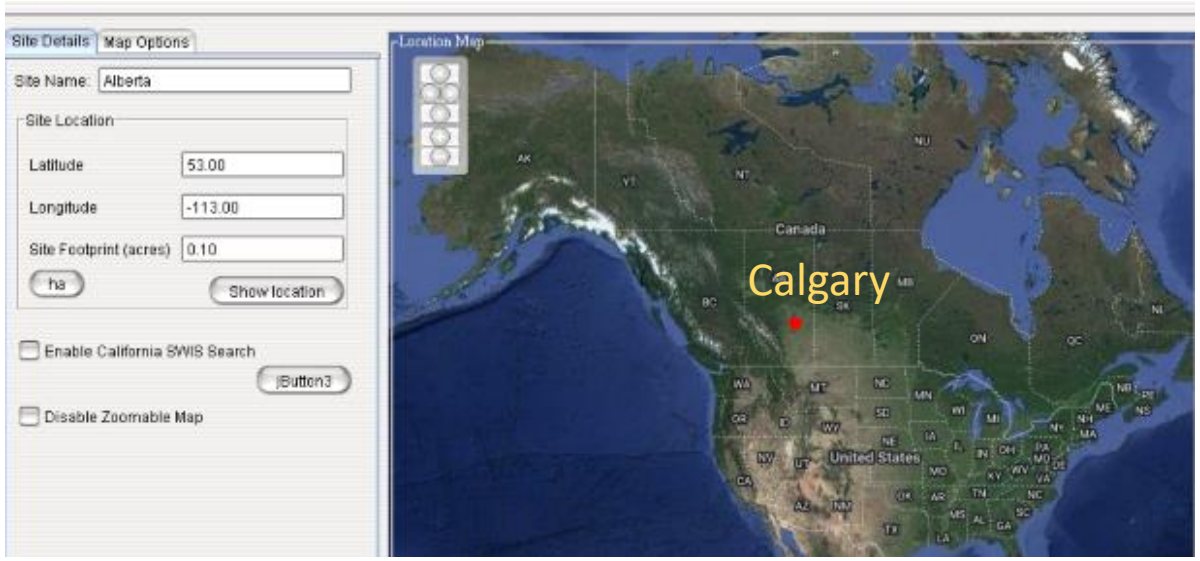
Numerous other papers summarized

Microbial Analysis Options

- **Particulate methane monooxygenase (pMMO)** - enzyme that catalyzes the 1st step in methane oxidation - $ - analysis of compost samples indicated results < detection
- **qPCR 16S Amplicon genetic sequencing** – known sequences of bacteria and archaea – information on specific bacteria (phylum) and diversity - $$ - Microbiome Insights, Richmond, BC to conduct analysis
- **Next-generation or "shot-gun" metagenomic sequencing** – deeper insight (more reads) into microbiome composition, gene diversity and genomic diversity of bacteria, archaea and fungi - $$$
- **Meta-transcriptomics** - messenger RNA analysis that targets only active communities - $$$

CALMIM Model – see project workplan for details

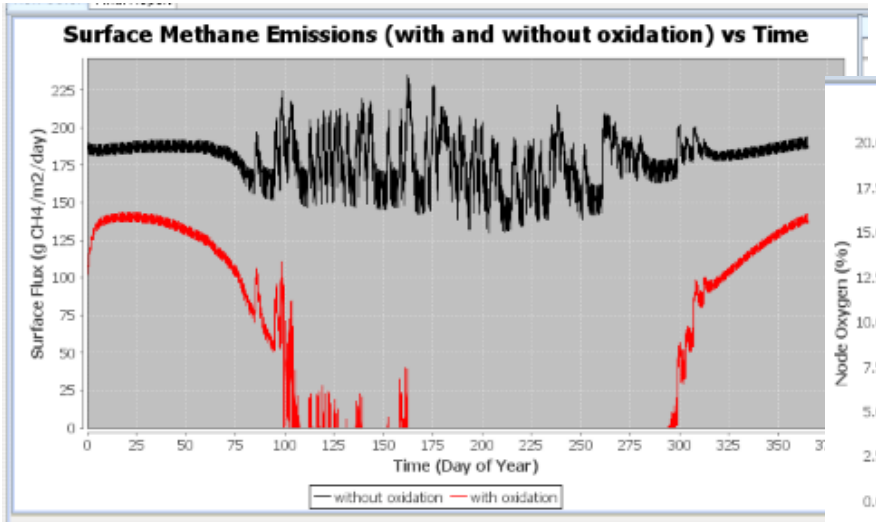
- Diffusion/Biodegradation Model for Methane Oxidation in Landfill Biocovers
- Variable Soil Moisture and Temperature, uses site specific climatic data, calibrated mostly US landfills
- Initial modelling was conducted for a hypothetical 1-m thick biocover consisting of compost



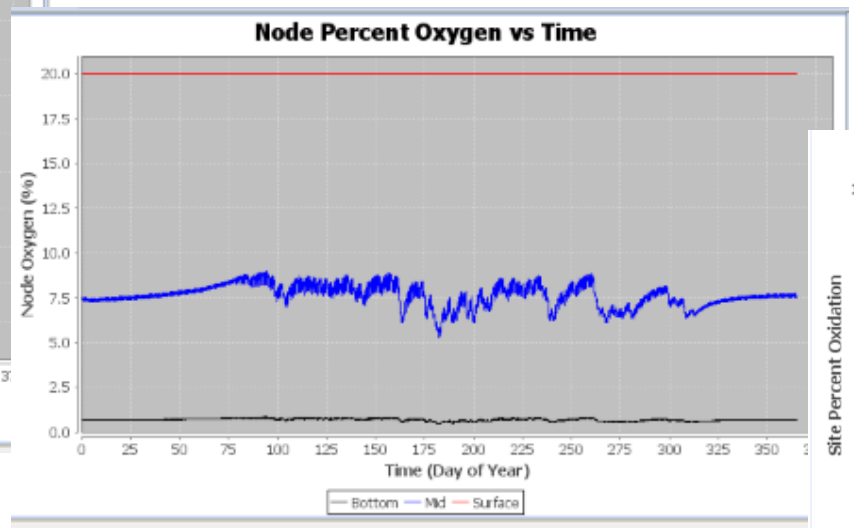
*	New Cover
Methane Concentration Base of Cover	5.0
Oxyegn Concentration Base of Cover	0.0
Max. Methanotroph Oxidation Rate (ug/g/day)	400.0
Emission Data	
Methane Emission without Oxidation (g/m^2/day)	16.83
Methane Emission with Oxidation (g/m^2/day)	1.74
Remaining Oxidation Capacity(g/m^2/day)	84.11
% Oxidation	90.08
Site Calculations	
Total Cover Emissions with Oxidation (kg/year)	256.35
Total Cover Emissions without Oxidation (kg/year)	2486.41

CALMIM Model – see project workplan for details

- Diffusion/Biodegradation Model for Methane Oxidation in Landfill Biocovers

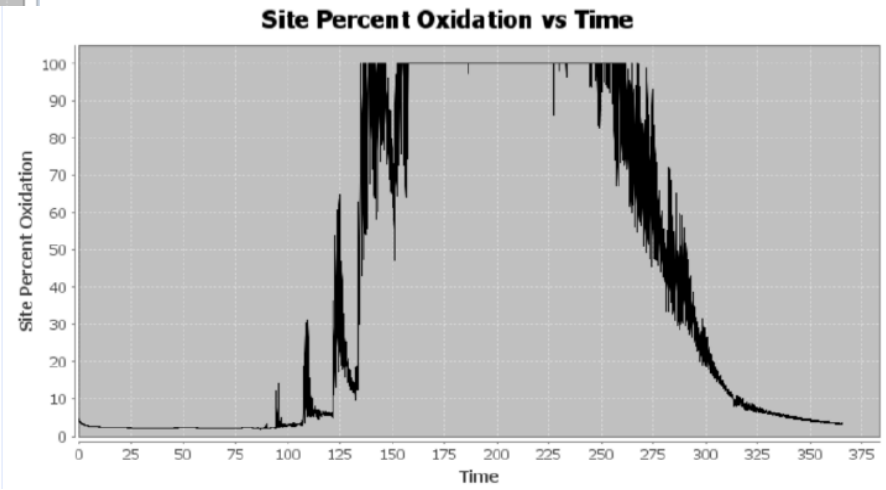


% O2



Doesn't seem follow expected seasonal trend; possibly a function assumed porosity / moisture content

% Percent Oxidation



Strong seasonal trend – our test shows this for compost respiration

- Additional modelling being conducted using CALMIM and thermal models

Challenges Encountered

- Site Attainment
- Compost
- Site/experiment construction
- Alberta Winter (important)!!!

All led to delays in CH4 injection

However, now poised to begin….

Next Steps

- Samples for microbial analysis
- Completion of installation of gas injection system (late May – Sequoia)
- CH4 gas injection starting beginning of June
- Continued bio-cell monitoring
- Evaluate passive air injection as needed
- Analyze and interpret results with a view to appraising use of biocovers for CH4 mitigation at marginally leaking wells…

Questions or Comments