High-rate Methanotrophic Biofiltration (HMBF) Technology to Minimize Atmospheric Emission of Greenhouse Gas

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Key message(s)

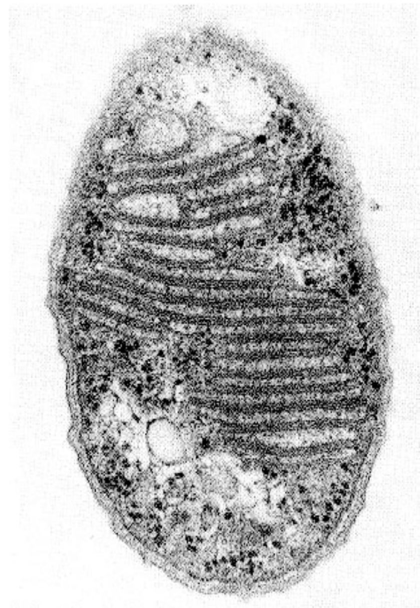
- Methanotrophic applications to control methane emissions go beyond landfill biocaps (most popular; talked about) or passively aerated methane biofilters (MBFs) with low methane elimination capacity
- MBFs with multiple air/gas injection systems utilize the entire filter bed and operate at very high capacity
- Field-systems could handle much more gas than lab-systems (almost double the elimination capacity)
- Temperature changes could be a surrogate for continuous measurement of methane oxidation (in field systems)

Microbial Techniques to Control Methane Emissions

Oxidize methane to carbon dioxide using naturally available microorganisms known as “methanotrophic bacteria” or “methanotrophs”

Methanotrophs

- aerobic, attached-growth organisms
- found in paddy fields, around natural gas leaks and in landfill cover soils
- Type I, II and X are the most common
- require:
  - Oxygen (could operate at low oxygen)
  - Moisture (optimum MC around 20%)
  - High temp (optimum around 25-35^{o}C)
  - Nutrients (N, P. Carbon source is methane)



(Methylomonas methanica)

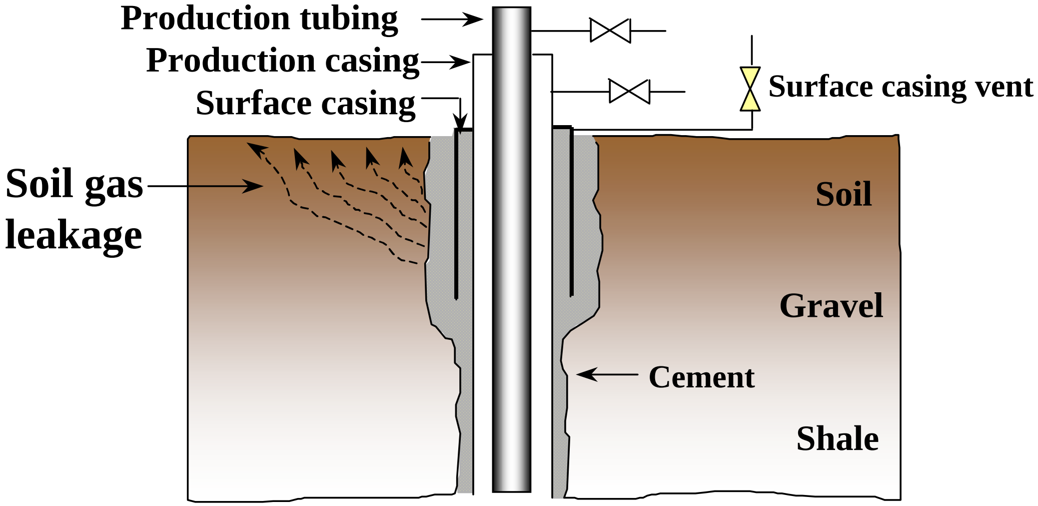
Engineering Applications of Methanotrophy

- Landfill Biocaps or LBCs - at landfills to control diffused sources
- MBF (Methane-biofilter)
    - to control point emissions in oil/gas industry
    - To treat gas collected from landfills (instead of flaring)

Control of Point Source Emissions in Oil and Gas Industry

Oil and gas industry contributes about 15% of the global emissions of CH_4. Primary sources include:

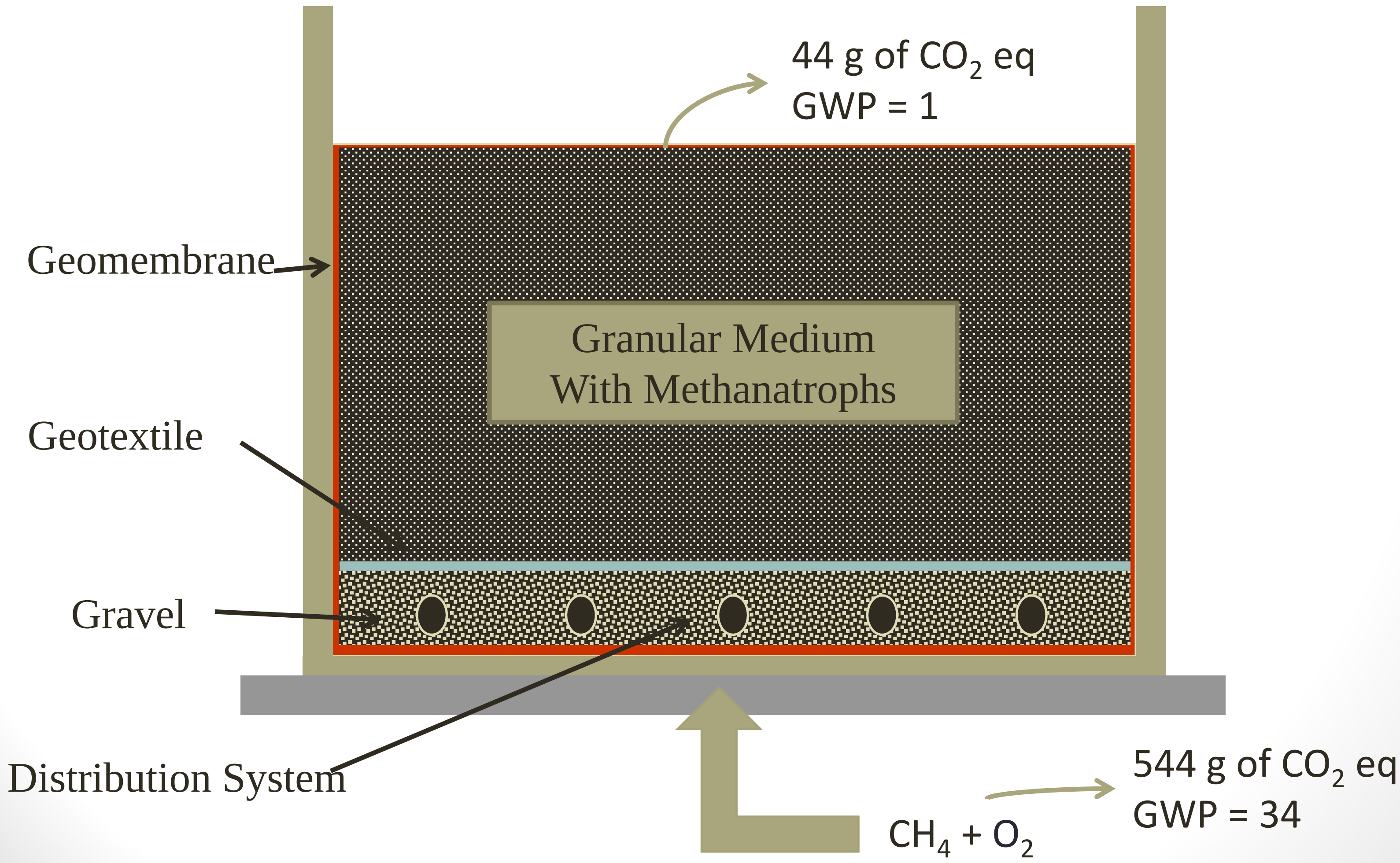
- Solution gas/Production casing gas
- Fugitive emissions and engineered emissions



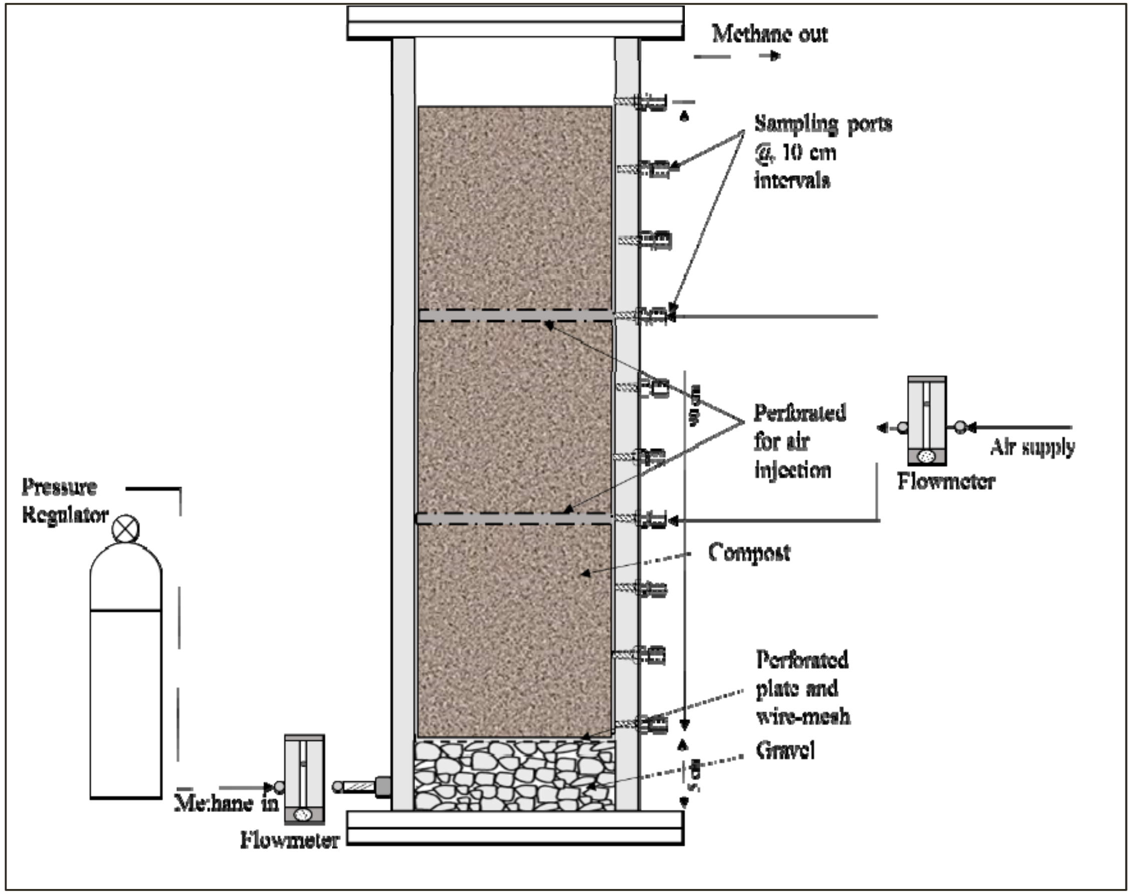
Schematic of typical well completion

Casing gas emissions constitute 30% of the oil industry's CH_4

Typical MBF – Passive aeration



Column Experiments -Apparatus

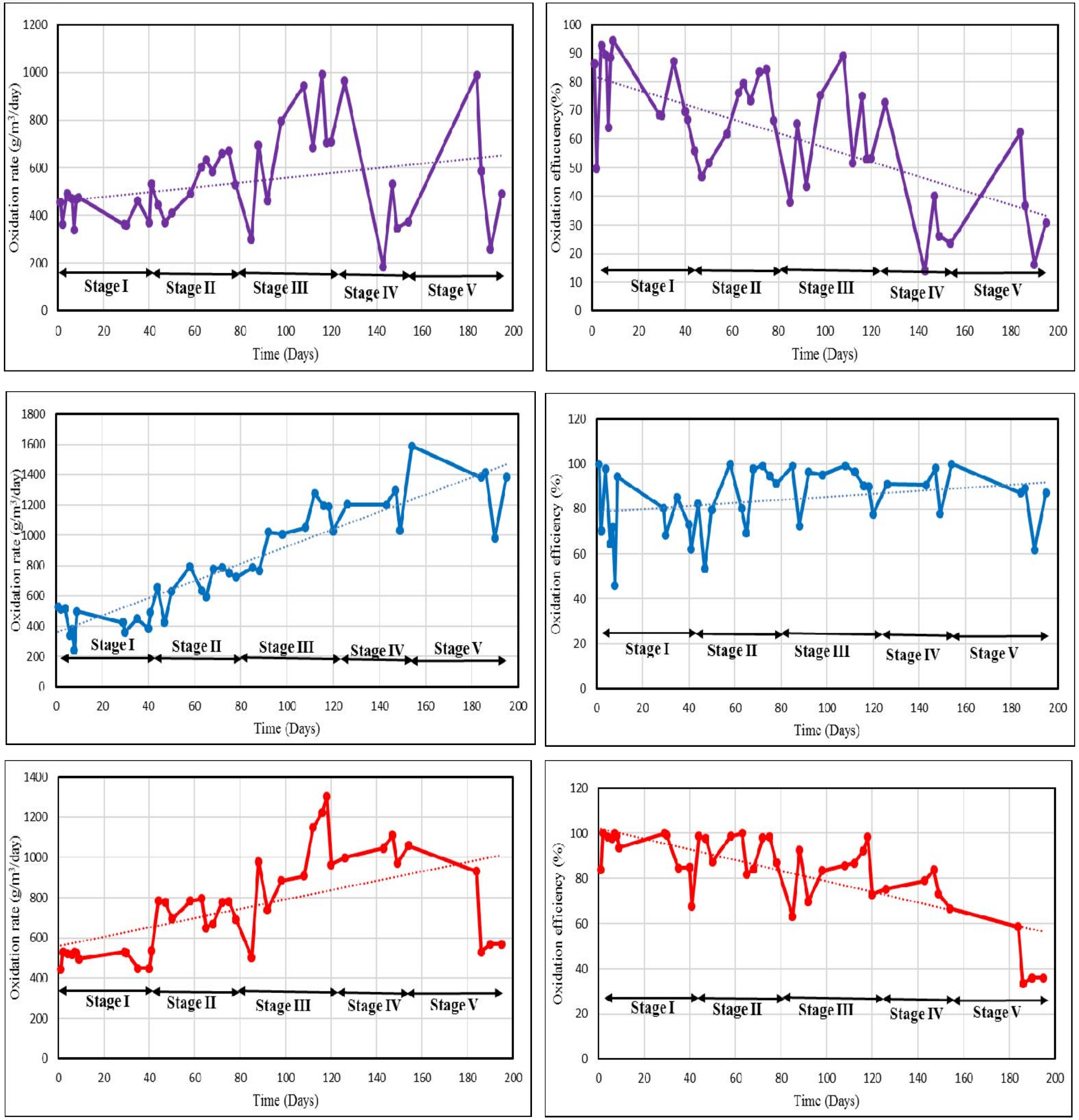


Column Experiments - Details

- Gas injected from the bottom and air injected at different locations
  - Column C1: aerated at only one level with the air probe positioned at the bottom.
  - Column C2: aerated at two levels; one injection located at the bottom, and the other located 35 cm above.
  - Column C3: aerated at three levels; with one injection located at the bottom, and the other two located 23 cm and 46 cm above.
- Columns operated continuously for 195 days
- Gas concentrations at inlet, outlet and locations along the column were measured

Aerated Columns - Results

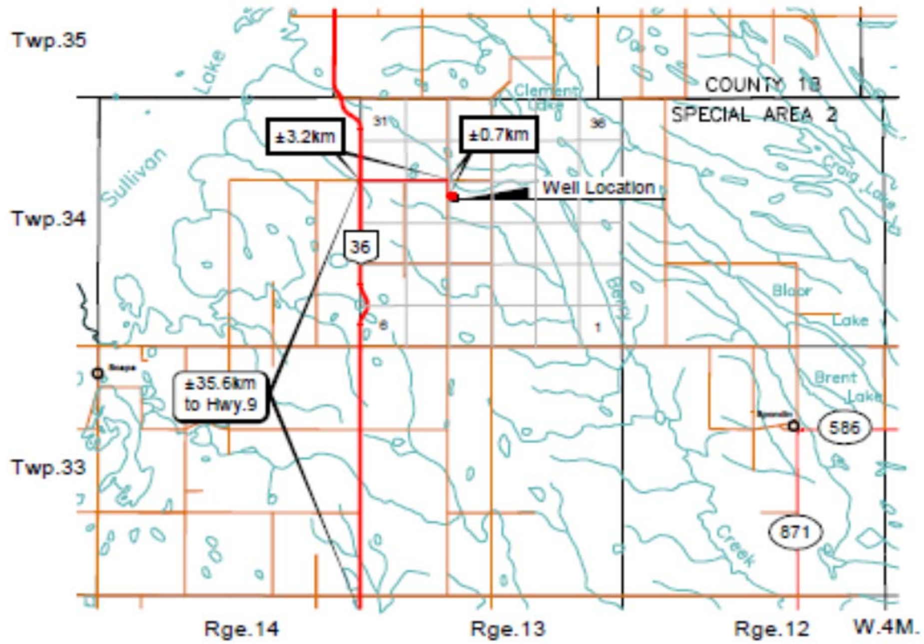
Stage	Loading rate (g/m³/d)	Oxidation rate (g/m³/d)			Aeration efficiency (%)		
		C1	C2	C3	C1	C2	C3
I	529	420	423	501	78	77	95
II	794	519	671	704	65	84	89
III	1059	716	1025	931	65	**92**	84
IV	1324	600	1217	**1083**	45	89	80
V	1588	563	**1309**	**633**	35	82	40



- **Column 1**
- **Column 2**
- **Column 3**

High-Rate Actively Aerated MBF in Hanna, AB

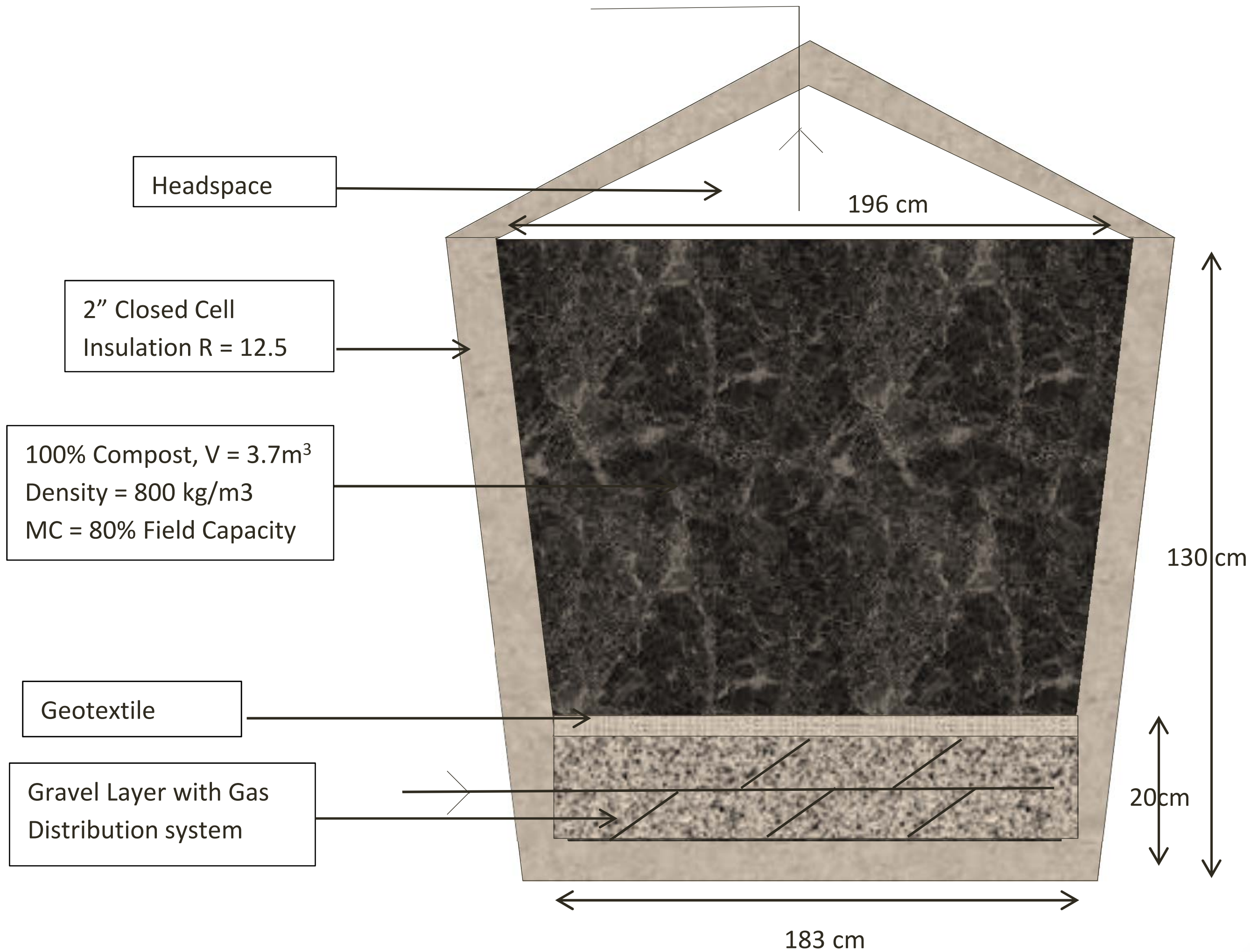
- Field-scale HMBF at a single-well battery Site
  - The battery separates production fluid into solution gas (> 90% methane), crude oil and salt water. Solution gas is vented into the atmosphere.



HMBF Design Considerations

- Inlet feed rate should be up to 50 m^3/d (more than 2000 $g/m^2/d$) consisting of solution gas with 92% CH_4
- Ensure mixing of air and gas between 10:1 to 5:1
- MBF should be self-sufficient – no external power source (use solar power)
- MBF should withstand extreme weather (provide insulation and heating of air and gas)
- HMBF should be transportable

Detailed Schematic of HMBF

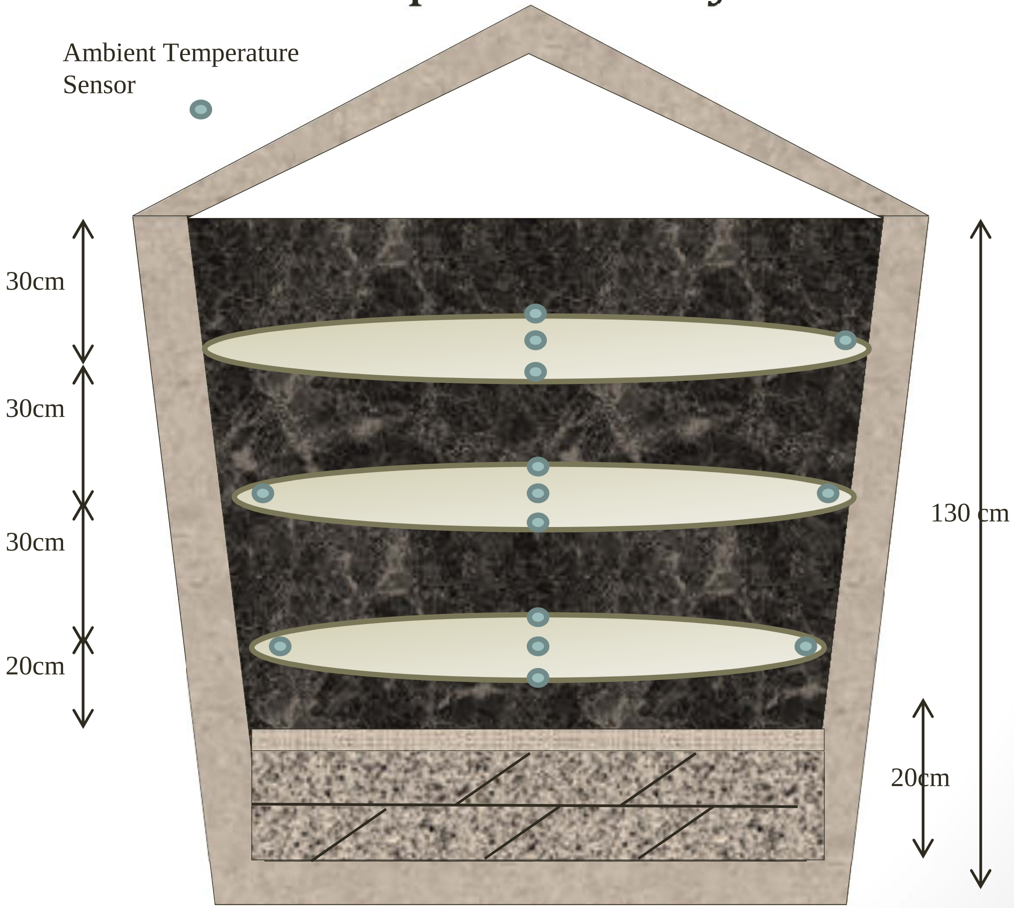


HMBF Construction

HMBF Monitoring

Continuous temperature measurements

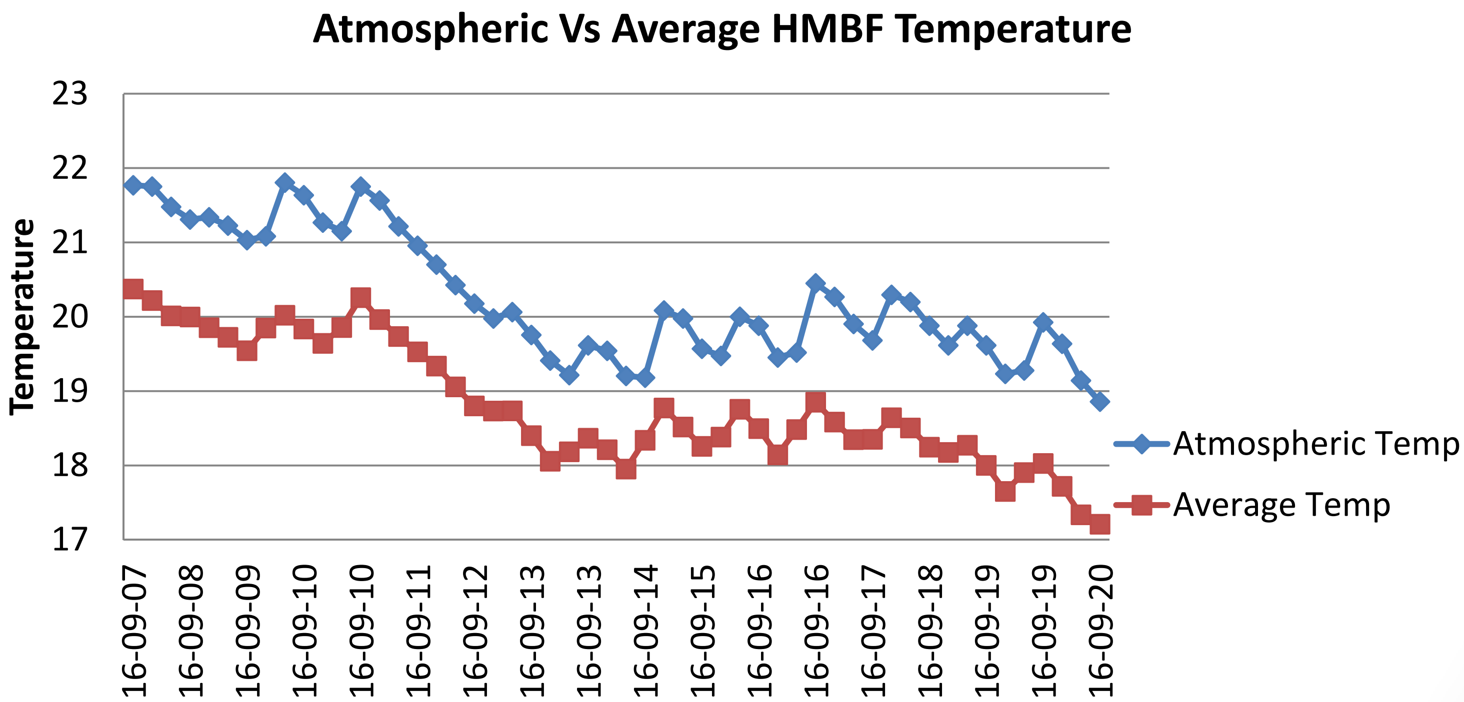
- 15 temperature sensors
- As an indicator of methanotrophic activity



HMBF Monitoring – Temperature data

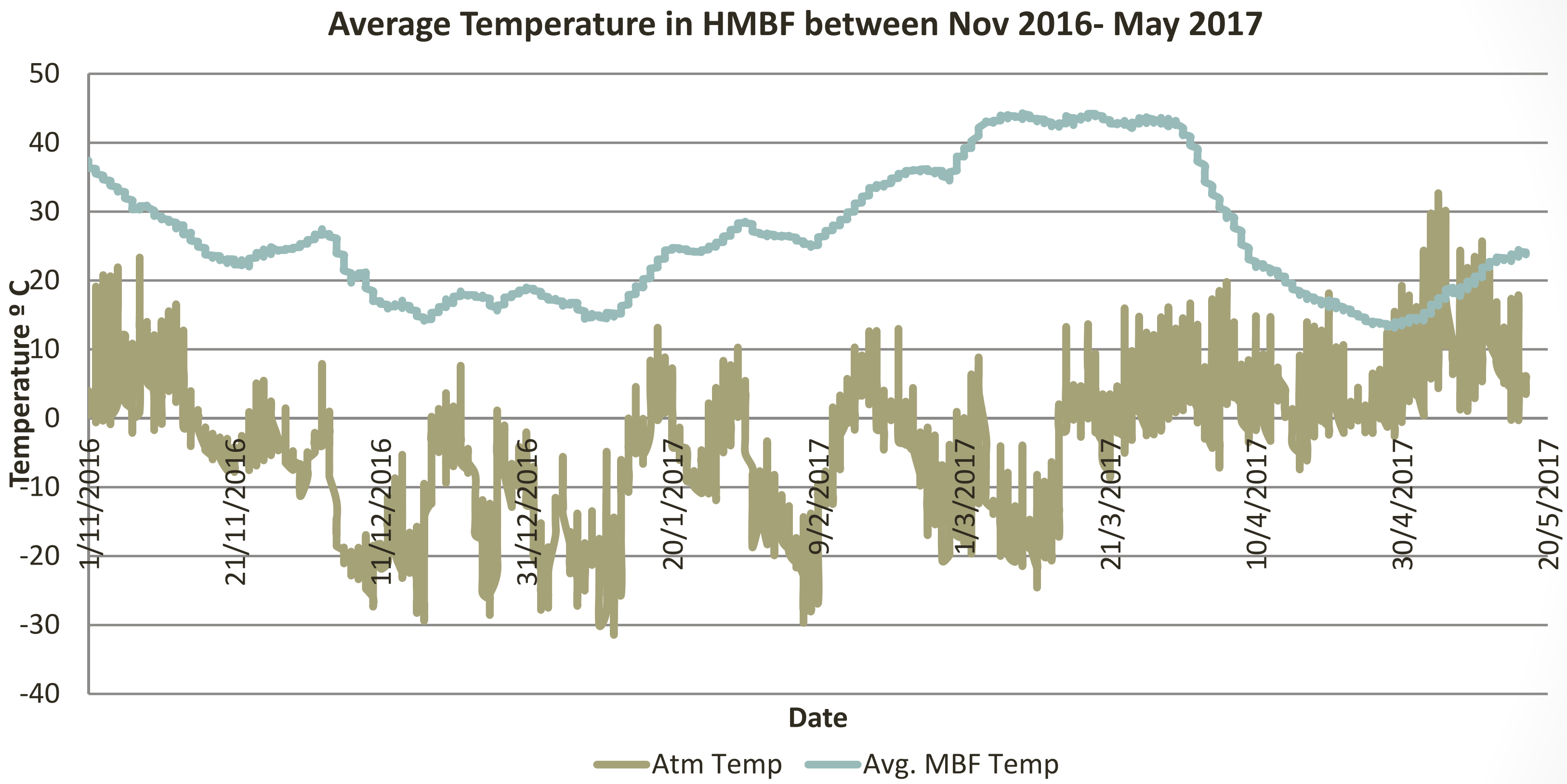
Baseline temperature measurements (before activity)

- Effect of solar radiation, wind and soil insulation on HMBF temperature



Thermal Resistance caused by HDPE walls, insulation and compost of the causes a ~ 2 ºC difference between atmospheric and MBF temperature.

Temperature data (during HMBF operation)



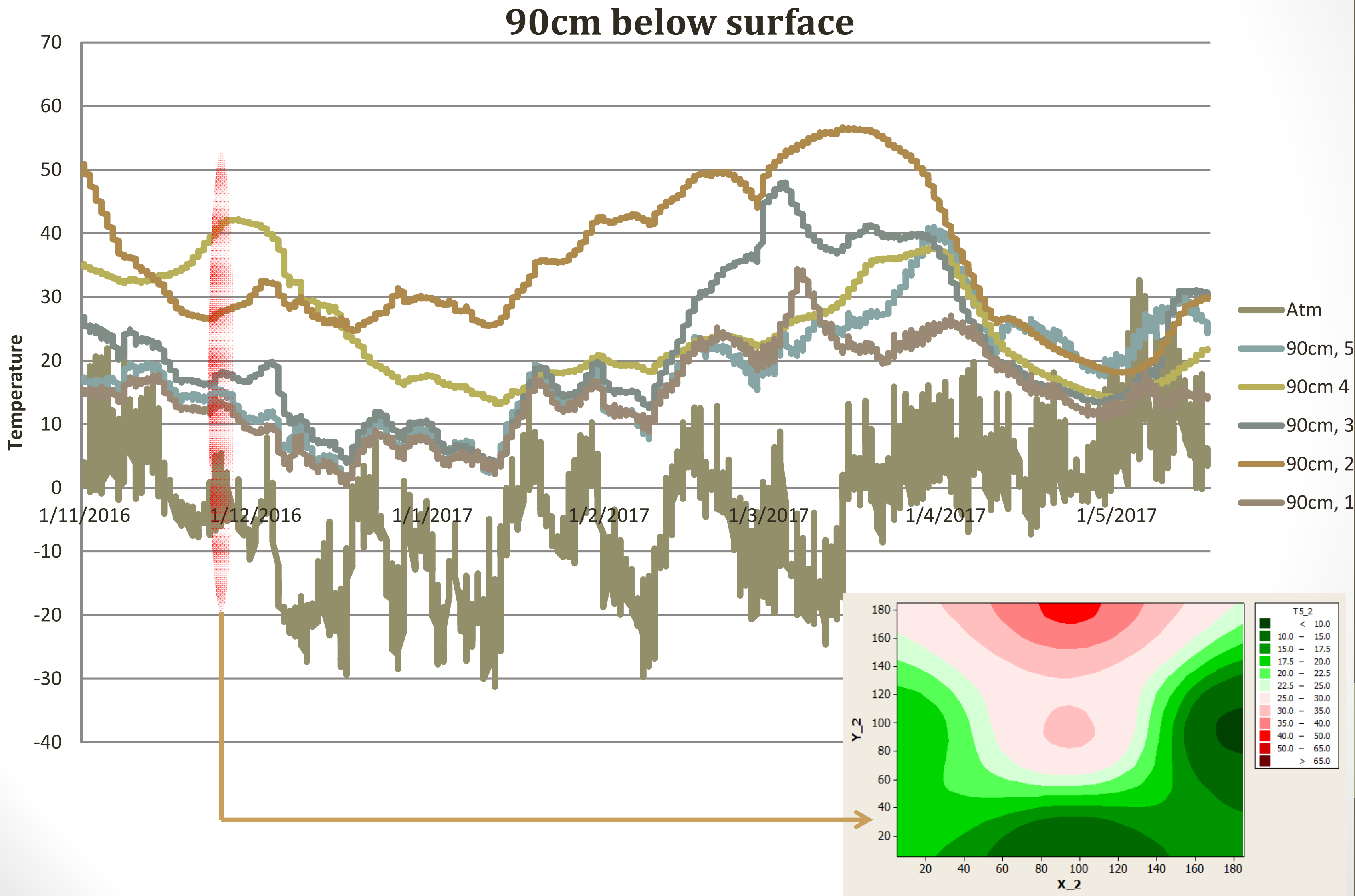
- Low methanotrophic activity during the seeding period.
- Temperature rise after December 2017.

Early Results – Methane Removal

		Inlet Flowrate		Gas	Normalized GC		Efficiency (%)
		(m^3/day)	(g/m^2/day)		Inlet	Outlet	
27/02/2017	Solution Gas	23	5709	CH_4	11.1	7.2	38.73
	Air	121	52562	O_2	18.6	18.8	
				N_2	70.3	74.1	
				CO2	0.0	0.0	
13/03/2017	Solution Gas	**23**	5709	CH_4	9.5	6.5	34.13
	Air	**171**	74282	O_2	20.8	20.9	
				N_2	69.7	72.4	
				CO2	0.0	0.2	
8/5/2017	Solution Gas	23.83	5915	CH_4	13.2	7.3	**48.93**
	Air	130.55	56711	O_2	18.4	19.5	
				N_2	68.3	73.3	
				CO2	0.0	0.0	
14/05/2017	Solution Gas	15.4	3823	CH_4	6.6	3.5	48.90
	Air	137	59512	O_2	19.9	20.3	
				N_2	73.5	76.2	
				CO2	0.0	0.0	

$$Efficiency = (CH_{4,in} - CH_{4,out} * (N_{2,in}/N_{2,out}))/CH_{4,in} * 100$$

Early Results -Temperature Fluctuations



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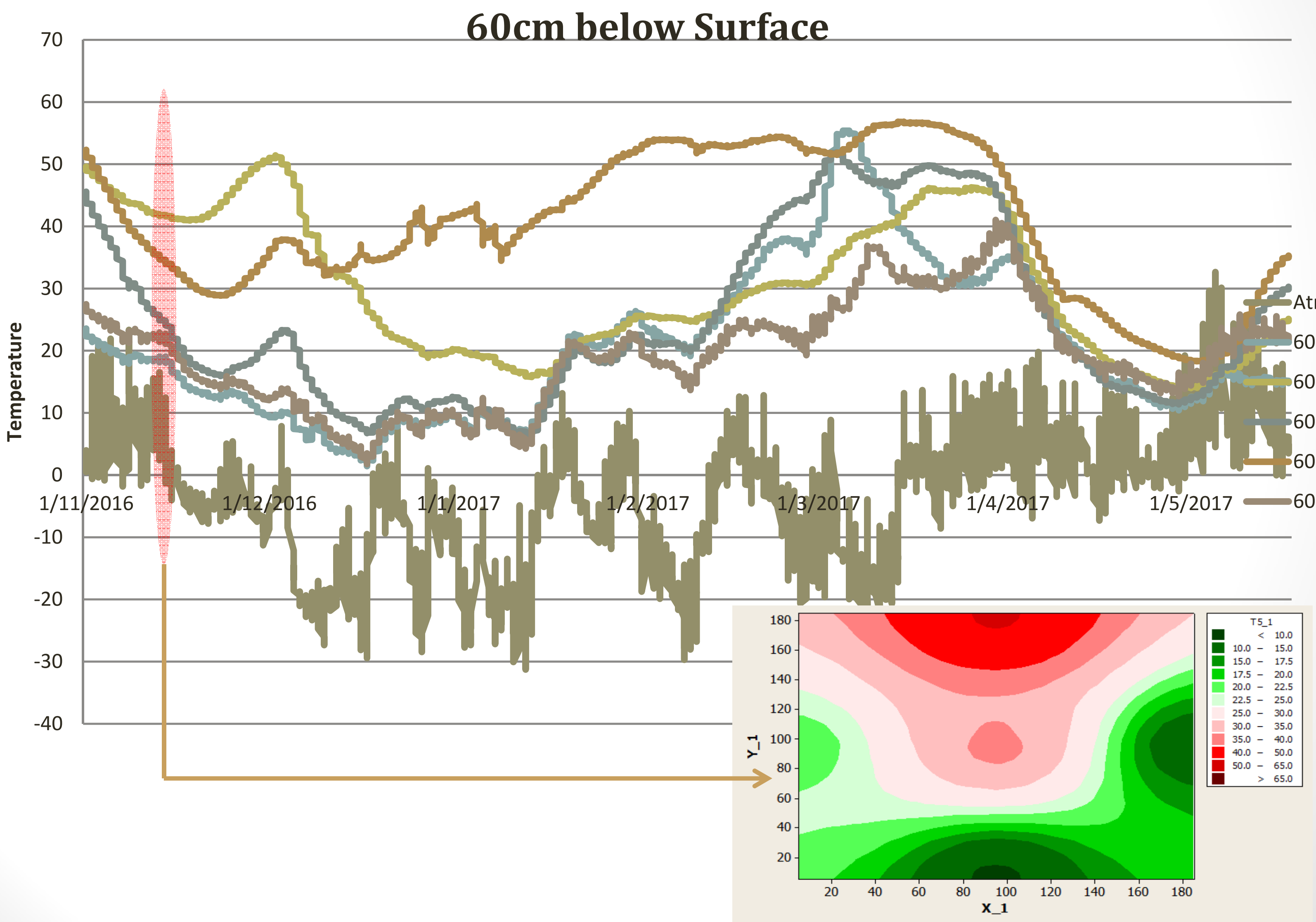

Conclusions

- In lab experiments, active aeration increased CH_4 elimination capacity by 3-5 times that of passive aeration
- Use of two or more air injection points increases CH_4 elimination capacity significantly (2-level operation provides consistent results)
- Field-scale actively-aerated HMBF eliminated more than 2500 $g/m^2/d$ of CH_4 (higher than lab-based systems or reported by others working with methanotrophy)
- Temperature profiles indicate zones of high microbial activity, and may be used as a “surrogate” for continuous methane oxidation efficiency monitoring: long term data being collected to develop predictive models

Thank You