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)
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°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

Casing gas emissions constitute 30% of the oil industry’s CH$_4$
Typical MBF – Passive aeration

Granular Medium
With Methanotrophs

CH₄ + O₂

44 g of CO₂ eq
GWP = 1

544 g of CO₂ eq
GWP = 34

Geomembrane
Geotextile
Gravel
Distribution System
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

<table>
<thead>
<tr>
<th>Stage</th>
<th>Loading rate (g/m³/d)</th>
<th>Oxidation rate (g/m³/d)</th>
<th>Aeration efficiency (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>C1</td>
<td>C2</td>
</tr>
<tr>
<td>I</td>
<td>529</td>
<td>420</td>
<td>423</td>
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<tr>
<td>II</td>
<td>794</td>
<td>519</td>
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<tr>
<td>V</td>
<td>1588</td>
<td>563</td>
<td>1309</td>
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</table>
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

- Headspace
- 2" Closed Cell Insulation R = 12.5
- 100% Compost, V = 3.7 m$^3$
  - Density = 800 kg/m$^3$
  - MC = 80% Field Capacity
- Geotextile
- Gravel Layer with Gas Distribution system

Dimensions:
- Width: 183 cm
- Height: 130 cm
- Depth: 20 cm
HMBF Construction
HMBF Monitoring

Continuous temperature measurements
• 15 temperature sensors
• As an indicator of methanotrophic activity
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 \(~ 2 \, ^\circ C\) difference between atmospheric and MBF temperature.
• Low methanotrophic activity during the seeding period.
• Temperature rise after December 2017.
# Early Results – Methane Removal

<table>
<thead>
<tr>
<th>Date</th>
<th>Inlet Flowrate</th>
<th>Gas</th>
<th>Normalized GC</th>
<th>Efficiency (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(m³/day)</td>
<td>(g/m²/day)</td>
<td>Inlet</td>
<td>Outlet</td>
</tr>
<tr>
<td>27/02/2017</td>
<td>Solution Gas</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>23</td>
<td>5709</td>
<td>CH₄ 11.1</td>
<td>7.2</td>
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<tr>
<td>Air</td>
<td>121</td>
<td>52562</td>
<td>O₂ 18.6</td>
<td>18.8</td>
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<tr>
<td></td>
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<td></td>
<td>N₂ 70.3</td>
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<td></td>
<td>CO₂ 0.0</td>
<td>0.0</td>
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<tr>
<td>13/03/2017</td>
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<td>23</td>
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<td>N₂ 68.3</td>
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<tr>
<td>14/05/2017</td>
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<tr>
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<td>15.4</td>
<td>3823</td>
<td>CH₄ 6.6</td>
<td>3.5</td>
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<tr>
<td>Air</td>
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<td>O₂ 19.9</td>
<td>20.3</td>
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<td>N₂ 73.5</td>
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<td></td>
<td></td>
<td></td>
<td>CO₂ 0.0</td>
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</tr>
</tbody>
</table>

\[
Efficiency = \left( CH_{4,in} - CH_{4,out} * \left( N_{2,in} / N_{2,out} \right) \right) / CH_{4,in} \times 100
\]
Early Results - Temperature Fluctuations

90cm below surface

Fluctuations
Early Results - Temperature Fluctuations

60cm below Surface

Temperature fluctuations at various depths below the surface, with a peak on 1/11/2016.
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