Efficiency and microbiology of novel, Horizontal Flow Biofilm Reactors (HFBRs) treating methane-contaminated air at 10°C

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Introduction

Anthropogenic sources of methane include landfills and wastewater treatment facilities. Legislation dealing with generation and treatment of gases and odours (EC, 2005) is increasingly stringent.Horizontal Flow Biofilm Reactors (HFBRs) have been used to treat domestic (Rodgers and Clifford, 2009) and dairy wastewater (Rodgers et al., 2007). The HFBR flow regime ensures contact between wastewater and biofilm, alleviating problems of clogging, channelling, compaction and pressure drop. Three HFBRs were designed to treat low CH₄ concentrations at 10°C. Oxidation activity, as well as the diversity and distribution of species, were determined to assess the efficiency of the novel systems.

Methods

HFBR design and operation

The three HFBR units each comprised a stack of 57 plastic sheets positioned one above the other. CH₄ loading was 12.84 g CH₄/m³/h (0.8 mol CH₄/m³/h; average air CH₄ concentration, 1.55%). Gas loading was 1.2 m³/m³/h. HFBRs were operated for 177 d at 10°C, except during a ‘Cold Period’, comprising 17 d (d 90-107) at 1-5°C. A 14-d ‘Shutdown period’ (d 120-133), comprised stopping the CH₄ supply. HFBRs were initially seeded with activated sludge. By 1 month, no oxidation was detected. A methanotroph-rich biomass was cultivated and added to re-seed the HFBRs (‘day 0’), and bio-augment biofilm already present.

Molecular analyses

Each reactor was notionally divided into six distinct zones and biofilm was sampled on: days 0 (immediately prior to re-seeding with enriched biomass), 44, 84, 108 and 177. Bacterial 16S rRNA genes were targeted for an enzyme-based genetic fingerprinting campaign. Several biofilm samples on day 177 were also examined by Fluorescence in-situ Hybridization (FISH). Ten-micrometre-thick sections were cut and hybridized using CY5-labelled Type I and Cy3-labelled Type II methanotroph-specific probes.

Maximum oxidation activity assays

Methane oxidation potential of samples was calculated on day 177. Oxidation rates were calculated using batch incubations.

Results

Reduced removal efficiency was observed in response to perturbations, although HFBRs recovered with normal conditions. Highest removal rates were achieved in R1 during ‘Steady State 2’ (‘SS2’; Table 1). Cumulative CH₄ removal, as well as discrete removal by certain zones, from ‘SS1’ and ‘SS2’ were calculated. Cumulative removal followed a similar trend during SS1 and SS2. Low removal was observed in the uppermost zone (sheets 1-4), but rates were linear throughout the remaining sheets. Cumulative and discrete data indicated that efficiency improved with time (data not shown).
Maximum potential activity varied between zones and HFBRs.

**Table 1.** Methane removal efficiency (%) of HFBRs during trial periods.

<table>
<thead>
<tr>
<th>Day</th>
<th>Period</th>
<th>R1</th>
<th>R2</th>
<th>R3</th>
<th>R4</th>
<th>H2S</th>
</tr>
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<tr>
<td>0-04</td>
<td>Start Up</td>
<td>24.5</td>
<td>77.8</td>
<td>29.3</td>
<td>26.0</td>
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<td>Steady-State 1</td>
<td>38.7</td>
<td>25.0</td>
<td>34.5</td>
<td>35.0</td>
<td>0</td>
</tr>
<tr>
<td>55-60</td>
<td>Steady-State 2</td>
<td>65.0</td>
<td>65.0</td>
<td>65.0</td>
<td>65.0</td>
<td>0</td>
</tr>
<tr>
<td>187-210</td>
<td>Recovery Period 1</td>
<td>28.2</td>
<td>28.7</td>
<td>28.3</td>
<td>27.5</td>
<td>0</td>
</tr>
<tr>
<td>120-123</td>
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<td>24.6</td>
<td>24.4</td>
<td>24.4</td>
<td>0</td>
</tr>
<tr>
<td>134-137</td>
<td>Recovery Period 2</td>
<td>29.7</td>
<td>19.1</td>
<td>18.1</td>
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<td>144-177</td>
<td>Steady-State</td>
<td>47.8</td>
<td>10.4</td>
<td>39.3</td>
<td>38.1</td>
<td>0</td>
</tr>
</tbody>
</table>

**Figure 2.** Methane removal efficiency (%).

The distribution of methanotrophs was observed throughout the biofilm by FISH experiments. Type I methanotrophs were present in low concentrations and clumped together in small, well-defined clusters. Type II methanotrophs were more widely and evenly distributed in larger cell clusters. The majority of the biofilm consisted of other unidentified prokaryotes. Genetic fingerprinting indicated bacterial diversity decreased during the trial (data not shown).

**Discussion and Conclusions**

HFBR efficacy was demonstrated for abatement of low concentrations of methane at 10°C. An average steady state removal rate of 38.6% was achieved at loading of >12 g CH₄/m³/h. A low-temperature perturbation resulted in significantly reduced efficiency. Maximum CH₄ oxidation varied significantly between zones and across the three HFBRs. Fingerprinting indicated stability over time but reduced diversity. It is clear that HFBR technology can be effectively applied for CH₄ mitigation in a simple, cost-effective manner. Optimisation is now being investigated with new trials to treat H₂S and NH₄.

**Figure 3.** Typical FISH image showing small clusters of Type I (circled) and larger clusters of Type II methanotrophs (arrows).

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**Disclosures**
The authors have nothing to disclose.

**References**