Impact of hydraulic retention time and temperature on an anaerobic moving bed biofilm reactor treating brewery wastewater

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High-rate processes for industrial wastewater

Industry needs:
   Small footprint
   High capacity

Anaerobic digestion requires:
   Long SRT

1) High settleable sludge aggregates

2) Biofilm on high-density carriers

3) Biofilm on packing material
Anaerobic moving bed biofilm reactor

Influent ➔ Biogas ➔ Effluent

www.aqwise.com

www.veolia.com

www.headworksinternational.com

www.mutag-biochip.com
Objectives

- Examine performance under:
  - Increasing organic loading (4 to 22 kg sCOD/m³ d)
  - Decreasing hydraulic retention time (24 to 6 h)
  - A range of temperatures (35 to 15 °C)

- Performance measures:
  - COD removal and surface area loading rates (SALR)
  - Gas production/composition
  - Suspended/attached solids

- Develop design parameters
## Brewery wastewater

- Rich in organic carbon
- Valuable for biogas production

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Typical brewery wastewater</th>
<th>Fort Garry Brewery</th>
<th>Limit for sewer discharge</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Winnipeg (Canada)</td>
</tr>
<tr>
<td>BOD$_5$ (g/L)</td>
<td>1 – 3.5</td>
<td>5</td>
<td>0.3</td>
</tr>
<tr>
<td>COD (g/L)</td>
<td>2 – 6</td>
<td>7</td>
<td>0.45</td>
</tr>
<tr>
<td>TSS (g/L)</td>
<td>0.2 – 1</td>
<td>0.4</td>
<td>0.35</td>
</tr>
<tr>
<td>pH</td>
<td>4.5 – 12</td>
<td>4 – 11</td>
<td>5.5 – 9.5</td>
</tr>
<tr>
<td>Temperature</td>
<td>24 – 30.5</td>
<td>N.A.</td>
<td>-</td>
</tr>
</tbody>
</table>

1 City of Winnipeg (Canada) bylaw No.92/2010
2 D. Lgs. 152/06 (Parte Terza, Allegato 5, Tabella 3) for Veneto Province
Setup – Hydraulic retention time (HRT)

Feed Tank

Heat Exchanger

Mixer

Biogas

Effluent

Headworks BIO - AC920
Protected surface area
680 m²/m³
Three reactors (4L):

- 40% media fill
- 1.1 m² available surface area

**HRT** (hours):
- 24
- 18
- 12
- 10
- 8
- 6

**OLR** (kg COD/m³ d):
- 4
- 5.5
- 10
- 14
- 21
- 22
Setup – Temperature (T°C)

Operational parameters

15°C
25°C
35°C

Three reactors (4L):
50 % Media fill
1.4 m² available surface area
Performance – HRT

Influent
~ 3.5 g sCOD/L

sCOD removal (%)

OLR as TCOD

Influent
~ 3.5 g sCOD/L

Organic loading rate
(kg TCOD/m³d)

8h HRT
80% Removal

Time (d)
8h HRT pH drops down
Increased alkalinity addition

62 % CH₄
32 % CO₂
Engineering significance – HRT

Process less efficient above 50 g sCOD/m²d
Attached solids – T°C

Thickness decreases as Temperature increases

Total suspended solids (mg/one unit media)

Temperature (°C)

TSS
UASB Vs AMBBR solids – T°C

Upflow anaerobic sludge blanket* 
~ 6.2 g VSS/L at room temperature 
(19-24 °C) 
with organic loading rate of 
3 kg COD/m³d

Volatile suspended solids (g/L)

VSS

Temperature (°C)

15
25
35

Influent 3.5 g sCOD/L

Performance – T°C

Specific removal rate (g sCOD/g VSS d)

- Correlation

Organic loading rate (kg sCOD/m³d)

Strong correlation $R^2 = 0.9966$
Biogas – T°C

Biogas composition (%)

<table>
<thead>
<tr>
<th>Temperature (°C)</th>
<th>15</th>
<th>25</th>
<th>35</th>
</tr>
</thead>
<tbody>
<tr>
<td>CH₄</td>
<td>50</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>CO₂</td>
<td>50</td>
<td>50</td>
<td>50</td>
</tr>
</tbody>
</table>

Unit methane generation (m³ CH₄/kg sCOD)

<table>
<thead>
<tr>
<th>Theoretical values</th>
</tr>
</thead>
<tbody>
<tr>
<td>15°C</td>
</tr>
<tr>
<td>25°C</td>
</tr>
<tr>
<td>35°C</td>
</tr>
</tbody>
</table>
Engineering significance – T°C

![Graph showing sCOD removal vs. surface area loading rate at 35°C, 25°C, and 15°C.]

- **35°C**
- **25°C**
- **15°C**

**y-axis:** sCOD removal (%)  
**x-axis:** Surface area loading rate (g sCOD/m²d)
Conclusions

- At organic loading rates above 20 kg sCOD/m$^3$ d methanogenesis started to be decoupled from fermentation
- 80% COD removal with a methane yield of 0.36 m$^3$ CH$_4$/kg COD$_{rem}$
- Surface area loading rates must not exceed 50 g sCOD/m$^2$d

At typical brewery wastewater temperature of 28°C:

- Methane yield of 0.31 m$^3$ CH$_4$/kg COD$_{rem}$ is expected
- Surface area loading rates of 11 g sCOD/m$^2$d will ensure 80% sCOD removal
Questions?

University of Manitoba