Combined production of biogas and volatile fatty acids from a pure primary sludge: preliminary results of a pilot test

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**Smat - Società Metropolitana Acque Torino
Castiglione Torinese WWTP

- Municipal and industrial wastewater
- Capacity: 2,000,000 E.I. (1.5M civil inhabitants, 800 industrial plants)
- Average flow rate: 7 m3/s
### Biodegradability

<table>
<thead>
<tr>
<th></th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>q</strong></td>
<td>140 m³/h</td>
</tr>
<tr>
<td><strong>q (Primary Sludge)</strong></td>
<td>61.5 %</td>
</tr>
<tr>
<td><strong>q (Secondary Sludge)</strong></td>
<td>38.5 %</td>
</tr>
<tr>
<td><strong>Primary Sludge TSfed</strong></td>
<td>2,755 kg/h</td>
</tr>
<tr>
<td><strong>Primary Sludge VSfed</strong></td>
<td>1,975 kg/h</td>
</tr>
<tr>
<td><strong>Secondary Sludge TSfed</strong></td>
<td>1,562 kg/h</td>
</tr>
<tr>
<td><strong>Secondary Sludge VSfed</strong></td>
<td>1,076 kg/h</td>
</tr>
<tr>
<td><strong>Methane production</strong></td>
<td>650 Nm³/h</td>
</tr>
<tr>
<td><strong>CH₄(WAS)/ CH₄(Tot)</strong></td>
<td>15 %</td>
</tr>
<tr>
<td><strong>Primary Sludge TSdischarged</strong></td>
<td>1,860 kg/h</td>
</tr>
<tr>
<td><strong>Primary Sludge VSdischarged</strong></td>
<td>1,005 kg/h</td>
</tr>
<tr>
<td><strong>Secondary Sludge TSdischarged</strong></td>
<td>1,399 kg/h</td>
</tr>
<tr>
<td><strong>Secondary Sludge VSdischarged</strong></td>
<td>907 kg/h</td>
</tr>
</tbody>
</table>

**-49 %**

**-10 %**
The production of CH4 from COD in anaerobic processes is mainly determined by methanogenesis, with a maximum conversion efficiency of 0.25 kg CH4/kg COD, or \(0.35 \text{ Nm}^3 \text{ CH}_4/\text{kgCOD}\)

\[\text{CH}_4 + 2\text{O}_2 \rightarrow \text{CO}_2 + 2\text{H}_2\text{O(l)} \quad \Delta H^\circ = -890 \text{ kJ/mol CH}_4\]

suggesting that 13.91 kJ of energy could be obtained from each gram COD removed from wastewater. \((13.91 \text{ kJ/gCOD})\)

“….the A-stage is primarily designed for direct capturing or conversion of COD to methane gas via anaerobic treatment without producing excess sludge and the B-stage is designated for nitrogen and phosphorous removal – may offer a feasible engineering option for turning the operation of current municipal WWTPs from being energy-negative to energy self-sufficient.”
Temperature Phased Anaerobic Digestion (TPAD)

Research

Enhanced biological phosphorus and nitrogen removal (EBPNR)

Primary sludge

WAS

VFA

VFAs

HRT = 2 d

HRT = 2 d

HRT = 2 d

HRT = 2 d

38 °C

38 °C

55 °C

55 °C

55 °C

55 °C

Specific Methane Production
Materials and methods

Temperature Phase Anaerobic Digestion

Sludge

1st Stage

HRT = 2 d

55 °C

Biogas/Methane

2nd Stage

HRT = 20

38 °C

Biogas/Methane

Biogas/Methane

Digestate
Materials and methods

Pre-thickened primary sludge

- Total Solids %
- Volatile Solids %
- pH
- Acidity and Alkalinity
- sCOD mg/L
- sP mg/L
- NH₄⁺ mg/L
- VFAs

Digested sludge

- Total Solids %
- Volatile Solids %
- pH
- Acidity and Alkalinity
- sCOD mg/L
- sP mg/L
- NH₄⁺ mg/L
- VFAs
Results:

VFAs – Primary Sludge

Days

0 2 4 6 8 10 12

0 2 4 6 8

VFAs – Primary Sludge

Results:

Days

0 2 4 6 8 10 12

0 2 4 6 8
Results:

Mesophilic PS-AD

![Diagram of specific methane yield](image)

Specific Methane Yield

\[ \text{Nm}^3/\text{kg VS} \]

\[ \text{OLR} \ (\text{kg VS}/(\text{m}^3 \text{ day})) \]
Results: 1st Stage PS-AD

**1st Stage**

**Daily Methane Production**

- **Specific Methane Yield**

**Results:**
Results: TPAD WAS

- Biogas/Methane
- 38 °C
- HRT = 20

Specific Methane Production

Days

Nm³ CH₄/kgVS
Results:

Specific Methane Production

- Biogas/Methane at 38 °C
  - HRT = 20

- Biogas/Methane at 55 °C
  - HRT = 3 d

1st Stage

2nd Stage
the B-stage is designated for nitrogen and phosphorous removal – may offer a feasible engineering option for turning the operation of current municipal WWTPs from being energy-negative to energy self-sufficient
1st Stage PS-AD

VFAs Yield vs Specific Methane Production

Days

g COD/VFAs/g x COD/day
1st Stage PS-AD

VFAs Yield vs Specific Methane Production

g CODVFAs/g x CODadd

Days
Temperature Phased Anaerobic Digestion (TPAD)

On Going Research Activity (B-Stage)

Primary sludge

38 °C

HRT = 20

Chemically enhanced primary sedimentation

Anoxic Reactor

Aerobic Reactor

Enhanced biological phosphorus and nitrogen removal (EBPNR)

VFAs

PAO batch activity tests

Denitrification batch activity tests

Biological Activity Tests
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Thanks for your attention