Pre- and Intermediate Hybrid Hydrolysis Processes for the Improvement of the Anaerobic Digestion of Waste Activated Sludge
WAS Anaerobic Digestion

Anaerobic digestion (AD) is not completely effective towards WAS because the complexity of the substrate limits the efficacy of the biological process.

**Microbial cells, cell walls and membranes** in the WAS are strong barriers to the penetration of hydrolytic enzymes.

Also the **extracellular polymeric substances (EPS)** contained in WAS are believed to be a factor for poor AD of sewage sludge and its subsequent dewatering.

*From Shana et al., 2015*
WAS Anaerobic Digestion

Pre- or intermediate treatments

Mechanical
Chemical
Thermal
Biological
or a combination of them

from Ruffino et al., 2013
**THPs, thermal hydrolysis processes** (Cambi, Veolia, and Haarslev) (160-165°C, 6 bar, 30 minutes) → positive impact on solid de-waterability and rheology.

**CONVENTIONAL THP**

Primary → WAS → THP → Thermophilic digester

**IHP, INTERMEDIATE HYDROLYSIS PROCESS**

Primary → Thermophilic digester I → IHP → Thermophilic digester II

Adapted from Molokwu & Rus, 2015
## Pre vs. Intermediate Treatments

### State of the Art

<table>
<thead>
<tr>
<th>Author</th>
<th>Operating conditions</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nielsen et al. (2011)</td>
<td>80°C, 10-24-48 h 130°C-170°C autoclave, 15 min 170°C, pH 10 KOH, 15 min</td>
<td>+2% CH₄ (pre-HP) +28% (IHP)</td>
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<tr>
<td>Takashima and Tanaka (2014)</td>
<td>25, 100, 180°C pH 2, 4 and 6 (HCl) 1 hour</td>
<td>good performances in organic matter destruction and methane production</td>
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<tr>
<td>Li et al. (2013)</td>
<td>Extraction of sludge from semi-cont digester 0.1 mol/l NaOH 30, 60, 90, 120 min</td>
<td>+ 33% biogas (vs. untreated)</td>
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<tr>
<td>Zhang et al. (2016)</td>
<td>already anaerobically digested sludge samples FNA i.e. HNO₂, 0.77 – 3.85 mg N/l for 24 h</td>
<td>+ 40% methane at 0.77 mg N/l (vs. untreated)</td>
</tr>
</tbody>
</table>
**Materials and Methods**

**WAS Sample**

**Pre-Treatments**

- Alkali agents: NaOH - Ca(OH)₂
- Doses: 4-8 g alkali/100 g TS
- Contact time: 90 min
- Temperatures: 20 - 70 - 90°C

**Intermediate Treatments**

**Anaerobic Digestion tests**

- Batch, mesophilic
- Substrate: inoculum = 1.6

**Castiglione Torinese SMAT WWTP 2,300,000 e.i.**

**Digestate sample**
Results

Disintegration Rate (DR)

\[
\frac{SCOD_{\text{lys}} - SCOD_0}{COD_{\text{tot}} - SCOD_0} \cdot 100\%
\]

ECf/EC0

Disintegration Rate (DR)

- WAS 20°C
- Digestate 20°C
- WAS 70°C
- Digestate 70°C
- WAS 90°C
- Digestate 90°C
Results II

![Graph showing the variation of Nm³ CH₄/kg VS with days for untreated WAS and WAS treated at 20°C, 70°C, and 90°C with 4% NaOH.](image)

- **WAS untreated**
- **WAS 20°C, NaOH 4%**
- **WAS 70°C**
- **WAS 70°C, NaOH 4%**
- **WAS 90°C**
- **WAS 90°C, NaOH 4%**
Results III

- WAS untreated
- WAS 20°C, NaOH 4%
- WAS 70°C, NaOH 4%
- WAS 90°C, NaOH 4%
- DIG untreated
- DIG 70°C, NaOH 4%
- DIG 90°C, NaOH 4%

The graph shows the rate of conversion of volatile solids (VS) to methane (CH₄) in terms of Nm³/kg VS over a period of days. The conversion rates are compared under different thermal and chemical conditions.
Results IV

Methane specific yield vs. DR

- Digestate thermo-alkali
- WAS thermal
- WAS thermo-alkali

\[ \text{Nm}^3 \text{CH}_4/\text{kg VS} \]

DR (0\% to 40\%)
Preliminary assessment for technical and economic evaluation

Scenario Pre-treatment

- NaOH, 4%
- raw WAS
- $T = 70^\circ C$
- $T = 90^\circ C$
- HRT = 17 d
- $y = 0.233\text{ Nm}^3/\text{kg VS}$
- $y = 0.276\text{ Nm}^3/\text{kg VS}$

Scenario Intermediate Treatment

- raw WAS
- HRT = 10 d
- $y = 0.130\text{ Nm}^3/\text{kg VS}$
- $y = 0.165\text{ Nm}^3/\text{kg VS}$

- $+26.6\%$
- $+17.0\%$
- $y = 0.193\text{ Nm}^3/\text{kg VS}$
Conclusions

The main results obtained in the experimentation demonstrated that:

- thermal and hybrid treatments were, on average, more effective on WAS than on digestate, if the DR parameter is used to evaluate the performance of the treatment;

- for the treatment of both WAS and digestate NaOH had to be preferred to Ca(OH)$_2$. The combination with the thermal effect increased the amount of sCOD released;

- the only-thermal pre-treatment determined very low increases in methane specific yield if compared to performances of hybrid pre-treatments. Increases were of respectively 14% for the temperature of 70 °C and of 20% for 90 °C. These findings were in line with the results of a previous study(*) carried out on WAS samples collected in the same WWTP;


Conclusions

- the results of the digestibility tests carried out on the WAS samples pre-treated with an hybrid process (NaOH 4%, 70 °C or 90 °C) showed an increase in the methane specific production of approximately 40% for the sample treated at 70 °C and of more than 66% for the sample treated at 90 °C, compared with the untreated sample (**);

- the sample of untreated digestate showed a specific methane yield of 0.143 Nm³/kg VS, approximately 14% less than the raw WAS. With the hybrid treatment the capacity of producing methane of the digestate increased by 31%, at the temperature of 70 °C, and by 54% at 90 °C;

- a comparison between the two scenarios revealed that the substrate treated with an intermediate treatment carried out at 70 °C produces 27% more methane than the same substrate treated with a pre-treatment carried out in the same conditions.

Massimiliano Bolettieri and Simone Morra are gratefully acknowledged for their support in the experimental activities
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Thank you for your attention!