Sludge Disintegration: Improving Anaerobic and Aerobic Degradation of Biomass on Wastewater Treatment Plants

Dr.-Ing. Klaus Nickel, Dr. Silvana Velten, Jürgen Sörensen, Prof. Dr.-Ing. Uwe Neis

TUHH
Technische Universität Hamburg-Harburg

Technical University of Hamburg-Harburg
Institute of Wastewater Management & Water Protection
Email: neis@tuhh.de
Internet: www.tuhh.de

ULTRAWAVES GmbH
Water & Environmental Technologies
Email: info@ultrawaves.de
Internet: www.ultrawaves.de
Content

1. Ultrasonic Disintegration of Biomass
2. Enhancing Anaerobic Biomass Digestion
3. Enhancing Aerobic Biomass Digestion
4. Combating Filamentous/Foaming Sludge
5. Development of US-reactor
1. Ultrasonic Disintegration of Biomass on WWTP
Options for Biomass Disintegration

- Intensification of anaerobic biosolids digestion
- Intensification of aerobic biosolids digestion
- Combating bulking and foaming sludge
Disintegration of Biomass

- sludge floc
- sludge water
- bacteria
- inert particles
- extracellular polymers
Light-microscopical Analysis

untreated WAS → 30s sonicated → 90s sonicated
Effect of Sonication on Particle Size Distribution

![Graph showing the effect of sonication on particle size distribution. The graph plots the volume cumulative percentage against particle size in micrometers. Different lines represent different conditions: 30 W/L, 20s (= 0.17 Wh/L), 80 W/L, 20s (= 0.44 Wh/L), 220 W/L, 20s (= 1.28 Wh/L), and 310 W/L, 20s (= 1.72 Wh/L). The reference line is indicated by a red line.]
2. Enhancing Anaerobic Biomass Digestion
Pilot scale plant Set-Up

- Digester 5: HRT = 4 d
- Digester 4: HRT = 8 d
- Digester 3: HRT = 16 d
- Digester 2: HRT = 8 d
- Digester 1: HRT = 16 d

- Ultrasound Reactor
- Conventional Sludge Digestion

TWAS
Anaerobic Biomass Degradation

VS degradation [%]

Digestion time [d]

- Untreated sludge
- Disintegrated sludge

<table>
<thead>
<tr>
<th>Digestion time</th>
<th>Untreated sludge</th>
<th>Disintegrated sludge</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>32.0</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>27.0</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>38.1</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>32.3</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>42.4</td>
<td></td>
</tr>
</tbody>
</table>
Bamberg WWTP, Germany
Bamberg WWTP, Germany

Initial Conditions:
- Design capacity: 220,000 PE
- Actual Load: 330,000 PE
- 150 m³/d primary sludge, 250 m³/d WAS
- (3) egg shaped digesters with 18 d digestion time
- 35% average VS degradation

Desired Goal:
- Achieved a minimum of 40% VS degradation
  - Solution 1: Build another 3,000 m³ egg shaped digester
  - Solution 2: Use of ultrasound to increase VS destruction
Bamberg WWTP, Germany

Ultrasound installation in 2004:
Sonication of 30% (in 2004) - 80% (in 2008) of the WAS (~ 70 – 100 m³/d) @ 2 - 3 kWh/m³
Bamberg WWTP, Germany

Results of US Installation:
- Volatile solids destruction improved from 34 to 60%
- Significantly increased biogas production
- Avoided construction of a new digester = savings of 1.5 million EUR
3. Enhancing Anaerobic Biomass Digestion
Experiences

- Sonication of RAS (or alternatively TWAS)
- Reduction of excess sludge

What happens?

- Solubilisation of cell substances ("internal C-source" for denitrification)
- Increase of enzymatic activity
- Shift in composition of biomass by imposed selection
Bünde WWTP, Germany
Initial Conditions:

- Design capacity: 40,000 PE
- Actual Load: 54,000 PE
- Alternating nitrification and denitrification @ 22 d sludge age
- Floating sludge due to excessive growth of filamentous micro-organisms

Desired Goal: Reduction of process fluctuations

- Minimization of waste activated sludge production
- Sustainable reduction of N-conc. in the effluent
- Combating filamentous organisms
Bünde WWTP, Germany

Ultrasound Installation in 2006:
Sonication of 30% of the TWAS (~ 30 m³/d) @ 4.0 kWh/m³
Bünde WWTP, Germany

Results of US Installation:

– No foaming or bulking sludge in the activated sludge tank
– 25% reduction of waste activated sludge mass
– Reduction of the nitrogen concentration in effluent (N < 3 mg/l)
4. Combating Filamentous/Foaming Sludge
Combating Filamentous Sludge

Original → Short Sonication → Long Sonication
Seevetal WWTP, Germany (165,000 PE)
Sonication of Return Activated Sludge (1% RAS @ 2 kWh/m³)
Meldorf WWTP, Germany
Meldorf WWTP, Germany

Initial Conditions:

- Design capacity: 70,000 PE
- 2 digesters (each 2,000 m³ vol.)
- Cofermentation
- Foaming digesters (high portion of filamentous organisms in the biological sludge)

Desired Goal: Combating foam in the digesters
Meldorf WWTP, Germany

Ultrasound installation in 2004:
Sonication of 100% of the TWAS (~ 30 m³/d) @ 4.0 kWh/m³

Activated sludge process → Final clarifier → WAS thickener → Ultrasound reactor → Anaerobic digestion
Results of US Installation:

– Foaming problems stopped
– Feeding of co-substrates became possible again
– Significantly improved digestion performance
5. Development of US-reactor
US-reactor for Biomass Treatment

Requirements

- Treatment of large volumetric sludge streams
- High degree of biomass cell disintegration
- Continuous operation despite of varying sludge properties
- Resistant against reactor blockage (sludge impurities)
- Automatic system
- Low maintenance
Full-scale Ultrasound Reactor

- Reactor volume: 30 L
- Power consumption: 5 kW
- Continuous operation
- No. of oscillators: 5
- Frequency: 20 kHz
- Intensity: 25 to 50 W/cm²
- Sonication time: 1 to 3 min
- Sonication dose: 3 to 9 kWh/m³
ULTRAWAVES – Partners
Conclusions

• Biomass treatment with ultrasound is an established technology

• Detailed studies have demonstrated the potential of ultrasound for enhanced biodegradation of biomass
Thank you for your attention!