High-power Ultrasound Treatment to improve Biomass Digestion

Larry Henderson, P.E.  
Energenecs  
WWOA Oct. 2019
Who We Are and What We Do

• Water and wastewater system integrator
• 40+ personnel
• Systems approach
• Emphasis on energy efficiency
• Emphasis on cost-effective integration of process and controls
Corporate Headquarters, Saukville, WI
Sustainability: Shifting from waste to resource recovery

- Pretreated biosolids
- Digester mixing and covers
- IEC Membrane gas holders
- Groth biogas safety equipment
- Unison biogas conditioning
-Recovered heat
- High value fertilizer
- Filtrate
- Multiform Harvest to phosphorous harvesting
- Huber Q press
- Puregas renewable natural gas
- Tech 3 IC engine
- BioCNG vehicle fueling system
- Capstone microturbines with heat recovery
- Renewable Energy
- Biogas-to-Energy System with Substrate and Biogas Optimization

Technology Partner/System Integrator:energenecs
700 East Milan Drive Saukville, WI 53080
262-377-6360
9/2017
CONTENT

1. Ultrasonic Disintegration of Biomass
2. Enhancing Biomass Digestion on wastewater treatment plants (WWTP)
3. Combating Filamentous/Foaming Sludge
4. Enhancing Anaerobic Biomass Digestion on farmland biogas plants (FBP)
5. Enhancing Anaerobic Digestion of Spent-Wash
6. Enhancing Anaerobic Biomass Digestion on food waste biogas plants (FWBP)
7. Development of HPUS-reactor
ULTRASONIC DISINTEGRATION OF BIOMASS
ANAEROBIC DIGESTION – LIMIT OF DEGRADATION

![Graph showing VS reduction vs digestion time](image)

- **Y-axis:** VS Reduction [%]
- **X-axis:** Digestion Time

**Graph Details:**
- The graph shows a curve representing the VS reduction over digestion time.
- The VS reduction increases with time up to a certain point, after which it reaches a plateau.

**Key Points:**
- The marked point on the graph indicates the limit of degradation.

**Producer Information:**
- Energenecs
- Process Control Service
- [Logo]
Disintegration of Biosolids

- Sludge floc
- Sludge water

Energy

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.](image)

Legend:
- Red: Reference
- Blue: 30 W/L, 20s (0.17 Wh/L)
- Green: 80 W/L, 20s (0.44 Wh/L)
- Cyan: 220 W/L, 20s (1.28 Wh/L)
- Purple: 310 W/L, 20s (1.72 Wh/L)

- **Volume cumulative [%]**
- **Particle size [µm]**

- **y-axis**: 0% to 100%
- **x-axis**: 1 to 1000 µm
Enhancing biomass digestion on wastewater treatment plants (WWTP)
Options for Biosolids Disintegration

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

TWAS → Conventional Sludge Digestion
Anaerobic biomass degradation

![Graph showing VS degradation vs digestion time for untreated and disintegrated sludge. The vertical axis represents VS degradation in percentage, and the horizontal axis represents digestion time in days. The graph shows that disintegrated sludge has a higher VS degradation than untreated sludge at all digestion times.]

- Untreated sludge: 32.0% at 4 days, 27.0% at 8 days, 32.3% at 16 days.
- Disintegrated sludge: 38.1% at 8 days, 42.4% at 16 days.
INTRODUCTION OF US-Tech. ON WWTP

1. Questionnaire

2. Lab test

3. Full-scale test

4. Full-scale installation
Ultrawaves Lab Testing
Ultrawaves Lab Testing
Ultrawaves Pilot
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

Goal:
- Achieve 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 2007) of the WAS (~ 70 - 100 m³/d) @ 2 - 3 kWh/m³
Bamberg WWTP, Germany

Results:
- Volatile solids destruction improved from 34 to 50%
- Significantly increased biogas production (+45%)
- Avoided construction of a new digester = savings of 1.5 million EUR
Energy-self-sufficient operation on Bamberg WWTP
LEINETAL WWTP, GERMANY
Combating Filamentous/Foaming Sludge
**Leinetal WWTP, Germany**

**Initial Conditions:**
- Design capacity: 50,000 PE
- Actual Load: 65,000 PE
- Extended aeration (simultaneous aerobic sludge digestion) @ 18 d sludge age
- Floating sludge due to excessive growth of filamentous micro-organisms

**Desired Goal:**
- Improvement of aerobic sludge treatment
  - Solution 1: Build another activated sludge tank
  - Solution 2: Use of ultrasound to increase VS destruction
Leinetal WWTP, Germany

Ultrasound Installation in 2003:

Sonication of 30% of the WAS (~ 33 m$^3$/d) @ 3.6 kWh/m$^3$
Leinetal WWTP, Germany

Results of US-installation:
- Reduction of sludge mass of about 25%
- Better stabilised end product (reduced organic content)
- No foam and no floating sludge in the aeration tank
- Avoided construction of a new aeration tank

![Graph showing waste activated sludge mass for disposal over time:]

- **2000**: 71.5
- **2001**: 68.4
- **Oct 02**: 72.5
- **Nov 02**: 78.8
- **Dec 02**: 62.2
- **Jan 03**: 51

Introduction of US-technology
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 ($N < 5$ mg/l)
Ultrawaves at Bunde WWTP
Germany
Ultrawaves at Bunde WWTP Germany
Denite System at Bunde
Combating Filamentous Sludge

Original → Short Sonication → Long Sonication

Energy
Seevetal WWTP, Germany (165,000 PE)

Sonication of Return Activated Sludge (1% RAS @ 2 kWh/m³)
Enhancing anaerobic biomass digestion on Farmland Biogas plants (FBP)
BORDESHOLMERLAND FBP, GERMANY
Initial conditions:
- 2 parallel lines
- size 2 x 537 kW
- 2 main digester à 2.500 m³, 2 post digester à 2.500 m³,
  2 storage à 2.500 m³
- input: 2 x 25 t/d maize
- retention time: 90 days/digester
- biogas production: 2 x 6150 m³/d
- methane concentration ca. 50%

Goal:
- reduce amount of substrate
Ultrasound installation in 2011:
Sonication of partial flow (36 m$^3$/d) from post digester to main digester (@ 3.3 kWh/m$^3$) in line 2
Results:  
- 2.2 t/d less substrate on line 2 compared to line 1  
- increase in methane content to 53% (+ 3%)  
- increase in el. power production from 537 kW (line 1) to 570 kW (line 2)
Farm Digester Feed Substrate
Farm Digester with Ultrawaves Since 2005
New Farm Digester - CHP
New Farm Digester System
New Farm Digester System
New Farm Digester – Substrate Bunker
ENHANCING ANAEROBIC DIGESTION OF SPENT-WASH
AD OF SPENT-WASH: LOBURG DISTILLERY, GER

Initial Conditions:
- Power capacity: 560 kW
- 2 MD @ 1.270 m³, 1 ST @ 2.280 m³
- Feed: maize silage, maize silage waste, sorghum silage, spent-wash (wheat), cow manure
- HRT: 40 d/digester

Desired Goal:
- Reduction of the daily feed
- Improvement of the specific biogas production
ULTRAWAVES HPUS BIOSONATOR installation since 2012:

- Sonication of 29 m³/d (5 kW, 4.1 kWh/m³) of activated biomass from MD 2 and recirculation into the MD 1.
**AD of Spent-Wash: Loburg Distillery, GER**

- **Results of the HPUS-Installation:**
  - 8% less substrate (-17% cost reduction, 52,000 EUR/a)
  - Stabilized and increased gas production (+16%, 19,800 EUR/a)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Maize silage</td>
<td>2,266 t</td>
<td>2,288 t</td>
<td>+22 t</td>
</tr>
<tr>
<td>Maize silage waste</td>
<td>406 t</td>
<td>402 t</td>
<td>-4 t</td>
</tr>
<tr>
<td>Millet silage</td>
<td>891 t</td>
<td>750 t</td>
<td>-141 t</td>
</tr>
<tr>
<td>Rye grain, grinded</td>
<td>275 t</td>
<td>155 t</td>
<td>-120 t</td>
</tr>
<tr>
<td>Corn mash (wheat)</td>
<td>2,414 t</td>
<td>3,072 t</td>
<td>+658 t</td>
</tr>
<tr>
<td>Cattle liquid manure, dairy cattle</td>
<td>2,778 t</td>
<td>3,184 t</td>
<td>+406 t</td>
</tr>
<tr>
<td>Fresh bulk, sum</td>
<td>9,030 t</td>
<td>9,850 t</td>
<td>+820 t</td>
</tr>
<tr>
<td>Dry solids, sum</td>
<td>1,606 t</td>
<td>1,631 t</td>
<td>+25 t</td>
</tr>
<tr>
<td>Thereof fast degradable dry solids (rye grain + wheat mash)</td>
<td>385 t</td>
<td>319 t</td>
<td>-66 t</td>
</tr>
<tr>
<td>Total costs substrate</td>
<td>152,719 EUR</td>
<td>126,797 EUR</td>
<td>-25,922 EUR</td>
</tr>
<tr>
<td>Total costs substrate per year</td>
<td>305,438 EUR</td>
<td>253,594 EUR</td>
<td>-51,844 EUR</td>
</tr>
</tbody>
</table>
ENHANCING ANAEROBIC BIOMASS DIGESTION ON FOOD WASTE BIOGAS PLANTS (FWBP)
Mariks FWBP, Germany
Mariks FWBP, Germany

Initial conditions:
- 2 main digester à 1.800 m³, 1 post digester à 1.800 m³, storage tank à 5000 m³
- input: 73 t/d
- retention time: 40 days
- electrical power production: 700 kW
- methane concentration ca. 56-61%

Goal:
- increase in biogas production
Mariks FWBP, Germany

Ultrasound installation in 2011, April - August:
Sonication of partial flow (34 m³/d) from post digester to main digester (@ 3.5 kWh/m³)
Mariks FWBP, Germany

Results:

- improved electrical power production from 697 to 786 kW (+13%)
- decrease of VS concentration from 56% to 52% in post digester
BIOSONATOR: P&P-SYSTEM

Components:

- Macerator (1)
- Modified Excentric Screw Pump (2)
- HPUS (3)
- Volumetric flowmeter (4)

Completely automated (24/7) & simple integration
AD on FBP/FWBP: More Cases

- Beerlage FBP, GER (1,500 kW)
- Bispingen FBP, GER (1,100 kW)
- Ense FBP, GER (3,500 kW)
- Hellweg FBP, GER (500 kW)
- Haren FBP, GER (590 kW)
- Lindow FBP, GER (500 kW)
- Löhndorf FBP, GER (1,000 kW)
- Wittenburg FBP, GER (716 kW)
- Wulkow FBP, GER (400 kW)
Conclusions

- Biomass treatment with ultrasound is an established technology

- Detailed studies have demonstrated the potential of ultrasound for enhanced biodegradation of biomass

- More than 200 Ultrawaves HPUS reference installations
Ahrensburg Germany installation for AD enhancement
Process Control Service

Questions?