High-power Ultrasound Treatment to improve Biomass Digestion

Dr.–Ing. Klaus Nickel, Dipl.-Ing. Gunnar Klingspor, Prof. Dr.–Ing. Uwe Neis

ULTRAWAVES GmbH
Water & Environmental Technologies
Tel: 040 / 325 07 203
Email: info@ultrawaves.de
Internet: www.ultrawaves.de

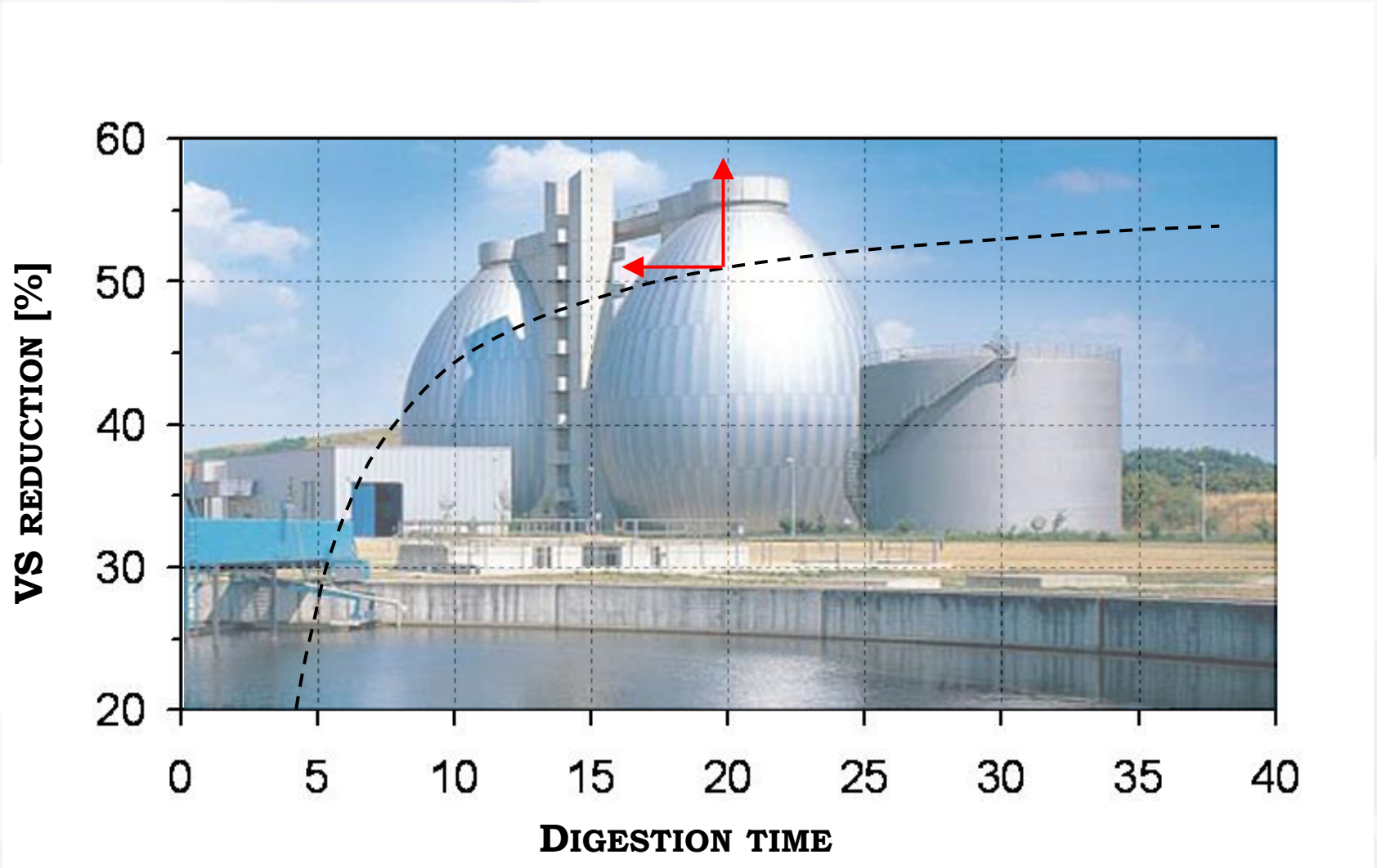
CONTENT

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**

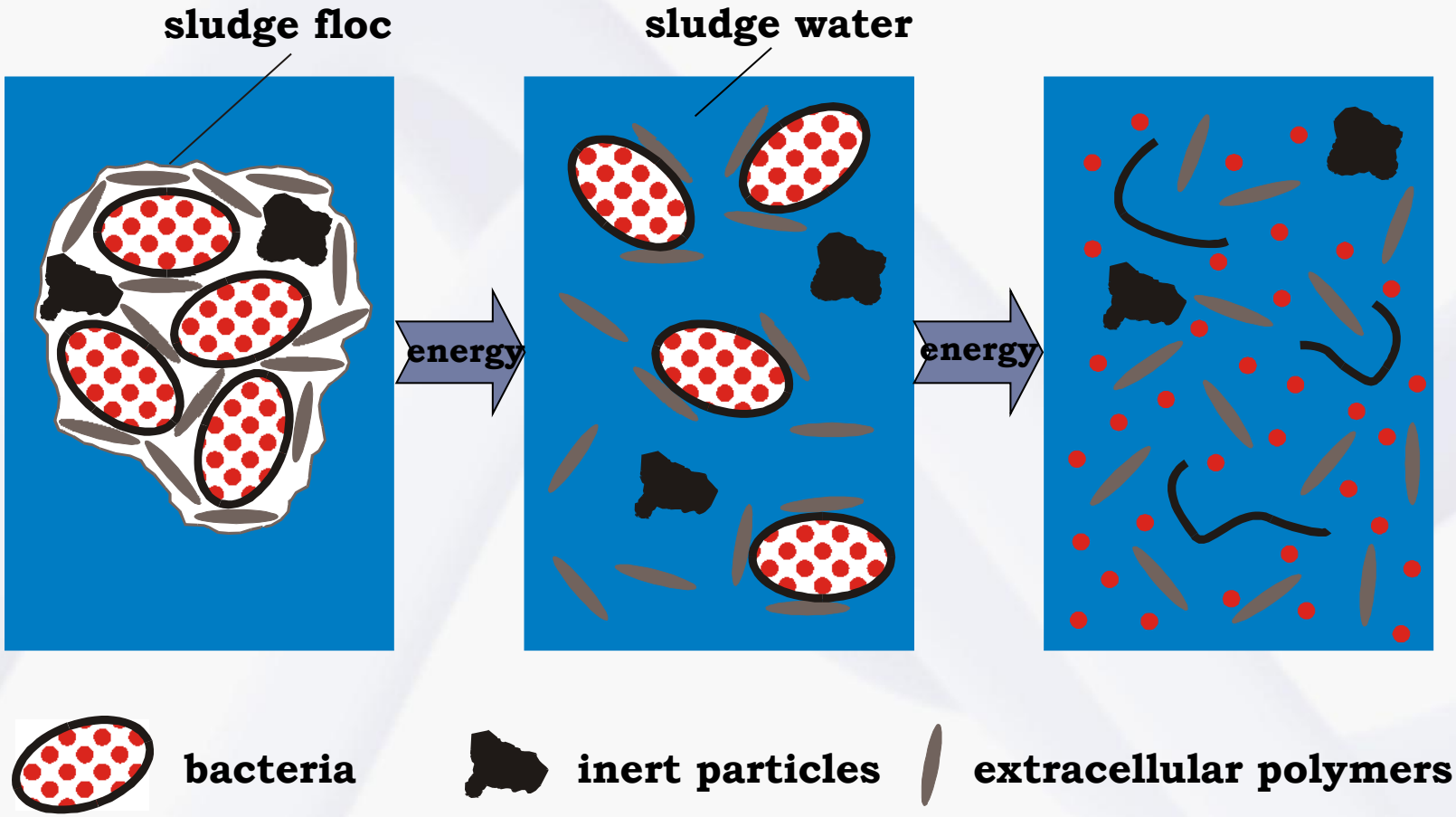


ULTRASONIC DISINTEGRATION OF BIOMASS

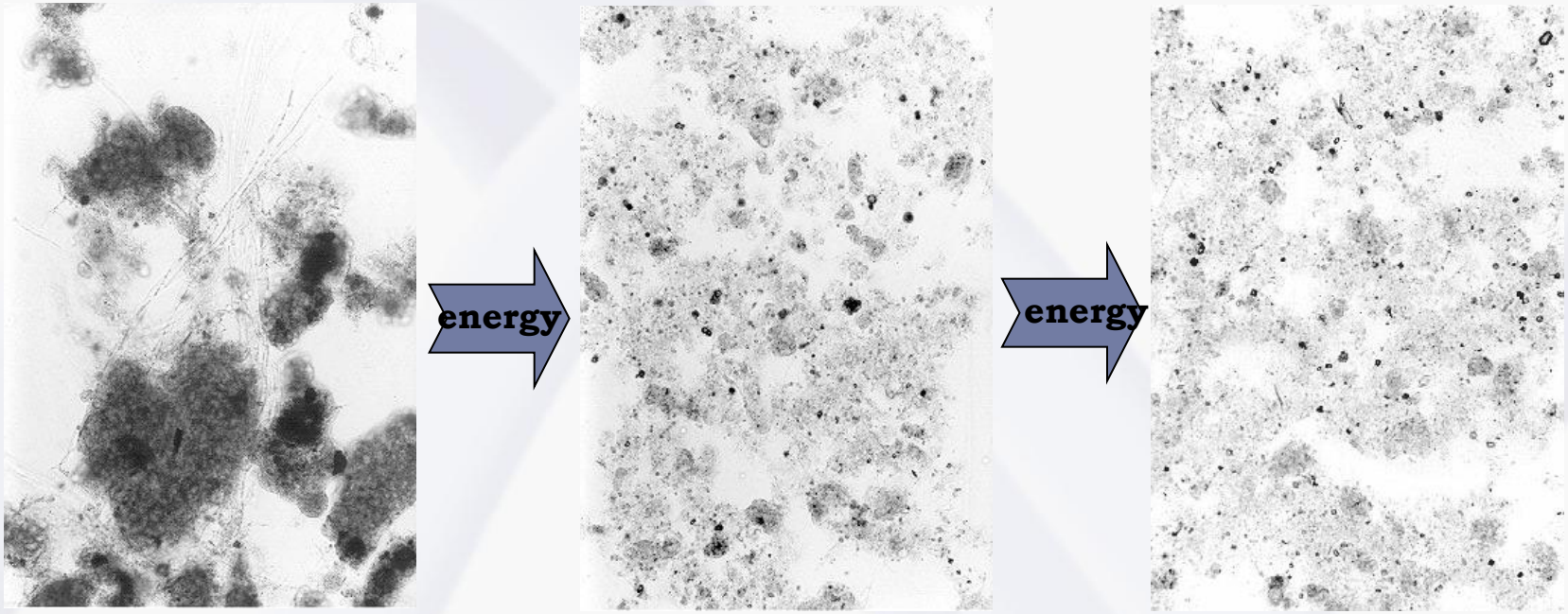
Anaerobic digestion – limit of degradation



Disintegration of Biosolids

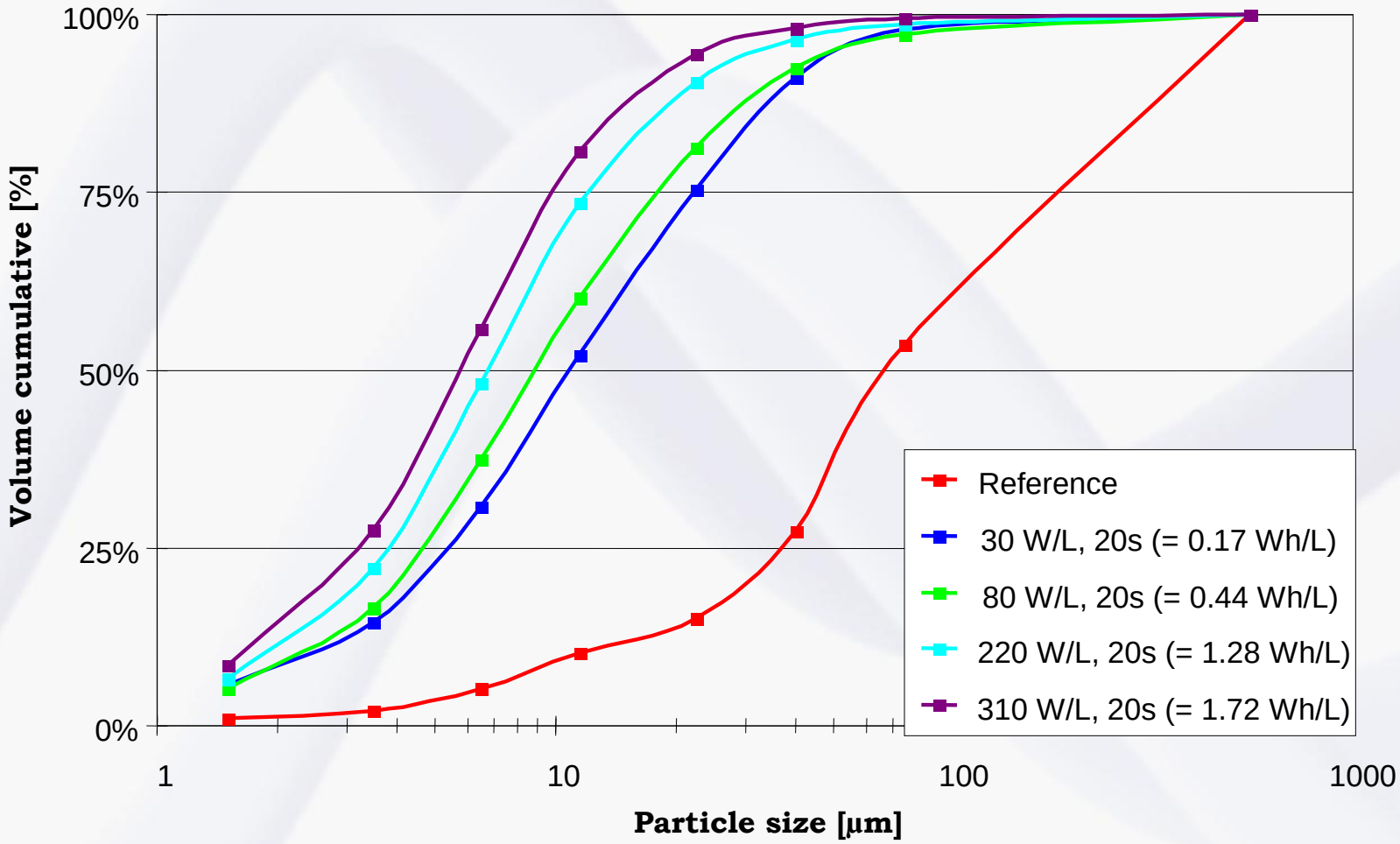


Light-microscopical Analysis



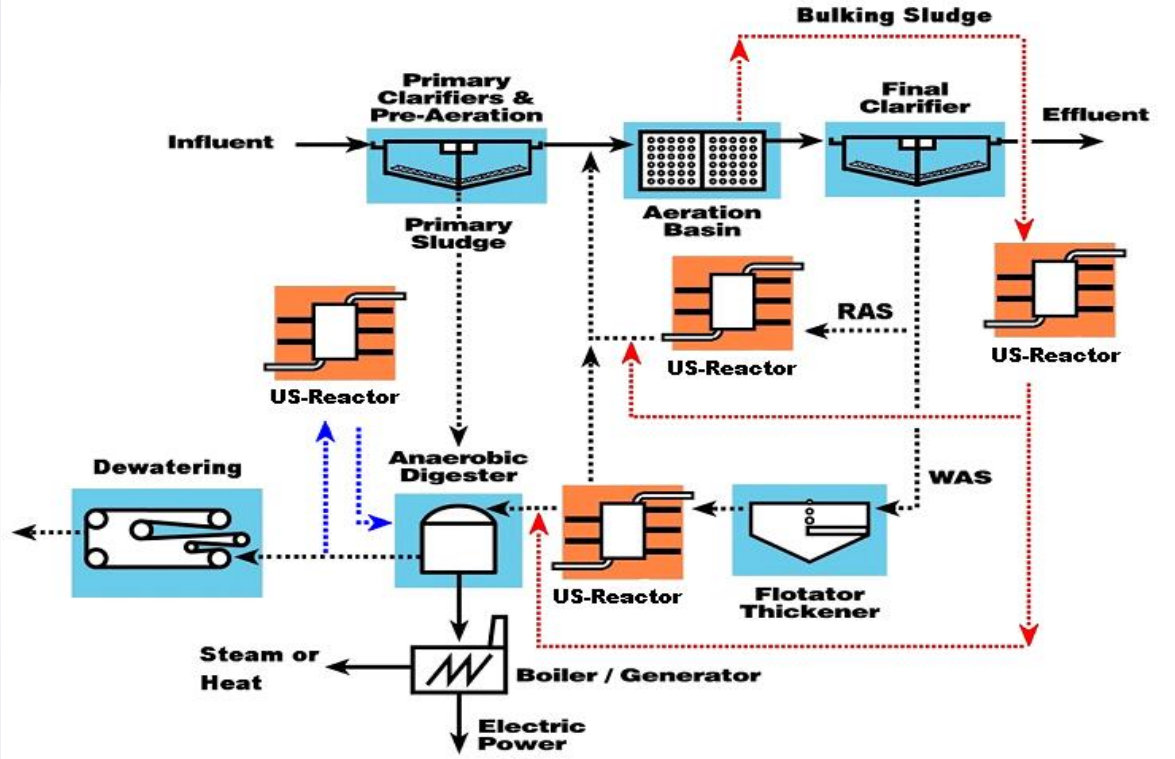
untreated WAS **30s sonicated** **90s sonicated**

Effect of sonication on particle size distribution



Enhancing biomass digestion on wastewater treatment plants (WWTP)

Options for Biosolids Disintegration

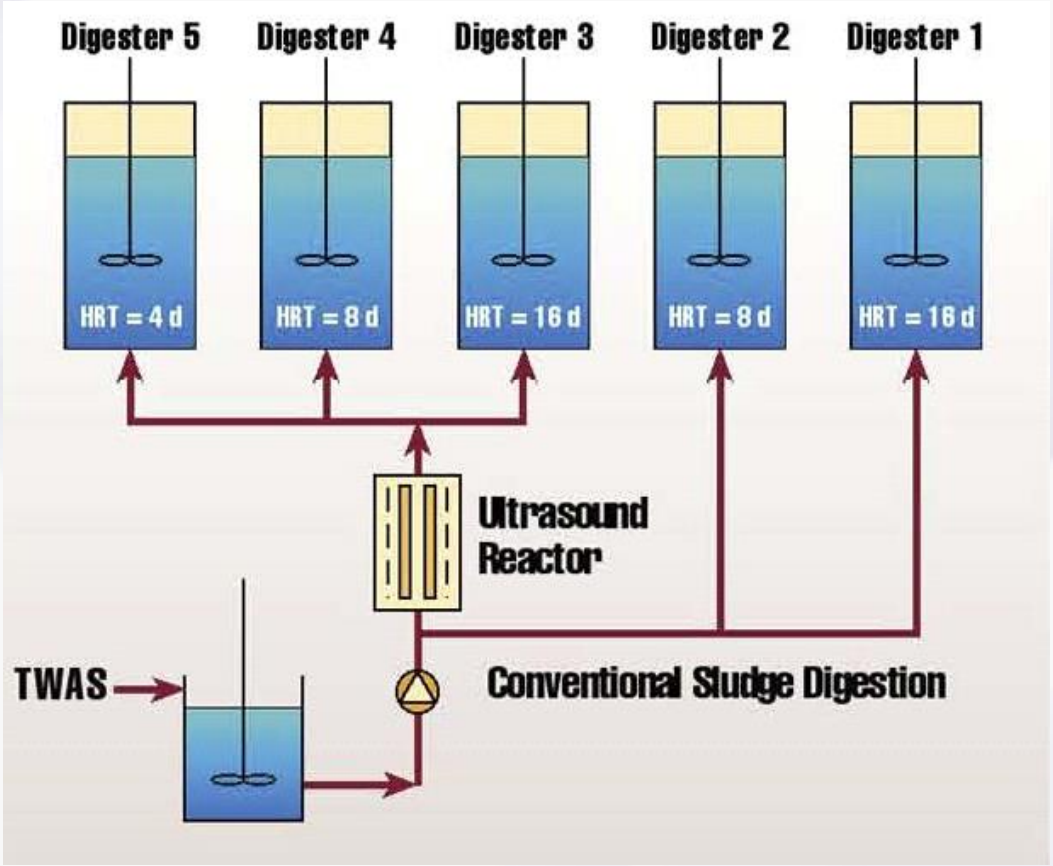


- Intensification of anaerobic biosolids digestion
- Intensification of aerobic biosolids digestion
- Combating bulking and foaming sludge

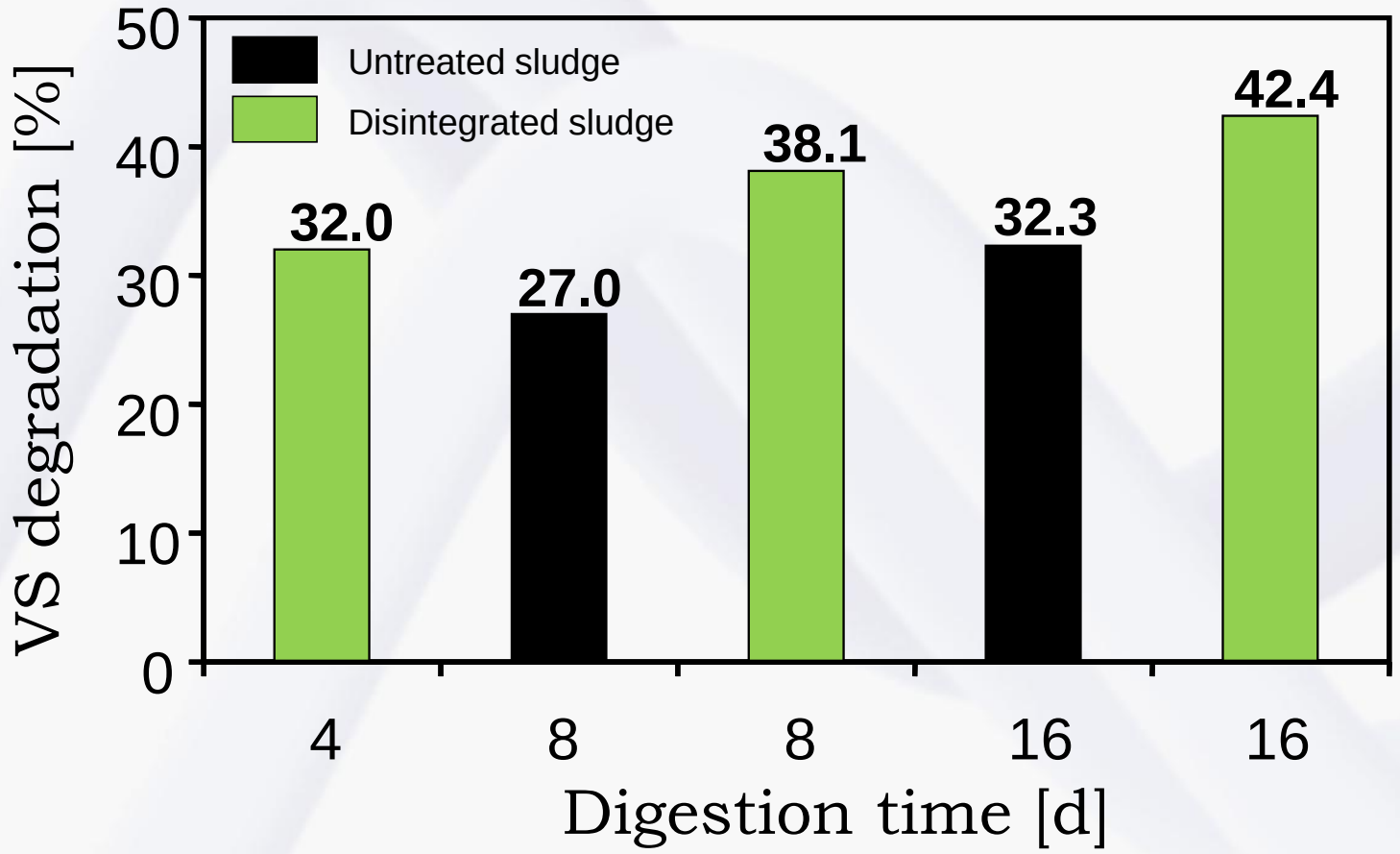
Pilot scale plant set-up







Anaerobic biomass degradation

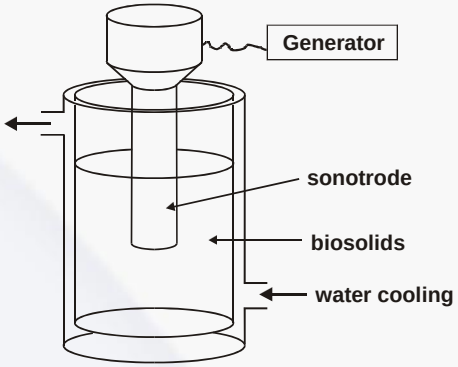


Introduction of US-Tech. on WWTP

1. Questionnaire



2. Lab test



3. Full-scale test



4. Full-scale installation



Ahrensburg WWTP, Germany



Ahrensburg WWTP, Germany

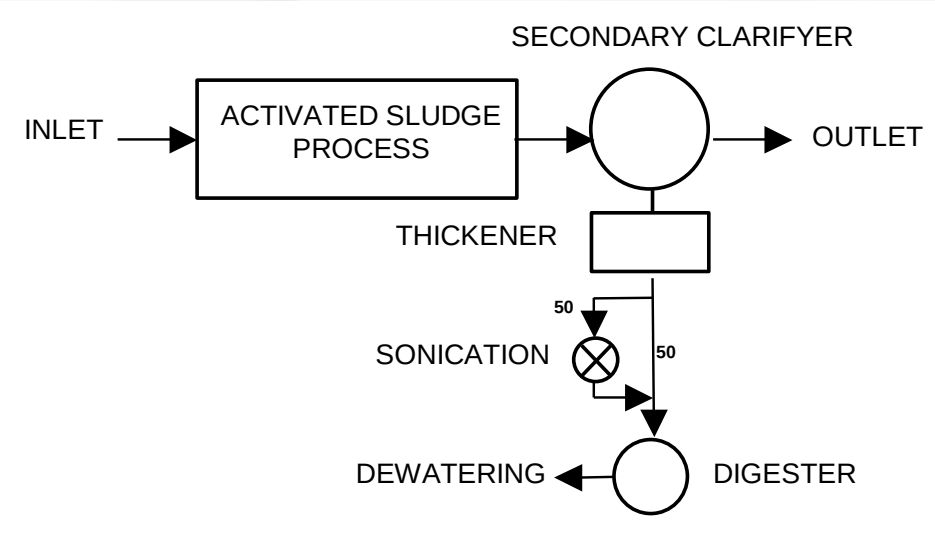
Initial Conditions:

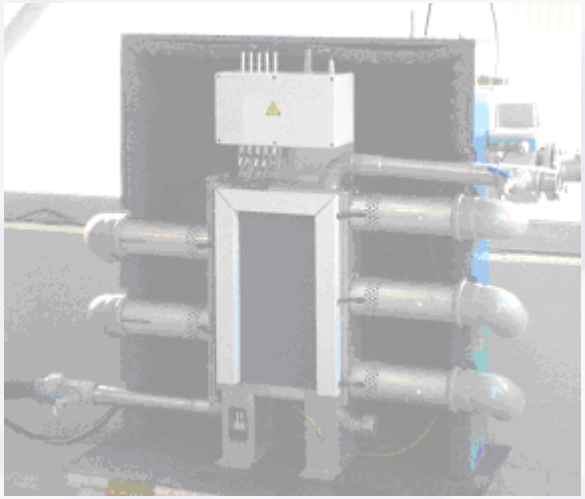
- **Design capacity: 50,000 PE**
- **Actual Load: 38,000 PE**
- **No primary sludge, 60 m^3/d TWAS**
- **(1) digester with 40 d HRT**
- **40% average VS degradation**

Desired Goal:

- **Achieve a minimum of 45% VS degradation**

Ahrensburg WWTP, Germany

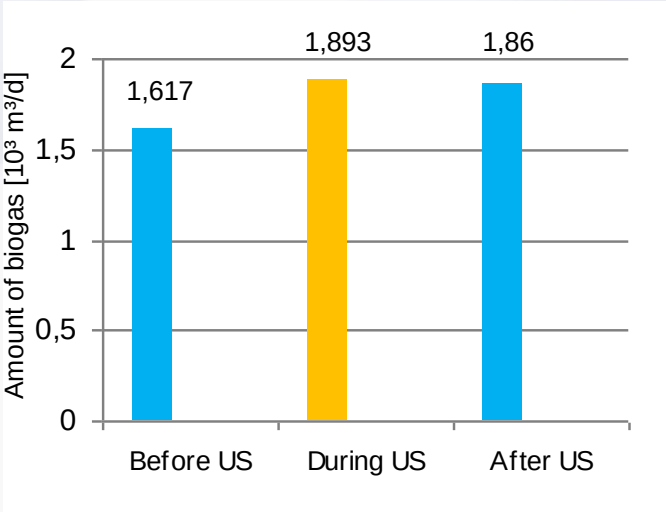


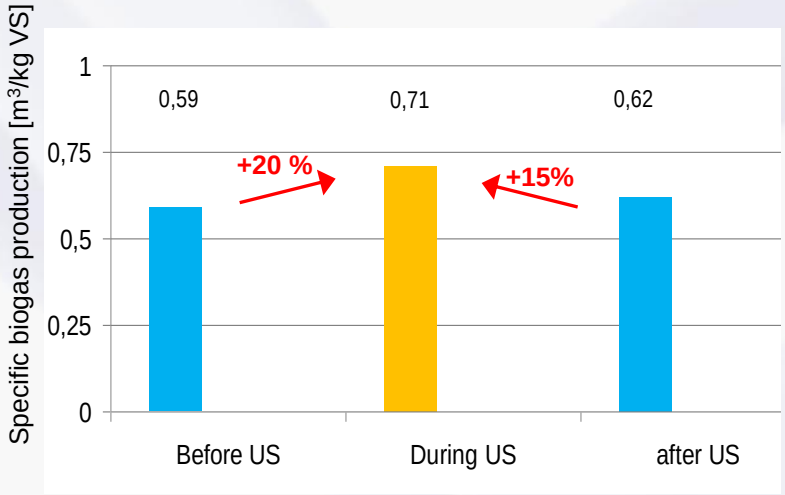


Ahrensburg WWTP, Germany

Results of US Installation:

- Volatile solids destruction improved from (below) 40 to 48%
- 20% increase in biogas production
- Improved sludge dewatering @ lower polymer consumption





Dabrowa Gornicza WWTP, Poland



Dabrowa Gornicza WWTP, Poland

Initial Conditions:

- **Design capacity: 150,000 PE**
- **Actual Load: 200,000 PE**
- **No primary sludge, 100 m^3/d TWAS**
- **(2) digesters with 18 d HRT**
- **40% average VS degradation**

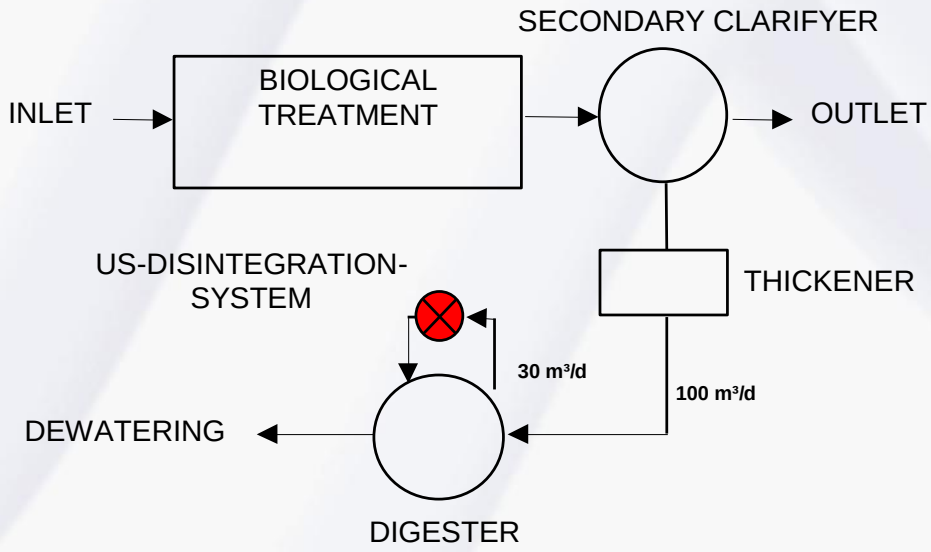
Desired Goal:

- **Achieve a minimum of 45% VS degradation**
  - **Solution 1: Build another 1,700 m^3 digester**
  - **Solution 2: Use of ultrasound to increase VS destruction**

Dabrowa Gornicza WWTP, Poland

Ultrasound installation in 2008:

Sonication of the digested sludge (~ 30 m³/d) @ 3 kWh/m³

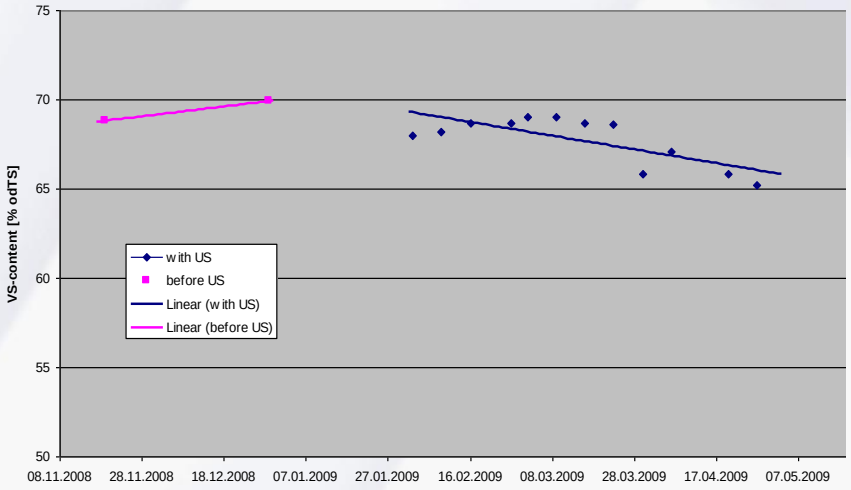


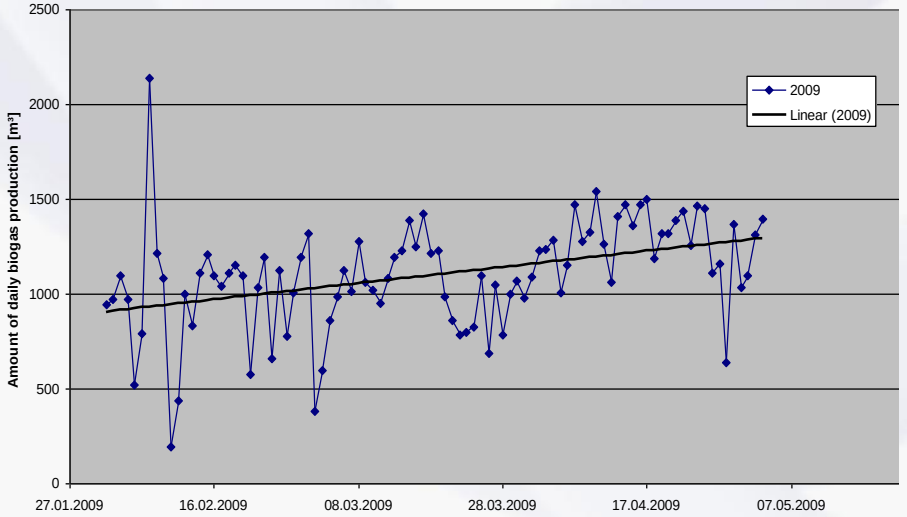


Dabrowa Gornicza WWTP, Poland

Results of US Installation:

- Volatile solids destruction improved from 40 to 52%
- 30% increase in biogas production
- Avoided construction of a new digester = savings of 0.8 million EUR





Bamberg WWTP, Germany



Bamberg WWTP, Germany

Initial conditions:

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

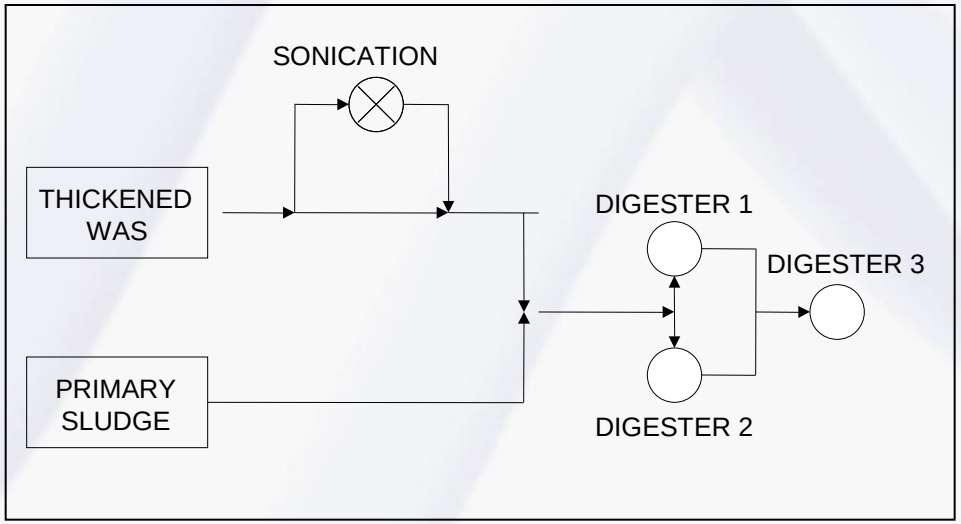
Goal:

- Achieve a minimum of 40% VS degradation
  - Solution 1: Build another 3,000 m^3 egg shaped digester
  - Solution 2: Use of ultrasound to increase VS destruction

Bamberg WWTP, Germany

Ultrasound installation in 2004:

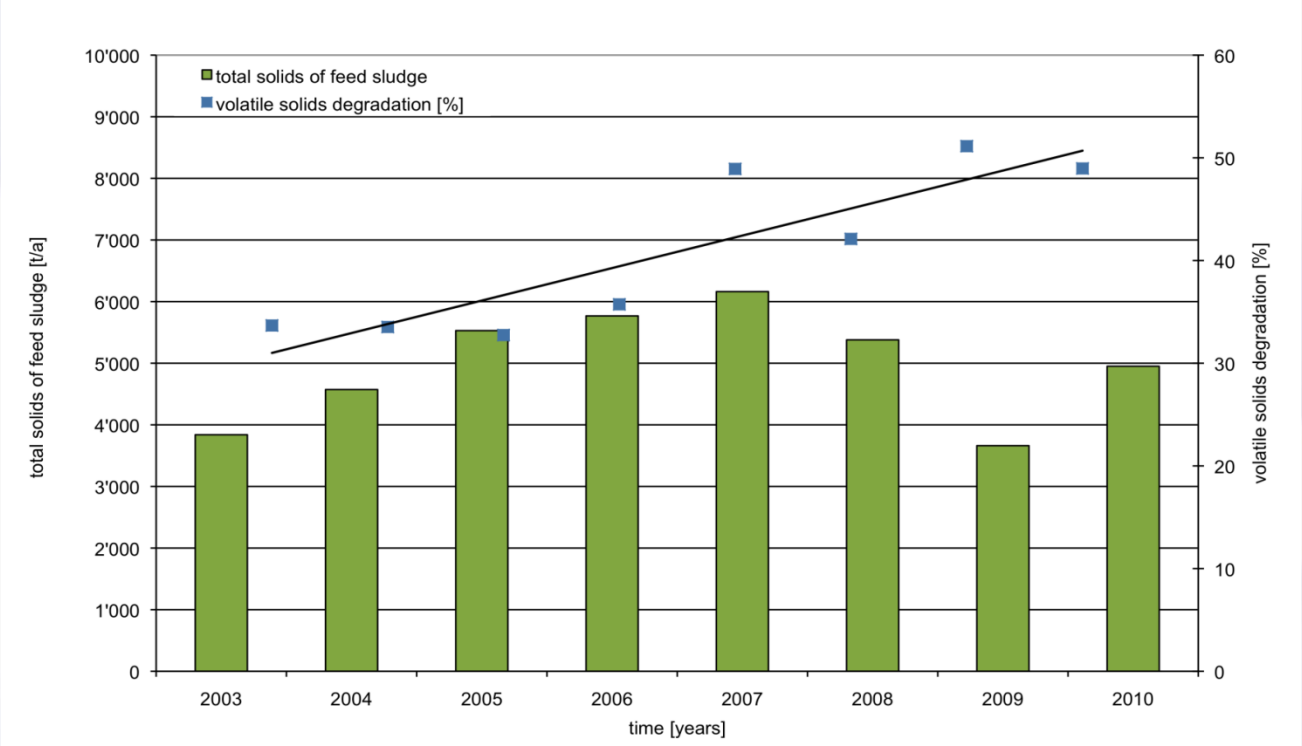
Sonication of 30% of the TWAS
(~ 70 – 100 m³/d) @ 2 - 3 kWh/m³



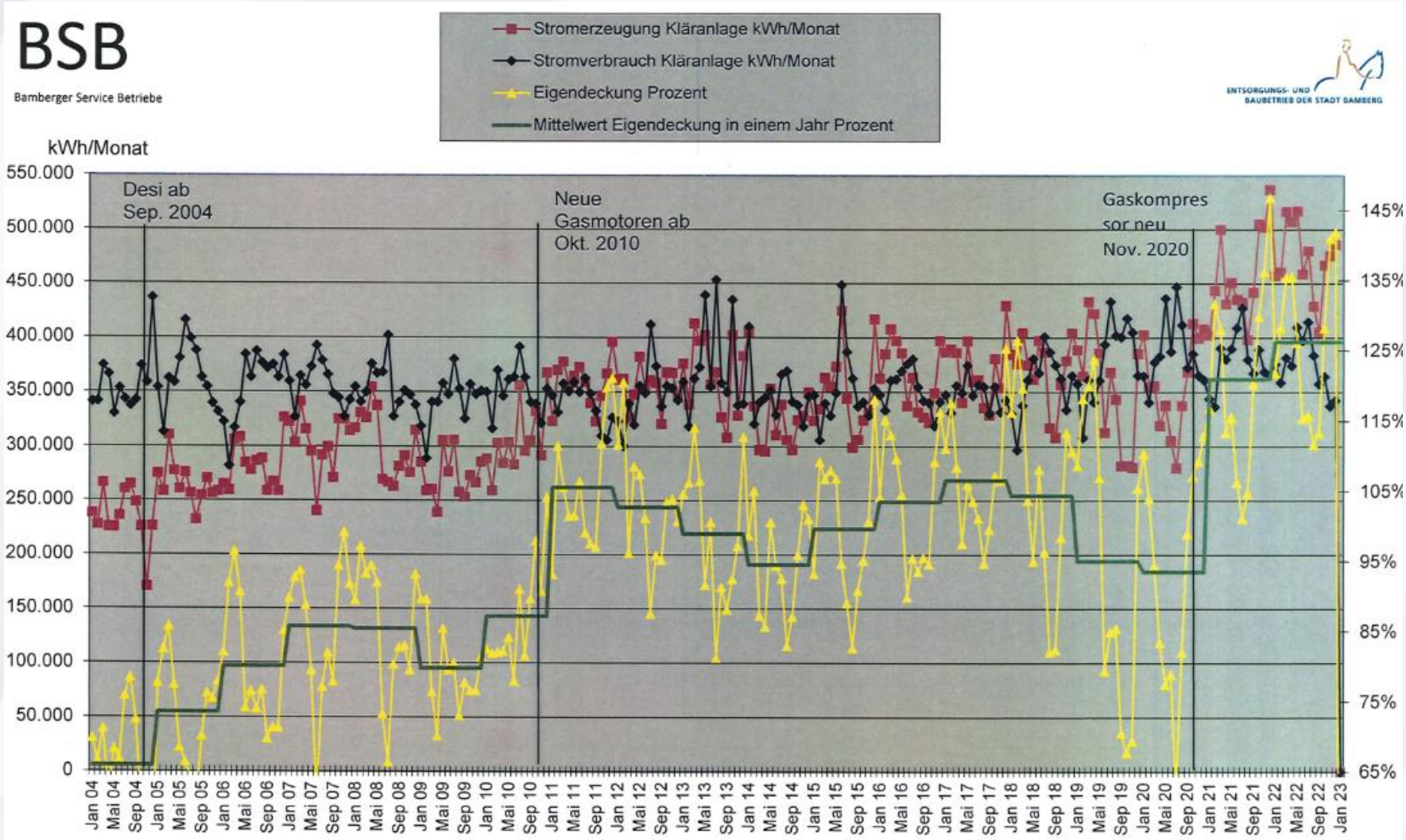


Bamberg WWTP, Germany

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



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:

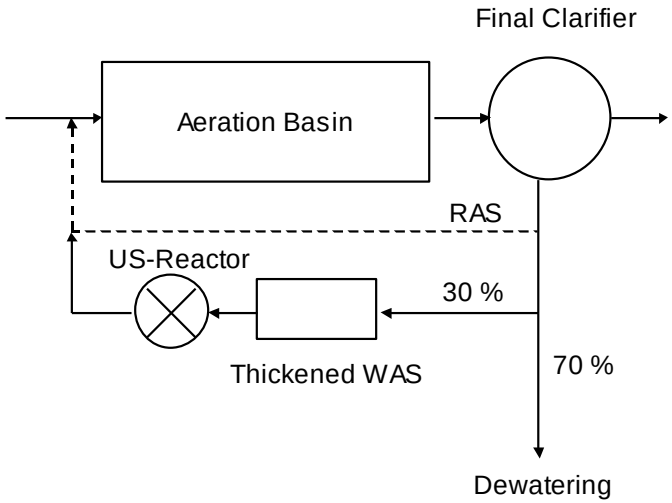
- Improvement of aerobic sludge treatment
  - Solution 1: Build another activated sludge tank
  - Solution 2: Use of ultrasound to increase VS destruction



LEINETAL WWTP, GERMANY

Ultrasound Installation in 2003:

Sonication of 30% of the WAS (~ 33 m³/d) @ 3.6 kWh/m³

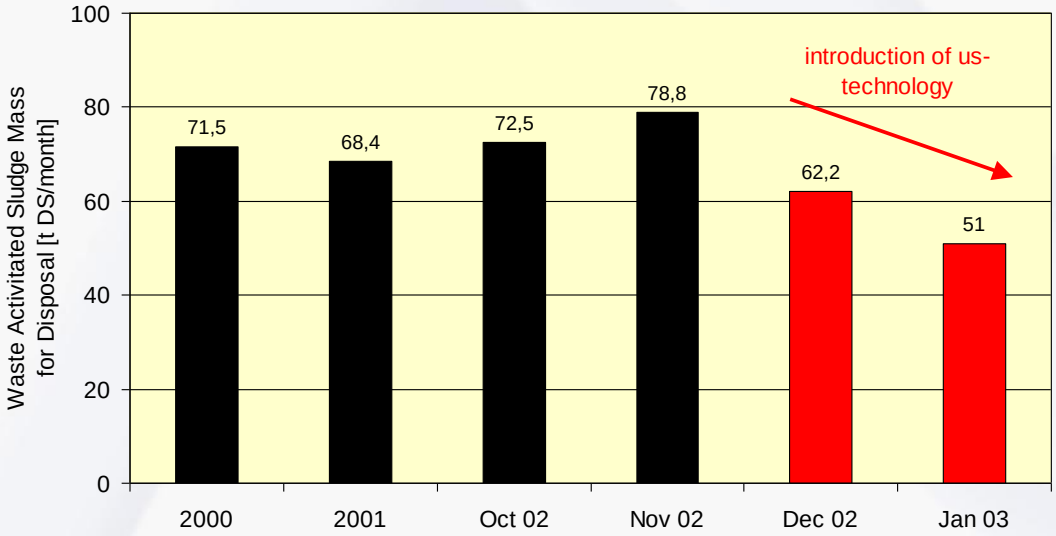




LEINETAL WWTP, GERMANY

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



Bünde WWTP, Germany



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

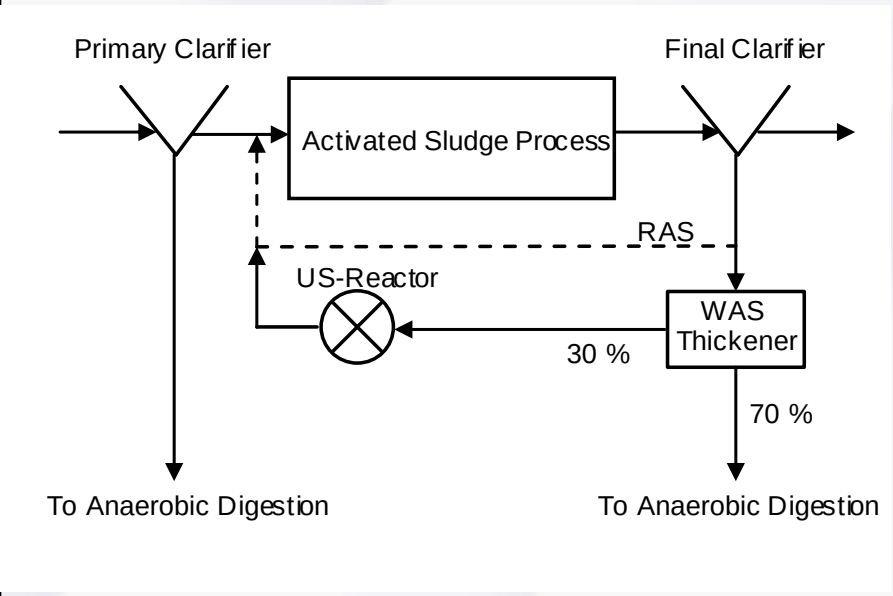
Desired Goal: Reduction of process fluctuations

- 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

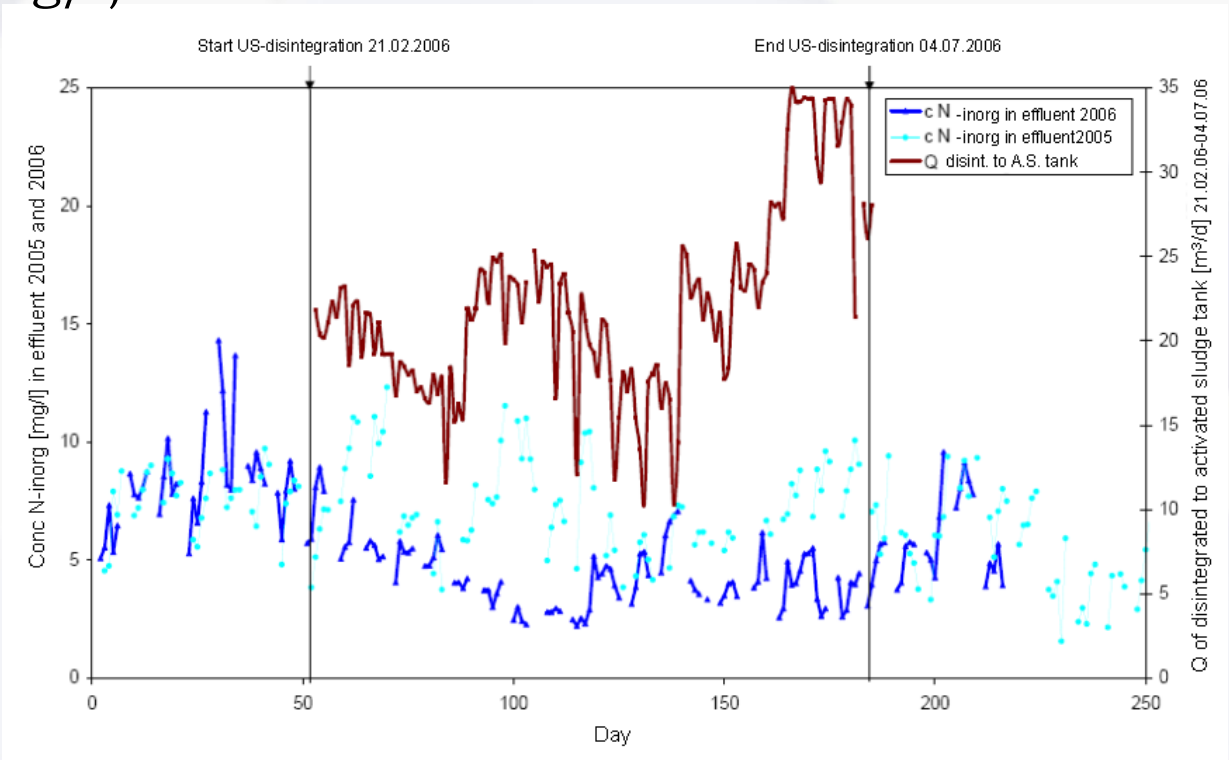




BÜNDE WWTP, GERMANY

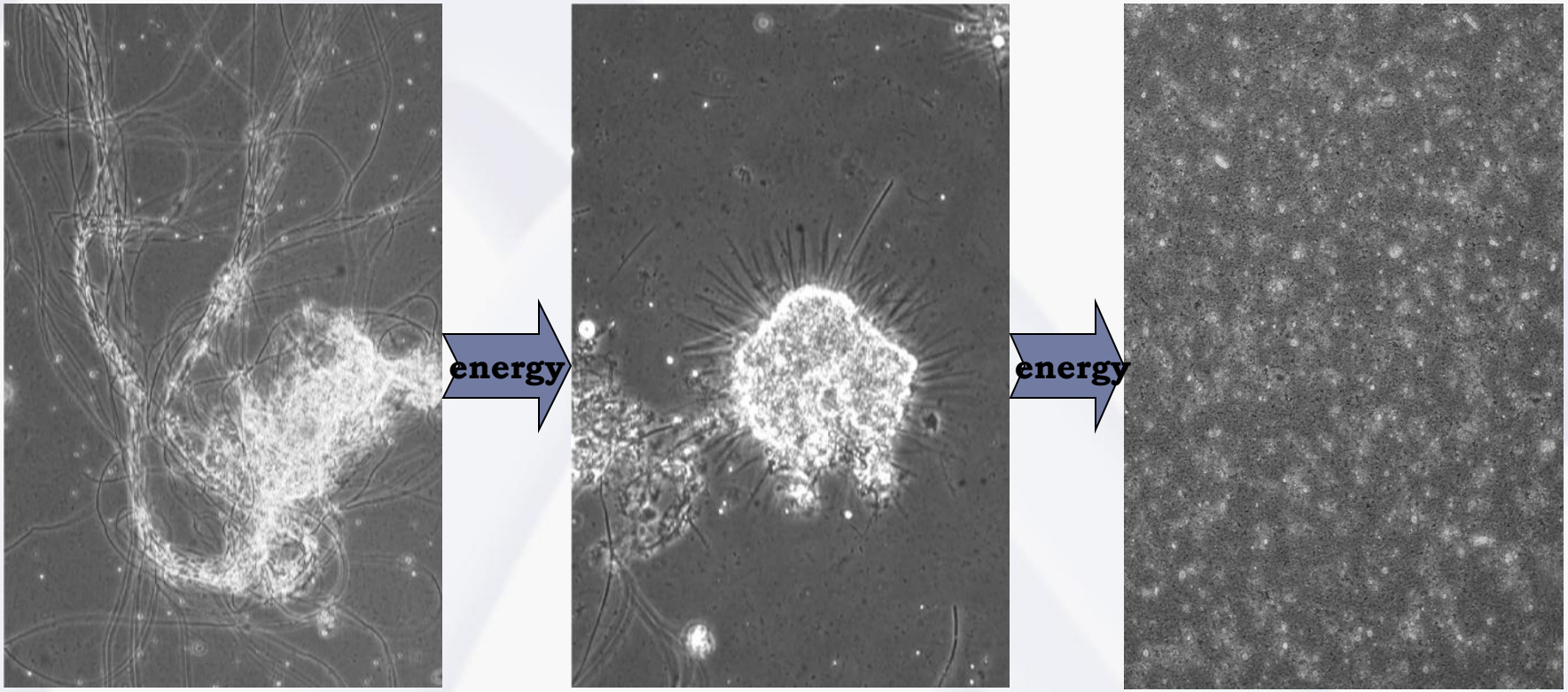
Results of US Installation:

- 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)



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)





Kirkby in Ashfield WWTP, UK (32,000 PE)

Sonication of Return Activated Sludge (1% RAS @ 1.2 kWh/m³)

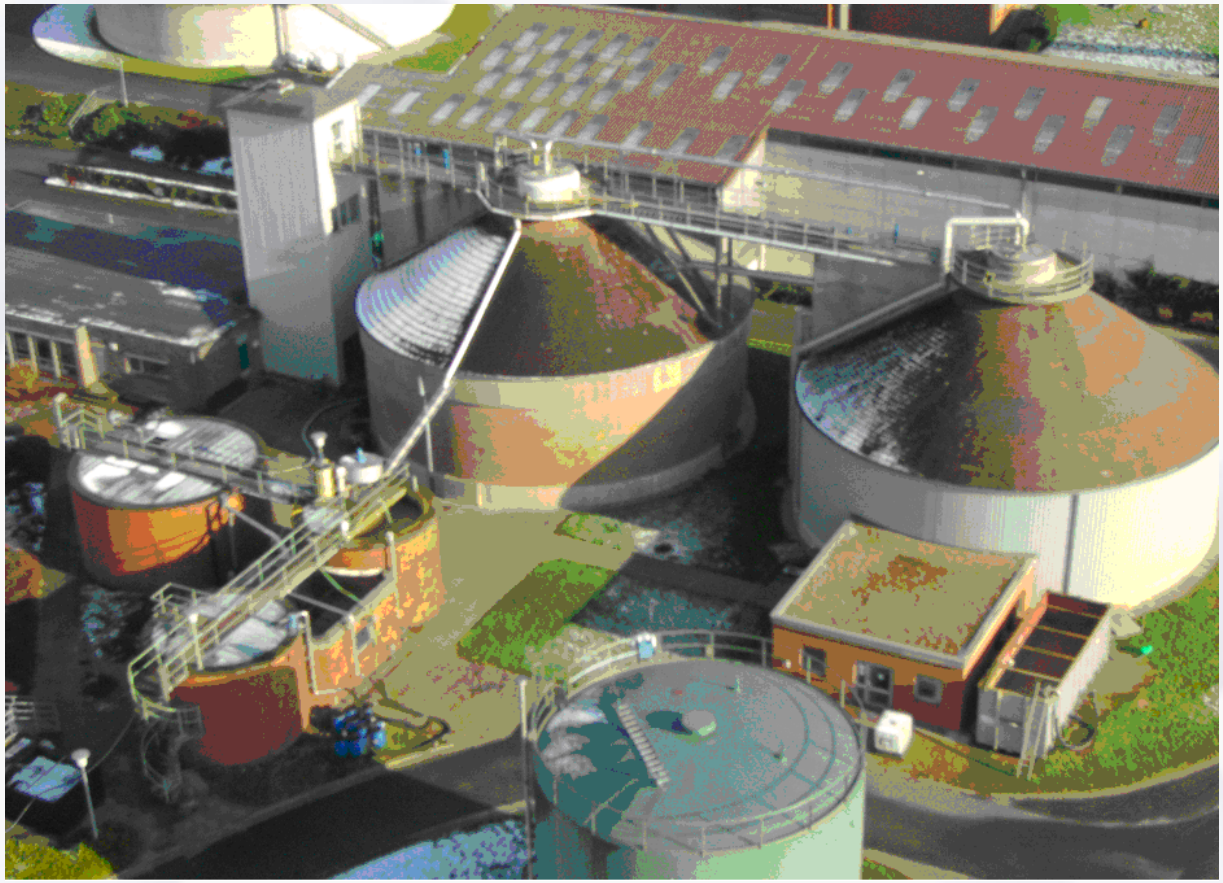








Meldorf WWTP, Germany



Meldorf WWTP, Germany

Initial Conditions:

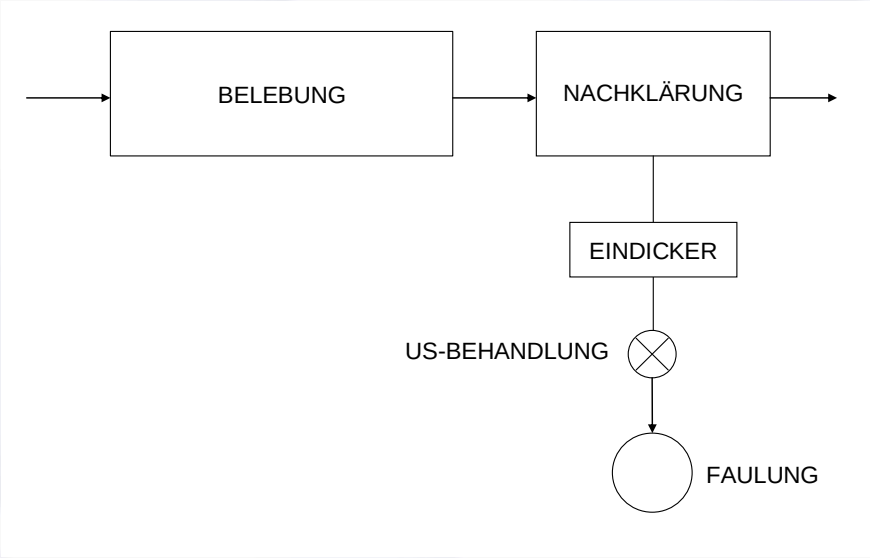
- Design capacity: 70,000 PE
- 2 digesters (each 2,000 m^3 vol.)
- Cofermentation
- Foaming digesters (high portion of filamentous organisms in the biological sludge)

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

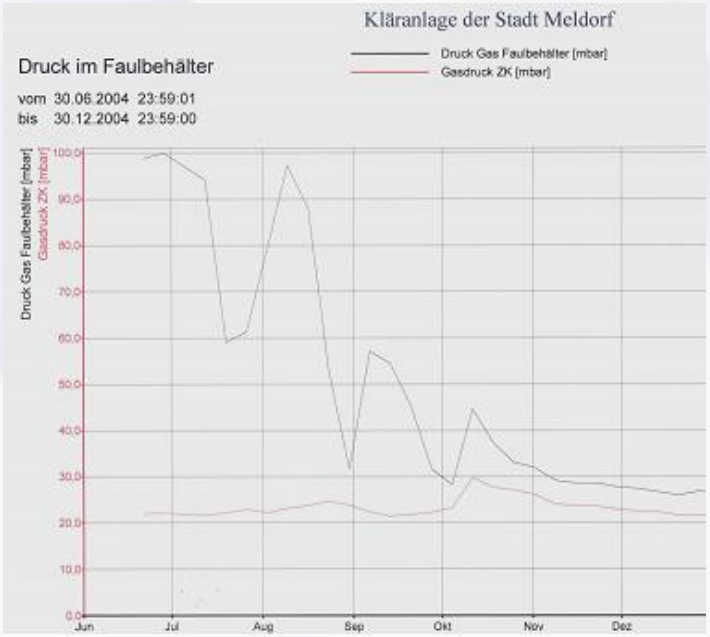


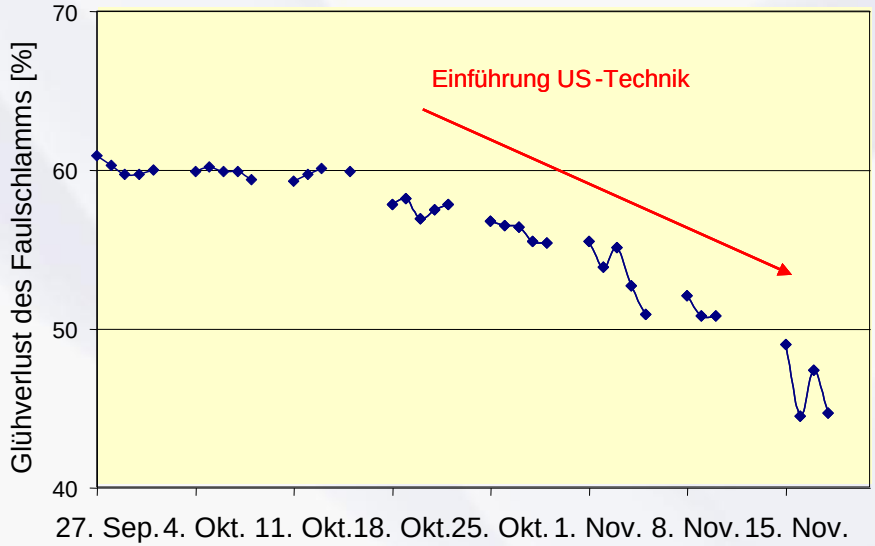


Meldorf WWTP, Germany

Results of US Installation:

- Foaming problems stopped
- Feeding of co-substrates became possible again
- Significantly improved digestion performance





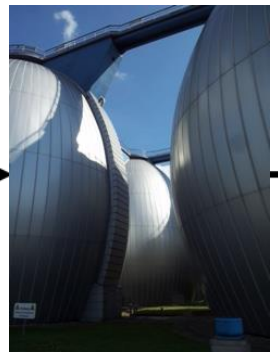
Outlook: P-Recovery from Biosolids

TU Bergakademie Freiberg
Institut für Technische Chemie

Ultrawaves GmbH

SC Consult GmbH

Poll
Umwelt- und Verfahrenstechnik GmbH



ULTRAWAVES disintegration

Phosphorous precipitation and separation

ZetaOptimizer

Sludge dewatering

PARFORCE => Phosphoric acid

Plant available phosphate

Pyrolysis

Cement plant

Co-incineration

Enhancing anaerobic biomass digestion on Farmland Biogas plants (FBP)

BORDESHOLMERLAND FBP, GERMANY



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%

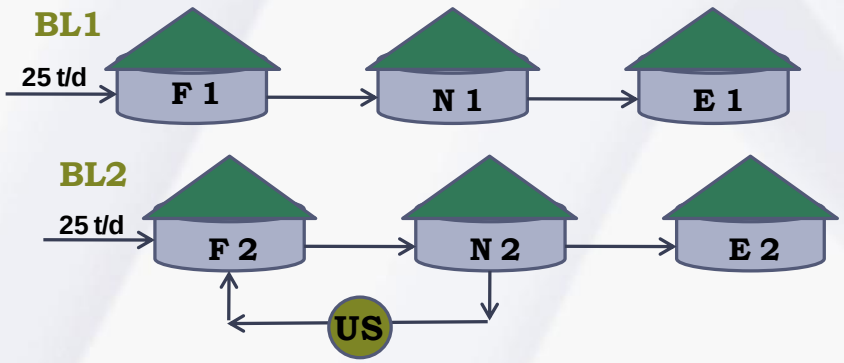
Goal:

- reduce amount of substrate

BORDESHOLMERLAND FBP, GERMANY

Ultrasound installation in 2011:

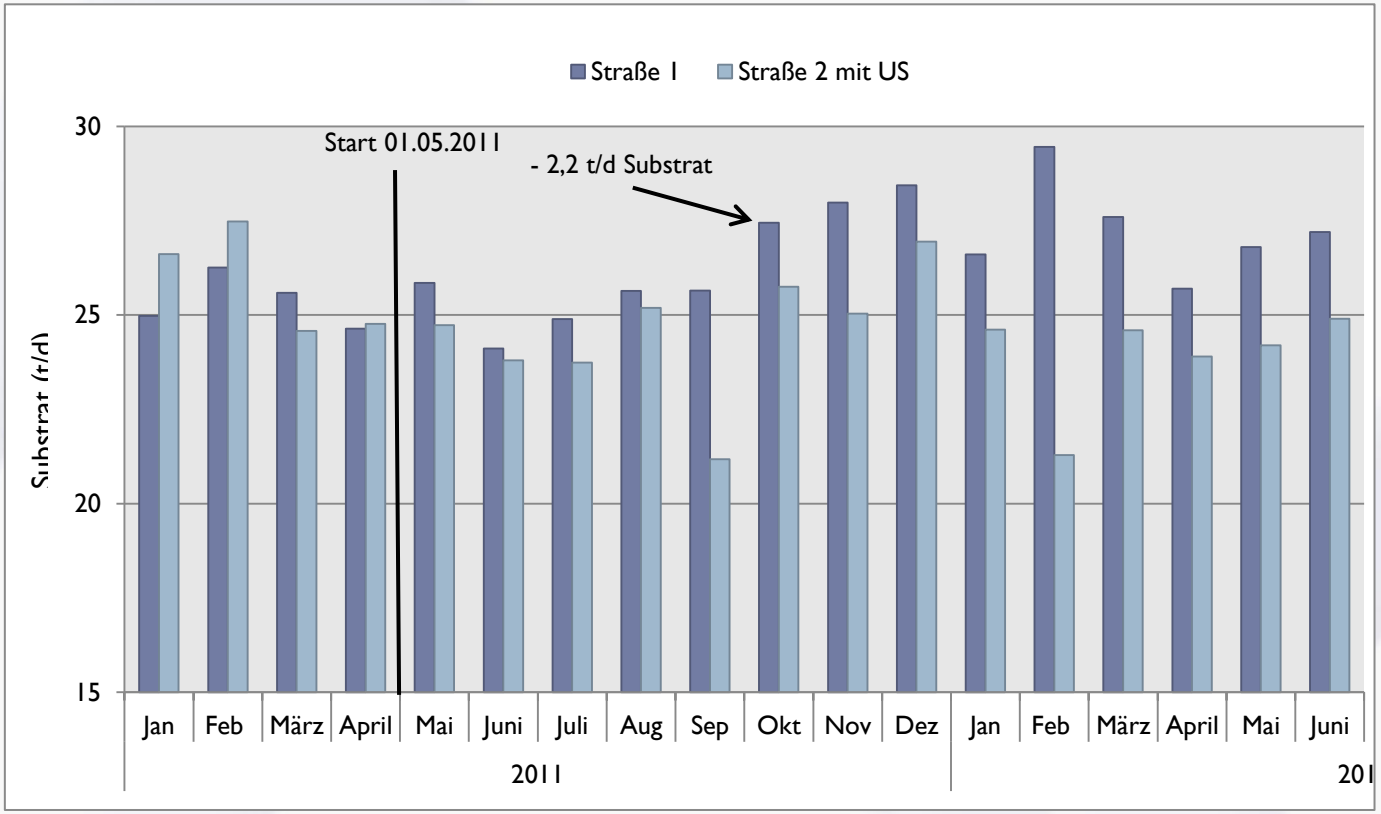
Sonication of partial flow (36 m^3/d) from post digester to main digester (@ 3.3 kWh/m^3) in line 2



Sonication of 36 m^3/d



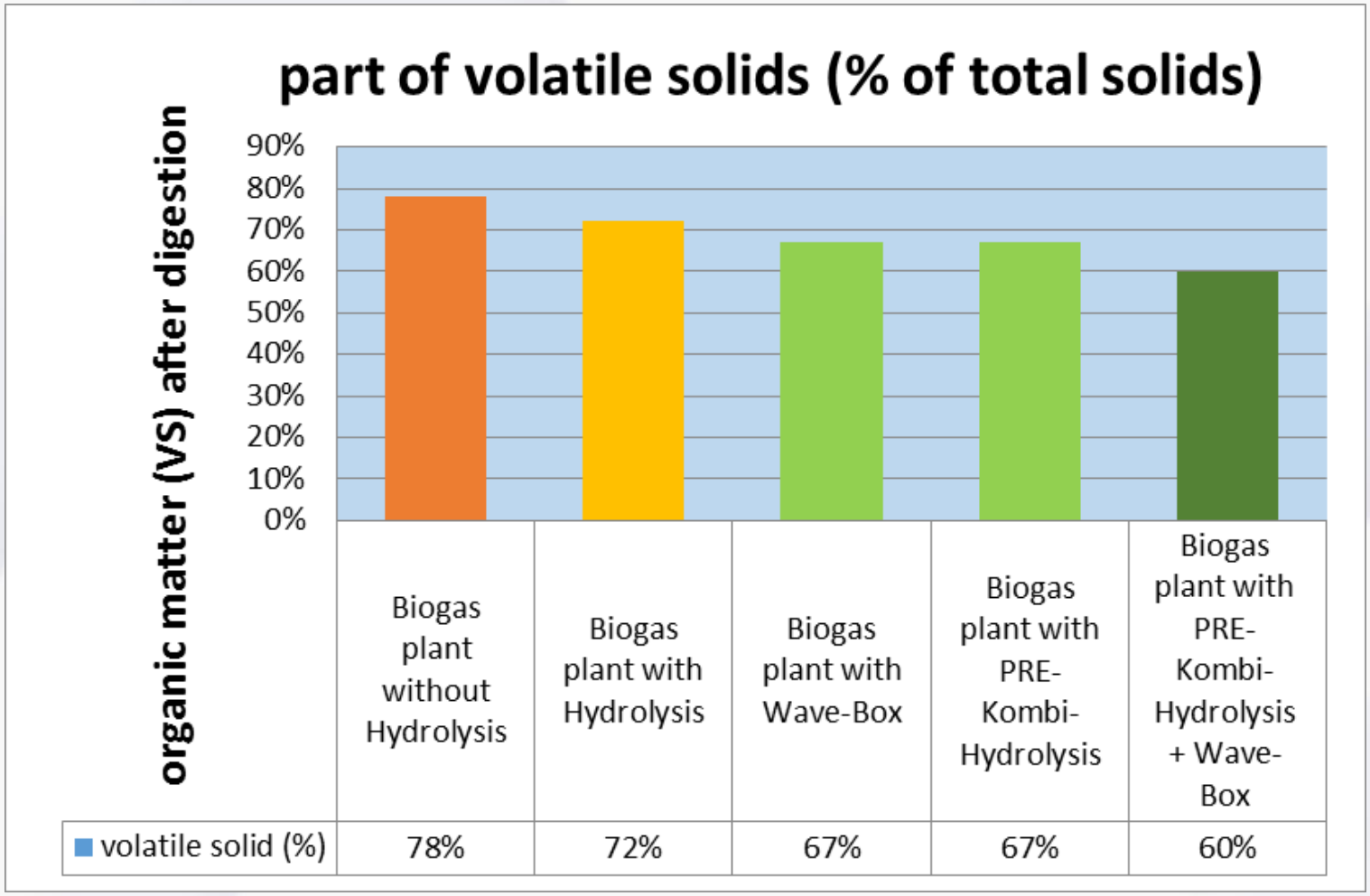
BORDESHOLMERLAND FBP, GERMANY



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)

Degradation of Organic Matter



Enhancing anaerobic digestion of Spent-Wash

AD of Spent-Wash: Loburg Distillery, GER

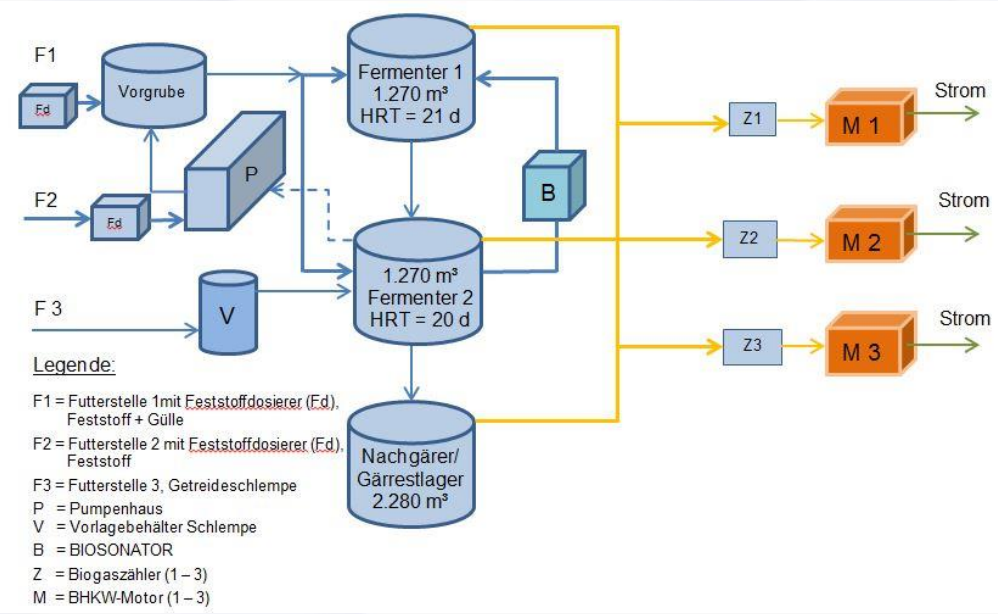
- **Initial Conditions:**
  - Power capacity: 560 kW
  - 2 MD @ 1.270 m³, 1 ST @ 2.280 m³
  - Feed: maize silage, maize silage waste, sorghum silage, spent-wash (wheat), cow manure
  - HRT: 40 d/digester



- **Desired Goal:**
  - Reduction of the daily feed
  - Improvement of the specific biogas production

AD OF SPENT-WASH: LOBURG DISTILLERY, GER

- **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)

	01.04.2012 till 31.09.2012 without BIOSONATOR	01.02.2013 till 30.07.2013 with BIOSONATOR	Difference related on **6** comparable month
Maize silage	2.266 t	2.288 t	+22 t
Maize silage waste	406 t	402 t	- 4 t
Millet silage	891 t	750 t	-141 t
Rye grain, grinded	275 t	155 t	-120 t
Corn mash (wheat)	2.414 t	3.072 t	+658 t
Cattle liquid manure, dairy cattle	2.778 t	3.184 t	+406 t
Fresh bulk, sum	9.030 t	9.850 t	+820 t
Dry solids, sum	1.606 t	1.631 t	+ 25 t
Thereof fast degradable dry solids (rye grain + wheat mash)	**385 t**	**319 t**	**- 66 t**
Total costs substrate	152.719 EUR	126.797 EUR	- 25.922 EUR
Total costs substrate per year	305.438 EUR	253.594 EUR	- 51.844 EUR

Enhancing anaerobic biomass digestion on Food waste Biogas plants (FWBP)

MARIKS FWBP, GERMANY



MARIKS FWBP, GERMANY

Initial conditions:

- 2 main digester à 1.800 m^3, 1 post digester à 1.800 m^3, storage tank à 5000 m^3
- input: 73 t/d
- retention time: 40 days
- electrical power production: 700 kW
- methane concentration ca. 56-61%

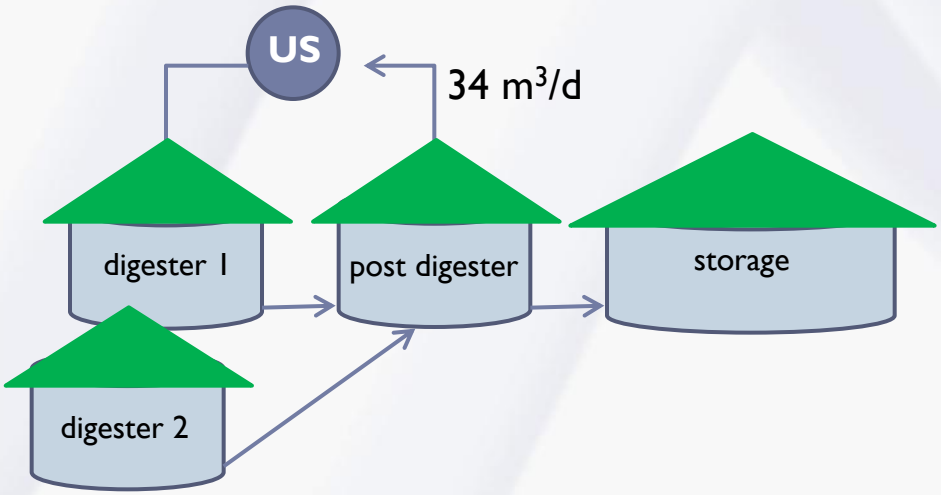
Goal:

- increase in biogas production

MARIKS FWBP, GERMANY

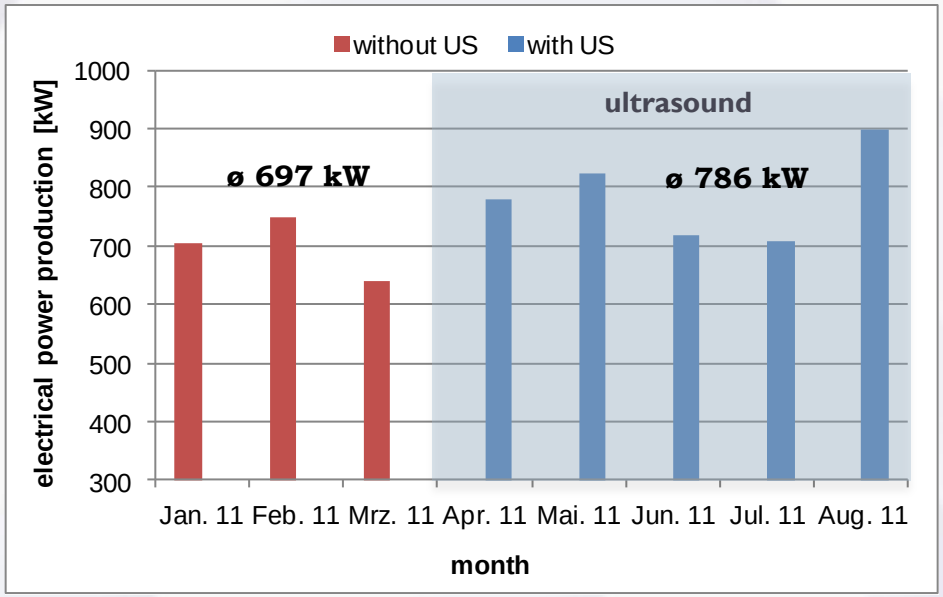
Ultrasound installation in 2011:

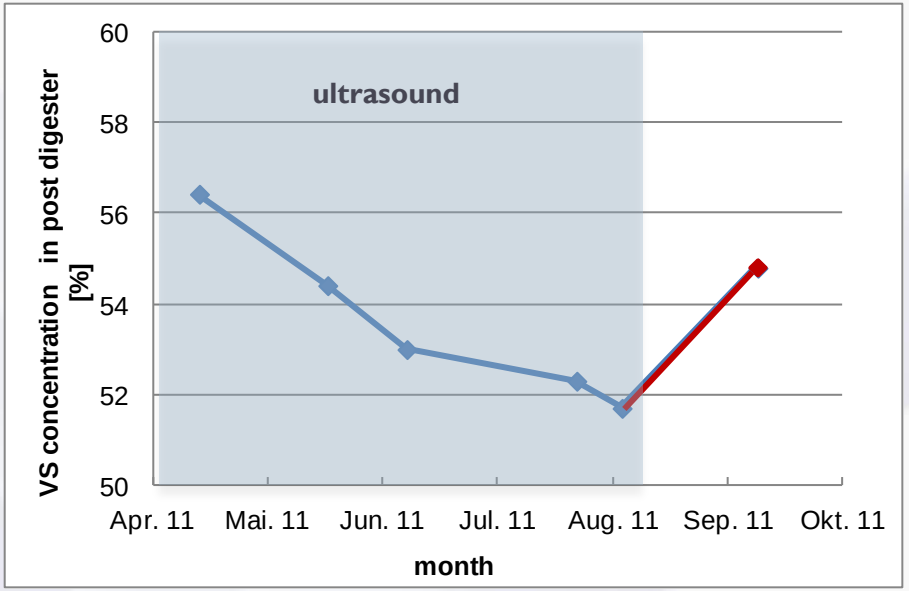
Sonication of partial flow (34 m^3/d) from post digester to main digester (@ 3.5 kWh/m^3)





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

US-reactor for biomass treatment
Requirements

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

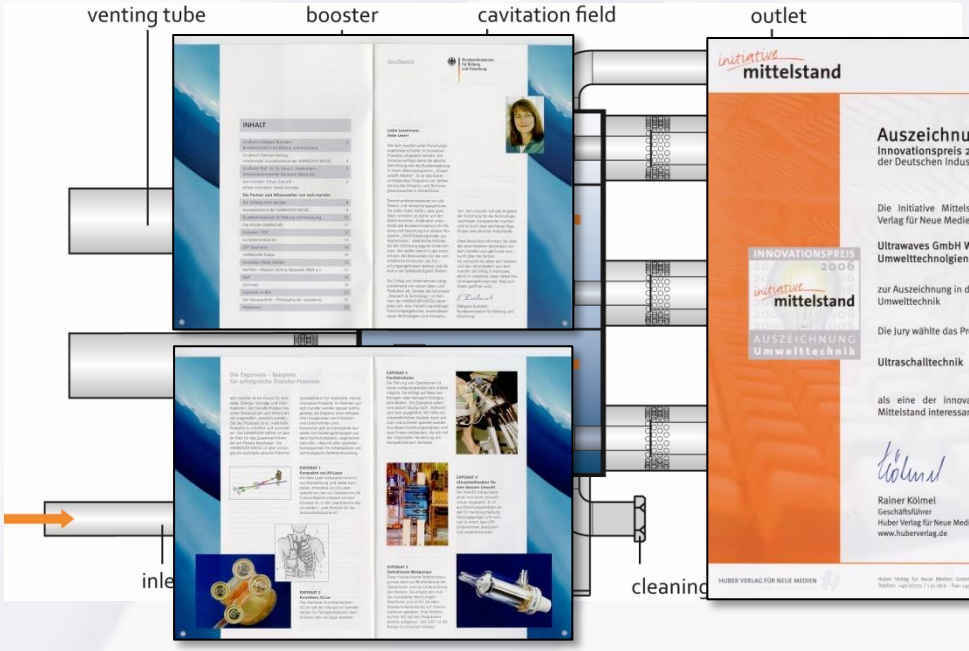


Full-scale HP-Ultrasound System 2006

Technology Transfer Innovation 2002

Innovation Award German Industry 2006

Innovation Award Baden Württemberg 2007





- Reactor volume: 30 L
- wer co
- ntinuou
- . of osc
- equency
- ensity: 1
- nicatio
- nicatio

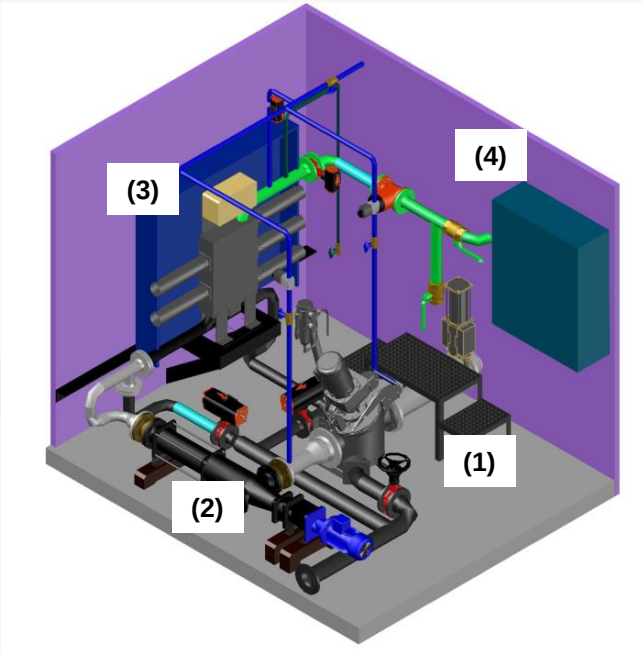
/m³

TUHH

Technische Universität Hamburg-Harburg

BIOSONATOR: P&P-SYSTEM

BIOSONATOR



- 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)





ULTRAWAVES – partner



Conclusions

- **Biomass treatment with ultrasound is an established technology**
- **Detailed studies have demonstrated the potential of ultrasound for enhanced biodegradation of biomass**
- **More than 150 Ultrawaves HPUS reference installations**

