
**Two years experience on a large German sewage treatment plant
with acoustic disintegration of waste activated sludge
for improved anaerobic digestion**

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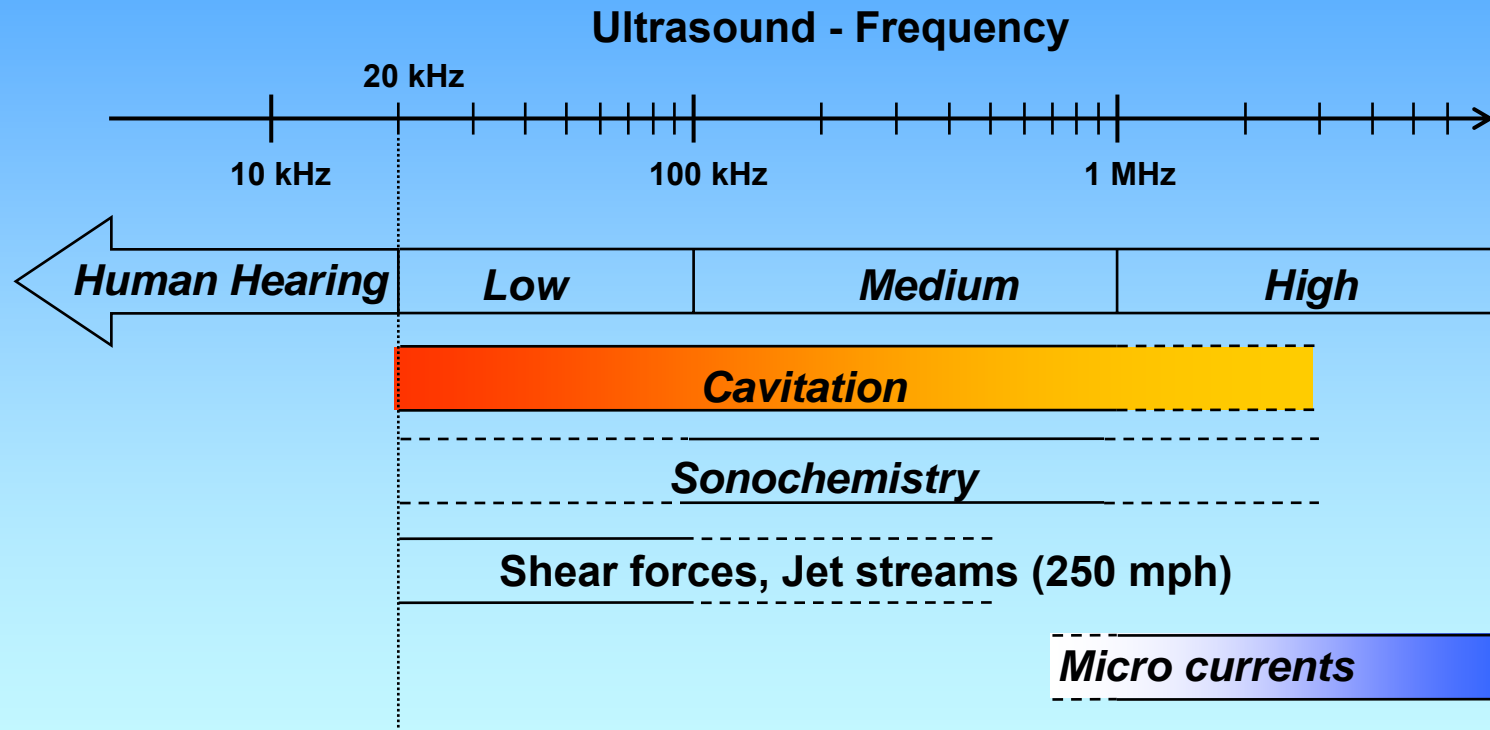
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Outline

- **Introduction to ultrasound and cavitation**
- **Impact of cavitation on biological cells**
- **Applications of ultrasound**
- **Intensification of anaerobic digestion**
- **Full scale at Bamberg STP, Germany**
- **Conclusion**



Ultrasound frequencies and predominant processes

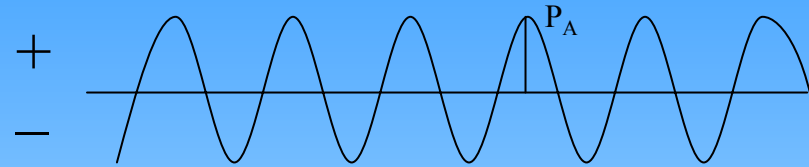




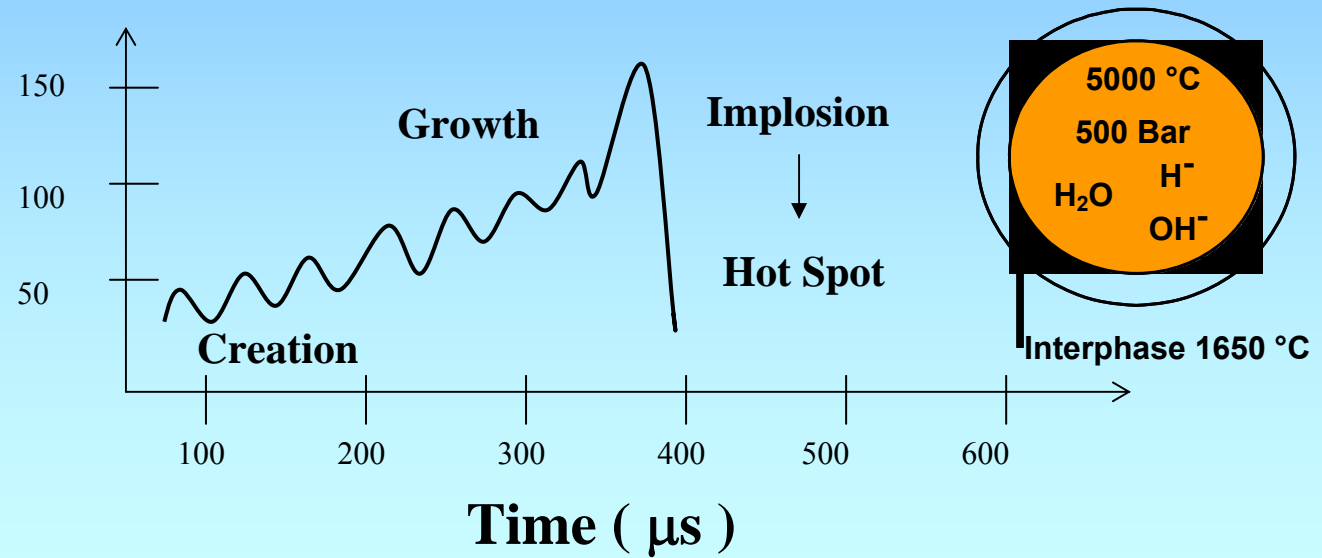
Acoustic cavitation

$$P = P_A \cdot \sin 2\pi \cdot f \cdot t$$
$$(P_A)^2 = 2 \cdot I \cdot \rho \cdot c$$
$$I = (W/cm^2)$$
$$c = \lambda \cdot f \text{ (m/s)}$$

Sound Wave



Radius of Bubbles (μm)



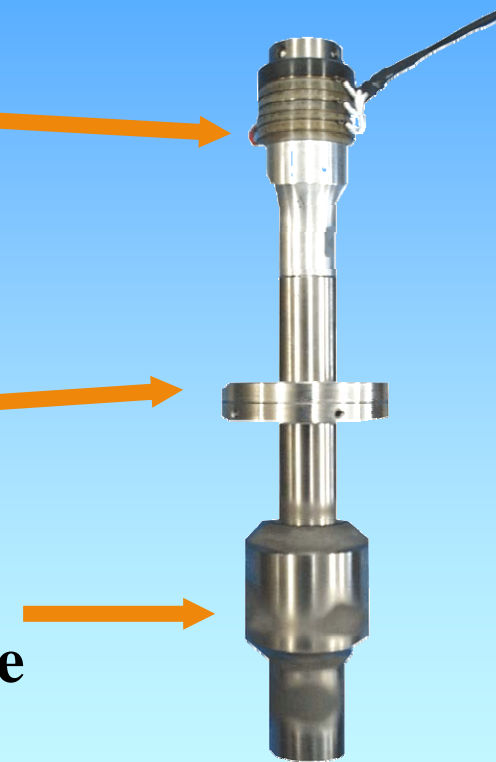


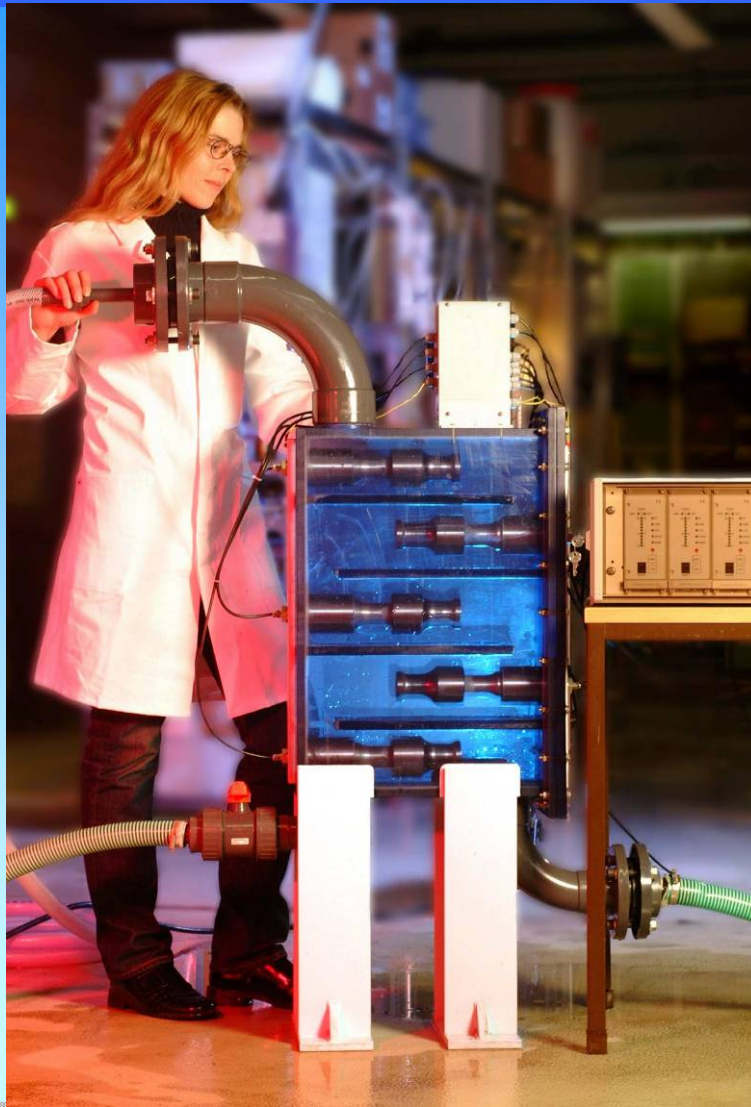
COMPLETE OSCILLATING UNIT

The *transducer* with a stack of piezoelectric ceramics (energy converter)

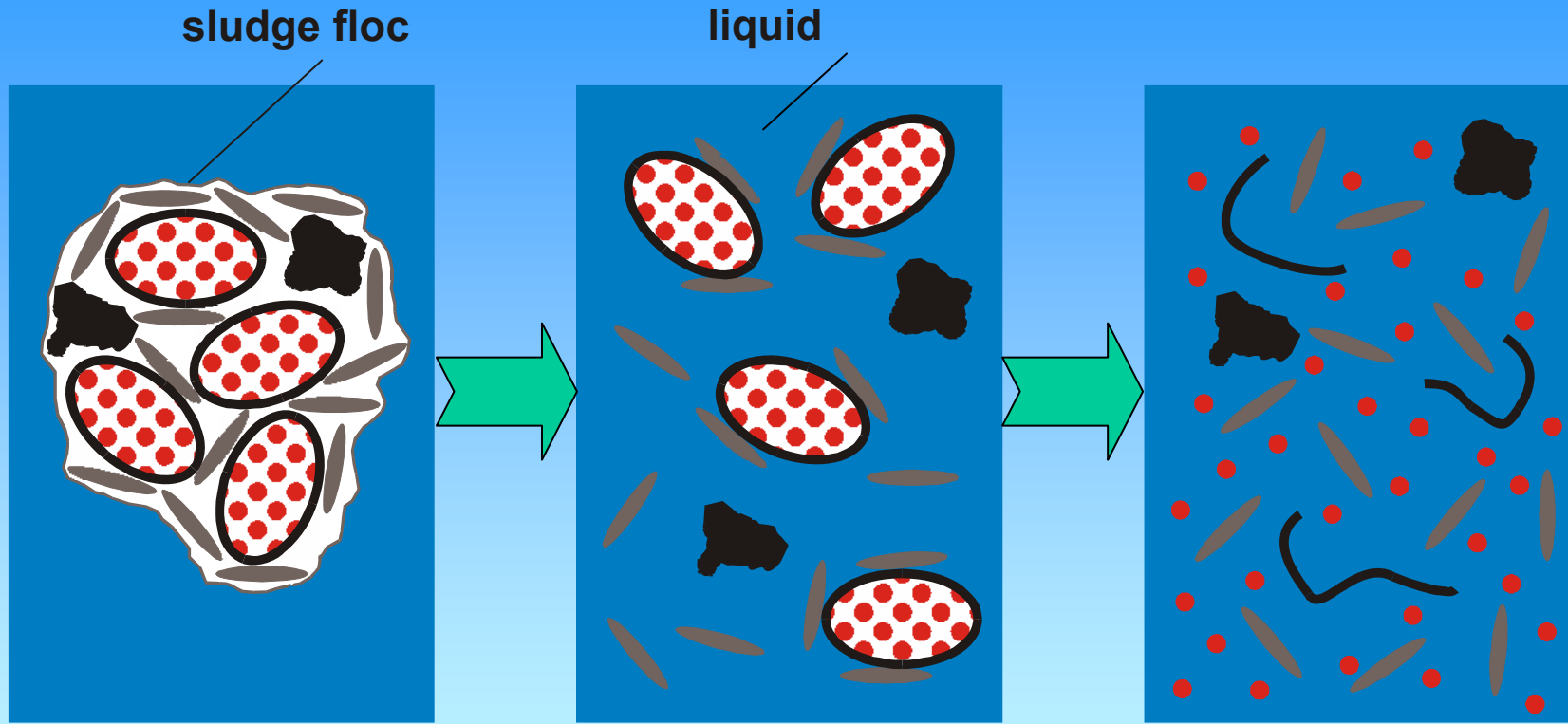
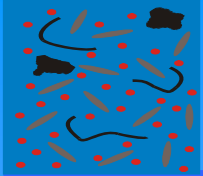
The *booster* (with flange)

The *Sonotrode* (or *horn*), which transmits the ultrasonic energy to the medium.





High-energy ultrasound module
Prototype 2001



bacteria

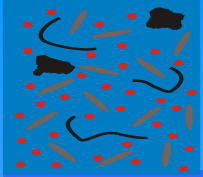


inert particle

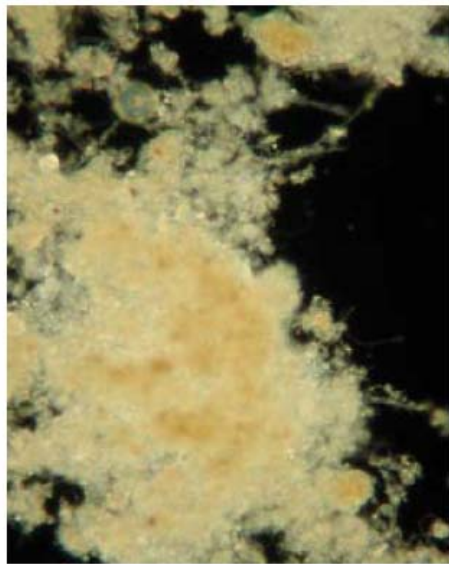


extra-cellular polymer

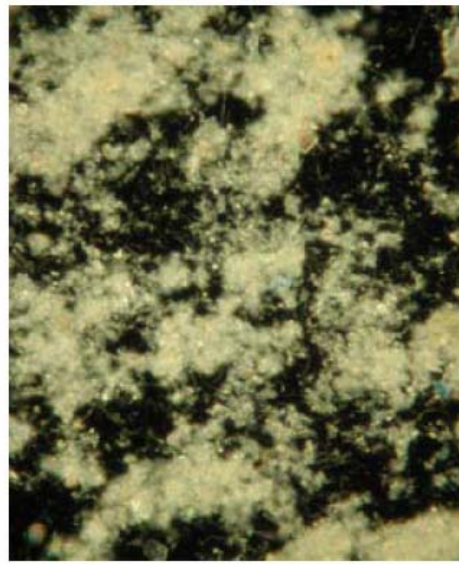
Sonication of activated sludge



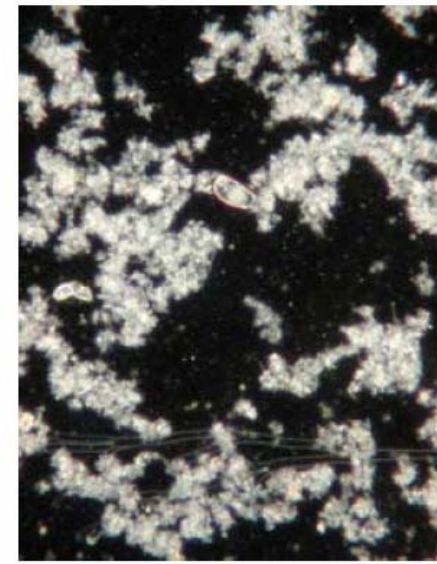
Sonication of activated sludge flocs



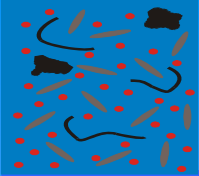
untreated



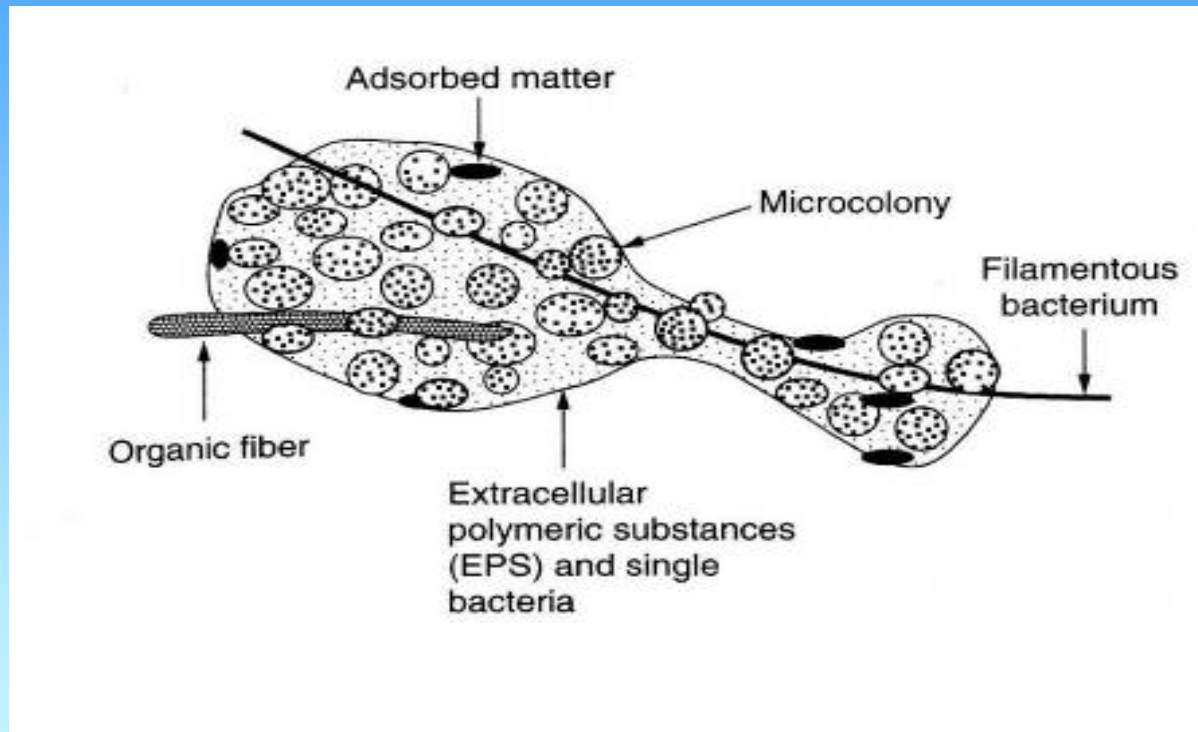
US energy 2,4 Wh/l



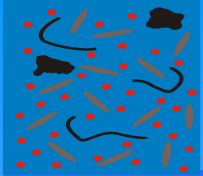
US energy 9,8 Wh/l



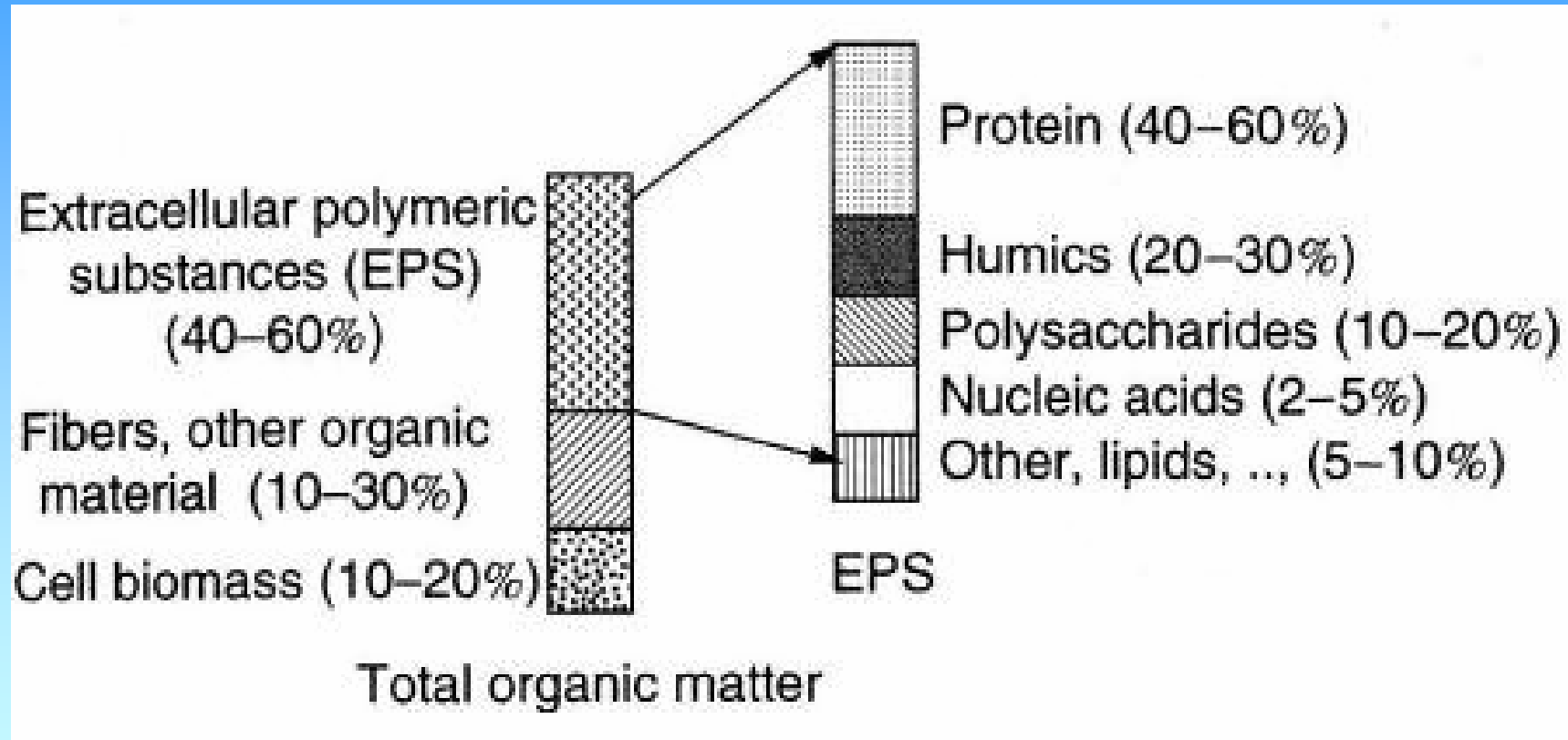
Constituents of activated sludge flocs

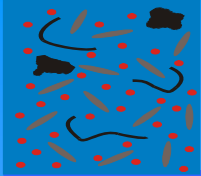


Nielsen, Per Halkjaer (2002). Activated Sludge - the floc. Encyclopedia of environmental microbiology

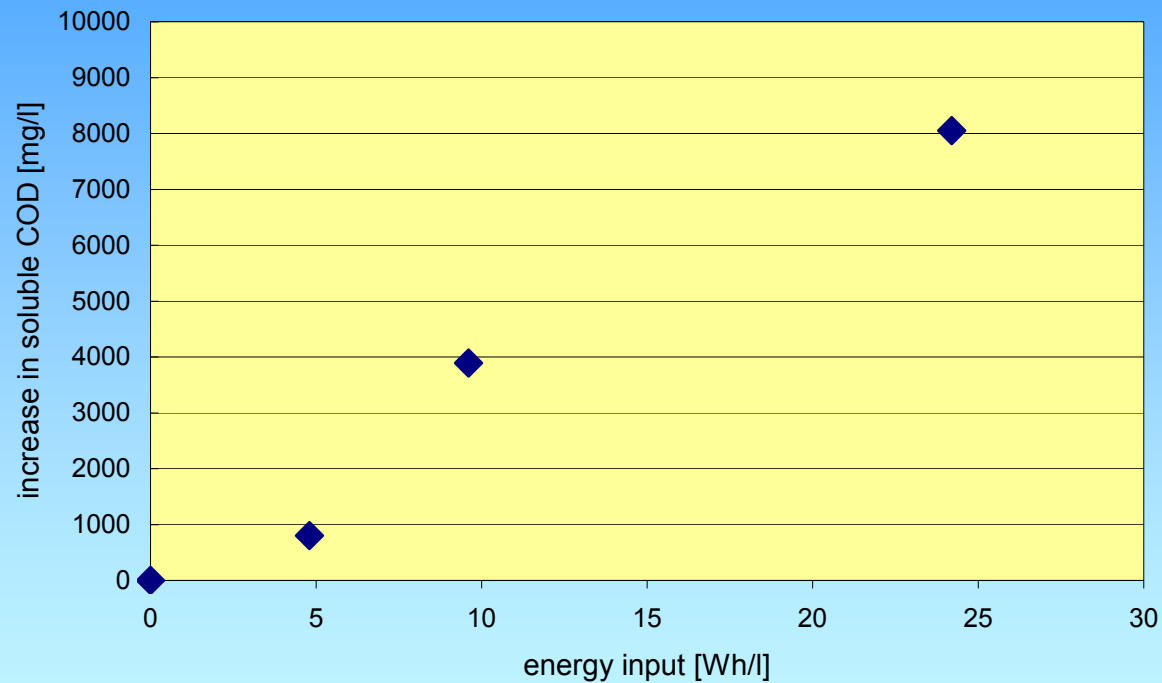


Composition of the organic part of activated sludge

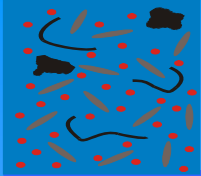




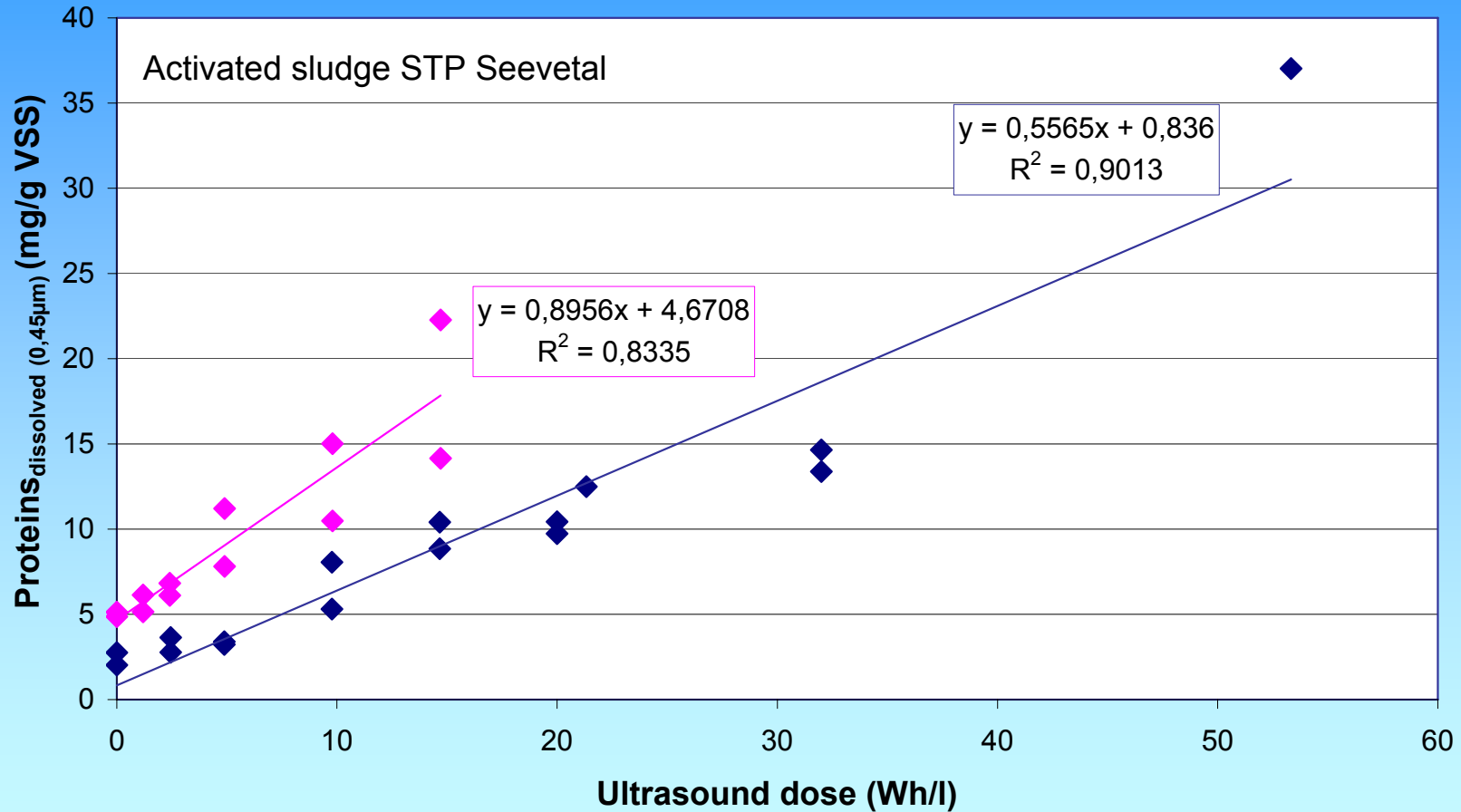
Impact of sonication of TWAS on soluble phase – COD



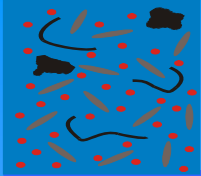
TWAS: TS = 6.5%, VS = 74.1%



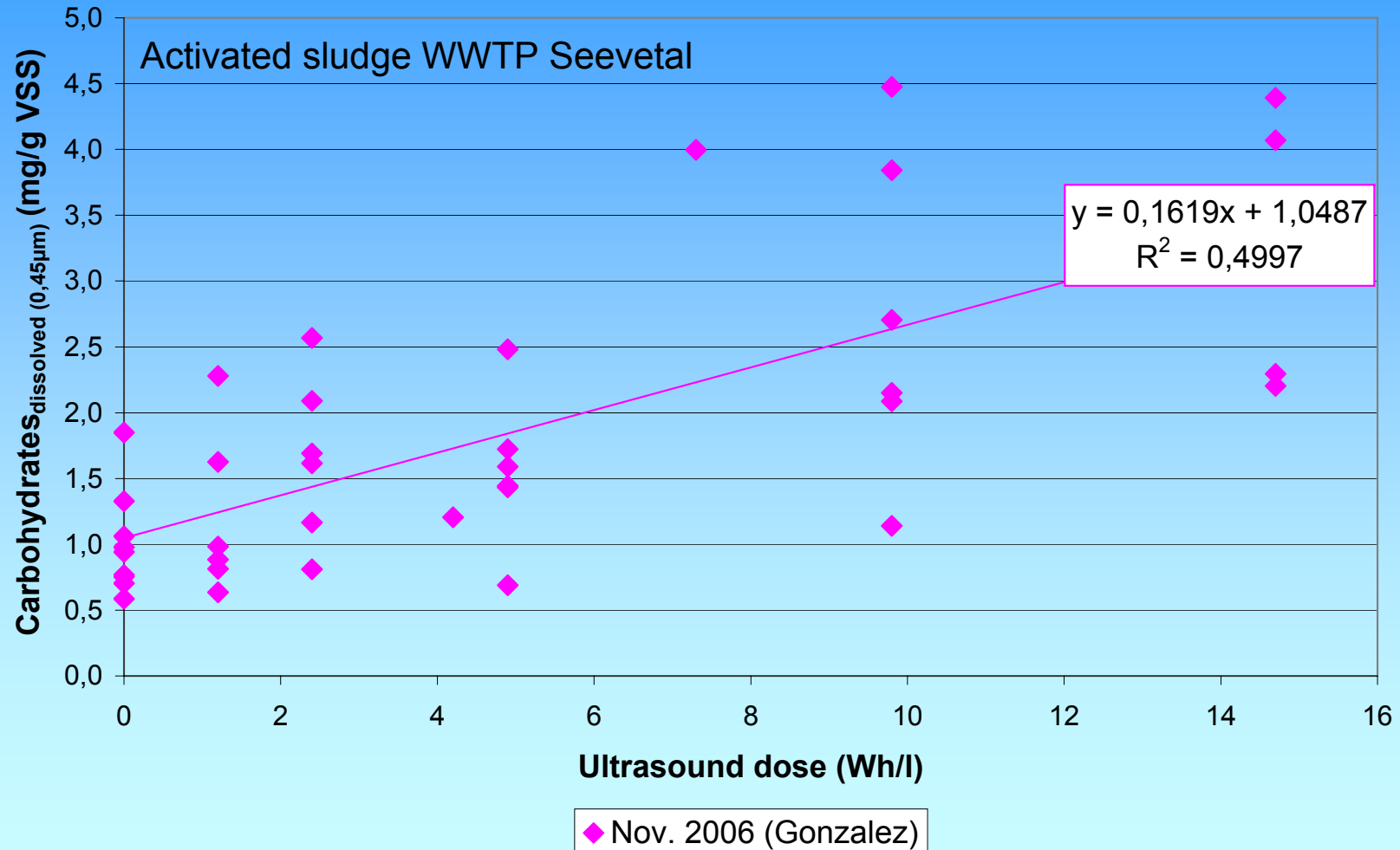
Impact of sonication on soluble phase - proteins

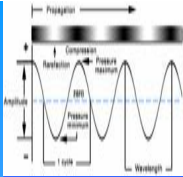


◆ Sept./Oct. 2006 (Bolle) ◆ Nov. 2006 (Gonzalez)

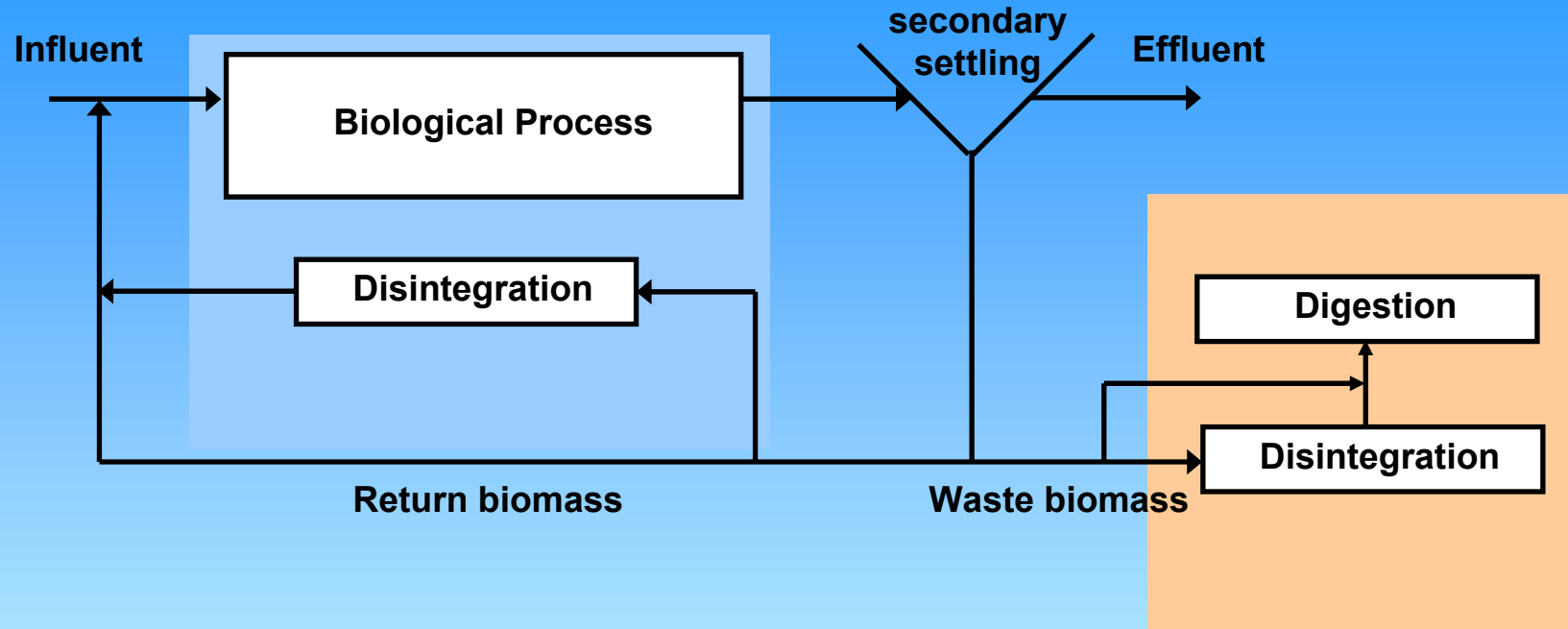


Impact of sonication on soluble phase - carbohydrates



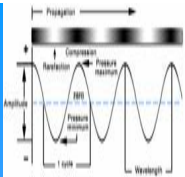


Applications of ultrasound

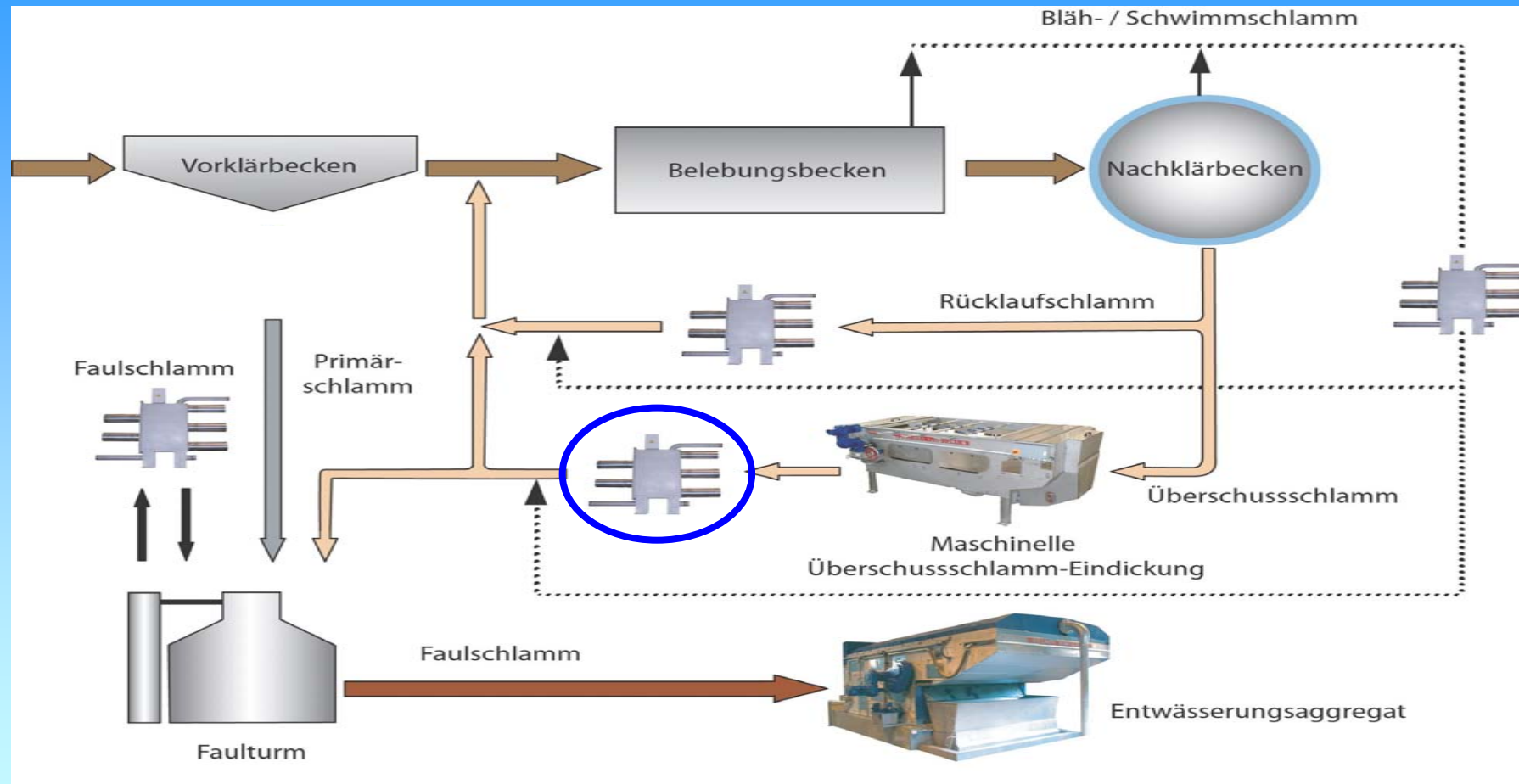


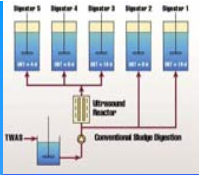
- **Anaerobic Digestion Improvement**

- Combatting filamentous bacteria
- Reduction of waste activated sludge biomass production
- Better performance of the denitirification process

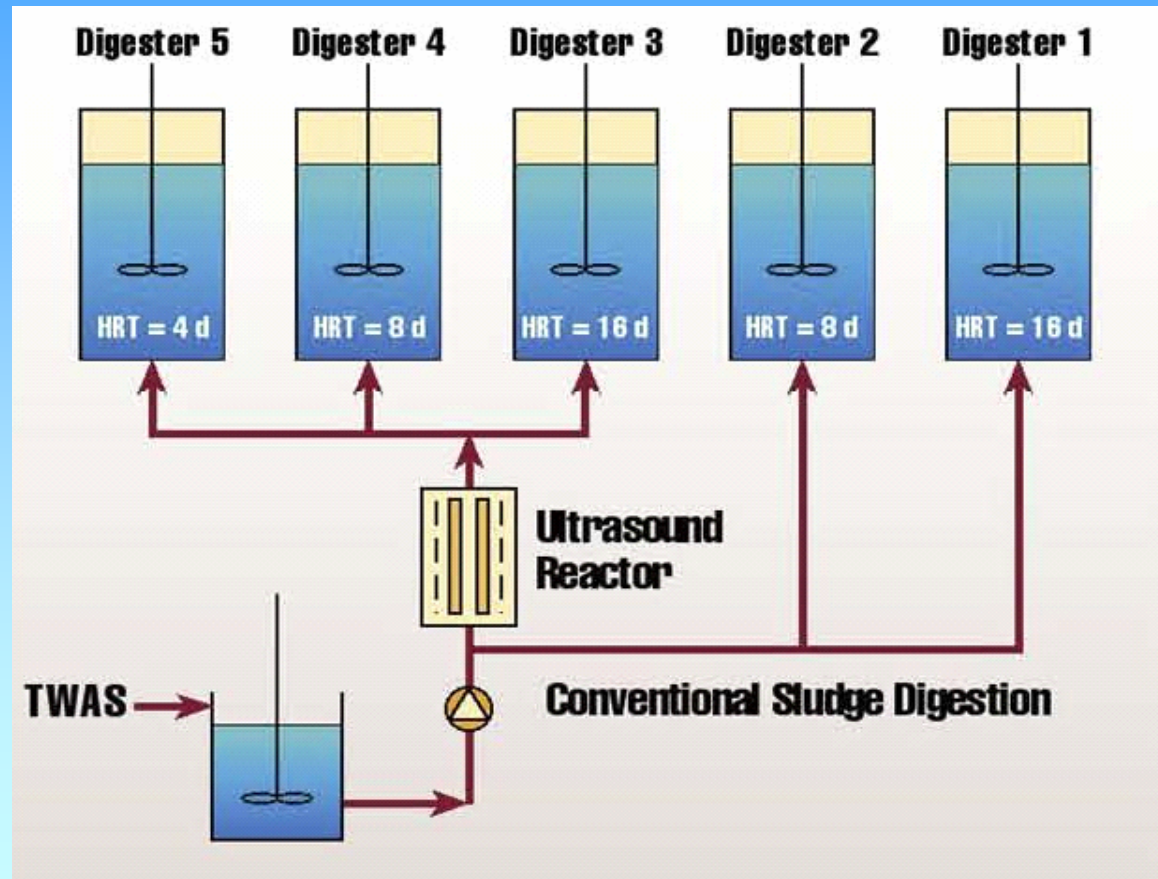


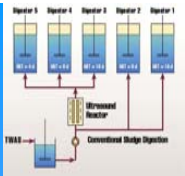
Applications of ultrasound



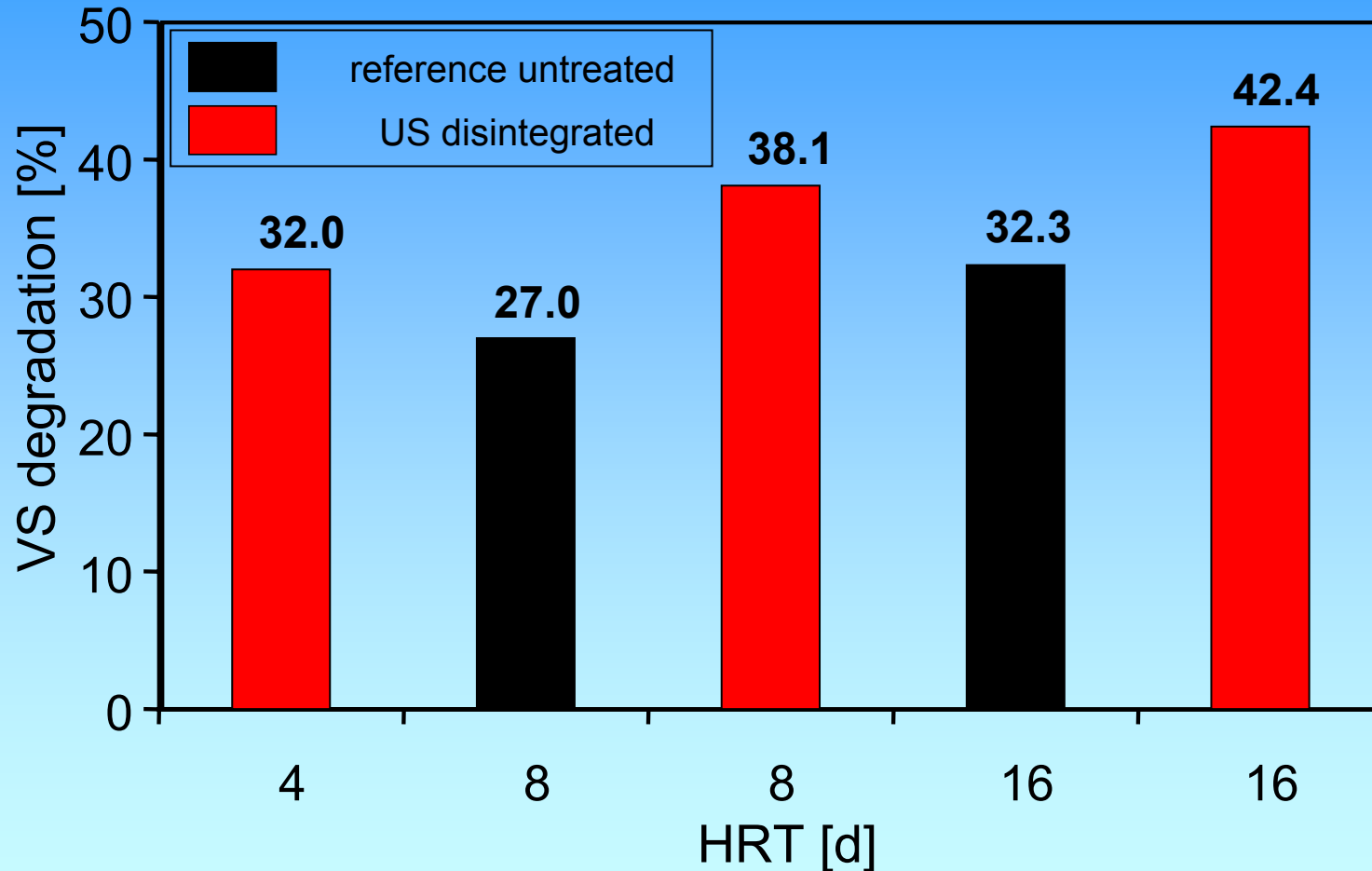


Pilot Scale Plant - Bad Bramstedt





WAS anaerobic degradation – pilot scale Bad Bramstedt





Full scale at Bamberg STP





Initial Conditions (2002):

Design capacity: 220,000 PE

Actual Load: 330,000 PE

150 m³/d primary sludge, 250 m³/d WAS

3 digesters with 18 d digestion time

42% average VS degradation

Desired Goal:

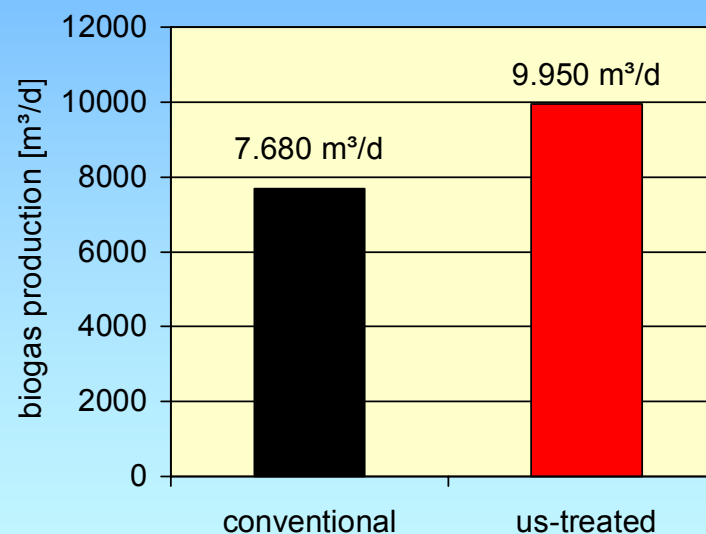
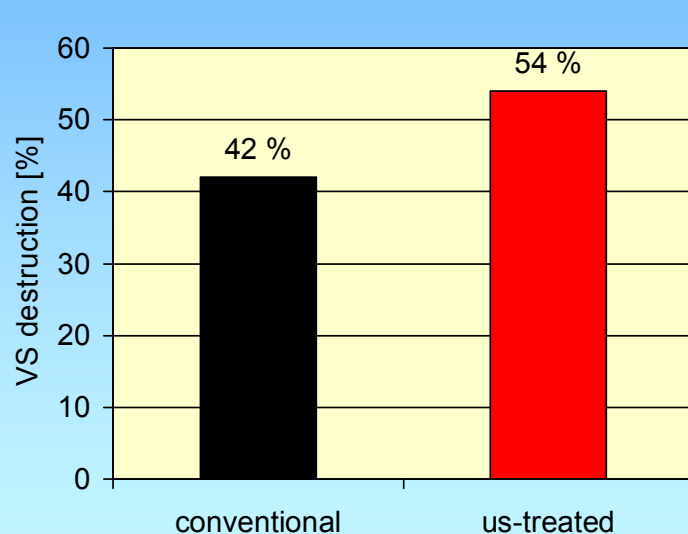
Achieve a minimum of 45% VS degradation

- **Option 1: new 3,000 m³ digester**
- **Option 2: application of US to increase digester performance**



Results preliminary full scale tests (May –Aug 2002):

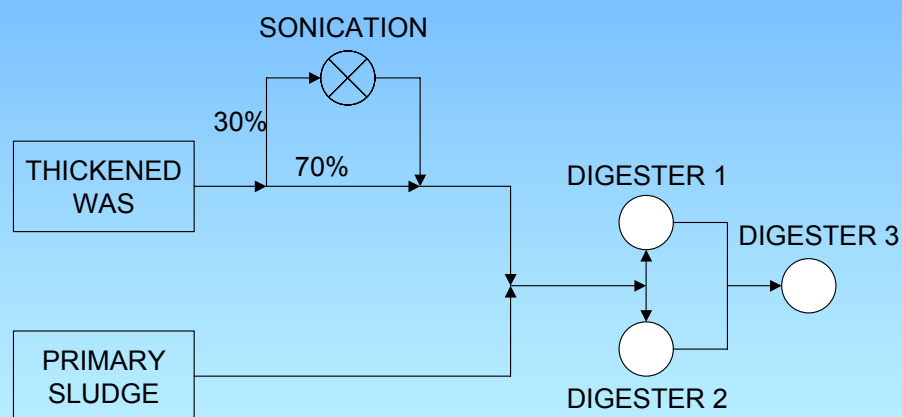
- VS degradation improvement from 42 to 54%
- Biogas production increase by 30%
- VS in digested sludge reduced from 60 % to 54%



Avoids construction of a new digester

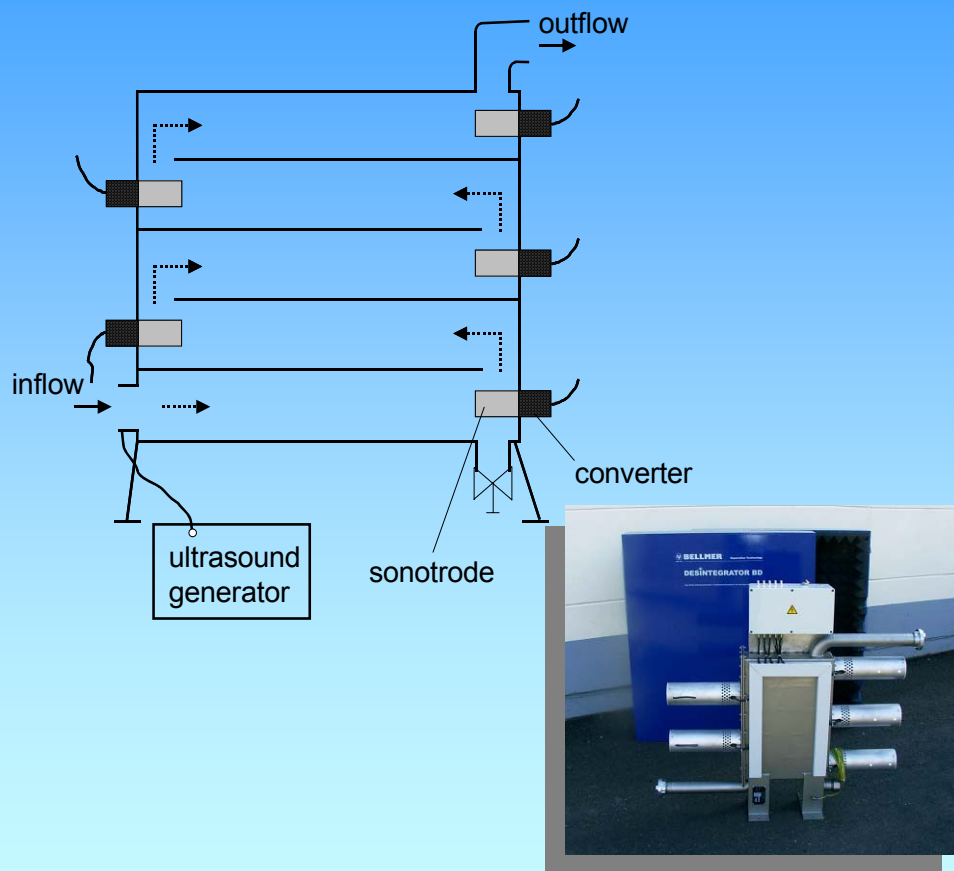


Full scale ultrasound installation in August 2004
Partial sonication of 30% WAS (~ 75 m³/d)





Ultrawaves – 5 kW ultrasound reactor



- Reactor volume 28 L
- Continuous operation
- Power supply 5 kW
- No. of oscillators 5
- Frequency 20 kHz
- Intensity 25-50 W/cm²
- Sonication time 67 s
- Energy consumed 2.6 kWh/m³



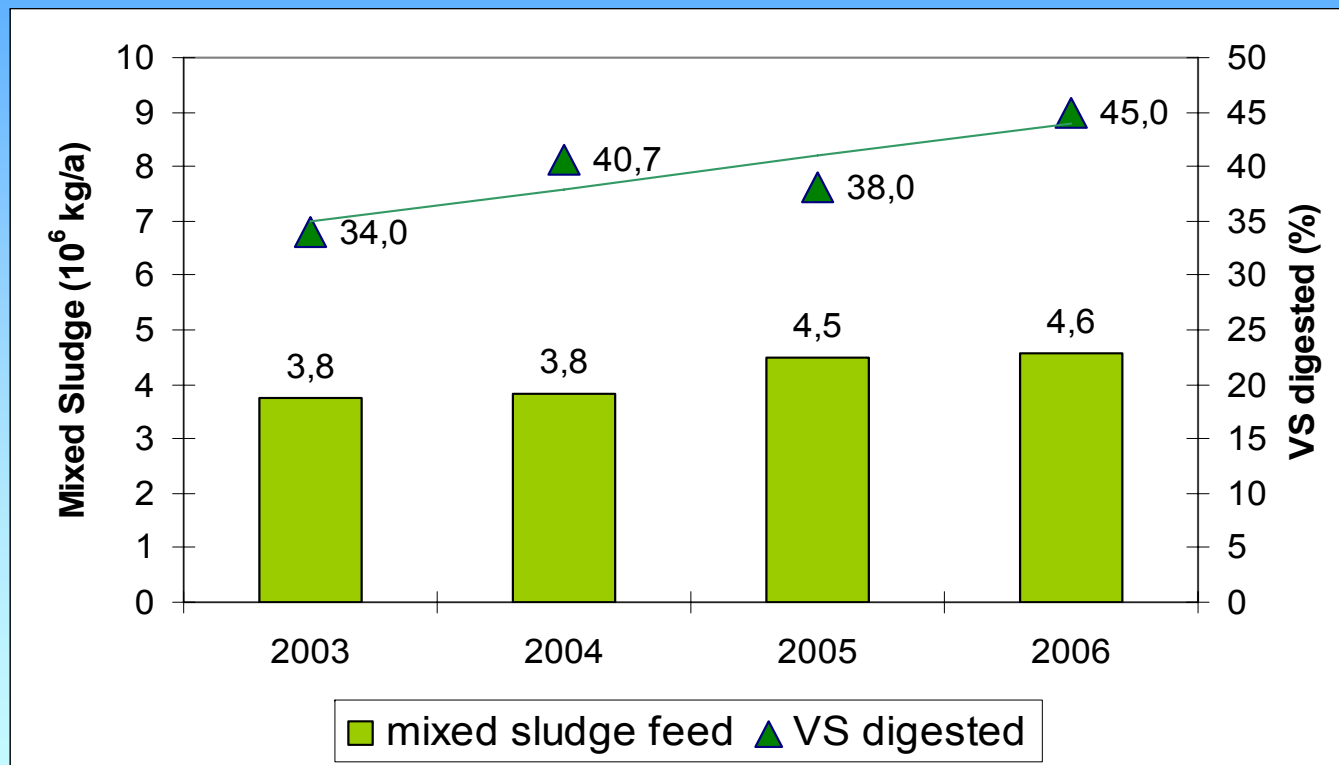
Sludge flows

Sludge (10 ³ kg/a)	2003	2004	2005	2006
Primary	1,820	1,301	2,472	2,589
Secondary WAS	1,944	2,522	2,034	1,985
Sonicated TWAS	-	-	900*	1,591
Mixed sludge	3,764	3,823	4,506	4,574
VS digested	944	1,088	1,285	1,586
VS digested (%)	34.0	40.7	38.0	45.0
HRT D 1+2 (5000m³) (d)	14.7	13.9	15.3	15.5
HRT D 1+2+3 (7000m³) (d)	20.6	19.4	21.4	21.7



Mixed sludge feed and VS degradation

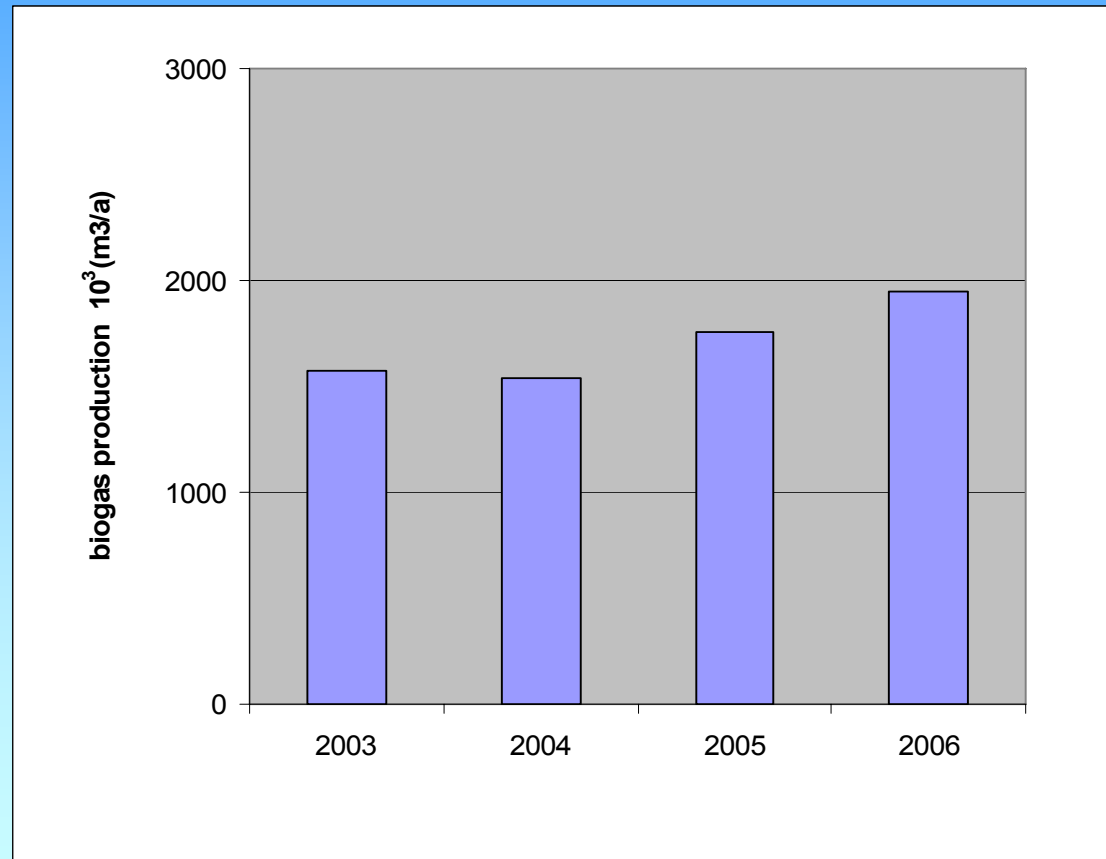
Ultrasound TWAS disintegration since August 2004





Biogas production

Ultrasound TWAS disintegration since August 2004





Biogas production

	2003	2004	2005	2006
Biogas (10 ³ m ³ /a)	1,571	1,542	1,756	1,952
Biogas (m ³ /kgVS _{in})	0.57	0.58	0.52	0.55
Biogas (m ³ /kgVS _{deg})	1.66	1.42	1.37	1.23
Biogas (m ³ /m ³ *d)	0.61	0.60	0.69	0.76



Cost – benefit - calculation

30% WAS (75m³/d) sonicated →
2 US-units

Cost:

a) Investment: 220,000€ (10a)

32,000 €/a

b) Operation:

power (**2.6 kWh/m³**)

new sonotrodes (15,000h)

maintenance (1h/week)

10,106 €/a

Total 42,106 €

30% Increase in digester performance -
VS degradation up from 42% to 54%

Benefit:

a) Reduction sludge disposal costs

371,250 kg DS/a · 0.10€/kg DS =

37,125 €/a

b) Increase of methane production

259,875 m³/a → 2,598,750kWh/a,

40% efficiency CHP , 0.079€/kWh_{el}

→ **83,160 €/a**

Total 120,285 €

Conclusion

- The impact of sonication on sludge flocs/cells is multifold:
floc deagglomeration → better mass transfer and EPS release...
cell destruction → production of SCOD and proteins ...
→ intensification of the anaerobic process
- Acoustic disintegration of waste activated sludge can be an economic process regarding the benefits gained at output level by more biogas and less digested sludge
- Reliable ultrasound equipment is available for sludge disintegration and intensification of anaerobic digestion