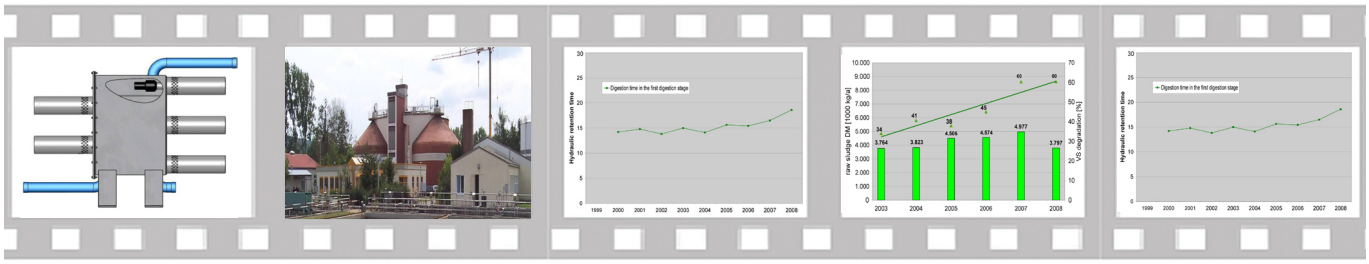
Ultrasound Treatment:
For Sludge Control & Reduction



A great amount of effort has been devoted to studying acoustic disintegration (ultrasound) processes and their effects on sludge. Investigations in the field originated over a decade ago and since then, advances have been made in this area of research.

By Kalpesh Dankhara, Dr. Klaus Nickel & Hiren Trivedi

Biosolids (or sewage sludge) are the solid organic particles produced in wastewater treatment processes. The amount of sludge produced in wastewater treatment plants is continually increasing. The processing, beneficial utilization and disposal of biosolids commands a treatment cost varying from 40-60% of the total wastewater treatment expenditures in typical plants. Effective sludge reduction can be achieved using the Ovivo Sonolyzer, ultrasound technology. The advantage of ultrasound treatment is that it does not require chemicals or extreme environmental conditions. Ultrasound treatment disintegrates the sludge through a process known as 'ultrasonic cavitation'.

There are several techniques (chemical, thermal, and mechanical) available in the market today, which claim to improve anaerobic digestion of wastewater treatment plants. A great amount of effort has been devoted to studying acoustic disintegration (ultrasound) processes and their effects on sludge. Investigations in the field originated over a decade ago and since then, advances have been made in this area of research.

It has been proven that low-frequency (below 100 kHz) high-intensity ultrasound generates the cavitation necessary to produce the mechanical shear forces associated with sludge disintegration. The enzymatic-biological hydrolysis, which is the rate-limiting step in the anaerobic substrate degradation process is replaced and catalyzed by acoustic-mechanical sludge disintegration. Ultrasound can be used to disintegrate waste activated sludge (WAS) before it is fed to the digester in order to enhance the performance of anaerobic treatment process. High power ultrasound in a liquid medium creates cavitation. The bacterial cells in the sludge are subsequently destroyed, as the effects of cavitation are so powerful that microbial cell walls are broken when the cavitation bubbles implode. The contents of the cells are then released into the medium, resulting in a higher degree of substrate bio-availability for the remaining living micro-organisms.

Anaerobic Digestion Acceleration and Enhancement

Bamberg WWTP, Germany

The Bamberg STP was designed for 220,000 PE. However, as a result of an improvement and extension of the sewerage system, the load at the plant increased to about 330,000 PE. The plant is equipped with three mesophilic anaerobic digesters to treat a mixture of primary and secondary sludge (WAS). As a consequence of the increased load, more sludge was produced and the hydraulic retention time (HRT) in the digesters dropped to just 20 days.

The initial plan was to construct a new, fourth digester with a volume of 3,000 m3. However, in 2002 the management

of the plant decided to test the newly developed ultrasound technology at full scale. In the same year ultrasound equipment from the Ultrawaves Company in Hamburg was installed and operated for a trial period of four months. After feeding the digesters with ultrasonically treated WAS, the gas production showed a marked increase of almost 30%. The methane content also increased slightly making the biogas a more attractive and energy rich product. The residual Volatile Solids (VS) content in the digested sludge was reduced from 60% to 54%. The desired goal to reach a minimum of 45% VS degradation was not only met, but surpassed.

After a successful trial period in 2002, the Bamberg STP management decided to purchase two Sonolyzer ultrasound reactors (2 x 5 kW) instead of building a new digester, avoiding the costly undertaking of such a construction. The ultrasound units were installed in August 2004 with the same objective of enhancing VS degradation to a minimum of 45%. In order to achieve this, the system was designed to sonicate at least 30% of the thickened waste activated sludge (TWAS) flow before feeding it to the digesters. Parallel to that, separate WAS thickening by a centrifuge was implemented. Primary sludge is still thickened by gravity.

Results

The assessment of the impact of ultrasonic TWAS disintegration on the anaerobic digestion process at Bamberg STP was based on routinely-collected data sets. Since August 2004 the high-power ultrasound units are in operation with no interruption all year round. Table 1 presents a list of the sludge masses recorded during the studied periods.

Table 1 also shows that the share of sonicated waste activated sludge has increased considerably, and is today at about 90% of the total TWAS. Prior to being fed to the digesters the TWAS is thickened by a mechanical thickening process leading to an average dry solids concentration of 5.8%. The comparison between the pre and post sonication period shows an increase in the percentage VS degraded from 34% in 2003 to 60.4 % in 2008. The high VS-degradation was also determined for the years 2009 and 2010.

This increase in digester performance is shown graphically in Figure 3. The yearly gas production was rather constant at 1.9 Mio m^3 in the time before 2003 (data not shown), it decreased in 2004 and since 2005 it is increasing again until 2007 and 2008 on a constant high level (Figure 4).

The volume of the first di¬gestion stage in Bamberg is 5,000 m^3. Digestion stage one combines the two di¬ge¬sters FB1 and FB3, which are operated in parallel. The volume of digestion stage two (FB 2) is 2,000 m^3. Looking at the gas production after implementation of the ultrasound units we can see the variation of the first digestion stage (FB1 plus FB3) and the digestion stage two (FB2). The values of percentage of gas production are corresponding more or less to the volu¬metric ratio between digestion stages one and two.

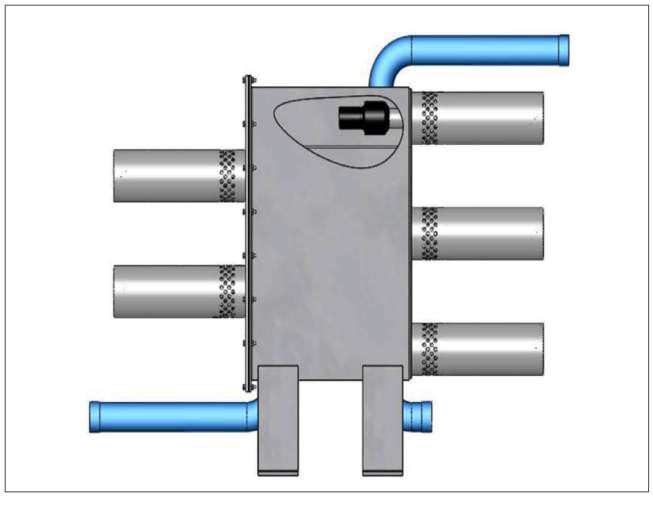


Figure 1: Ovivo Sonolyzer System, Ultrasound Sludge Control And Disintegration

Figure 2: Bamberg WWTP, Germany

As Figure 5 illustrates, the hydraulic retention time in stage one varies at a relatively narrow range between 14 and 19 days. In spite of this short reaction time the anaerobic digestion process proceeds with no problem. The mixed sludge (PS plus WAS) organic matter fed has increased significantly between 2005 and 2007. Logically the volumetric loading rate also increased (from 0.38 to 0.91 kg VSdeg/m^3.d) while the degradation of the organic sludge fraction improved significantly from 34% to 60%. In 2008 the high degradation level of 60% was held on and confirmed.

The specific gas production per kg of VS input seems to decrease slightly in total as well as in stage one, which can be explained by the ever increasing share of disintegrated TWAS, which is now becoming better degradable after sonication but as a substrate is less yielding as compared to primary sludge.

The total volume of sonicated TWAS in 2008 was 32,310 m^3, corresponding to 88 m^3/d. This represents an ideal volumetric flow for the two installed ultrasound reactors. The resulting sonication time is only 57 seconds. The ultrasound units are in

Sludge (10^3 kg DS/a)	2003	2004	2005	2006	2007	2008
Primary (PS)	1,820	1,301	2,472	2,589	2,712	2,712
Secondary (WAS)	1,944	2,522	2,034	1,985	2,265	2,022
WAS sonicated	-	-	900*	1,591	2,075	1,874
Mixed (PS+WAS)	3,764	3,823	4,506	4,574	4,977	3,797
Digested VS	1,831	1,588	2,094	1,936	1,521	1,157
Degraded VS	944	1,088	1,285	1,586	2,321	1,767
Specific degrad. (kgVSdeg/m^3*d)	0.38	0.42	0.50	0.62	0.91	0.69
HRT 1st stage digestion (d)	14.7	13.9	15.3	15.5	16.5	18.6
HRT total digestion (d)	20.6	19.4	21.4	21.7	22.7	24.8

Table 1: Sludge Streams At Bamberg STP Between 2003-2008

	2003	2004	2005	2006	2007	2008
Biogas (103m^3/a)	1,810	1,556	1,762	1,874	2,712	2,007
Biogas (m^3/kgVSin)	0.65	0.58	0.52	0.53	0.49	0.69
Biogas (m^3/kgVSdeg)	1.92	1.43	1.40	1.18	0.78	1.14
Biogas 1.stage (10^3m^3/a)	1,290	1,299	1,488	1,592	1,533	1,449
Biogas 1.stage (m^3/kgVSin)	0.46	0.49	0.44	0.45	0.40	0.50
Biogas 1.stage (m^3/kgVSdeg)	1.37	1.19	1.16	1.00	0.66	0.82

Table 2: Biogas Production From 2003 To 2008

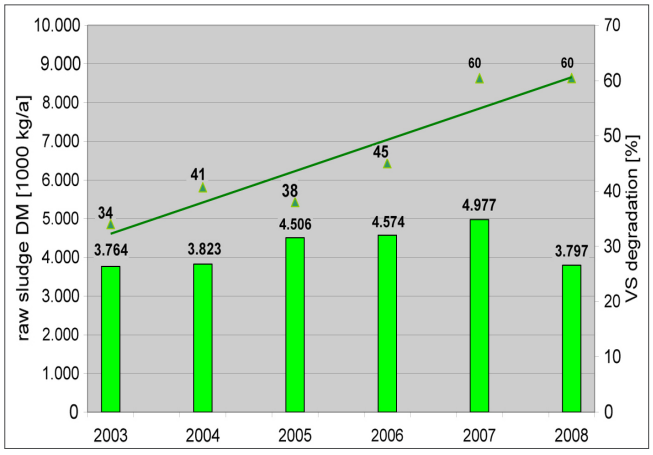


Figure 3: Sludge feed and increase in VS degradation; ultrasonic disintegration in operation since August 2004

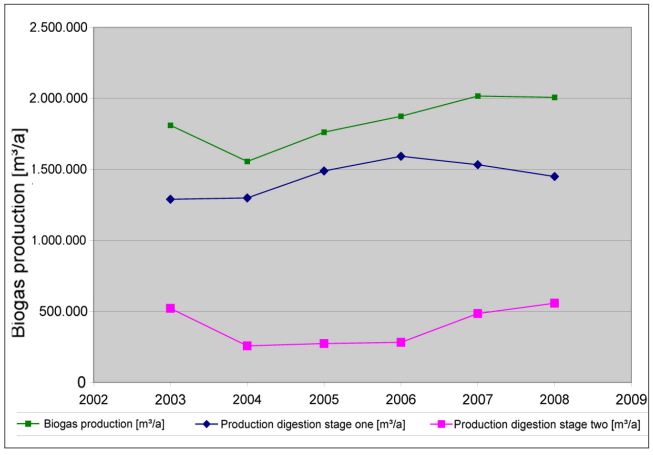


Figure 4: Total Biogas Production And Gas Production Of Sole First Digestion Stage; Variation In Gas Production Share Of First Stage

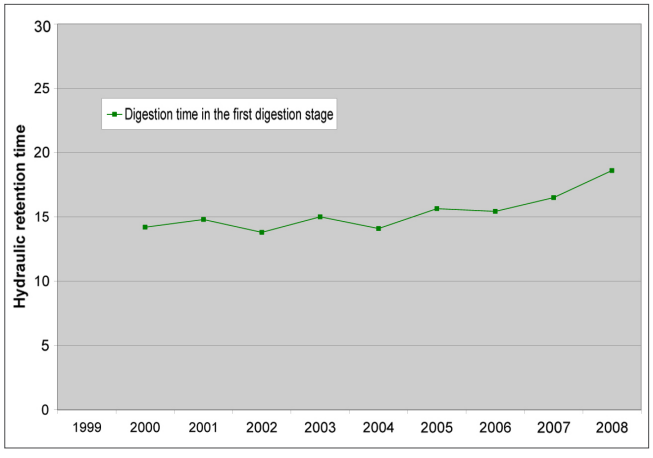


Figure 5: Monthly Variation Of The Hydraulic Retention Time In The First Digestion Stage. Ultrasound Disintegration Is In Operation Since August 2004.

operation 24 hours-a-day all year round and at an average of 80% of the maximum power. The energy consumed was 70,800 kWh/a, representing 1.5% of the total energy consumption at the plant. The calculated average specific energy dose of the ultrasound units is 2.4 kWh/m^3 TWAS (0.041 kWh/kg DS or 148 kJ/kg DS), a value which is well below data published previously by a number of authors (not referred to here) from experiences not collected in real life situations at full scale.

Cost-Benefit Analysis

A condensed cost-benefit analysis taking into account the current Bamberg data reveals that considerable economic benefit can be derived from the new ultrasound installation.

Total yearly benefit: 108,112 €.

Cost/benefit ratio: 42,106 €/108,112 € = 0.39

Ratio energy gain/energy consumption by ultrasound: 963,900 kWhel /70,800 kWhel = 13.6

Net energy gain in 2007 (not taking into account heat energy of CHP): 963,900 kWhel/a - 70,800 kWhel/a = 893,100 kWhel/a

Today Bamberg WWTP is the very first wastewater treatment plant at which the net electrical energy is produced just by the anaerobic treatment of their own sludge. Due to the high performance energy of anaerobic sewage sludge digestion, electrical energy production is higher than electrical energy consumption of the whole WWTP.

About The Authors

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