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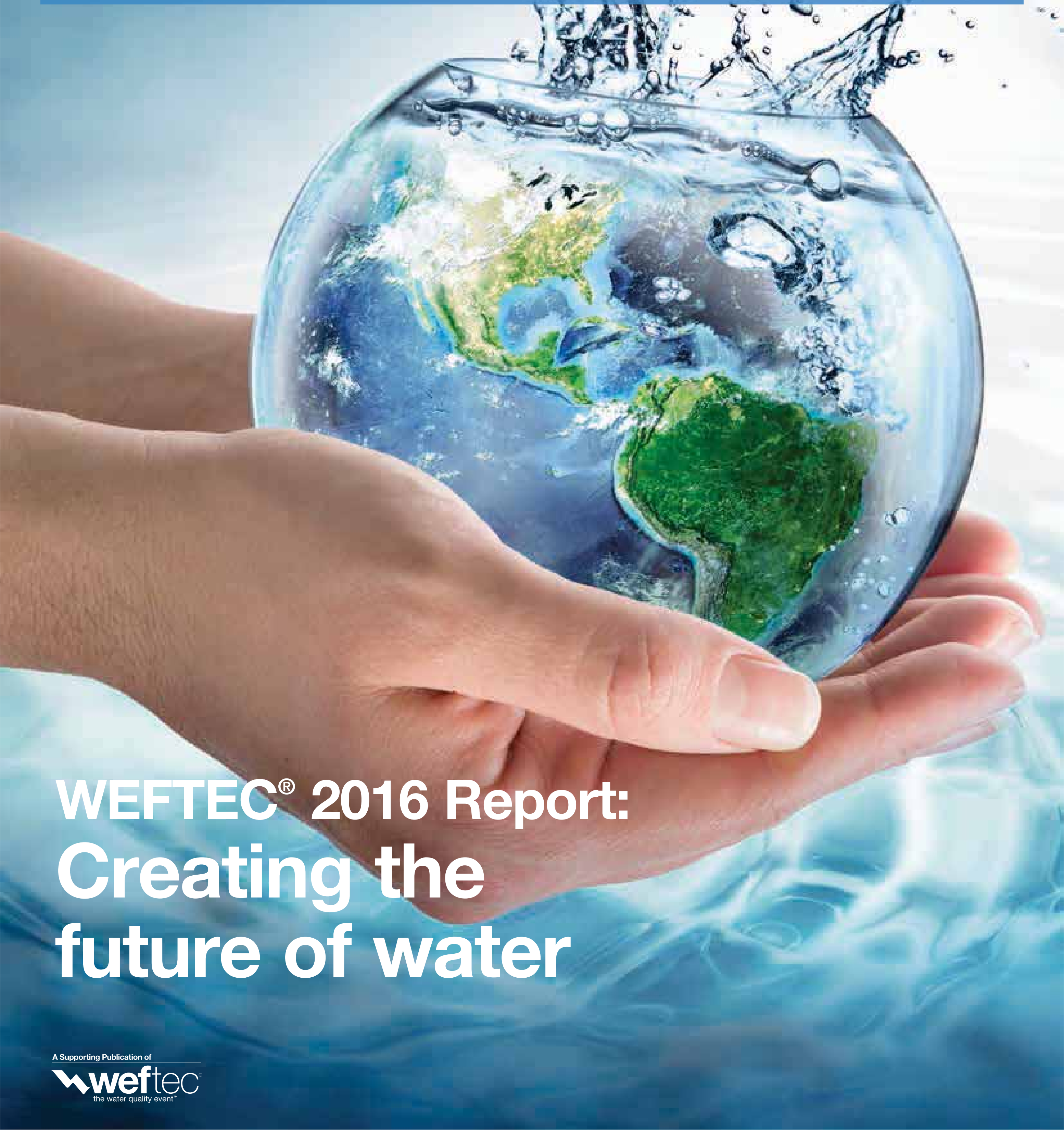

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Ultrasound technology to achieve energy self-sufficiency

The use of high-power ultrasound to intensify the sludge digestion process improves the operational efficiency of water resource recovery facilities in multiple ways, according to **Gunnar Klingspor**, **Dr. Klaus Nickel**, and **Professor Uwe Neis** of Ultrawaves Wasser & Umwelttechnologien GmbH. The authors explain the benefits of the technology and how it works.

Energy independence is now an attainable goal for water resource recovery facilities. Biogas, produced from sewage sludge during the energy-intensive wastewater treatment process, is being used to fuel the energy needs of increasing numbers of municipal treatment facilities around the world, including the Al Aweer wastewater treatment plant in Dubai, United Arab Emirates, and the Arrudas wastewater treatment plant in Belo Horizonte, Brazil. This strategy also helps to reduce the volume of sludge that must be disposed of safely while helping to reduce high-energy costs borne by municipalities.

In 2001, the German company Ultrawaves developed an innovative, high-power ultrasound (HPUS) technology in partnership with Hamburg Technical University (TUHH) in order to improve the efficiency of sewage sludge treatment. Since then, Ultrawaves has made further advances based on experiences from research and praxis. Today, more than 100 of the patented Ultrawaves HPUS systems are installed in 20 countries worldwide.

Ultrasound, the conversion of electrical energy into mechanical oscillations, has a frequency range greater than or equal to 20 kilohertz (kHz). Acoustic waves cause periodical compression and expansion in fluids. Cavitation can be generated by using ultrasound with high acoustic intensity of greater than 5 watts per square centimeter (W/cm^2). During the underpressure phase, small bubbles containing gas and steam are generated and implode in the following pressure phase. In microscale, local pressures of up to 500 bar and temperatures of up to 5,000 degrees Celsius (°C) occur. The implosions create fast local streams, so-called jet streams, thereby releasing extreme mechanical shear forces, which lead to the effective decomposition of the particulate biomass. The result is an accelerated hydrolysis phase, which is the rate-determining step within a conven-tional anaerobic degradation process. This technical limitation can be overcome in an ultrasound-intensified digestion process. Additionally, the technology can sustainably eliminate operational problems such as foaming in the digesters and the formation of bulking sludge. The use of ultrasound also enhances aerobic sludge stabilization, thereby increasing plant efficiency in many ways.

Intensifying anaerobic sludge stabilization

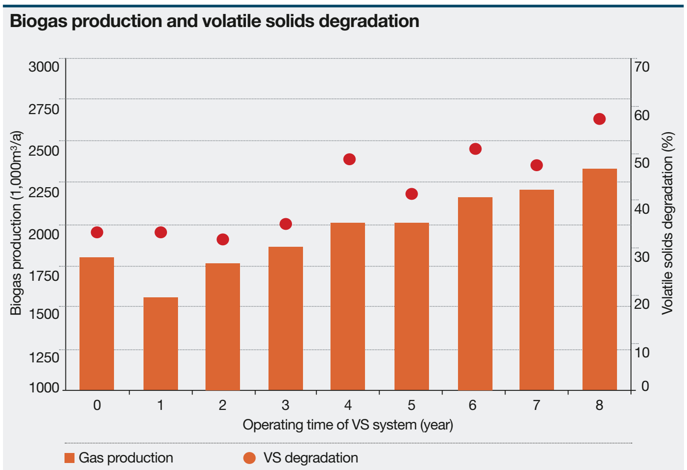
Anaerobic sludge stabilization is limited by the rate-determining hydrolysis of the particulate phase. Conventional anaerobic sludge stabilization rarely achieves 50 percent degradation of organic sludge. Low rates of degradation are caused by the low accessibility of the excess sludge bacteria cells for the active anaerobic and facultative anaerobic bacteria, respectively. During ultrasonication the excess sludge is disintegrated, improving its availability to undergo the following biological-enzymatic degradation process.

In the degradation process, a low ultrasound energy input breaks down the floc structure, which releases exoenzymes. This occurrence increases the interface between the solid and the fluid phase, thereby facilitating the enzymatic attack of the active microorganisms. A higher energy input leads to the complete disruption of bacteria cells, which results in the release of cell contents and endoenzymes. These enzymes lead to a further acceleration of the degradation process. Consequently, the limitations inherent in the hydrolysis step are overcome, which enables the whole digestion process to be intensified, and the organic fraction can be further degraded.

In summary, this process leads to an increase in biogas production, a better yield of the energy carrier methane, and less sludge for disposal. Using ultrasound increases at least tenfold the electrical energy generated from the additional biogas. To explain in more detail, the use of Ultrawaves' high-power ultrasound technology improves the sludge degradation process by 20 to 30 percent, which, in turn, improves biogas production by 20 to 30 percent. Biogas consists of 50 to 60 percent methane and 40 percent carbon dioxide. The methane is used as fuel in a combined heat and power plant (cogeneration plant). Assuming that the improvement in biogas production is 20 percent and the methane concentration is 50 percent, 10 percent more electrical power can be generated using high-power ultrasound technology.

Furthermore, the volume of residual sludge for disposal will be significantly lower. Consequently, costs for disposal can be saved, and the dewaterability will be improved as internal cell water becomes available for the dewatering device after disintegration. Also advanta-

Results of ultrasound HPUS units installed at the Bamburg water resource recovery facility. Photo by Ultrawaves




Microscopic analysis of filamentous structures before (left) and after (right) sonication. Photo by Ultrawaves

geous, the sonicated sludge is less viscous, which is especially important for operational purposes because less energy is needed for mixing the digesters. The application of ultrasound enables long-term operation of systems that are driven at their maximum load without any problems. Therefore, new digesters can be designed with a shorter retention time right from the beginning as the degradation process occurs much faster with an installed ultrasound technology.

Energy surplus

An installation of Ultrawaves HPUS technology at the Bamberg, Germany, water resource recovery plant has helped enable the plant to generate more electrical power produced from anaerobic sludge digestion than is necessary to treat wastewater. At the Bamberg facility, following the city's upgrade and expansion of its collection system, a 50 percent increase in wastewater load – from a 220,000 persons equivalent (pe) to 330,000 pe – resulted in the production of more sludge and a reduction in total retention time in the three existing digesters to less than 20 days. The problem could have been solved by building a new digester; however, the technical managers decided to avoid the cost of constructing a new US$2.7-million digester. Instead, they installed two Ultrawaves HPUS systems in 2006 after demonstration tests confirmed the technology efficacy, revealing that the ultrasound system increased degradation of organic sewage sludge components from 34 percent in the conventional case to 58 percent with disintegration. It also increased biogas production by more than 30 percent. Such an improvement is typical and has also been demonstrated at the Dabrowa-Gornicza, Poland, wastewater treatment plant (HPUS since 2008) and at the Shek Wu Hui, Hong Kong, wastewater treatment plant (HPUS in 2014), for example.

Given this experience, the long-term effects of excess sludge ultrasonication can be verified. In October 2010, new gas engines with higher electrical efficiency were installed at the Bamberg facility, which led to further improvement. Together with the enhancement caused by the HPUS technology, the Bamberg facility became the first European energy-autarkic water resource recovery facility of its size (330,000 pe) in producing an excess of electrical power. Additionally, the Bargteheide wastewater treatment plant in Germany has been energy-independent since Ultrawaves HPUS technology was installed in 2012. In recognition of these achievements, the community was awarded with the gold medal of the Energy Olympics by the Federal State of Schleswig-Holstein one year later.

Preventing bulking sludge and foaming

The problems with bulking sludge in wastewater treatment plants often occur on a seasonal basis and can be prevented by the installation of an ultrasound system. In most cases, the problems arise due to filamentous bacteria present in the sludge. Foaming in the digesters is also a familiar phenomenon that may lead to serious operational problems. The ultrasonication of excess sludge creates permanent stress – through cavitation and alternating pressures in the fluid – to causative bacteria biomass. In particular, this process affects filamentous bacteria and can eliminate it permanently. Consequently, the formation of bulking sludge can be prevented by the application of ultrasound in order to ensure stable operation of the treatment plant.

For example, the Meldorf, Germany, water resource recovery facility struggled with operational problems in its two digesters for many years. The facility treats wastewater with a high fraction of industrial effluent (sour products) of approximately 70,000 pe.

Filamentous bacteria (Microthrix parvicella) in the excess sludge caused a strong foaming, which led to excessive foaming in the digesters

>> **The problems with bulking sludge in wastewater treatment plants often occur on a seasonal basis and can be prevented by the installation of an ultrasound system.** >>

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and caused problems with biogas production. Foam formation was so high that up to one third of the total digester content streamed out and was spread over the buildings and the treatment site. The costs of cleanup and disposal were enormous, and the use of biogas during the foaming was impossible, resulting in further loss.

To solve the foaming problems, an Ultrawaves ultrasound system was tested in August 2004. Immediately after the beginning of the test phase, foam formation during anaerobic digestion decreased and finally stopped. After a short time, the co-ferments (sauerkraut brine) could be added again without causing operational problems.

Ultrasound disintegration had to be stopped due to renovation works at the treatment plant, and the foaming problems occurred again. However, they again stopped after ultrasound disintegration was restarted. The comparison of microscopic images of the excess sludge before and after the sonication serves as a proof of the success. While the sludge flocs were very stringy before the ultrasound disintegration, the filamentous micro-organisms were totally disintegrated after ultrasonication. Since the ultrasound system was installed on a permanent basis in May 2005, no foam formation has occurred. This immediate consequence was also recorded at wastewater treatment plants in Schleswig, Germany, and in Kirkby-in-Ashfield, United Kingdom, since HPUS were installed in 2011 and 2014, respectively. Bulking or foaming never occurred again in these facilities.

Improving aerobic sludge stabilization

Another advantage of Ultrawaves HPUS technology is that it allows biological nitrogen degradation during wastewater treatment to occur without the addition of carbon carriers such as methanol.

The biological nitrogen decomposition, performed by nitrification and denitrification, requires the dosage of additional carbon to the denitrification step. Conventionally, an external carbon source is added, but during sonication of a biomass suspension, the material is cracked, and cell components are set free, which could serve as an internal carbon source for the denitrification step. For this reason, biological nitrogen degradation in the treatment process may happen without adding external carbon carriers. Moreover, the recirculation of a partial flow of the sonicated excess sludge automatically leads to a reduction of the sludge amount that must be disposed.

As an example, the Bünde water resource recovery facility in Germany is methanol-independent because it uses ultrasound for denitrification. In 2006, the Bünde treatment plant, which has a capacity of 40,000 pe, installed a 5-kW Ultrawaves HPUS system to sonicate 40 to 50 percent of the thickened excess sludge. The plant was required to eliminate nitrogen in its treated effluent to comply with very low nitrogen regulatory limits.

The ultrasonicated volumetric flow was pumped back into the activated sludge tanks. During the 4-month test phase, nitrogen concentration in the outflow was significantly reduced by 3 milligrams per liter (mg/l). Similar values were achieved in wastewater treatment plants following installation of HPUS at the Wuijang II facility in China and at the Maroochydore plant in Australia in 2008 and 2013, respectively.

In Bünde, the costs for the ultrasound system could be allocated entirely against the fee for the effluent charge of the last 3 years before its installation. An added benefit is that the system enabled the treatment facility to become independent from methanol as an external carbon source. The Ultrawaves HPUS system was permanently installed at the Bünde treatment plant in September 2006, and a second 5-kW unit was installed in 2007 to intensify sludge digestion.

Conclusion

The treatment of excess sludge with Ultrawaves HPUS technology can improve the efficiency of water resource recovery facilities in multiple ways – by improving aerobic and anaerobic sludge stabilization, preventing foaming problems during digestion, increasing biogas production, and providing additional beneficial effects. The German technology is sold worldwide via local sales partners, and in 2016 Ultrawaves already signed new distribution agreements for Israel and South Korea.

Author's Note

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Onsite treatment recycles produced water for irrigation

Two US companies – OriginClear and ECT Services & Solutions – team up to recycle produced water on the site of oil and gas operations for use in agricultural lands in drought-stricken California. OriginClear CEO Riggs Eckelberry explains how the innovative, modular ECOPOD system works.

As burgeoning industries and a rapidly growing global population continue to strain the planet's limited freshwater, water security has become one of the world's greatest challenges. Among the largest consumers of water are the agriculture and industrial sectors, with industry consuming nearly 60 percent of available water in high income countries, according to the United Nations. In light of this trend, it is imperative that industrial water recycling and large-scale municipal water reclamation should be a high priority worldwide.

The fossil fuel and power sectors consume the most water among industrial players, making this a ripe area for reevaluating water reuse and conservation. Petroleum refineries, power plants, and others across the value chain are collectively responsible for billions of liters of polluted wastewater every day, much of which is pumped into deep-injection wells to remain indefinitely out-of-sight and out-of-mind. In other cases, producers of polluted water pay to have the liquid trucked offsite for treatment at purification plants thousands of miles away.

Two common motivators behind this behavior are strict water-quality standards at the local level and high costs for specialized water treatment. Trucking polluted water elsewhere might seem to solve an immediate problem, but treating it offsite leads to high costs associated with getting rid of the acids, salts, toxins, and other contaminants, all of which must be filtered and removed before the produced water can be reintegrated into the municipal water system.

However, in sending polluted water away for treatment, businesses are throwing out what ought to be considered one of their most precious operating inputs merely for the sake of controlling costs. While this practice may

Produced water at varying stages of treatment using the ECOPOD system, which incorporates OriginClear's EWS technology. Photo by OriginClear