Ultrasonic Sludge Disintegration is a "Bubbly" Solution for an Anaerobic Digestion or BNR Process

Bryen Woo, PE
Aeration/Aerobic Digestion Product Manager
OVIVO USA, LLC
2404 Rutland Drive
Austin, Texas 78758
Ph: 512-652-5818
E-Mail: bryen.woo@ovivowater.com

James Goldhardt
Anaerobic Digestion Marketing Manager
OVIVO USA, LLC
4225 Lake Park Blvd, Suite 100
Salt Lake City, UT 84120
Ph: 801-931-3070
E-Mail: james.goldhardt@ovivowater.com

INTRODUCTION

One of the ongoing challenges in wastewater treatment facilities is handling the Biosolids. It has been found that the total Biosolids generation continues to increase each year. In fact, the processing, treatment and disposal of sludge for beneficial use accounts for approximately 40% to 60% of the total wastewater treatment plant expenditures. These expenditures can certainly add up over the life of a wastewater treatment plant, therefore it is important when designing a wastewater treatment plant, to have an efficient and effectively operated solids handling system. Ultrasonic sludge disintegration, by way of ultrasound, is a proven method to help mitigate this very issue.

BACKGROUND AND DESCRPTION OF ULTRASOUND AND THE ULTRASONIC SLUDGE DISINTEGRATION TECHNOLOGY

Sound travels in waves and generates acoustic energy. The human audible frequency range is between 20 Hz to 20 kHz, anything above that is referred to as ultrasound. A sound wave, at any given frequency, has a minimum and maximum point referred to as rarefaction and compression. During the rarefaction stage particles move away from each other into lower density areas to create a lower pressure. In the compression stage, particles move together into high density areas to create a higher pressure (or the opposite of rarefaction).

By way of ultrasound, acoustic cavitation can be created. When sonicating liquids (applying acoustic energy to agitate particles), the sound waves alternating between compression and rarefaction cycles, where small voids are created in the liquid creating micorbubbles As shown in Figure 1, the bubbles will grow until they attain a volume at which they can no longer absorb any energy. At that state, the bubbles implode violently (during the compression cycle). This implosion is referred to as cavitation and in liquids, produces an enormous amount of energy. It is estimated that these bubbles (from cavitation) have temperatures as hot as 8,900 deg F and pressures as high as 7,250 psi.

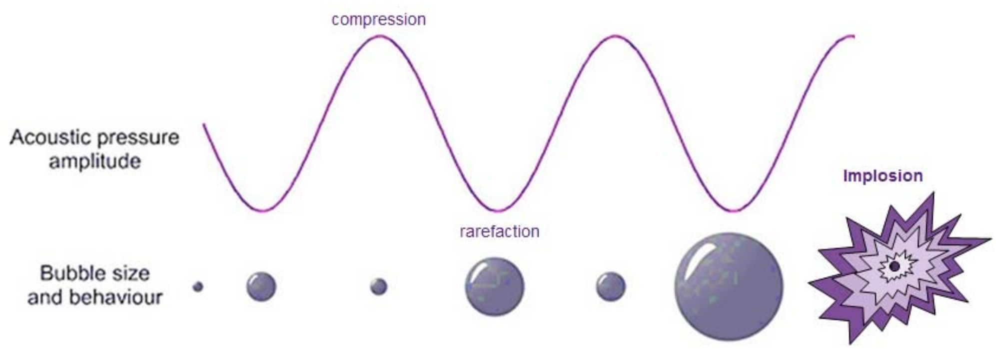

Figure 1 - Acoustic Cavitation

Ultrasonic sludge disintegration uses acoustic cavitation as a means to provide the necessary physical and chemical changes in order to rupture the cell walls of sludge microorganisms. Ultrasonic energy is very effective primarily because the compression of the bubbles during cavitation is more rapid than thermal transport allowing for a localized “hot spot” to be created. The localized hot spot allows for sludge disintegration to occur easily as it only takes approximately 100 microseconds for cavitation to occur and less than 400 microseconds for microorganism cell walls to rupture.

Ultrasonic Sludge Disintegration is a prime application for improving the anaerobic digestion process and for Biological Nutrient Removal (BNR) processes. A typical Ultrasonic Reactor shown in Figure 2 below consists of a 5 kW control power supply producing ultrasonic energy and an oscillating unit consisting of a transducer, booster, and horn that is positioned within the contacting reactor applying ultrasonic energy to the feed sludge.

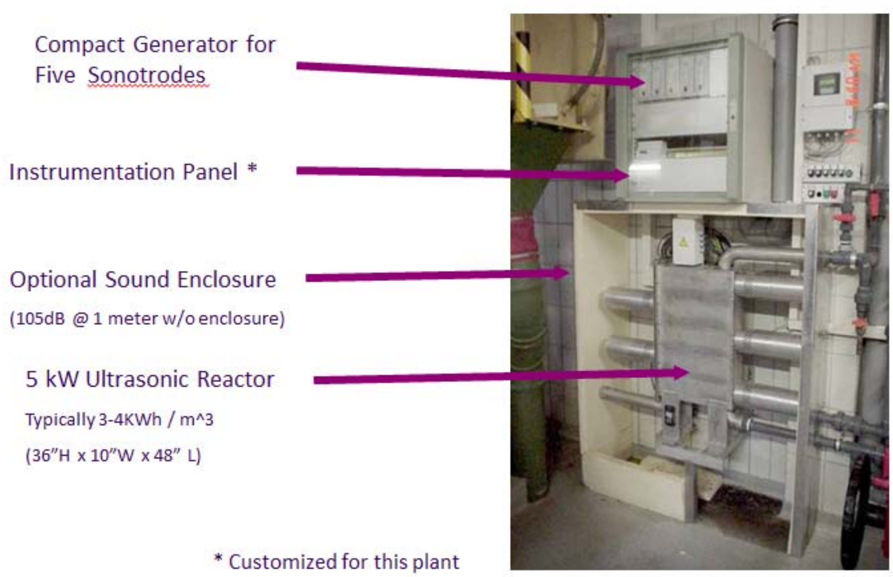

Figure 2 - Ultrasonic Reactor

Certain criteria are needed for optimizing the Ultrasonic Reactor, one of which is the feed sludge type. Since primary waste is highly degradable, it is recommended that only the thickened waste active sludge (TWAS) be treated. The TWAS being treated should be in the range of 30,000 to 60,000 mg/L solids concentration. A thicker solids content optimizes the effectiveness of the reactor because water in sludge acts as a barrier from the ultrasound minimizing the effectiveness of the acoustic cavitation. Sludge with minimal water content will cause rupturing of the microorganisms more effectively. Figure 3 shows the optimal locations (as described above) for placing the Ultrasonic Reactor in a wastewater treatment process. The Ultrasonic Reactor can be placed in either of the two locations shown below; however, they can also be used in both.

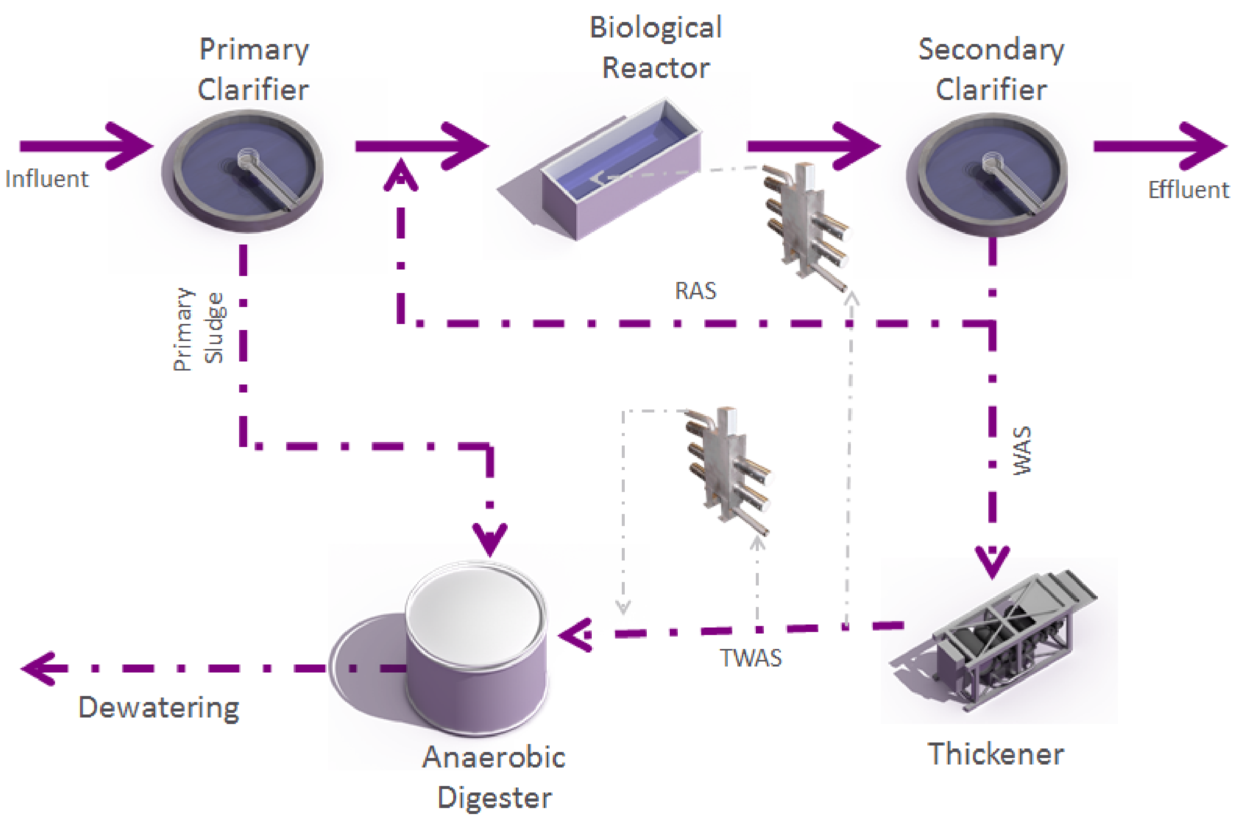

Figure 3 - Ultrasonic Reactor Placement Locations

ULTRASONIC DISINTIGRATION IN ANAEROBIC DIGESTION APPLICATIONS

Providing pretreatment with the ultrasonic reactor prior to the anaerobic digestion process provides several benefits including a 15% to 30% improved methane gas production, increased volatile solids destruction (resulting in reduced sludge disposal costs and/or reduced tank sizes and retention times), viscosity reduction, foaming control, and even improved dewatering.

There are four stages of the anaerobic digestion process and it is well known that the first stage, hydrolysis (complex organic matter to soluble organic molecules), is the rate limiting step and therefore should this stage be altered or “boosted” the Anaerobic Digestion process is able to be improved. Ultrasonic Disintegration not only breaks the sludge floc apart, but with the appropriate dose, the microorganism cell walls are ruptured providing easy access to the intercellular material (See Figure 4).

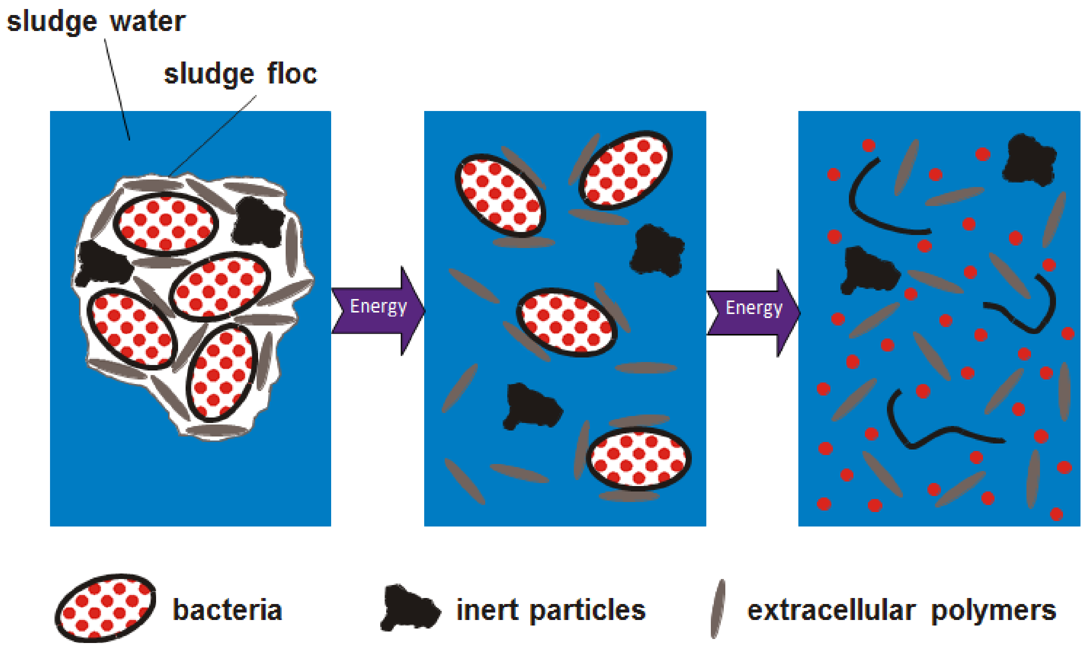

Figure 4 - Ultrasonic Sludge Disintegration

The cell lysis created by the Ultrasonic Reactor has been shown to change the reaction kinetics of the anaerobic digested sludge. The process allows for improved volatile solids (VS) reduction, which in turn correlates to an increased gas production. Because of the change in the reaction kinetics, the hydraulic retention time (HRT) is also altered allowing for more capacity in the digester tank. One study found (comparing treated vs. non-treated sludge) that the VS destruction with a 4 day HRT on a treated sample had the same VS destruction on a non-treated sample with a 16 day HRT.

Ultrasonic sludge disintegration is an excellent application for Anaerobic Digesters that have a short HRT (overloaded), low VS destruction or even low gas production. Utilizing the ultrasonic reactor is an excellent way to help "supercharge" an anaerobic digester.

ANAEROBIC DIGESTION APPLICATION CASE STUDY: BAMBERG WWTP, GERMANY

The Bamberg WWTP is a traditional activated sludge plant having a 12 MGD design capacity, however, was actually being loaded around 15 MGD equating to an 18 day digestion time in the anaerobic digesters. The plant selected to use Ultrasonic Sludge Disintegration to pretreat the sludge prior to entering the digester. The Ultrasonic Reactor was tested to determine if the technology could be used in lieu of building a new digester.

Results: The Ultrasonic Reactor was tested for a four month period where 30% of the TWAS flow was treated (as shown as one of the placement locations in Figure 3, going from the TWAS to the digester). After the testing period, the data showed the following:

- Improved VS destruction from 42% to 54%
- Digested sludge VS reduced from 60% (as percent of TS) to 54%
- Biogas production increase by 30%

Due to the successful testing, the plant elected to keep the Ultrasonic Reactor and avoided the construction of a new digester.

ULTRASONIC SLUDGE DISINTIGRATION IN BNR APPLICATIONS

In order to achieve complete nitrogen removal the denitrification process must occur. Denitrification is the biological reduction of nitrate (NO_3) into nitrogen gas by facultative heterotrophic microorganisms. There are three items required to achieve denitrification: 1) heterotrophic bacteria, 2) nitrate which is used as an energy source by the microorganisms to metabolize and oxidize organic matter and, 3) organic matter which serves as a food source for the heterotrophic bacteria to survive.

Carbon requirements are a very important aspect of the denitrification process. As a rule of thumb a 6:1 carbon to nitrogen ratio is required to achieve complete nitrogen removal. Many wastewater treatment facilities find maintaining this ratio can be problematic especially ones with solids handling processes that recycle excessive nitrogen back to the liquid treatment processes which causes depletion of the carbon to nitrogen ratio. There are up to 200 wastewater treatment facilities in the United States that add methanol to achieve denitrification. Although the addition of methanol is common and relatively inexpensive there are disadvantages such as increases in sludge loads and disposal costs, fluctuating prices (typically between $1.50 to $3.50 gallon) since most of it is imported, and very dangerous to handle since methanol is flammable.

Ultrasonic Sludge Disintegration is an excellent application for any wastewater treatment facilities that have Biological Nutrient Removal (BNR) processes that are adding external carbon sources such as methanol or MicroC™ to achieve the denitrification process for complete nitrogen removal. Ultrasonic pretreatment technology causes the cell walls of microorganisms to rupture which allows their cellular material to be available as an additional source of organic matter. Ultrasonic pretreatment technology provides an internal carbon source and prevents the addition of external carbon sources. There is substantial operating cost savings by preventing the addition of external carbon source. It requires approximately 3.5 pounds of methanol to remove 1 pound of nitrogen. For example, a 5MGD wastewater treatment facility will spend approximately $80,000 annually on methanol addition for every 10 mg/L of nitrogen (420 pounds per day of nitrogen) that needs to be removed and this assumes a methanol cost of $1.00 per gallon.

BNR APPLICATION CASE STUDY: DATANSHA WWTP, GUANGZHOU, CHINA

Datansha WWTP in Guangzhou, China operates a conventional activated sludge process where they added methanol to achieve denitrification. In order to eliminate methanol addition Datansha WWTP added an Ultrasonic Reactor downstream from the sludge thickener (as shown as one of the placement locations in Figure 3, going from the TWAS to the biological reactor). After the sludge passes through the Ultrasonic Reactor it is fed into the Bio Tanks of the activated sludge process and used as a carbon source to achieve denitrification. In comparison to methanol addition, by using the ultrasonic reactor at Datansha WWTP, there was a 20% to 30% increase in nitrogen removal, 80% cost savings, and sludge minimization of 15%