Effect of Ultrasound in Improving Dewatering and Stabilization of Anaerobic Digested Sludge

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Introduction
Large quantities of sludge are produced in biological wastewater treatment. This kind of sludge or biosolids are very putrescible. The primary sludge being produced in primary sedimentation tank is very putrescible, odorous, and grey, from which 60-70 percent is volatile solids. The secondary sludge being produced in primary sedimentation tank is brown, odourless and highly microbial containing 70-80 percent volatile solids. The sludge with these properties has problems not less than domestic wastewater. Therefore, the sludge should be stabilized for safe utilization and disposal in environment.

In large wastewater treatment plants high quantities of sludge are produced. Therefore, prior to disposal, solids must be processed for dewatering and reduction of its volatile solids. The processes prior to sludge disposal are thickening, dewatering and stabilization. Dewatering of sludge is reducing transfer and disposal costs. Typical methods for dewatering are filtering, centrifuge and drying sludge bed. At the present time, sludge undergoes many important technical challenges and about 50% of the investments and operation costs are associated with sludge treatment.

Usually for the stabilization of sludge, biological digestion processes are used. The digestion methods could be aerobic or anaerobic process. The anaerobic digestion has been studied many years ago and was used for sludge stabilization. This process includes degradation of organic and inorganic compounds in the absence of molecular oxygen. The main application of stabilization process is thickening of sludge from wastewater treatment plants and treatment of industrial wastes. The anaerobic process is a standard technique for sludge stabilization.

With regard to the limitation in hydrolysis phase, anaerobic degradation of sludge is a very slow process. This process requires a high fermentative microorganism mass with typical detention time of more than 20 days for sludge digestion. The rate of degradation of organic compounds is in the range of 50 to 60%. Investigation showed that for a better sludge hydrolysis, the following processes is suggested:
1) Chemical solubilisation, 2) thermal pre-treatment, 3) mechanical sludge degradation, and 4) ultrasonic cell degradation.

Some advantages of ultrasound pre-treatment of sludge are as below:
- Low cost and efficient operation compared to other pre-treatment processes.
- Complete process automation.
- Potential to control filamentous bulking and foaming in the digester.
- Better digester stability.
- Improved volatile solid destruction.
- Better sludge dewatering ability.
- Improved sludge quality.

The Usage of ultrasonic process for pollutant degradation in water and wastewater treatment was an advanced oxidation process, which is developed as an efficient technology in different fields of environmental engineering science in order to protect the environment from pollutants and as a key technology for future in the world.

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Since 1954, experimental and laboratory studies have shown that the ultrasonic wave in water and wastewater leads to remove organic pollutants due to OH radicals produced by acoustic cavitation. Therefore, ultrasonic process is an AOP leading to a haemolytic shear in water molecules. The process itself and directly or indirectly with other methods such as ozonation, UV etc, in order to degrade pollutants such as VOCs, organic chlorinated pollutants, benzene compounds, MTBEs, organic toxins, THMs, TNTs etc, is quite efficient and leads to achieving better results in comparison with each individual method.

Recent reports show an increase in the application of ultrasonic wave in the degradation of sludge in large scale. Also, ultrasonic wave is effective on the hydrolysis and improvement of biological degradation of various organic compound in dairy industry and aerobic digestion in activated sludge.

Due to high detention times for the stabilization and difficulties in sludge dewatering, sludge digestion requires the application of other methods in order to reduce the detention time and neglect any limitation and finally decrease the operation and maintenance costs. Ultrasonic process increases the enzymatic activity and thus decreases the detention time and time of hydrolysis which is a limiting factor in digestion process. The objective of this investigation is to determine the effect of ultrasound in improving dewatering and stabilization of anaerobic digested sludge.

Materials and methods

In this investigation samples of anaerobic sludge digester were collected from local full-scale wastewater treatment plant in Tehran. Twenty samples were collected from each type of digester. Two samples were taken every week. Sludge samples were taken to the Laboratory of Public Health Tehran University of Medical Sciences. Two frequencies of 35 and 131 kHz of ultrasonic waves were used. Each of the sludge samples were exposed with four different times of 15, 30, 60 and 90 minutes. On the raw samples and samples under the ultrasonic wave, tests of total solids, volatile solids, pH, temperature, total COD, dissolve COD and settetable solids can be done. Testing methods of 2540 for solids, 5220C, 5520D for COD, 2540 E for settetable solid from the standard methods were used.

Results

According to the experiments conducted, the average parameters measured in the samples of raw sludge and sludge weakened by sound waves at ultrasonic frequencies of 35 and 131 kHz, at four different times in the local full-scale wastewater treatment plant of Tehran, are shown in Table 1.

Table 2 presents the comparison between the performances of ultrasonic waves at the frequencies and different times in anaerobic digester.

Table 1: Means of measured parameters in anaerobic digestion and sonication sample

<table>
<thead>
<tr>
<th>Time (min)</th>
<th>15</th>
<th>30</th>
<th>60</th>
<th>90</th>
<th>Raw Sludge</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency (kHz)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TS (mg/L)</td>
<td>35</td>
<td>802</td>
<td>7775</td>
<td>427</td>
<td>7.07</td>
</tr>
<tr>
<td>VS (mg/L)</td>
<td>310</td>
<td>733</td>
<td>7075</td>
<td>410</td>
<td>6.99</td>
</tr>
<tr>
<td>TCOD (mg/L)</td>
<td>5891</td>
<td>949</td>
<td>6725</td>
<td>455</td>
<td>6.92</td>
</tr>
<tr>
<td>DCOD (mg/L)</td>
<td>3500</td>
<td>1172</td>
<td>7525</td>
<td>375</td>
<td>6.95</td>
</tr>
<tr>
<td>pH</td>
<td>650</td>
<td>810</td>
<td>6650</td>
<td>510</td>
<td>6.95</td>
</tr>
<tr>
<td>S. Solids (mg/L)</td>
<td>53.00</td>
<td>933</td>
<td>8750</td>
<td>480</td>
<td>6.90</td>
</tr>
<tr>
<td>Temperature (°C)</td>
<td>28.0</td>
<td>723</td>
<td>7825</td>
<td>700</td>
<td>6.90</td>
</tr>
</tbody>
</table>

Table 2: Reduction percent of volatile solids in the aerobic and an anaerobic digestion samples at different sonication times

<table>
<thead>
<tr>
<th>Time (min)</th>
<th>15</th>
<th>30</th>
<th>60</th>
<th>90</th>
<th>Raw Sludge</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency (kHz)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reduction of VS (%) in Anaerobic Digestion</td>
<td>40.0</td>
<td>29.3</td>
<td>12.76</td>
<td>39.7</td>
<td>46.2</td>
</tr>
</tbody>
</table>

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Discussion
In this study, to measure the total COD, samples were diluted 10 times and to measure the amount of soluble COD, filtered samples were measured without dilution. As it is shown in Table 1, the SCOD increased after sonication in both frequencies. TCOD in the anaerobic digestion sample at raw sludge samples is high and rarely decreases after sonication.

In the anaerobic digester, the highest reduction of VS was in the frequency of 35 kHz at 90 min that equals to 46.2%, and in 131 kHz at 15 min that equals to 45.4%. The results were conformed according to the studies of Klaus Nickel in 2007 in Germany and also the results of the studies of P. Zhang from China in 2007.

The rate of temperature in sonicated sample increased due to heat produced by ultrasonic waves. This increase of temperature was related to the time of sonication and the type of frequency. In higher times of sonication, increase of temperature is higher. The highest increase in temperature was at 90 min and the lowest was at 15 min.

The rate of pH is reverse with temperature, as the sonication samples were reduced. The rate of decrease proportional to frequency and time of sonication, in the higher time and frequency rate of decrease pH is higher. Decrease of pH due to increase of temperature is created by ultrasonic waves.

The rate of settleable solids in imhoff cone with 250 cc at the 30 min are measured for both frequencies and four times of sonication. In anaerobic digester, except for the time of 15 min at the frequency of 35 kHz, settleable solids in other sample were declined. Decrease of settleable solids at the same MLSS creates the thickness of sludge and better dewatering in 131 kHz compared to 35 kHz. The study results of Seungmin Na in South Korea in 2006 conformed this.

Conclusion
The results showed that the application of ultrasonic waves increases the TCOD, SCOD and temperature and reduce volatile solids, pH and settleable solids. Application of ultrasonic waves at frequencies of 131 kHz reduced the volatile solids and sludge dewatering effectively, and increase the ability of the frequency is 35 kHz and the highest efficiency at 15 minutes duration and frequency of 131 kHz. Digestion can improve due to increased activity of enzymes by ultrasonic radiation and alter protein polysaccharides and extracellular enzymes. Therefore, ultrasonic waves help digestion and sludge dewatering and increase functionality as an option in helping Sludge treatment and reducing the volatile solids.

Key words
Anaerobic Digestion, Dewatering, Stabilization, Ultrasonic Wave
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