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EFFECT OF ULTRASOUND FIELD ON DEWATERING OF SEWAGE SLUDGE

PAWEŁ WOLSKI, IWONA ZAWIEJA

Częstochowa University of Technology
Faculty of Engineering and Environmental Protection
Institute of Environmental Engineering
Brzeźnicka 60A, 42-200 Częstochowa, Poland
Corresponding author's e-mail: pwolski@is.pcz.czest.pl

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Abstract: The paper presents the investigations aimed at the determination of the effect of time and wavelength of ultrasound field on the value of capillary suction time (CST), sludge thickening and dry matter of the excess sludge subjected to the process of stabilization.

The investigations were carried out on the excess sludge which comes from communal waste treatment plant. The sludge was exposed to ultrasound field, using ultrasound generator with power of 1500 W, frequency of 20 kHz and amplitude 39.42 μm (which corresponded to the amplitude of 100%). Sonication of the sludge was carried out for different amplitudes and sonication times. The non-conditioned sludge and the sludge initially conditioned with ultrasound field were subjected to the process of stabilization in laboratory flasks ($V = 0.5$ dm^3) for the period of 10 days. On each day, sludge thickening and dewatering capacities were determined.

The sludge subjected to the effect of ultrasound field exhibited elevated levels of CST. However, the sonication time had positive effect on the increase in the degree of thickening for each of the amplitudes studied. Also, the process of stabilization positively affected final thickening and dewatering of the sludge.

INTRODUCTION

Building new sewage treatment plants generates sewage sludge which is treated as waste and increases its amount every year. Legal regulations clearly state that there is a possibility of managing sewage sludge, however, in order to make this feasible sewage sludge should be recovered first and then utilized. The sludge generated in sewage treatment plants is qualified as hazardous, therefore, the negative effects it may have on the natural environment should be neutralized.

The processes used in practice in order to neutralize sewage sludge are connected with stabilization of chemical composition through limitation of the concentration of the organic substrate and volume, and with hygienisation, i.e. deactivation of all pathogenic microorganisms. In order to reduce the volume of the sludge the processes of thickening and dewatering are used. The dewatering processes are associated with the processes of stabilization. The use of anaerobic stabilization of raw sludge improves the degree

of sludge dewatering. Methane fermentation leads to the mineralisation of organic matter and use of the process of conditioning before the dewatering causes the release of the liquid contained in sludge flocs [2, 6].

The use of ultrasound disintegration as one of methods of conditioning leads to the dispersion of the structure of sewage sludge and thus affects intensification of the process of methane fermentation [10, 12, 13]. According to the literature [3, 7, 14], pre-conditioning of the excess sludge subjected to the process of methane fermentation with the ultrasound field positively affects the increase of COD and VFA values in the supernatant liquor. This causes that the interference in the process of methane fermentation through modification of sludge before the process of stabilization affects its final susceptibility to dewatering. Stabilization which is initially supported by the conditioning changes physicochemical composition of the sludge through relaxation of the bonds between the particles of water and sludge. This directly affects the dewatering capacity of the sludge [7, 9].

Knowing the positive impact of pre-conditioning with ultrasound field on the parameters which characterize the effectiveness of stabilization (increase in VFA, COD, biogas generation) [1, 11, 15], the focus of the present study was to verify the effect of exposure time and wavelength of ultrasound field on the level of capillary suction time (CST), sludge thickening and dry matter content in sludge subjected to methane fermentation. The study also aimed at demonstrating that although ultrasonic field deteriorates CSK excess sludge, this has no negative consequences for the filtration properties of sediments after fermentation.

METHODOLOGY

Excess sludge obtained from the Warta Sewage Treatment Plant in Częstochowa was the substrate used in investigation. The function of inoculation was performed by the fermented sludge which was added to the activated sludge in the amount of 10%.

The sludge in the study was exposed to ultrasound field using an ultrasound processor VCX 1500 with the power of 1500 W, frequency of 20 kHz and the amplitude of 39.42 μm (which corresponded to the amplitude of 100%). The investigations were carried out using five amplitudes (20, 40, 60, 80, 100%) and sonication time up to 10 minutes. A sonotrode used in the study was made from titanium 630-0617 tip length of 254 mm and a diameter of 25 mm (recommended for sample volumes up to 4 dm^3). Sonic pre-treatment was conducted in a glass beaker of 0.5 dm^3 capacity. The volume of each sample was 500 ml. Before and after the process of sonication, capillary suction time (CST) and degree of thickening of the samples were determined. For the non-sonicated sludge and the sludge exposed to the ultrasound field with two selected amplitudes (60 and 80%, sonication time of five minutes), the process of stabilization in laboratory flasks (V = 0.5 dm^3) was carried out for the period of 10 days. In order to ensure optimal temperature of mesophilic fermentation (± 35°C), the flasks were placed in a laboratory thermostat. At the same time, for a particular fermentation process 10 samples were subjected to modification, so that each day the analysis could be performed after taking the sample out of the incubator.

Each sample was run in 3 replications. CST time, thickening curves and dry matter content were determined on each day of the process. For the amplitude 60% and sonication time of 5 min the amount of energy supplied in the ultrasonic field pretreatment of tested

samples was 55923 J, which corresponds to 0.0155 kWh, and for 80% it was 69917 J, which corresponds to 0.0194 kWh.

The measurement of the capillary suction time was carried out according to Baskerville's and Galle's methodology based on the measurements of transition of frontal boundary layer of the filtrate as a result of the effect of suction forces in the used paper (Whatman 17).

Gravitational thickening was carried out in 100 ml measurement cylinders. The samples were subjected to the process of sedimentation and volumes of sedimented sludge were read off at the time intervals of 5, 10, 15, 20, 25, 30, 45, 60, 90 and 120 minutes. Based on the measurements of the volume of sludge vs. time, the thickening curves were determined.

RESULTS

The exposure of the excess sludge to ultrasound field caused an increase in the value of capillary suction time and extension of sonication time (Fig. 1).

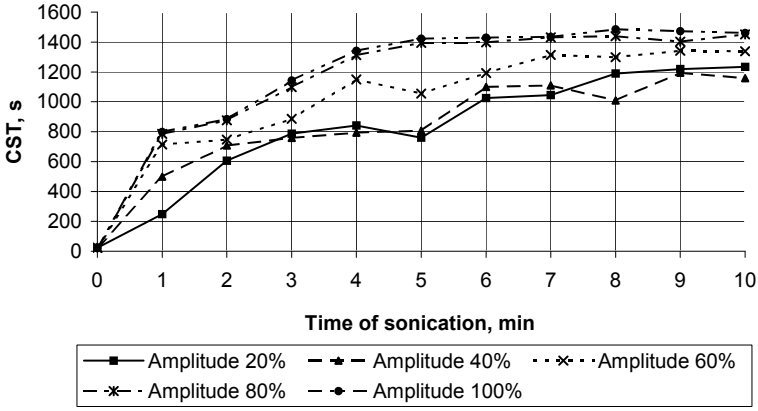


Fig. 1. Effect of amplitude and sonication time on the CST value of sewage sludge

With a higher wavelength of the ultrasound field, the conditioned sludge exhibited longer capillary suction times. The highest level of CST (1461 s) was obtained for 10-minute exposure time to ultrasound field with 100% amplitude which corresponds to the amplitude of 39.42 μm.

When exposing the sludge to ultrasound field, an increase in effectiveness of water release from sewage sludge in the process of thickening was observed. It was found in the sludge subjected to the effect of ultrasound field that the increase in sonication time causes an improved effect of sedimentation which was particularly noticeable after 5 minutes of exposure (Fig. 2). Regardless of the amplitude of the ultrasound field, the sludge after this time exhibited enhanced sedimentation. The best thickening was found for the sludge subjected to the amplitude of 100% and the exposure time of 10 minutes, with final value being 130 ml.

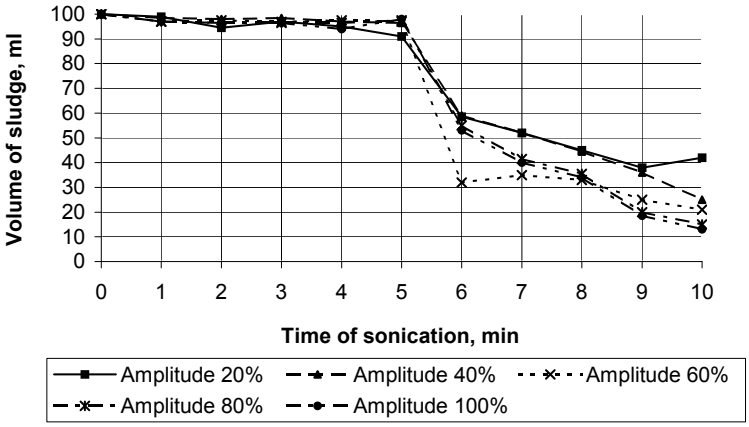
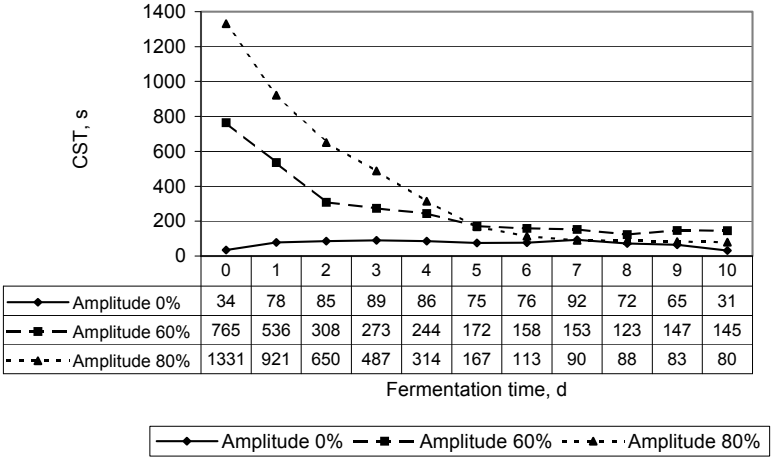


Fig. 2. Effect of amplitude and sonication time on the effectiveness of sludge thickening after 30 min of sedimentation



	0	1	2	3	4	5	6	7	8	9	10
Amplitude 0%	34	78	85	89	86	75	76	92	72	65	31
Amplitude 60%	765	536	308	273	244	172	158	153	123	147	145
Amplitude 80%	1331	921	650	487	314	167	113	90	88	83	80

Fig. 3. Effect of fermentation time on the value CST of excess sludge

In order to determine the effect of fermentation on the dewatering effectiveness of the non-conditioned sewage sludge and the sludge conditioned with ultrasound field (amplitude 60 and 80% and sonication time of 5 minutes), the determination of CST time, thickening curves and dry matter was carried out on each day of the process. The 5-minute ultrasonic field pretreatment was selected because of the first visible changes occurring in the process of sonication. Economic issues of UD field energy consumption were also taken into consideration.

CST values for the non-conditioned sludge subjected to the process of stabilization ranged from 31 to 92 seconds (Fig. 3). Before the process of fermentation, the sludge conditioned with ultrasound field was characterized by high levels of CST (CST for the amplitude of 60% was 765 s, whereas in the case of 80% amplitude this value was

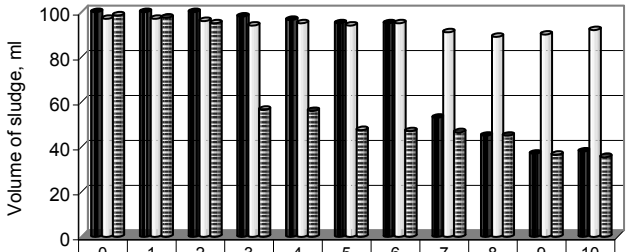
1331 s). It was found that anaerobic stabilization substantially affected the reduction in the value of capillary suction time. On the 5th day of the process, the sludge conditioned with the ultrasound field with the amplitude of 80% showed lower values compared to the CST time for the sludge conditioned with the amplitude of 60% and were similar to the values obtained for non-conditioned sludge.

Stabilization of the sewage sludge positively affected the effectiveness of thickening. This fact was confirmed by the result of thickening presented in Fig. 4. It was observed that on the 3rd day of the process for the sludge exposed to ultrasound field with the amplitude of 80% a noticeable increase in the degree of separation after sedimentation occurred and continued throughout consecutive days of the investigations. The lowest value of the final volume of the thickened sludge was obtained for the sample after the 10th day of the fermentation process and it amounted to 354 ml. After the seventh day of the process, the non-conditioned sludge exhibited enhanced sedimentation, reaching the level of 380 ml on the 10th day.

A decline in dry matter content was observed on consecutive days of the process of stabilization which is connected with biodegradation of the sludge (Fig. 5). No effect of initial conditioning on the increase in the degree of reduction in dry matter was observed. On each day of the process, the degree of dry matter reduction remained at the same level for each sample in the study.

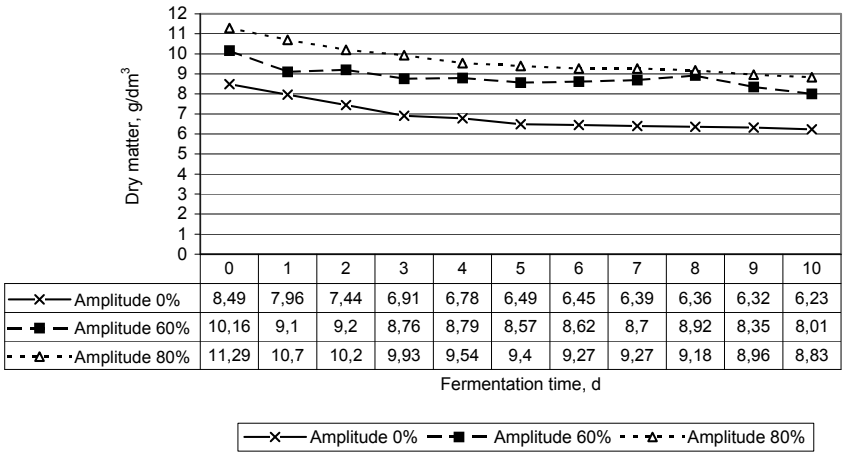
SUMMARY AND CONCLUSIONS

Based on the investigations discussed in the presented paper, the effect of ultrasound field and fermentation on final effect of dewatering of excess sludge was found. Physical modification caused an increase in the value of capillary suction time proportionally with an increase in ultrasound field amplitude. Similar correlations were obtained by Feng and Huan [4, 5], who demonstrated that higher wavelength of ultrasound field, and, consequently, higher energy consumption, resulted in deterioration of the effect



	0	1	2	3	4	5	6	7	8	9	10
Amplituda 0%	100	100	100	98	96,5	95	95	53	45	37	38
Amplituda 60%	97	97	96	94	95	94	95	91	89	90	92
Amplituda 80%	98,5	97,5	95	56,5	56	47,5	47	46,5	45	36,5	35,5

Fig. 4. Effect of ultrasonic pre-conditioning of excess sludge on the change of thickeninig depending on the time fermentation



	0	1	2	3	4	5	6	7	8	9	10
Amplitude 0%	8,49	7,96	7,44	6,91	6,78	6,49	6,45	6,39	6,36	6,32	6,23
Amplitude 60%	10,16	9,1	9,2	8,76	8,79	8,57	8,62	8,7	8,92	8,35	8,01
Amplitude 80%	11,29	10,7	10,2	9,93	9,54	9,4	9,27	9,27	9,18	8,96	8,83

Fig. 5. Effect of ultrasonic pre-conditioning of excess sludge on the change of dry mass depending on the time fermentation

of sludge dewatering. The sludge dispergated as a result of the process of sonication caused clogging of the pores in filtration paper, thus reducing the filtration capacity of the medium, which is an unfavourable effect for the process of dewatering. Changes in the structure caused by the action of ultrasonic field improved the ability of sludge sedimentation. The fragmented particles of the sludge were packed more effectively, thus releasing the excess of free water, which could be observed after 5 minutes of exposure to ultrasound field and thus obtaining noticeable improvement in sludge thickening.

Previous studies have demonstrated that stabilized sewage sludge which was not subjected to initial modification is characterized by worse dewatering capacity. Initial conditioning of excess sludge subjected to the process of fermentation causes reduction in the value of capillary suction time and increase in the degree of thickening. An intervention in the structure of sewage sludge caused gradual reduction in CST value observed on each day of stabilization and improved a degree of separation after sedimentation.

The following conclusions based on the investigations have been drawn:

- Subjecting excess sludge to the exposure to ultrasound field results in a prolonged capillary suction time. The dispersion of sludge flocs, and consequently, the increase in the value of CST, occurred proportionally to the wavelength and time of exposure to ultrasound field.
- Dispersion of flocs in the sludge subjected to ultrasound field caused an increase in the effectiveness of densification of the sludge. Sedimentation occurred more intensively for the sludge after 5 minutes of sonication.
- Fermentation of initially sonicated sludge affected the reduction of CST value. On the eighth day of the process, these values were similar to the capillary suction times observed for the non-conditioned sludge. Stabilization of the excess sludge also contributed to improved sedimentation, thus increasing the effectiveness of sludge thickening.

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REFERENCES

[1] Barański M., I. Zawieja: *Wpływ termicznej hydrolizy na zmiany struktury osadów nadmiernych poddanych stabilizacji beztlenowej*, Inżynieria i Ochrona Środowiska, **13**, 2, 85−91 (2010).
[2] Bień J.: *Osady ściekowe – teoria i praktyka*, Wydawnictwo Politechniki Częstochowskiej, Częstochowa 2007.
[3] Bień J., L. Wolny, I. Zawieja, M. Barański, M. Worwąg: *Wpływ termicznej dezintegracji osadów nadmiernych na generowanie lotnych kwasów tłuszczowych, Oczyszczanie ścieków i przeróbka osadów ściekowych*, Monografia pod red. Z. Sadeckiej, Zielona Góra, 63−69 (2010).
[4] Feng X., J. Deng, H. Lei, T. Bai, Q. Fan, Z. Li: *Dewaterability of Waste Activated Sludge with Ultrasound Conditioning*, Bioresource Technology, **100**, 1074–1081 (2009).
[5] Huan L., J. Yiying, R.B. Mahar, W. Zhiyu, N. Yongfeng: *Effects of Ultrasonic Disintegration on Sludge Microbial Activity and Dewaterability*, Journal of Hazardous Materials, **161**, 1421–1426 (2009).
[6] Machnicka A, K. Grübel, J. Suschka: *The Use of Disintegrated Foam to Accelerate Anaerobic Digestion o Activated Sludge*, Archives of Environmental Protection, **35 (3)**, 11−19 (2009).
[7] Małkowski M., P. Wolski: *Wpływ termicznego kondycjonowania na efektywność odwadniania osadów ściekowych poddanych stabilizacji beztlenowej*, Inżynieria i Ochrona Środowiska, **13 (2)**, 103−109 (2010).
[8] Onyeche T.I., O. Schläfer, H. Bormann, C. Schräder, M. Sievers: *Ultrasonic cell disruption of stabilised sludge with subsequent anaerobic digestion*, Ultrasonics, **40**, 31–35 (2002).
[9] Wolski P., L. Wolny, I. Zawieja: *Kondycjonowanie osadów nadmiernych poddanych stabilizacji a ich odwadnialność*, Inżynieria i Ochrona Środowiska, **13 (1)**, 67−77 (2010).
[10] Yin X., X. Lu, P. Han, Y. Wang: *Ultrasonic treatment on activated sewage sludge from petro-plant for reduction*, Ultrasonics, **44**, 397–399 (2006).
[11] Zawieja I., L. Wolny: *Wpływ mocy procesora ultradźwiękowego na biodegradowalność osadów ściekowych*, Rocznik Ochrony Środowiska, **13 (2)**, 1719−1730 (2011).
[12] Zawieja I., L. Wolny, P. Wolski: *Influence of excessive sludge conditioning on the efficiency of anaerobic stabilization process and biogas generation*, Desalination, **222**, 34−7381 (2008).
[13] Zawieja I., L. Wolny, P. Wolski: *Influence on the modification of food industry excess sludge structure on the effectiveness increase of the anaerobic stabilization process*, Polish Journal of Environmental Studies, Series of monographs, **2**, 261−267 (2010).
[14] Zielewicz E.: *Indicators of ultrasonic disintegration of sewage sludge*, Polish Journal of Environmental Studies, Series of monographs, **2**, 268−272 (2010).
[15] Zielewicz E.: *Dezintegracja ultradźwiękowa osadu nadmiernego w pozyskaniu LKT*, Politechnika Śląska, Gliwice 2007.

WPŁYW POLA ULTRADŹWIĘKOWEGO NA ODWADNIANIE OSADÓW ŚCIEKOWYCH

W artykule przedstawiono badania mające na celu określenie wpływu czasu i długości fali pola ultradźwiękowego na wartości czasu ssania kapilarnego (CSK), zagęszczania oraz suchej masy osadów nadmiernych poddanych procesowi stabilizacji.

Do badań wykorzystano osady nadmierne pochodzące z komunalnej oczyszczalni ścieków. Osady poddano działaniu ekspozycji pola UD, wykorzystując procesor ultradźwiękowy o mocy 1500 W, częstotliwości 20 kHz i długości fali 39,42 µm (co odpowiadało amplitudzie równej 100%). Nadźwiękawianie osadów prowadzono przy różnych długościach fal i czasach sonifikacji. Osady niekondycjonowane oraz wstępnie kondycjonowane polem UD poddano procesowi stabilizacji w kolbach laboratoryjnych (V = 0,5 dm^3) przez okres 10 dni. W każdym dniu prowadzenia procesu oznaczano zdolność osadów do ich zagęszczania i odwadniania.

Osady poddane działaniu pola UD posiadały wyższe wartości CSK. Czas nadźwiękawiania miał jednak pozytywny wpływ na zwiększenie stopnia zagęszczania dla każdej z badanych amplitud. Również proces stabilizacji wpłynął pozytywnie na końcowe zagęszczanie i odwadnianie badanych osadów.