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Ultrasonic Processors and Drainage of Sewage Sludge

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1. Introduction

Implementation of new technologies in sewage treatment involves generation of even greater volumes of sewage sludge which, in the raw form, is considered as a dangerous substance. According to the standards used in Poland, sewage sludge should be subjected to treatment and then properly managed [1, 5, 11].

The volume of sludge is reduced using the process of thickening and dewatering [9, 10]. In order to intensify this process, sludge is subjected to different methods of conditioning (physical, chemical) [2, 4, 7]. One of the methods which have been researched extensively in different technological processes of environmental engineering is exposure to the ultrasonic field [6, 8, 13, 15]. Sonication causes dispersion of the particles in the sludge flocs, which affects their properties during thickening and dewatering. Effectiveness of using the ultrasonic field depends on the amplitude used, time of exposure and volume of the samples subjected to modification [3, 14,16].

Disintegration of sewage sludge is carried out using ultrasonic processes. Previous studies have demonstrated the improvement in the effects of dewatering, thus reducing the costs of final sludge management. The ultrasonic field does not case a secondary pollution to the environment [12, 17].

The paper presents the results obtained for thickening and dewatering of sewage sludge expressed by capillary suction time (CST), subjected to the effect of ultrasonic processors with varied power, amplitudes and volume of the samples sonicated.

2. Experimental methodology

The study examined excess sewage sludge collected from a mechanical and biological wastewater treatment plant. Non-conditioned sewage sludge and the sludge conditioned with the ultrasonic field was analysed. In order to determine the effect of power of ultrasonic processors on thickening and dewatering, the study used three ultrasound disintegrators: VCX 1500 (power 1500 W, frequency 20 kHz, amplitude 100%, corresponding to the wavelength of 39.42 μm), VC 750 (power 750 W, frequency 20 kHz, amplitude 100% corresponding to the wavelength of 61 μm) and UD 20 (power 180 W, frequency 22 ± 1,65 kHz, amplitude 100%, corresponding to the wavelength of 16 μm). Sewage sludge used in the study was conditioned with the amplitudes of 0%, 60%, 80% during sonication for 0, 2, 4, 6, 8, 10 minutes with volumes of sonicated samples of 0.25 L, 0.5 L, 1 L. The effect of the parameters of sonication adopted on changes in thickening and dewatering was presented by means of the values obtained after 120 minutes of thickening in Imhoff cones and values of capillary suction time determined by means of the set for CST measurements.

3. Results and discussion

3.1. Thickening

Sewage sludge exposed to the ultrasonic field showed improved effectiveness of thickening. This relationship was found for the sludge subjected to the three ultrasonic processors with different powers. Effectiveness of sedimentation was higher for longer times of exposure. The improvement in thickening was reported after 30 minutes of sedimentation. The sludge was thickened the most noticeably at the amplitude of 60% and sonication time of 10 minutes where, after 120 minutes, the volume of sludge was 620 ml (processor 1500 W) (Table 1). Similar relationships were observed in other disintegrators used in the study. In the processors with power 750 W and 180 W, the sludge after 10 minutes of sonication and amplitude of 60% were thickened more effectively for each of the samples studied. Improved thickening of sludge with time was observed in all the cases.

Table 1. Thickening of sewage sludge subjected to the effect of different amplitudes and times of exposure to the ultrasonic field
Tabela 1. Zagęszczanie osadów ściekowych poddanych działaniu różnym amplitudom i czasom działania pola ultradźwiękowego

Thickening of the sewage sludge, ml												
Thickening time, min		0	5	10	15	20	25	30	45	60	90	120
Non-conditioning sludge		1000	990	990	990	990	980	980	970	960	950	940
Ultrasonic disintegrator 1500W	Amplitude 60%,5 min	1000	1000	1000	1000	1000	1000	1000	990	990	990	990
	Amplitude 80%,5 min	1000	1000	1000	1000	1000	1000	1000	990	990	990	980
	Amplitude 60%,10 min	1000	990	980	980	960	960	970	750	700	670	620
	Amplitude 80%,10 min	1000	990	980	970	960	950	940	810	790	770	720
Ultrasonic disintegrator 750W	Amplitude 60%,5 min	1000	1000	1000	990	990	990	990	990	990	990	990
	Amplitude 80%,5 min	1000	1000	1000	990	990	990	990	990	990	990	990
	Amplitude 60%,10 min	1000	980	960	940	920	900	880	820	800	700	650
	Amplitude 80%,10 min	1000	980	970	960	950	930	910	860	800	680	630
Ultrasonic disintegrator 180W	Amplitude 60%,5 min	1000	990	980	970	970	970	960	950	930	890	850
	Amplitude 80%,5 min	1000	990	990	990	990	980	980	970	960	940	910
	Amplitude 60%,10 min	1000	980	980	980	980	970	970	950	940	920	880
	Amplitude 80%,10 min	1000	980	980	980	980	980	970	960	960	950	920

Analysis of the results of examination of the effect of the ultrasonic field at different volumes of samples showed that the best effects of thickening were recorded for the sample with volume of 500 ml. This relationship was observed for processors with power of 1500 and 750 W

(Table 2). Sewage sludge subjected to 10 minutes of exposure to the ultrasonic field and then thickened by 120 minutes had the volume of 620 ml (for the processor of 1500 W) and 650 ml (for the processor of 750 W). An insignificant reduction in the volume of the sample subjected to disintegration was observed in the case of the processor with power of 180 W (volume of the sludge of 250 ml, time of sedimentation 120 minutes, volume of the sludge 990 ml). The best thickening was found for the sludge with volume of 1000 ml, which, after 120 minutes of sedimentation, reached the value of 790 ml.

Table 2. Thickening of sewage sludge subjected to the effect of ultrasonic field with different power and for different volumes of the samples
Tabela 2. Zagęszczanie osadów ściekowych poddanych działaniu procesorom ultradźwiękowym o różnej mocy przy różnych objętościach próbek

Thickening of the sewage sludge, Amplitude of vibration 60%, Time 10 min												
Thickening time, min		0	5	10	15	20	25	30	45	60	90	120
Non-conditioning sludge		1000	990	990	990	990	980	980	970	960	950	940
Ultrasonic disintegrator 1500 W,	250 ml	1000	990	980	980	970	970	970	980	980	980	980
	500 ml	1000	990	980	980	960	960	970	750	700	670	620
	1000 ml	1000	990	980	980	970	970	970	970	970	970	970
Ultrasonic disintegrator 750 W	250 ml	1000	1000	1000	1000	1000	1000	1000	1000	1000	990	990
	500 ml	1000	980	960	940	920	900	880	820	800	700	650
	1000 ml	1000	1000	1000	1000	1000	1000	1000	1000	1000	995	995
Ultrasonic disintegrator 180 W	250 ml	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000
	500 ml	1000	980	980	980	980	970	970	950	940	920	880
	1000 ml	1000	980	980	980	960	960	950	930	900	790	790

3.2. Capillary suction time

The exposure to the ultrasonic field caused an increase in capillary suction time with respect to the non-conditioned sludge (Fig. 1, 2).

For the time of exposure to the ultrasonic field of 5 minutes, CST levels increased with higher ultrasound wavelengths. Capillary suction times for the processor 750 W were 500.4 s (amplitude 60%) and 1702.2 s (amplitude 80%), respectively, whereas for the processor 180 W, these values were 686.3 s (amplitude 60%) and 894.4 s (amplitude 80%), respectively. The highest CST times were found for the sludge conditioned with the processor with the highest power (1500 W; 3463 s; amplitude 60%) and 2774 s (amplitude 80%).

After extension of the time of exposure to the ultrasonic field to 10 minutes, higher values of CST were also recorded with respect to the non-conditioned sludge. However, longer time of exposure yielded shorter CST times in the sludge compared to the levels obtained for 5 minutes.

In all the disintegrators used, an increase in capillary suction time was recorded in the sludge for higher times of exposure to the ultrasounds (Fig. 3). After 8th minute of exposure, a decline in the value of the parameter discussed was observed. Lower values were found in all the ultrasonic processors used.

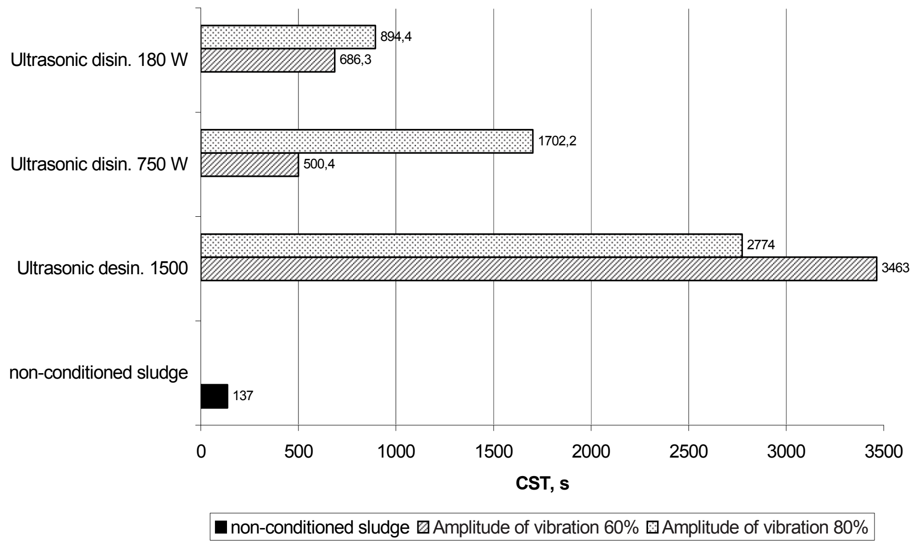

Fig. 1. Capillary suction time in sewage sludge exposed to the ultrasonic field with different power (5 minutes)
Rys. 1. Czas ssania kapilarnego osadów ściekowych poddanych działaniu procesorom ultradźwiękowym o różnej mocy (UD 5 min)

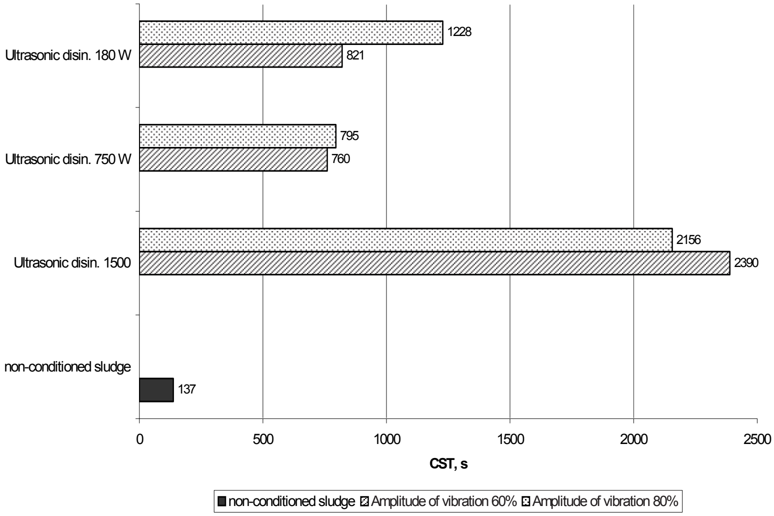

Fig. 2. Capillary suction time in sewage sludge exposed to the ultrasonic field with different power (10 minutes)
Rys. 2. Czas ssania kapilarnego osadów ściekowych poddanych działaniu procesorom ultradźwiękowym o różnej mocy (UD 10 min)

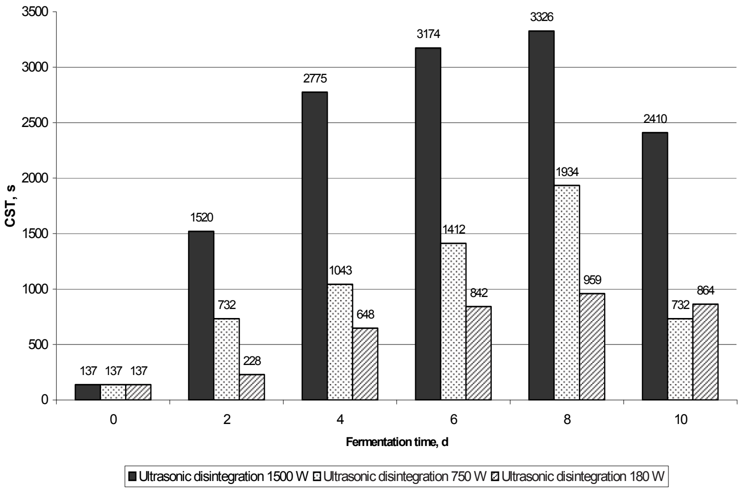

Fig. 3. Capillary suction time in sewage sludge subjected to different times of exposure to the ultrasonic field
Rys. 3. Czas ssania kapilarnego osadów ściekowych poddanych różnym czasom działania pola ultradźwiękowego

Changes in the capillary suction times were also observed for exposure of the sludge with different volumes. Sewage sludge conditioned at the lower volume of the sample (250 ml) had the highest values of CST. For the time of exposure of 5 minutes with the processor 1500 W, the highest values of CST were found for the volume of 500 ml (3463 sec), whereas the lowest level (1785 sec) was observed for the volume of 1000 ml (Fig. 4). In two processors (750W and 180W), the highest CST value was recorded for the volume of 250 ml, which was respectively 2105 s and 1094 s. High CST was found in all the processors used for the exposure time of 10 minutes and volume of the sample of 250 ml. The highest value 2962 s was found for the processor 1500 W with the volume of the sample of 1000 ml (Fig. 5). In the case of two other processors, the value of CST for this volume of the sample was much lower (below 1000 s). The lowest value of CST was observed for the sludge sonicated with processor 180 W at the volume of 1000 ml.

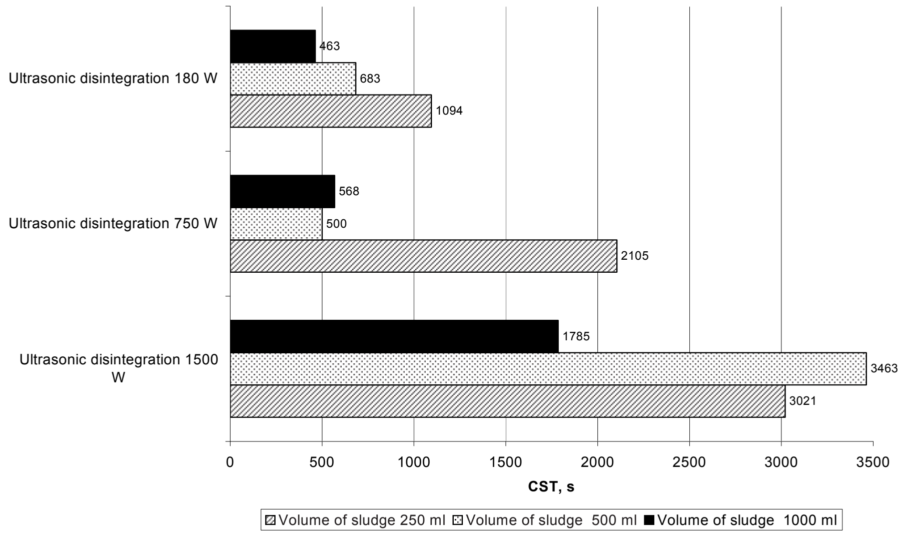

Fig. 4. Capillary suction time for sewage sludge subjected to 5-minute exposure to the ultrasonic field for different volumes of the samples
Rys. 4. Czas ssania kapilarnego osadów ściekowych poddanych 5 minutowemu działaniu polem ultradźwiękowym przy różnych objętościach prób

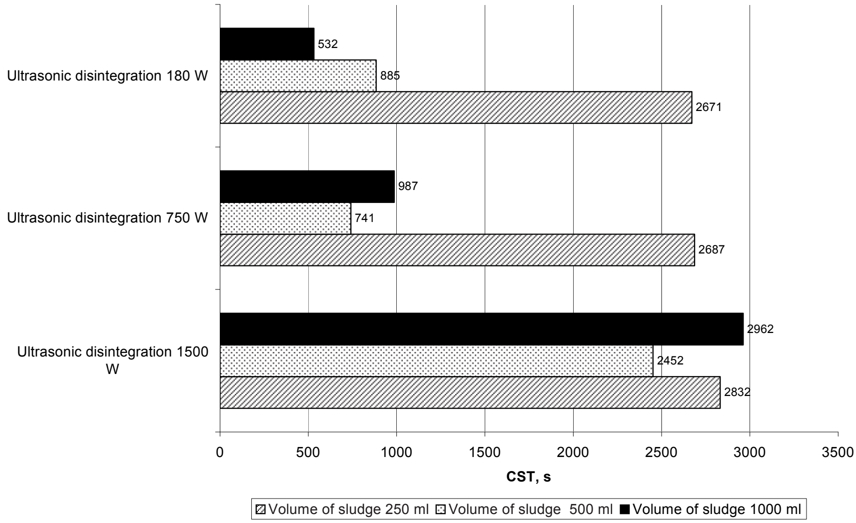

Fig. 5. Capillary suction time for sewage sludge subjected to 10-minute exposure to the ultrasonic field for different volumes of the samples
Rys. 5. Czas ssania kapilarnego osadów ściekowych poddanych 10 minutowemu działaniu polem ultradźwiękowym przy różnych objętościach prób

4. Summary and conclusions

The parameters of the ultrasonic field had a positive effect on thickening of the sewage sludge samples studied. The dispersive influence of the exposure to the ultrasonic field caused an increase in sedimentation capability in the sewage sludge studied. The ultrasonic field caused fragmentation of the structure of the sludge, thus causing better compression of the particles and improved release of the free water. The noticeable effect of the factor discussed on sedimentation capability was observed after 10 minutes of sonication. The best results of sedimentation were recorded for the volume of 500 ml.

The use of three ultrasonic processors showed higher CST times in the sewage sludge studied proportionally to the increase in wavelength and processor power. The process of disintegration caused dispersion of sewage flocs by clogging the pores in the filtration paper. This also resulted in prolonged capillary suction times and, consequently, reduction of the dewatering capability. CST increased until the 8th minute of sludge sonication, and then, for each of the processor used, a decline in the value of the parameter studied was observed. The highest values of capillary suction time were found for the VCX 1500 processor, whereas the lowest values were observed for the processor with the lowest power (UD 20).

The analysis of the results obtained in this study leads to the following conclusions:

- With longer times of exposure to the ultrasonic field, sewage sludge was thickened more effectively, which was caused by the dispersion of flocs in the sewage sludge studied. Lower amplitude and shorter duration of exposure to the ultrasonic field had more beneficial effect on sedimentation in the sewage sludge studied;
- For the parameters of the sonication process assumed, capillary suction time was extended in proportion to the increase in sonication time, ultrasound processor wavelength and processor power;
- Reduction in the volume of the samples conditioned caused an increase in capillary suction time in the sludge. Dispersion of particles caused clogging of the pores in the filtration paper, and, consequently, longer CST values.

Acknowledgements

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References

1. **Bień J.:** *Sewage sludge – theory and practice.* Czestochowa University of Technology Publishing House 2007.
2. **Bień J., Kamizela T., Kowalczyk M., Mrowiec M.:** *Possibilities of gravitational and mechanical separation of sonicated activated sludge suspensions.* Environment Protection Engineering. 35(2), 67–71 (2009).
3. **Bień J., Kowalczyk T., Kamizela M., Stępniak L.:** *The analysis of sedimentation and thickening of sewage sludges after ultrasonic disintegration.* Environment Protection Engineering. 30(4), 23–28 (2004).
4. **Dieudé-Fauvel E., Dentel S.K.:** *Sludge conditioning: Impact of Polymers on Floc structure.* Journal of Residuals Science and Technology. 8(3), 101–108 (2011).
5. **Grosser A., Worwąg M., Neczaj E., Grobelak A.:** *Semi-continuous Anaerobic Co-digestion of Mixed Sewage Sludge and Waste Fats of Vegetable Origin.* Rocznik Ochrona Środowiska (Annual Set the Environment Protection). 15, 2108–2125 (2013).

6. **Li H., Jin Y.., Rasool B. M., Wang Z., Nie Y.:** *Effects of ultrasonic disintegration on sludge microbial activity and dewaterability.* Journal of Hazardous Materials. 161, 1421–1426 (2009).
7. **Mikkelsen L.H., Keiding K.:** *Physico-chemical characteristics of full scale sewage sludges with implications to dewatering.* Water Research. 36, 2451–2462 (2002).
8. **Na S., Kim Y., Khim J.:** *Physiochemical properties of digested sewage sludge with ultrasonic treatment.* Ultrasonics Sonochemistry. 14, 281–285 (2007).
9. **Piecuch T., Piekarski J., Malatyńska G.:** *Filtration of mixtures forming compressible sediments.* Rocznik Ochrona Środowiska (Annual Set the Environment Protection). 15, 1, 39–58 (2013).
10. **Piecuch T., Piekarski J., Malatyńska G.:** *The equation describing the filtration process with compressible sediment accumulation on a filter mesh.* Archives of Environmental Protection. 39(1), 93–104 (2013).
11. **Podedworna J., Umiejewska K.:** *Technology of sewage sludge.* Warsaw University of Technology Publishing House, Warsaw 2008.
12. **Stańczyk-Mazanek E., Piątek M., Kępa U.:** *Effect of sewage sludge applied to sandy soils on the sorption complex properties.* Rocznik Ochrona Środowiska (Annual Set the Environment Protection). 15 (3), 2437–2451 (2013).
13. **Wolny L., Stępniak L., Stańczyk-Mazanek E.:** *Changes of Sludge Characteristic after Ultrasonic Field Action.* Polish Journal of Environmental Studies. 16(2A), III, 573–576 (2007).
14. **Wolski P., Wolny L.:** *Effect of disintegration and fermentation on the susceptibility of sewage sludge to dewatering.* Rocznik Ochrona Środowiska (Annual Set the Environment Protection). 13, 1697–1706 (2011).
15. **Zawieja I., Wolny L.:** *Effect of sonicator power on the biodegradability of sewage sludge.* Rocznik Ochrona Środowiska (Annual Set the Environment Protection). 13, 1719–1730 (2011).
16. **Zawieja I. Wolny L.:** *Ultrasonic disintegration of sewage sludge to increase biogas generation.* Chem. Biochem. Eng., 27(4), 491–497 (2013).
17. **Zhang G., Zhang P., Yang J., Liu H.:** *Energy-efficient sludge sonification: Power and sludge characteristics.* Bioresource Technology. 99, 9029–9031 (2008).

Procesory ultradźwiękowe a odwadnianie osadów ściekowych

Abstract

W Polsce najczęstszym sposobem końcowego zagospodarowania osadów ściekowych jest ich składowanie. Ze względu na skład i właściwości osadów często są one traktowane jako odpad, a nie surowiec. Osady ściekowe poddawane unieszkodliwianiu poddawane są różnym procesom technologicznym, gdzie jednym z nich jest zmniejszenie objętości. Odwadnianie to podstawowy proces zmniejszania objętości osadów. W celu zwiększenia zdolności osadów do oddawania wody stosuję się różne procesy wspomagające. Jedną z metod jest wykorzystanie działania pola ultradźwiękowego. Sonifikacja osadów ściekowych zmienia strukturę oraz właściwości osadów, powodując zakłócenia równowagi układu oraz wywołuję dyspersję cząstek, co sprzyja zwiększeniu zdolności do zagęszczania i odwadniania.

W artykule przedstawiono wyniki badań dotyczące zastosowania dezintegratorów ultradźwiękowych o różnej mocy (1500W, 750W, 180W) na zmianę stopnia zagęszczania i odwadniania osadów ściekowych. W badaniach wykorzystano różne długości fal dezintegratorów UD (60, 80%), czasy ekspozycji z przedziału od 2 do 10 sekund oraz różne objętości prób poddane działaniu pola ultradźwiękowego.

Przy założonych parametrach prowadzenia badań dezintegrujące działanie pola UD spowodowało znaczną poprawę zagęszczania osadów ściekowych w odniesieniu do osadów niekondycjonowanych. Duża moc procesorów ultradźwiękowych powodowała rozdrobnienie kłaczków osadowych zatykając przegrodę filtracyjną, co odnotowano w wartościach czasu ssania kapilarnego (CSK) oraz oporu właściwego osadów.

Słowa kluczowe:
osady ściekowe, dezintegracja ultradźwiękowa, zagęszczanie, odwadnianie

Keywords:
sewage sludge, ultrasonic disintegration, thickening, dewatering