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Dewatering of Excess Sludge Submitted Anaerobic Stabilization Assisted Conditioning Process

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1. Introduction

Final management of sewage sludge influences on the natural environment and is connected with ecological awareness of society, technological advances and, first and foremost, with economic criteria. Among a variety of methods of final waste management used in Poland, the most popular is landfilling. According to the EU directive, sewage sludge will not be allowed to be stored in landfills from 2013. This causes the necessity of finding more effective methods of final sludge management and considering sewage sludge as a product rather than waste [1, 17].

Methane fermentation is a popular and commonly used method of sludge stabilization. Proper process of fermentation should be aimed at mineralization of organic compounds thus causing reduction in mass and energy consumption, and, importantly, energy recovery in the form of biogas [5, 14, 18]. Initial ultrasounds processing of sewage sludge causes biochemical improvement of sludge decomposition in the process of anaerobic stabilization. The degree of fermentation affects the efficiency of sludge dewatering [8].

In many scopes or environmental engineering the new methods of the processes, which can eliminate or limit using of chemical reagents are searched. Ultrasonic field of 22 kHz frequency and intensity of which is possible to obtain the conditions of ultrasound phenomena increase, can intensify some of the technological processes [7, 12, 20].

Ultrasound disintegration is one of conditioning methods and it has essential effect on dispersion of the structure of sewage sludge and thus on intensification of the process of methane fermentation [6, 15]. The process of anaerobic stabilization contributes to significant reduction in the volume of substances, with odour and pathogenic microorganisms, reduction in the content of organic matter in sludge and facilitation of the processes of sludge dewatering. Affecting the process of methane fermentation through modification of the sludge before the process of stabilization determines its final susceptibility to dewatering. Initial facilitation of the stabilization through conditioning modifies physicochemical composition of sludge by loosening of chemical bonds between water and sludge particles. This directly affects sludge dewatering capacity [1, 9, 11].

The aim of the present study was to determine the effect of ultrasound conditioning of excess sewage sludge after anaerobic stabilization on sludge dewatering. After initial conditioning with ultrasound field, the sludge was stabilized in laboratory flasks and in bioreactors.

2. Experimental

2.1. Substrate

The substrate used in the study was excess sludge (90%), which was inoculated with fermented sludge that accounted for 10% of the research mixture. The sludge was sampled from municipal WWTP. The excess sludge was sampled before thickening, whereas the fermented sludge was sampled from the piping following the chamber of anaerobic stabilization.

Anaerobic stabilization was carried out for the following mixtures:

- Mixture A (excess sludge, non-conditioned + fermented sludge),
- Mixture B (excess sludge conditioned with ultrasound field amplitude 23,65 μm (Amplitude 60%) + fermented sludge),
- Mixture C (excess sludge conditioned with ultrasound field amplitude 31,54 μm (Amplitude 80% + fermented sludge).

2.2. Methodology

At the first stage of the study, the experiment was carried out using 0,5 dm^3 laboratory flasks which, in order to ensure mesophilic temperature (37^oC) that is adequate for fermentation, were placed in a laboratory thermostat. Both before the process and on each day of the experiment, one of the flasks was removed to determine its CST, degree of thickening and dry matter content.

The second stage of the experiment was carried out in a fermentation chamber with volume of V = 10 dm^3. An inoculum was added to non-conditioned sludge and the sludge after disintegration and then mesophilic fermentation was carried out for the period of 25 days.

Before loading the sludge into the chamber and after the process of fermentation, CST, degree of thickening and dry matter content were measured for each sample.

Sludge sonification was carried out for 5 minutes using Sonics VCX 1500W disintegrator with the frequency of 20 kHz and wavelength of 39.42 μm (which corresponded to the amplitude of 100%). Capillary suction time was measured according to the Baskerville and Galle methodology [3].

Gravitational thickening was carried out in 100ml measuring cylinders. The process of sedimentation in the tested samples was carried out by reading the volume of thickened sludge at adequate time intervals (5, 10, 15, 20, 25, 30, 45, 60, 90 and 120 minutes). Based on the measurements of thickened sludge volume, the thickening curves were determined [10].

3. Results and discussion

Analysis of the obtained results revealed that capillary suction time for the non-conditioned sludge after the process of 10-day stabilization ranged from 52 seconds on the day 0 of the process to its maximum value on the second day of fermentation, when it reached 125 seconds. After 4 days, an insignificant decline in capillary suction time was observed which, after 10 days of the process, reached 86 sec (Fig. 1).

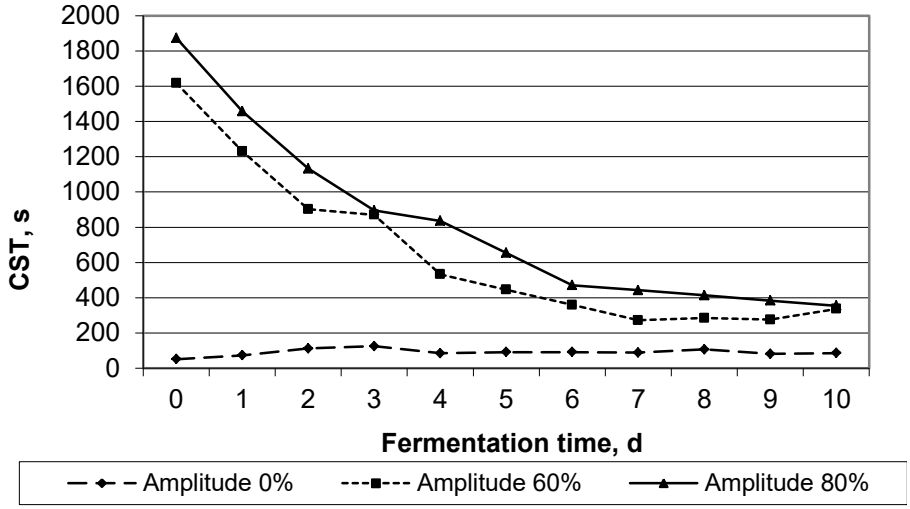

Fig. 1. Effect of fermentation time on CST in excess sludge after the sonification process
Rys. 1. Wpływ czasu fermentacji na CSK osadów nadmiernych po procesie sonifikacji

For the sludge after sonication, CST levels on the day 0 of the process were 1618 seconds for the sludge sonicated with 60% amplitude of ultrasonic field and 1874 seconds for the sludge prepared with 80% amplitude. A decline in the index discussed in this study was observed on each next day until it reached 337 seconds for the amplitude of 60%.

Analysis of the results obtained during the process of thickening revealed the effect of the ultrasound field on the efficiency of water removal from excess sludge. The sludge after initial disintegration had improved thickening capacity. The best sludge settleability was observed for 60% of disintegration power, for which a considerable thickening of the sludge studied was found after 2 days of the process (Fig. 3). After 5 minutes, the volume of the sludge decreased to 92 ml, whereas after 30 minutes, this volume was further reduced to 60 ml. From the fourth day of the process, the sludge was characterized by similar dewaterability (sludge volume ranged from 25 to 30 ml). The non-conditioned sludge before the process of fermentation was unresponsive to thickening, which is presented in Fig. 2.

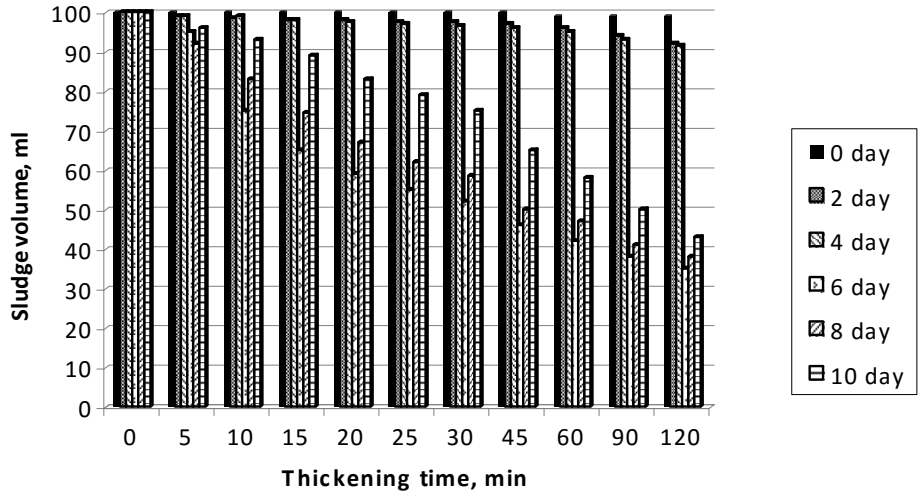

Fig. 2. Effect of fermentation time on the thickening of unconditioned excess sludge
Rys. 2. Wpływ czasu fermentacji na zagęszczanie niekondycjonowanych osadów nadmiernych

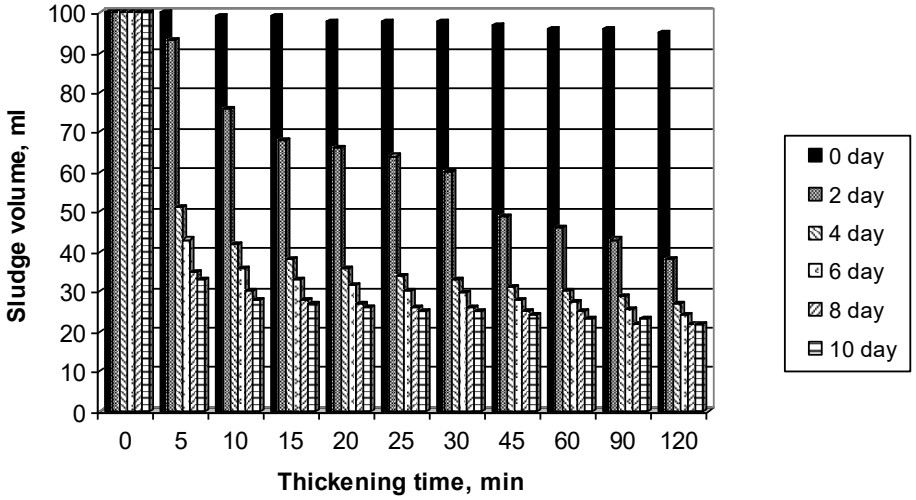

Fig. 3. Effect of fermentation time on thickening of conditioned excess sludge with ultrasonic field of 60% amplitude
Rys. 3. Wpływ czasu fermentacji na zagęszczanie kondycjonowanych osadów nadmiernych polem ultradźwiękowym (amplituda 60%)

The chart in Fig. 4 compares the values of final volume of the fermented excess sludge after conditioning with ultrasound field with 80% amplitude. The most effective process was observed after 20 minutes of thickening, regardless of the fermentation day. The obtained level of final volume of thickened sludge amounted in this case to 45 ml.

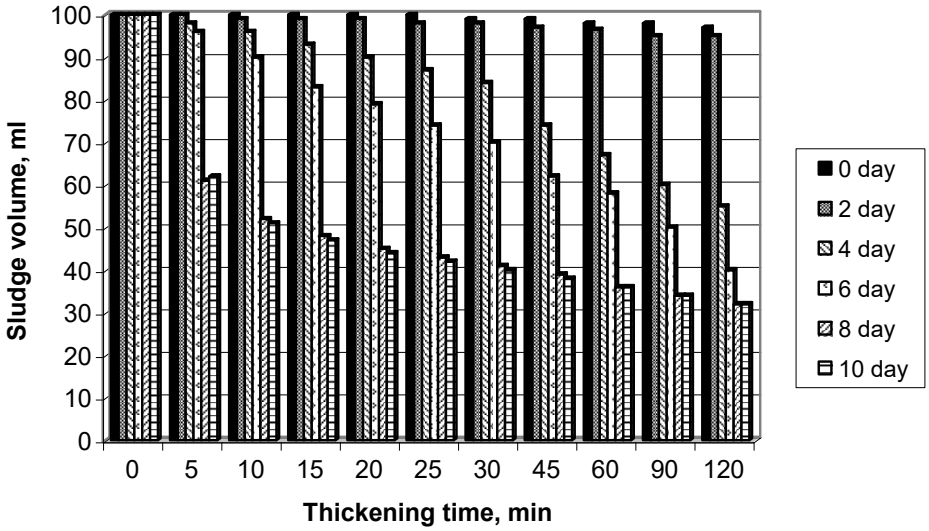

Fig. 4. Effect of fermentation time on thickening of conditioned excess sludge with ultrasonic field of 80% amplitude
Rys. 4. Wpływ czasu fermentacji na zagęszczanie kondycjonowanych osadów nadmiernych polem ultradźwiękowym (amplituda 80%)

During the process of sludge stabilization a significant decline in dry matter content on each day of the process was observed. Initial sludge conditioning caused a reduction in dry matter content during the first 10 days of the process. The highest reduction in the discussed parameter was observed for the amplitude of ultrasonic field of 60% and stabilization day 1 and day 3. For example dry matter of the conditioned sludge on the third day of the fermentation process was 9.80 g/dm^3 (Fig. 5).

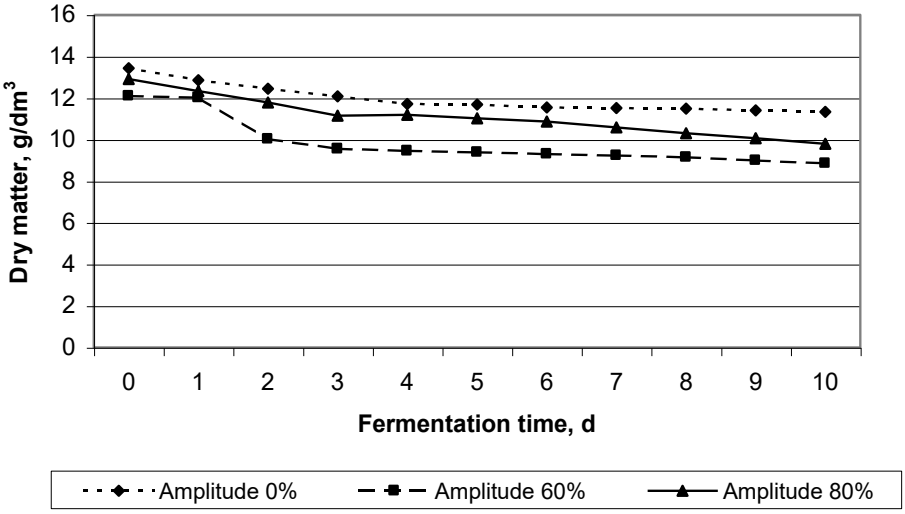

Fig. 5. Effect of fermentation time on dry matter in excess sludge after the sonification process
Rys. 5. Wpływ czasu fermentacji na suchą masę osadów nadmiernych po procesie sonifikacji

The second stage involved stabilization of the sewage sludge in bioreactors. Based on the results, it was found that the sludge samples after initial exposure to ultrasonic field were characterized by higher capillary suction times before the process of stabilization and a decline in this value after 25 days of the process. The highest difference was found for the sludge after exposure to ultrasound field with amplitude of 80%. A decline in capillary suction time from 1874 to 608 seconds was observed in this case. For the non-prepared sludge samples, an increase in the value of capillary suction time was observed (Tab. 1)

The sludge after the process of methane fermentation showed insignificant differences in dewaterability compared to the sludge after initial conditioning and the sludge without conditioning with ultrasound field (Fig. 6). It was observed after 60 minutes of thickening that the non-conditioned sludge has better dewaterability compared to the sludge exposed to ultrasonic field.

Table 1. Capillary suction time and dry matter in conditioned and stabilized sewage sludge
Tabela 1. Czas ssania kapilarnego i sucha masa kondycjonowanych i ustabilizowanych osadów ściekowych

	CST, s		Dry matter, g/dm^3	
	Sludge before biological treatment	Sludge after biological treatment	Sludge before biological treatment	Sludge after biological treatment
Non-conditioned sludge	52	227	13,43	8,50
Sludge + UD field Amplitude 60%	1618	812	12,09	7,30
Sludge + UD field Amplitude 80%	1874	608	12,91	8,60

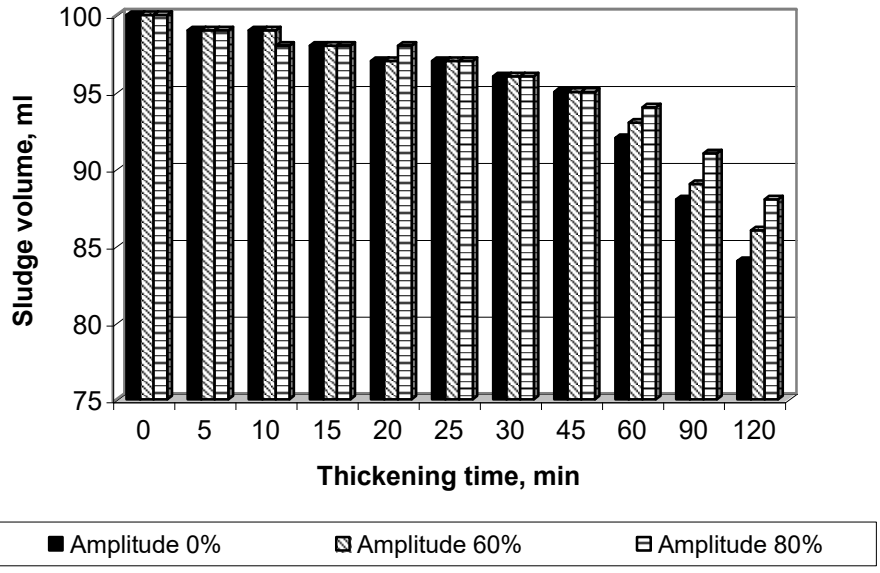

Fig. 6. Effect of fermentation on sewage sludge thickening after conditioning process
Rys. 6. Wpływ fermentacji na zagęszczanie osadów ściekowych po procesie kondycjonowania

4. Summary and conclusions

To date, stabilized sewage sludge has been initially processed chemically in order to improve process efficiency (increase in biogas production, VFA, COD). Recent studies have reported on scientific experiments on sewage sludge exposed to ultrasound field and the process of stabilization [16, 19]. Also in this case, the process modification contributes to improvement in final values of the tested parameters. Initial conditioning of sewage sludge after stabilization also affects final values in the dewatering process . Studies that have been carried out to date lead to the conclusions that conditioning with ultrasound disintegration of sewage sludge before the process of stabilization causes dispersion of its structure, which indirectly affects changes in dewatering parameters [4, 13].

The present study demonstrated that non-fermented sludge exposed to ultrasound field caused pore clogging in the filtration paper, which substantially elevated capillary suction times (ca. 1800 s) The process of stabilization caused a reduction in the CST, both for the sludge stabilized in flasks (5-time reduction in CST) and sludge samples stabilized in a bioreactor (2 to 3-time reduction in CST). Initial exposure to ultrasonic field contributed to more favourable values of the thickening process compared to non-conditioned sludge. Dispersed sludge particles were thickened more effectively. After 5 minutes of the process, a 50% reduction in sludge volume was obtained. It was observed that the best values for thickening process, capillary suction time and dry matter content can be obtained for the sludge initially conditioned with ultrasound field with lower amplitudes (60%). The studies carried out so far revealed that the most favourable values can be obtained for this amplitude, both for the process of sludge fermentation and dewatering.

The analysis of the results of the present study leads to the following conclusions:

1. Ultrasound led to higher CST in non-fermented sludge. Stabilization of the sludge caused a reduction of this index on each day of the experiment.
2. The sludge exposed to ultrasound field and then stabilized were thickened more effectively during 10-day stabilization. No changes in the process of thickening between non-conditioned sludge and the

sludge which was not initially exposed to ultrasonic field were found after the process of fermentation carried out in a bioreactor.

3. A decline in dry matter content was observed both in laboratory flasks and in the bioreactor. The highest degree of dry matter reduction of 53% was found for the sludge after initial ultrasonic disintegration.

Acknowledgements

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Odwadnianie osadów nadmiernych poddanych stabilizacji wspomaganej kondycjonowaniem

Streszczenie

Substratem badań był osad nadmierny. W badaniach zastosowano dezintegrator SONICS o mocy 1500 W, częstotliwości 20 kHz i długości fali 39,42 μm (amplituda 100%). Podczas badań zastosowano 2 amplitudy: 23,65 μm oraz 31,54 μm i czasie nadźwiękawiania 5 min dla każdej amplitudy. Badania prowadzono w bioreaktorze o pojemności 10 l i kolbach laboratoryjnych o pojemności 0,5 l, które po napełnieniu badanymi osadami umieszczono w cieplarce laboratoryjnej w temperaturze 37°C w celu zapewnienia optymalnych warunków dla fermentacji metanowej. Osady niekondycjonowane oraz kondycjonowane poddano stabilizacji przez okres 10 dni. W każdym dniu prowadzenia procesu oznaczano CSK, stopień zagęszczania, opór filtracji oraz zawartość suchej masy. Podczas badań zastosowano 2 amplitudy 60% i 80% mocy dezintegratora i czasie nadźwiękawiania 5 min dla każdej amplitudy Przeprowadzone badania wykazały wpływa pola ultradźwiękowego na proces odwadnianie osadów podczas stabilizacji beztlenowej.

Analiza wyników niniejszego badania prowadzi do następujących wniosków:

1. Ultradźwięki doprowadziły do wyższego CSK w niefermentowanym osadzie. Stabilizacja osadów powodowała zmniejszenie tego wskaźnika ciągu kolejnych dni eksperymentu.
2. Osad poddany działaniu pola ultradźwiękowego, a następnie ustabilizowany zagęszczał się bardziej skutecznie w czasie stabilizacji 10-cio dniowej. Nie występowały zmiany w procesie zagęszczania po procesie fermentacji prowadzonym w bioreaktorze pomiędzy niekondycjonowanym osadem a osadem, który nie był wstępnie poddany działaniu pola ultradźwiękowego.
3. Spadek zawartości suchej został zauważony zarówno w laboratorium jak i w bioreaktorze. Najwyższy stopień w obniżki suchej masy 53% stwierdzono dla osadów po początkowej ultradźwiękowej dezintegracji.

Słowa kluczowe: osady ściekowe, kondycjonowanie, nadźwiękawianie, stabilizacja, odwadnianie
Key words: sewage sludge, conditioning, ultrasounds, stabilization, dewatering