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THE ANALYSIS OF SEDIMENTATION AND THICKENING OF SEWAGE SLUDGES AFTER ULTRASONIC DISINTEGRATION

The article deals with the possibility of using the ultrasonic wave (UD) as a factor that improves sedimentation process and thickening of sludge particles. The investigations were focused on transformations in sediment, clarity and content of organic substances in separated supernatant. Determination of the most effective physical parameters characterizing ultrasonic field was an essential aim of investigations. Ultrasonic wave can be used for improving the sedimentation of sewage sludge. However, the best possible disintegration of the sewage sludge in ultrasonic field will require an adjustment of the values of energy to the characteristic parameters of sludge.

1. INTRODUCTION

An effective treatment of wastewater and sewage sludge is a target for new methods allowing us to improve the efficiency of unit processes used in the technological train in wastewater treatment plant. The technology of sewage sludges offers wide possibilities of their effective preparing before stabilization or dewatering. There are some mechanical and thermal methods, particularly high-pressure homogenization, ultrasonic disintegration, centrifugal technology, warming or freezing [1]. Ultrasounds in environmental engineering can be applied in a wide range. Ultrasounds of high frequencies have the ability to disintegrate effectively a sludge [2]. Ultrasonic disintegration in sludge stabilization and mechanical dewatering is well known by authors of publication [3]. Present research is aimed at the transformations of the sludge sediment after application of ultrasonic waves.

Sedimentation and thickening belong to the oldest unit processes. The simplicity and low energy consumption of such processes justify their wide use in different fields [4]. In clarifiers of wastewater treatment plants, the ultrasound application can

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bring distinct advantages. It was found that ultrasonic energy affects the change in the structure of aggregates, which also improves the sludge ability to sediment. Ultrasounds can be also applied in order to deal with flotating sludge, destroying flotating aggregates, hence favouring their settling [5].

2. MATERIALS AND METHODS

Ultrasonic model applied in our investigations is characterised by the following parameters: frequency of 22 kHz, amplitude of 8, 16 μm and the time of ultrasonication of 5, 10, 15, 60 and 120 seconds. The usability of these parameters was estimated based on the thickening effect, changes in pH value, turbidity and COD of supernatant. Settling of sludge particles was measured in 1000 cm^3 graduated measuring cylinders. Sewage sludge was prepared according to the following scheme:

- complete disintegration – 1000 cm^3 of sludge were subjected to ultrasonication,
- partial disintegration – 500 cm^3 of sludge were subjected to ultrasonication and 500 cm^3 of sludge were not prepared.

The samples of sewage sludge were pumped from the tunnel of a secondary settling tank in the Central Wastewater Treatment Plant P.S.W. "Warta", Częstochowa. Their general characteristics is as follows: pH 6.82, primary hydration 99.1%, dry weight of sewage sludge 14.9 g/dm^3, mineral substances content 9.0 g/dm^3, organic matter content 5.9 g/dm^3.

3. RESULTS

The results of sewage sludge settleability were expressed by the volume occupied by a thickened sewage sludge after 120 min settling (tables 1 and 2).

Table 1

The effect of gravitational thickening of a raw sludge subjected to ultrasonication. The wave amplitudes of 8 and 16 μm

Way of preparation	Volume of thickened sludge [cm^3]	
Unprepared sludge	Flotation	Flotation
	Ultrasonication	
Time of ultrasonication (UD)	Amplitude A = 8 μm	Amplitude A = 16 μm
UD 5 s	Flotation	620
UD 10 s	Flotation	700
UD 15 s	Flotation	600
UD 60 s	Flotation	600
UD 120 s	Flotation	550

Table 2

The effect of gravitational thickening of partially prepared sludge subjected to ultrasonication. The wave amplitudes of 8 and 16 μm

Way of preparation	Volume of thickened sludge [cm³]	
Unprepared sludge	Flotation	Flotation
	Ultrasonication	
Time of ultrasonication (UD)	Amplitude A = 8 μm	Amplitude A = 16 μm
UD 5 s	560	700
UD 10 s	610	650
UD 15 s	630	700
UD 60 s	650	720
UD 120 s	1000	750

Raw sewage sludge had an unfavourable characteristics of sedimentation. Because of a clear ability of the sludge to floate a gravitational process of its thickening did not bring any positive effects. The application of ultrasonic waves of 8 μm wave amplitude did not lead to any significant changes either. It was not until after the application of wave with amplitude of 16 μm that sludge begins to sediment, and sedimentation rate as well as final result of sedimentation are better at longer time of ultrasonication. Hence, it can be concluded that for a stubborn sludge such as flotating sludge, the ultrasonic wave of a higher output energy is required. In the case of partial sludge disintegration, all the combinations applied (variable amplitudes and time of ultrasonication) improve the sediment properties of sewage sludge. The fact that shorter time of propagation of ultrasonic wave is responsible for a maximum reduction in the volume occupied by thickened sewage sludge seems important. Comparison of the turbidity and COD values testified to some regularities being dependent on the amplitudes and time of the ultrasound wave propagation.

Table 3

Changes in COD and turbidy of supernatant after complete disintegration of sludge (the amplitudes of ultrasonic waves are 8 and 16 μm)

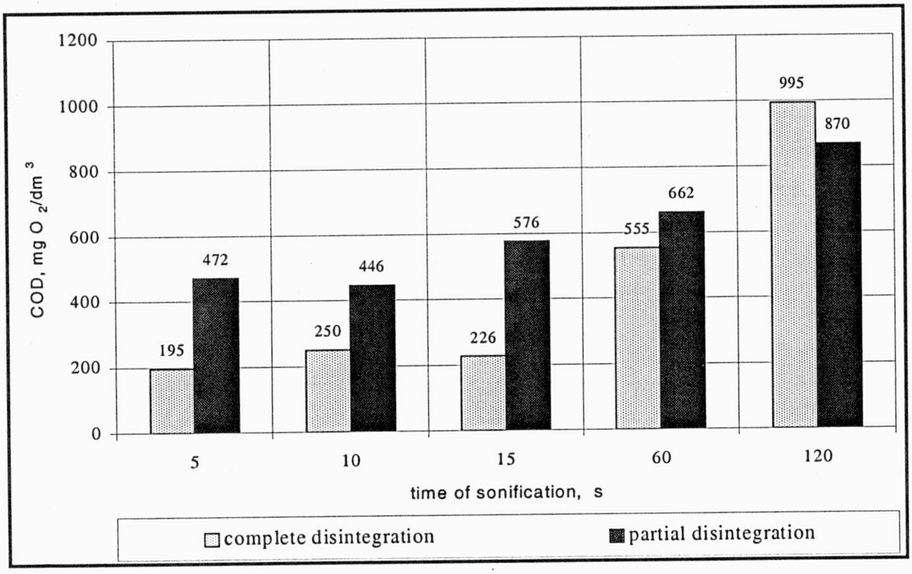
Way of preparation	Turbidy NTU	COD (mg O_2/dm^3)	Turbidy NTU	COD (mg O_2/dm^3)
Unprepared sludge	104	240	104	240
		Ultrasonication		
Time of ultrasonication (UD)	Amplitude A = 8 μm		Amplitude A = 16 μm	
UD 5 s	69	375	77	195
UD 10 s	141	442	111	250
UD 15 s	157	614	97	226
UD 60 s	78	220	327	555
UD 120 s	185	436	641	995

Table 4

Changes in COD and turbidy of supernatant after partial disintegration of sludge (the amplitudes of ultrasonic waves are 8 and 16 μm)

Way of preparation	Turbidy NTU	COD (mg O_2/dm^3)	Turbidy NTU	COD (mg O_2/dm^3)
Unprepared sludge	104	240	104	240
Ultrasonication				
Time of ultrasonication (UD)	Amplitude A = 8 μm		Amplitude A = 16 μm	
UD 5 s	108	355	250	472
UD 10 s	141	408	201	446
UD 15 s	156	432	139	576
UD 60 s	216	543	291	662
UD 120 s	350	965	456	870

Totally prepared sludge after partial disintegration is more concentrated and contaminated. An increased load of dissolved organic substances is due to an ultrasonic cavitation, which mechanically destroys cellular membranes of microorganisms and allows transfer of decomposition products, including enzymes, to sludge liquid. If a small volume of sludge is subjected to ultrasonication, the wave frequency increases. Since this frequency depends on surface propagation of wave, simultaneously an increase in a cellular decomposition takes place. The examples of COD values of sludges subjected to complete and partial disintegration by means of the waves of 16 μm amplitude are shown in the figure.



Comparison of COD values of supernatant after complete and partial disintegration of sludge (at the wave amplitude of 16 μm)

Turbidity of supernatant, both after partial and total disintegration, increases with prolonging the time of ultrasonication. However, ultrasonic disintegration applied to a partial stream of sludges generally increases turbidity. Based on turbidity and COD values it may be concluded that ultrasonic disintegration of sludge proceeds in two stages. In the first, the sludge aggregates are broken, and in the second stage microorganisms are destroyed by ultrasonic waves which leads to their decay. The biggest changes in COD and turbidity values occur at a partial sludge disintegration, i.e. at a higher frequency of acoustic wave. A decrease in pH value (pH 6.82 in the case of non-prepared sludge) occurs in the whole range of ultrasonic waves applied. pH value is stabilized in the range of 6.5–6.6, independently of the combination of ultrasonic wave propagation. pH measurement can prove that sonochemical reactions proceed in the prepared sewage sludges.

4. CONCLUSIONS

Modification of the sludge by its preliminary disintegration with ultrasonic wave allows us to analyse the changes that accompany the sludge ultrasonication and to estimate the efficiency of sedimentation and thickening process. These changes can be described as follows:

- Based on the sediment characteristic it can be concluded that ultrasonic disintegration increases the efficiency of gravitational thickening.
- A prolonged time of ultrasonication, i.e. one minute or longer, does not improve significantly the sludge thickening which is very similar to that after a few-second ultrasonication.
- A comparison of a partial and complete sludge disintegration proves that the ultrasound technique is advantageous to a partial stream of suspensions. Therefore it will be necessary to determine the changeable volume proportions of sludges in their prepared and non-prepared parts.
- The cavitation phenomenon that is associated with the propagation of ultrasonic wave affects disintegration of the suspension floccules and cellular decomposition, as well as formation of fine-fraction colloidal suspension. This is testified by an increase in the values of COD and turbidity of supernatant.

REFERENCES

[1] MULLER J.A., *Prospects and problems of sludge pre-treatment processes*, IWA, Sludge Management Entering the 3rd Millennium – Industrial, Combined, Water and Wastewater Residues, Taiwan, 2001, pp. 11–118.

[2] NEIS U., TIEHM A., *Ultrasound in waste water and sludge treatment*, Ultrasound in Environmental Engineering, TU Hamburg – Hamburg Reports on Sanitary Engineering, 25, 1999, pp. 39–61.

[3] BIEŃ J., KAMIZELA T., KOWALCZYK M., *Badania nad zastosowaniem ultradźwięków do poprawy odwadnialności osadów*, Ekotechnika, 2003, No. 2(26), pp. 32–25.

[4] DENTEL S.K., *Conditioning, thickening and dewatering: research update/research needs*, IWA, Sludge Management Entering the 3rd Millennium – Industrial, Combined, Water and Wastewater Residues, Taiwan, 2001, pp. 1–8.

[5] FRIEDRICH H., POTTHOFF A., FRIEDRICH E. H., *Improving settling properties and dewaterability of sewage sludges by application of the ultrasound technology*, TU Hamburg – Hamburg Reports on Sanitary Engineering 25, 1999; Ultrasound in Environmental Engineering, pp. 245–255.

ANALIZA SEDYMENTACJI I ZAGĘSZCZANIA CZĄSTEK OSADU ŚCIEKOWEGO PO PROCESIE DEZINTEGRACJI ULTRADŹWIĘKOWEJ

Przedstawiono możliwość zastosowania fali ultradźwiękowej jako czynnika wspomagającego proces sedymentacji i zagęszczania cząstek osadów. W badaniach skupiono się na przemianach w charakterystyce sedymentacyjnej osadów, klarowności oddzielonych wód osadowych oraz wielkości ChZT. Istotnym problemem było wyznaczenie jak najbardziej efektywnych parametrów fizycznych charakteryzujących działanie pola ultradźwiękowego. Po przeprowadzeniu badań dostrzega się w zastosowaniu fal ultradźwiękowych metodę, która umożliwi poprawę właściwości sedymentacyjnych osadów ściekowych. Uzyskanie jak najlepszych efektów dezintegracji osadów ściekowych w polu UD będzie wymagało jednak dostosowania wielkości wprowadzonej energii do charakterystycznych parametrów osadu.