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## THE CONTAMINATION OF SUPERNATANT AFTER SEDIMENTATION OF SONICATED ACTIVATED SLUDGE

The possibility of applying ultrasonic wave in the processes of sludge conditioning was presented. Our investigations were focused on the efficiency of sludge thickening and on the parameters of separated supernatants. The effect of ultrasonic wave propagation was observed as a function of characteristics for the time and the amplitude of sonification. The propagation of ultrasonic wave with specific physical parameters caused a significant changes in the characteristics of solid and liquid phases. The improvement in settling properties of sludge and reduction of its final hydration were observed as a result of sonification. Moreover, some negative effects were observed such as supernatant contamination by suspended matter of non-flocculated and non-settled particles. These phenomena were analyzed, based on input energy.

### 1. INTRODUCTION

The changes of characteristics of activated sludge after application of ultrasonic wave were investigated. The main aim of the experiments was to determine the possibility of using ultrasounds in gravitational separation process. The studies, being carried out earlier, provided a clear evidence of the adaptation of the ultrasonic technique to settling and thickening improvement of sewage sludge. The investigations confirmed that sonification caused the acceleration of sludge sedimentation, improvement of the sludge volume index and the decrease of the sludge hydration. Sonification also reduced the efficiency of separation and contributed to high concentration of suspended solids in supernatant. These changes and their intensity depended on an input sonification energy. This value was modelled by varying amplitudes of ultrasonic waves and sonification time. An increase of input energy resulted in an increase of the values of the process parameters. We noticed considerable differences in the structure and properties between sonicated and untreated sludge. This paper describes the stu-

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dies on the effect of contamination of supernatant. A preliminary test indicated that enhancement of the settling and thickening ability of sonicated sludge was strictly correlated with contamination of supernatant.

## 2. MATERIALS AND METHODS

The experiments were carried out on waste activated sludge (WAS) obtained from the municipal treatment plant Dźbów, Częstochowa. The suspension of activated sludge was sampled directly from an aeration tank. The dry mass of WAS samples ranged from 3.7 to 6.1 g/dm<sup>3</sup>. Sludge settleability was observed in measuring cylinders with the volume of  $V_o = 1000 \text{ cm}^3$  and the cross-section area of  $F = 29 \text{ cm}^2$ . Sonification was done with an ultrasound generator Hielscher UP 400S operating at the frequency  $f = 24 \text{ kHz}$ . In the research, the influence of both the amplitude of ultrasonic wave and the time of sonification on the separation process was established. The amplitudes of ultrasonic wave were  $A = 18, 45, 90 \text{ }\mu\text{m}$  and ultrasonic intensity:  $I(18 \text{ }\mu\text{m}) \approx 21 \text{ W/cm}^2$ ,  $I(45 \text{ }\mu\text{m}) \approx 52.5 \text{ W/cm}^2$ ,  $I(90 \text{ }\mu\text{m}) \approx 105 \text{ W/cm}^2$ . The time of propagation  $t = 60, 120, 180, 240, 300$  and  $360 \text{ s}$ . The following parameters were determined: the thickening degree, final hydration of thickened sludge. In a supernatant, the quantity of suspended matter, turbidity, BOD and COD were determined.

## 3. RESULTS AND DISCUSSION

One of the parameters that allows the efficiency of gravitational separation to be assessed is a thickening degree. Generally, ultrasounds caused a sequential deterioration of this parameter. An increase of input energy through an increase of amplitude of ultrasonic wave or time of sonification contributed to a contamination of supernatant (figure 1). At the longest sonification time  $t = 360 \text{ s}$  and the amplitude  $A = 90 \text{ }\mu\text{m}$ , the thickening degree amounted to  $n \approx 0.5$ . This meant that despite the two-hour period of the sedimentation, the half of dry matter remained in supernatant.

The effectiveness of gravitational solid–liquid separation of sonicated sludge at that value of amplitude and sonification time was  $n = 61\%$  (figure 2). In the range of input energy  $E$  from 1.26 to 37.8 kJ/cm<sup>2</sup>, the data analysis showed that an increase of the amplitude of ultrasonic wave was not so disadvantageous as extending a sonification time. Moreover, it was observed that an increase of input energy was not correlated with a decrease of sludge thickening. On the basis of these observations we can conclude that such parameters as frequency, amplitude and the time of sonification are

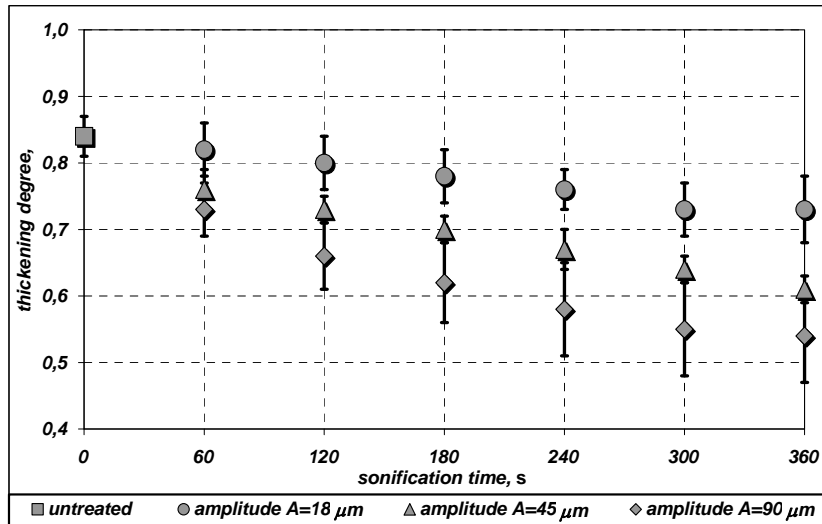


Fig. 1. Changes of the thickening degree as a result of sonification treatment

of prime importance for explaining the effect of ultrasounds on sludge thickening. For this reason the analysis of the effect of sonification only on the basis of the values of ultrasonic intensity may lead to false conclusions.

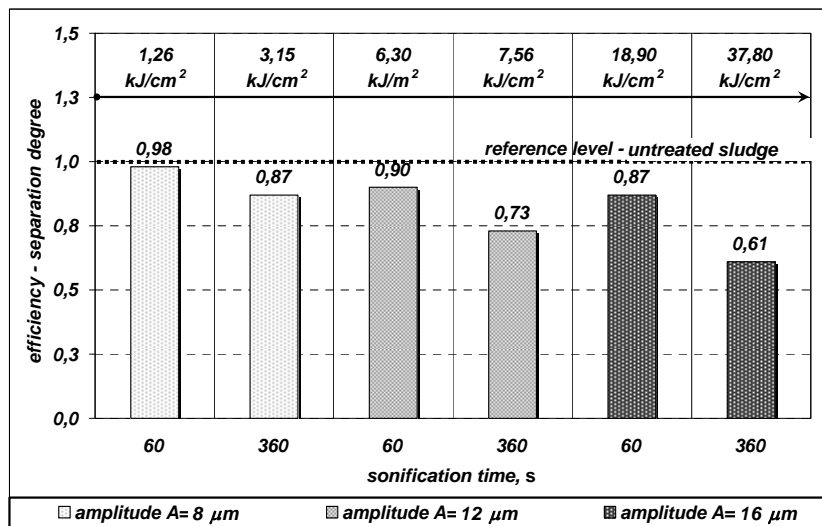


Fig. 2. Separation degree of sonicated sludge at chosen sonification parameters

The second important parameter which determines the efficiency of separation process is final hydration of thickened sludge. However, ultrasonic pretreatment of

sludge led to pushing out the sludge floc into smaller pieces and an increase in suspended solid content in supernatant; the dry mass in thickened sludge was more compressed. An increase of input energy was connected with a reduction of final hydration of treated sludge. Taking into consideration the results presented in figure 3, a sonification at the highest ultrasonic power  $E = 37.8 \text{ kJ/cm}^2$  caused the changes in the structure and properties of the sludge and in consequence 50% reduction of a thickened sludge volume.

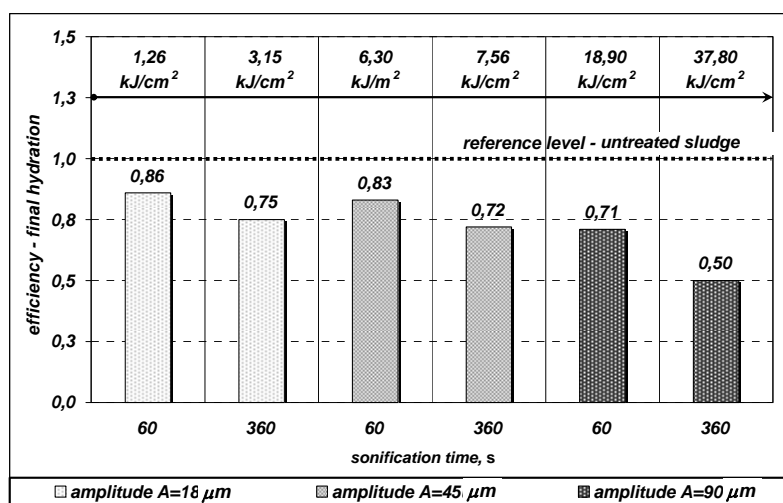


Fig. 3. Final hydration of sonicated sludge at chosen sonification parameters

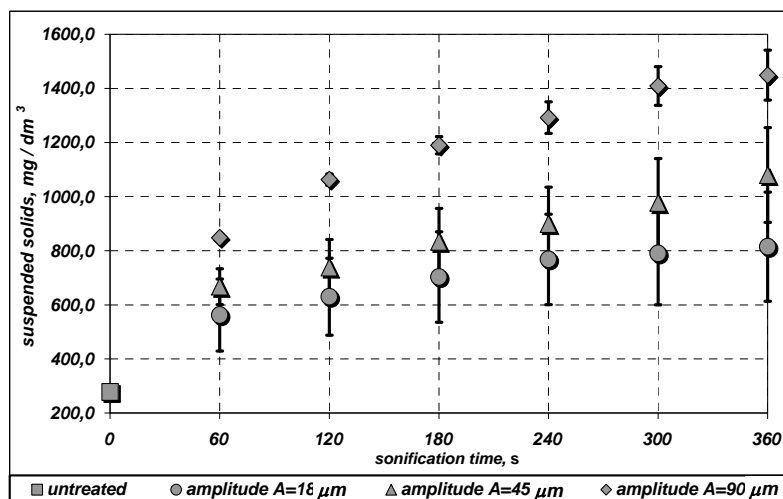


Fig. 4. The effect of ultrasonic wave amplitude and sonification time on suspended solid content

The most noticeable effect of sonification was the change of the supernatant turbidity. In some cases, a real turbidity was so high that the interface between settling sludge particles and supernatant was hardly distinguishable. The effect of turbidity becomes clear in association with a suspended solid content (figure 4). The analysis of the data indicated that extending sonification time or amplitude of ultrasonic wave contributed to deterioration of supernatant.

It was observed that an extended period of ultrasonic wave propagation was responsible for the diversity of sludge properties, which was expressed by a value of standard deviation. This proves the possibility of ultrasonic pretreatment as a method which allows considerable changes in sludge characteristics. After sonification at the input energy  $E = 37.8 \text{ kJ/cm}^2$ , the mass of suspended matter accumulated in supernatant was 5 times as high as the mass in supernatant of untreated sludge (figure 5). No relationships were observed between turbidity variations and suspended solid concentration as a function of input energy. In the range of ultrasonic intensities from  $1.26 \text{ kJ/cm}^2$  to  $37.8 \text{ kJ/cm}^2$  we observed an increase in the parameters tested, especially taking into consideration an actual sonification time  $t = 60 \text{ s}$  or  $t = 360 \text{ s}$ .

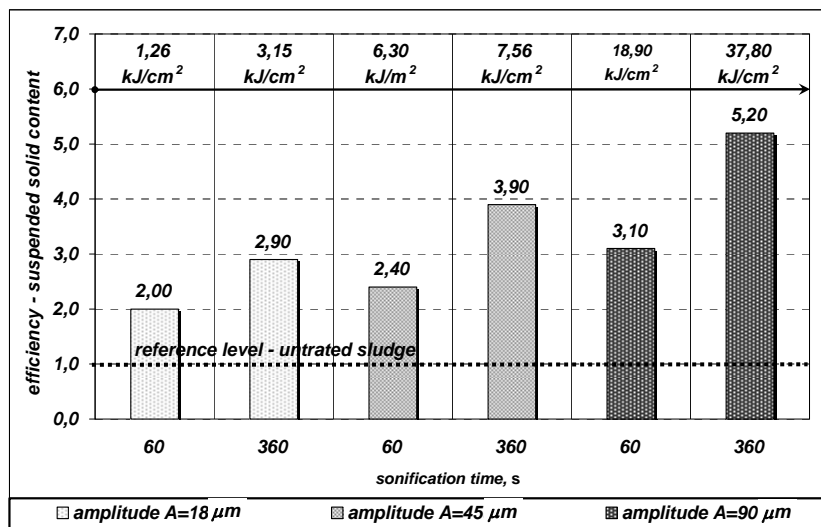


Fig. 5. Changes of suspended solid content in supernatant of sonicated sludge compared to supernatant of untreated sludge

In the supernatant, we also determined biological oxidation demand (BOD) and chemical oxidation demand (COD) (figures 6, 7). The test showed that higher amplitude and longer sonification time were responsible for increasing values of BOD and COD. During a ultrasonic pretreatment, the standard deviation of BOD and COD values in the supernatant were increasing with extending sonification time. Moreover,

many times higher concentrations of BOD and COD were obtained in treated sludge compared to untreated one. Additional information on the results of sonification can be gained by comparing a BOD/COD ratio. For all varying time and amplitudes of ultrasounds and for all combinations of these parameters, the BOD/COD ratio did not exceed of 0.3 (figure 8). This effect of ultrasound pretreatment testified to a low biodegradability of the supernatant.

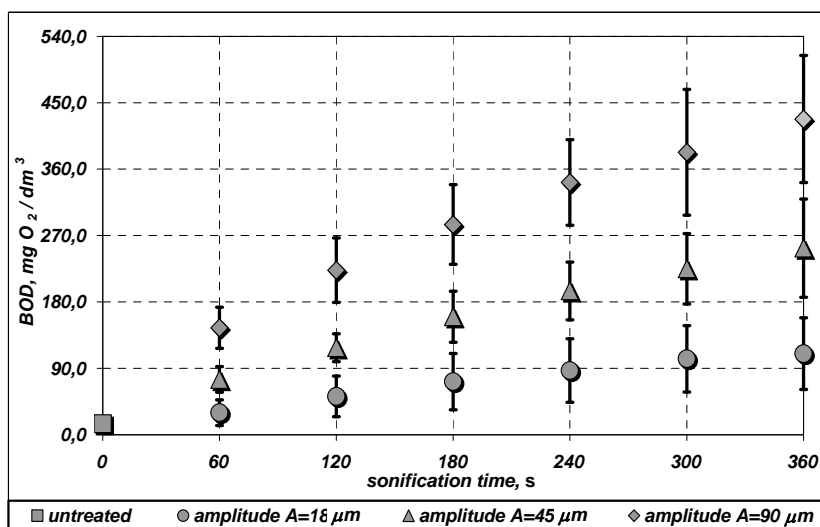


Fig. 6. The effect of ultrasonic wave amplitude and sonification time on BOD in supernatant

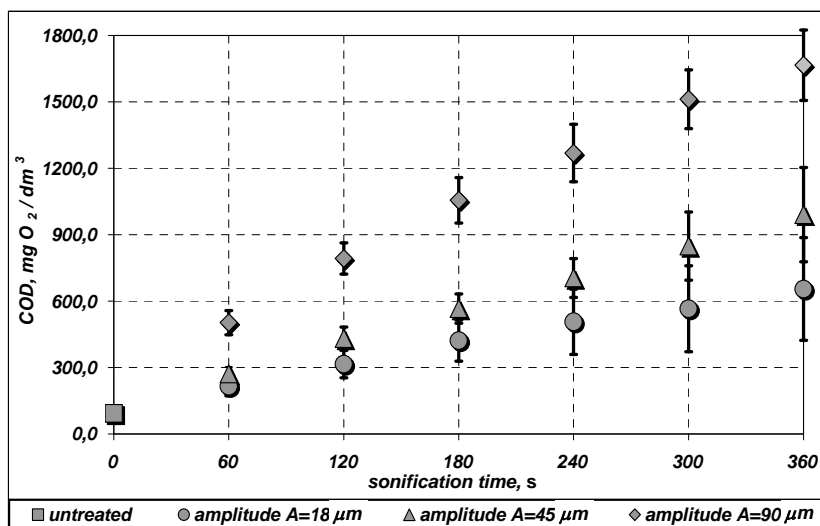


Fig. 7. The effect of ultrasonic wave amplitude and sonification time on COD in supernatant

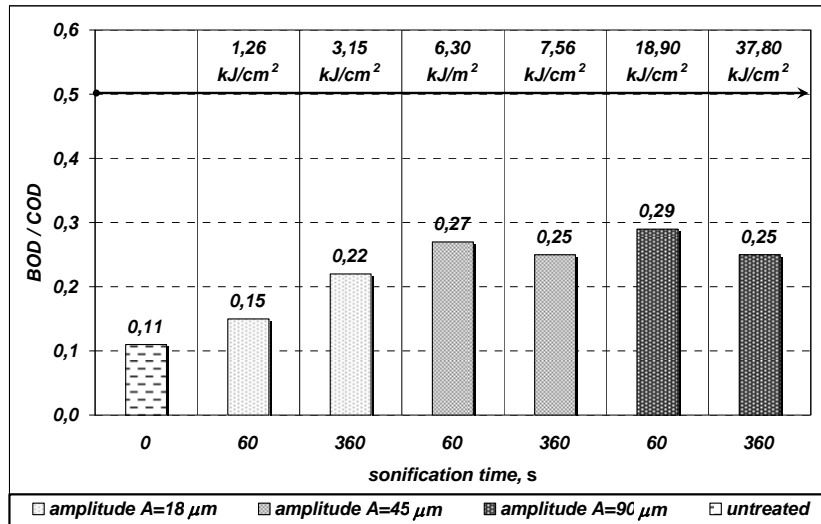


Fig. 8. The effect of ultrasonic energy input on biodegradability of supernatant

#### 4. CONCLUSIONS

Ultrasounds significantly changed the characteristics of solid particles and the properties of supernatant. An improvement of sludge thickening was feasible, although the ultrasonic wave had also some negative effects. Dispersion of sludge flocs and the lack of completed flocculation after sonification led to a secondary contamination of supernatant. A considerable amount of suspended particles was responsible for the deterioration of supernatant clarity and an increase in BOD and COD values. The sonification may be considered to be an appropriate technology of sludge pretreatment, provided that supernatant contamination is reduced, for example, through a decrease of an input energy. However, the deterioration as well as the improvement of the parameters investigated show a convergent direction of transformations towards expanding the input energy. The higher the ultrasonic intensity, the faster but also the least effective the separation of solid phase.

The value of an input energy was the function of frequency, amplitude and sonification time. Hence, there was a number of combinations of sonification parameters which can change to a large extent the characteristics of the system. However, the effect of ultrasonic wave application also depends on such parameters as temperature, pressure or the volume of dissolved gases. There is the necessity to select sonification parameters, which are very important for ultrasonic pretreatment. The aim of a further investigation will be also to take advantage of the properties of contaminated supernatant after sonification.

## ACKNOWLEDGEMENTS

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ZANIECZYSZCZENIE CIECZY OSADOWYCH  
PO PROCESIE SEDYMENTACJI SONIFIKOWANEGO OSADU CZYNNEGO

Badano możliwość wykorzystania energii fali ultradźwiękowej w procesach kondycjonowania osadów. Analizowano sprawność procesu separacji grawitacyjnej oraz wskaźniki charakterystyczne dla oddzielonych cieczy nadosadowych. Wynik nadźwiękowania określano na podstawie zmiennych procesu (czas sonifikacji oraz amplituda drgań fali ultradźwiękowej). Wynikiem sonifikacji było przyspieszenie procesu separacji oraz obniżenie uwodnienia końcowego osadów. Negatywne zmiany zaobserwowano w cieczach nadosadowych, które ulegają wtórnemu zanieczyszczeniu ładunkiem pozostałej zawiesiny. Zjawiska te analizowano, opierając się na wielkości wniesionej energii sonifikacji, określając tendencje występujące podczas propagacji fali ultradźwiękowej.