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# INFLUENCE OF CONDITIONING METHODS OF SLUDGE FROM WATER TREATMENT ON THE EFFECTIVENESS OF ITS MECHANICAL DEWATERING

The high compressibility of sludge leads to deterioration of the efficiency of its dewatering process. Therefore the conditioning of sludge before its dewatering is reasonable. This process allows both restsivity and compressibility of sludge to be reduced. It is possible to increase the sludge porosity by addition of chemical substances. In the sludge, they can create permeable and stiffer sludge space structure (i.e. grate). The structure developed in this way can be resistant to high pressure in a mechanical dewatering process. Through the application of ultrasonic field, as a factor that intensifies the action of chemical substances, we pursue boosting of dewatering effects. In this paper, we present the analysis of dewatering effectiveness of a pressure filtration process of sludge after its coagulation, being conditioned by different methods: only by polyelectrolytes, by ultrasounds + polyelectrolytes and by chemically neutral substances (ash, gypsum and cement).

## 1. INTRODUCTION

Technological processes applied in water treatment are the source of significant amounts of highly hydrated sludge. Still increasing sludge output is the consequence of growing requirements for drinking water quality as well as expansion and intensification of the treatment processes. The composition and properties of produced sludge depend on the composition of drawn water, its treatment technology, but mainly on the reagents applied. In the opinion of various authors, the volume of sludge after its coagulation is different. For instance, according to [10], [12], this volume is included between the minimum of 0.02–0.5% and the maximum of 3.0–5.0% in the proportion to coagulated water volume. To sum up, we must assume that the volume of after-coagulation sludge varies between 0.2% and 5.0% of produced water volume.

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Hydrophilic colloidal after-coagulation sludge consists mainly of metal hydroxides and natural additions occurring in a treated water [10]. Hydration of after-coagulation sludge (with its periodical draining from the settling tanks) ranges from 97 to 99.5%. However, when the hydration reaches 96%, the content of organic compounds in the dry mass of sludge reaches about 20–40%, and pH of after-coagulation sludge varies between 6.0 and 8.5. Sludge density is relatively low and varies from 1001.0 to 1019.8 $kg/m^3$. It has a characteristic significant filtration resistivity, ranging from about $5\cdot10^{12}$ to $60\cdot10^{12}$ m/kg. A biological contamination of this sludge depends mainly on a biological pollution (bacteria, viruses, parasites, algae) of treated water and on pre-disinfection before coagulation and sedimentation. Sludge produced during surface water treatment is much more contaminated with bacteria than the sludge from underground water treatment. In a former, a high number of bacteria and also the presence of viruses and cystes were identified [8], [9]. Sludge dewaterability depends principally on its solid phase structure and especially on the nature of binding between water and the surface of sludge solid phase. After-coagulation sludge has not been fully investigated so far, in spite of its essential theoretical and practical importance. The water contained in sludge can be classified as follows: volumetric water and physically, physicochemically and chemically bounded water. In the sludge with a physically bounded water, osmotic and capillary bonds occur. They restrain the water mechanically in pores and capillaries of pores. This is a volumetric water, despite its being under the action of capillary forces. Sludge rich in this water usually dewaters easily. Sludge containing physicochemically bounded water is very difficult to dewater. It consists mainly of mineral particles of amorphous structure and hydrophilic character. Water bounded chemically is the type of water most strongly bounded with the sludge solid surface. This water contains erystolic and hydrostatic water. Such a water is not removed from sludge in a dewatering process. Sludge conditioning processes are aimed to change the water bounded physically and physicochemically with the sludge into gravitationally free water [7]. Sludge conditioning by chemically inactive substances consists in adding, for example, gypsum, ash or diatomaceous soil in proper doses to sludge. These substances do not change the physical and chemical properties of treated sludge and affect positively its dewaterability [13]. The effect of coagulating action of ultrasonic field depends on the size of particles of sonicated suspended matter and on the sound frequency, while suspended soils of each size have their definite interval of oscillation frequency that ensures coagulation as the result of particles collisions. Active ultrasound action improves the ability of sonicated sludge particles to be better packed in space. Ultrasonic waves in a significant way influence the improvement of sludge dewatering conditions in the filtration process [5]. Application of ultrasonic field in the conditioning process is aimed at intensifying the sludge dewatering effect and limiting the usage of chemical reagents [1], [2], [3], [11].

## 2. EXPERIMENTAL

In the paper, an attempt at defining the pressure filtration effectiveness in the after-coagulation sludge dewatering, depending on the sludge preparation method, was made. Non-prepared (N) sludge, sonicated sludge (UD), sludge conditioned with polyelectrolyte (P), sludge both sonicated and conditioned with polylelctrolyte (UD +P), sludge prepared only with certain components (cement, gypsum, ash) and with mentioned earlier conditioning agents were analysed. The samples of mixed sludge, 100 $cm^3$ each, were tested.

Pressure filtration was carried out with a device composed of a pressure filter with filter cloth packed inside, bottle with compressed air, graduated cylinders for the filtrate, cut-off valves, manometer and stop watch. In the filtration process, compressed air of the pressure of 0.5 MPa was used. During the process the volume of filtrate was measured in relation to filtration time. This measurement was carried out till the moment of produced sludge cake breaking and releasing the air from the filter. Sludge cake was transferred to evaporating dishes of a known weight, weighted again and left to desiccation (to dry matter). In the calculation, the average value from 3 samples was taken.

As a chemical reagent a strongly anionic polyelectrolyte Praestol 2505 from German company Stockhausen was used in a dose of 0.25 mg/g of sludge dry matter in order to prepare a sludge. Components (cement, gypsum, ash) were used in the quantity of 1 g/100 $cm^3$ of sludge. The sludge structure was examined under microscope equipped with instruments to take photos in the transmissive light with the Minolta X-300 S camera.

Ultrasound disintegrator UP 4500 S with a frequency of 24 kHz, power of 400 W and the possibility of changing the wave amplitude and exposure time was used to sludge sonification. The process was carried out at the following sonification parameters: amplitude $A$ = 45 and 60 μm and sonification time $t$ = 60 and 120 seconds. After-coagulation sludge from water treatment station in Goczałkowice was chosen to the bests. In the coagulation process, aluminium sulphate was applied. The physico-chemical analysis of tested sludge is shown in the table.

Table

Physicochemical analysis of the sludge tested

| Denotation | Unit | Value |
|---|---|---|
| Initial hydration | % | 98.7 |
| Sludge dry mass | g/$dm^3$ | 13 |
| Mineral substance content | g/$dm^3$ | 8.9 |
| Organic substance content | g/$dm^3$ | 4.1 |
| CSK | s | 64 |
| pH | | 6.5 |

## 3. RESULTS

The research was conducted in order to establish the relationship between the sludge structure formed due to its conditioning and the effect of its dewatering in the pressure filtration process.

It has been shown that ultrasonic field, as a physical factor allowing modification of after-coagulation sludge conditioned with polyelectrolyte and chemically neutral substances, intensified the dewatering processes, which was proved by the results obtained. Exposing the sludge prepared with chemically neutral substances and conditioned with polyelectrolytes to the action of ultrasonic field led to a certain effect in the aspect of final hydration changes referring to the parameters of non-prepared sludge. Sludge sonification at a short exposure (60 and 120 s) leads to disturbances in system equilibrium. Such a process causes dispersion and partial homogenisation of

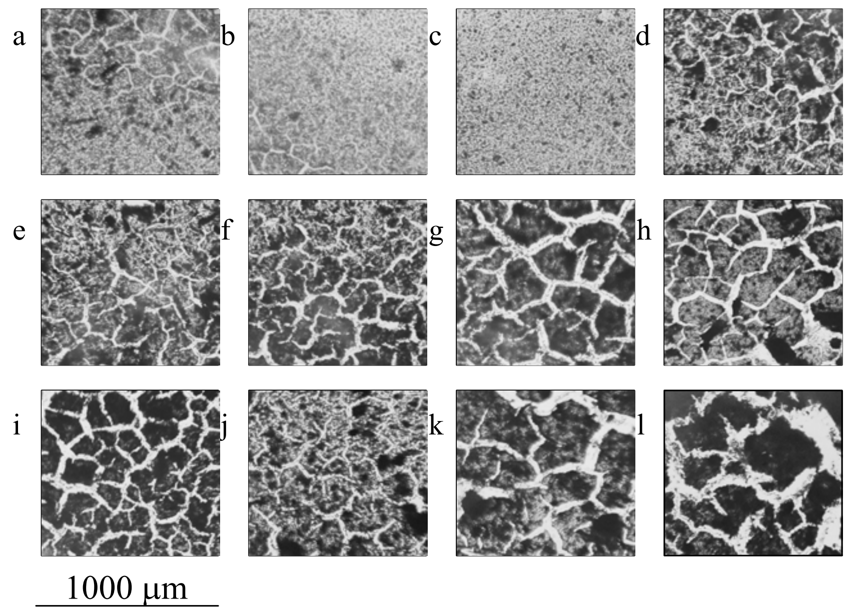
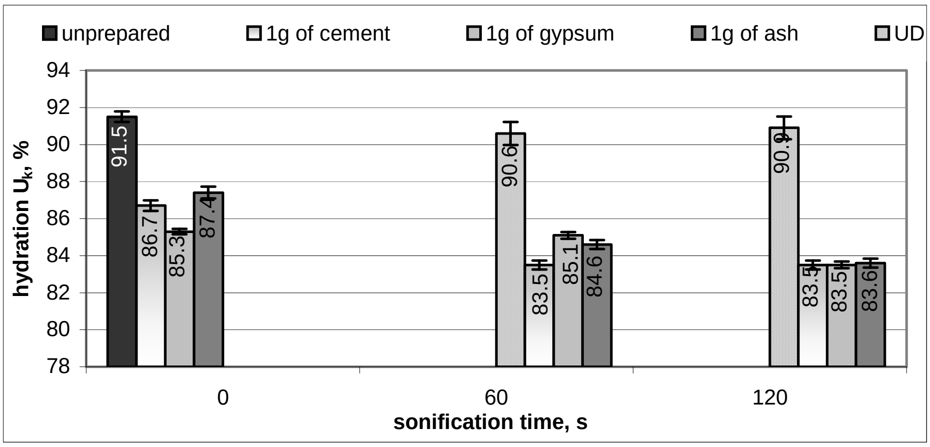
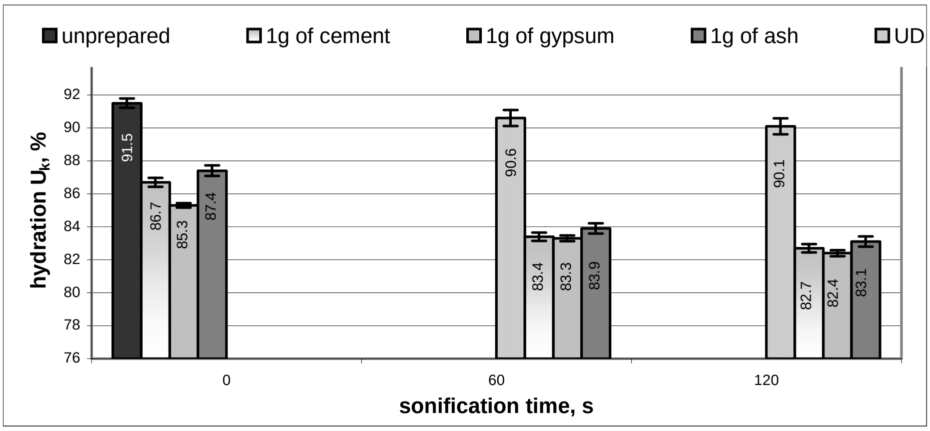



Fig. 1. Microscopic structure of after-coagulation sludge conditioned by different methods: a) unprepared sludge, b) sludge conditioned with ultrasonic field (UD), $A$ = 45 μm, $t$ = 60 s, c) sludge conditioned with ultrasonic field, $A$ = 90 μm, $t$ = 120 s, d) sludge conditioned with 1 g of cement, e) sludge conditioned with 1 g of ash, f) sludge conditioned with 1g of gypsum, g) sludge conditioned with UD, $A$ = 90 μm, $t$ = 120 s + 1 g of cement, h) sludge conditioned with UD, $A$ = 90 μm, $t$ = 120 s + 1 g of ash, i) sludge conditioned with UD, $A$ = 90 μm, $t$ = 120 s + 1 g of gypsum, j) sludge conditioned with UD, $A$ = 90 μm, $t$ = 120 s + polyelectrolyte dose of 0.25 mg/g d.m.o. and 1 g of cement, k) sludge conditioned with UD, $A$ = 90 μm, $t$ = 120 s + polyelectrolyte dose of 0.25 mg/g d.m.o. and 1 g of ash, l) sludge conditioned with UD, $A$ = 90 μm, $t$ = 120 s + polyelectrolyte dose of 0.25 mg/g d.m.o. and 1 g of gypsum




amplitude of 45 μm



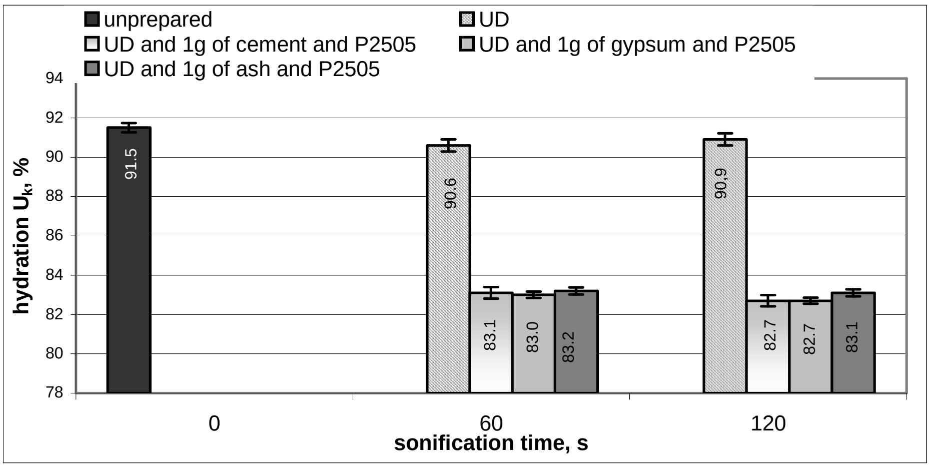

amplitude of 90 μm

Fig. 2. Influence of ultrasonic field and various chemical substances on the changes of sludge final hydration

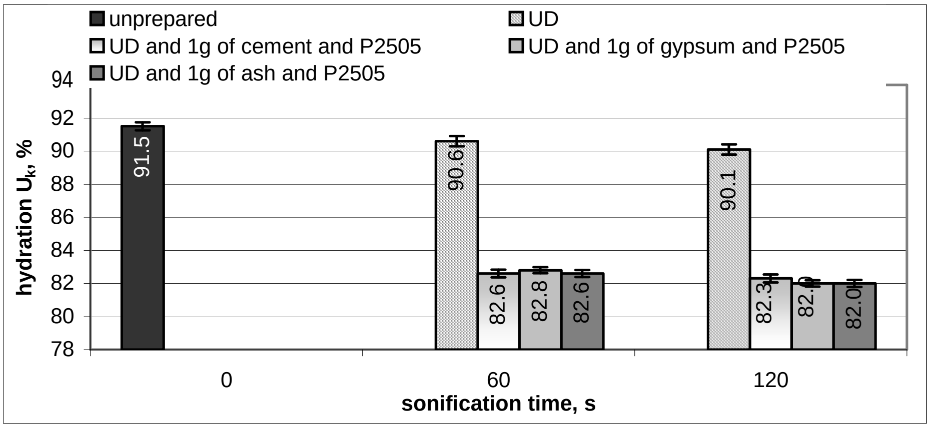
a suspended matter, which is shown in figure 1b, c. Sonochemical processes being caused by cavitation and resonance are mainly responsible for the changes observed in a sonicated sludge structure. This is the effect of mechanical forces generated in the pulsing bulbs of proper sizes, being in resonance with the wave of a defined frequency transmitting the sludge tested. Research carried out by BIEŃ et al. [4], [5], [6] proves that sludge sonification in shorter time than 60 s leads in every case to a rise of dispersion level. Longer sonification of mineral sewage sludge along with its elongated exposure to ultrasonic field were not observed for after-coagulation sludge (elongation of sonification was followed by intensification of sludge dispersion). Such a behaviour of after-coagulation sludge treated with ultrasonic field energy may be connected with its composition, principially different from that of sewage sludge, and with ultrasonic wave intensity. Application of pre-sonification and chemical substances (cement, gypsum, ash) in conditioning of tested after-coagulation sludge led to establishing the structure characterised by very big agglomerates of thickened sludge floccules and clear areas with free water (figure 1g, h, i). During mechanical dewatering sludge was characterised by a rigid structure of much lower compressibility capable of enduring high porosity accompanying high pressure. As a result of dewatering the sludge conditioned only with ultrasonic field, a slight decrease of its final hydration compared to non-prepared sludge was obtained (figure 2).

At the amplitude of 45 μm, the best was a 60 s exposure time, allowing a 0.9% decrease in final sludge hydration in comparison with non-sonicated sludge. Application of 90 μm amplitude did not decrease significantly a sludge final hydration; the best effect (90.1%) was achieved by using the longest sludge exposure (120 s) to ultrasonic field. The structure of sludge characterized by very strong dispersion and no visible fields of free water were responsible for such dewatering results (figure 1b, c). Also the comparison was made of conditioning process for tested sludge ultrasonic field and components (cement, gypsum and ash (figure 2)) in that aspect of mentioned dewatering result and observed macrostructure (figure 1g, h, i). In the case of sludge sonicated for 120 s and amplitude of 45 μm, the lowest final hydration was achieved by application of cement and gypsum (83.5%). With bigger amplitude and the same sonification time gypsum (82.4%) proved to be the best conditioning component. The structure of sludge conditioned in such a way is characterized by abundance of densely packed sludge agglomerates and by visible places of free water. No single dispersed particles were noticed. Sludge prepared in this way increased its dewaterbility.

The results of dewatering the sludge prepared by means of joined method, ultrasonic field, polyelectrolyte and chemical components, which improve dewatering results, are presented in figure 3. Irrespective of the kind of a chemically neutral substance used (cement, ash, gypsum), the lowest final hydration (82%) was achieved at the oscillation amplitudes of 90 μm, the time of 120 s and polyelectrolyte. In the structure of sludge conditioned in this way, very dense agglomerate (figure 1j, k, l) were observed. In a visual field single, flocculent sludge conglomerates were observed. No dispersed particles were noticed. Distinct boundaries between sludge floccules and fields of free water were visible.




amplitude of 45 µm




amplitude of 90 µm

Fig. 3. Influence of a combined effect of ultrasonic field, various chemical substances and polyelectrolyte (Praestol 2505) on the changes of sludge final hydration

## 4. CONCLUSIONS

1. Sonification is an effective method that facilitates a flocculating action of polyelectrolyte and chemically neutral substances. The results of applying such means manifested themselves as the change of the sludge structure, which leads to establishing the structure characterized by very big agglomerates of dense sludge floccules

and distinct areas of free water. During mechanical dewatering the sludge is characterized by a rigid structure with significantly decreased compressibility capable of maintaining high porosity at high pressures.

2. It is possible to decrease final hydration of after-coagulation sludge even by 4% (from 86.7% to 82.7%) due to application of ultrasonic field which facilitates the action of chemical substances in the process of sludge conditioning.

3. Combined methods (presonification + polyelectrolyte + chemical components) proved to be the most effective conditioning methods. Such a system of conditioning agents in a pressure filtration process allowed a decrease in a final hydration to 82%, hence a dry matter concentration in sludge reaches 18%.

4. With application of chemical components in the conditioning of after-coagulation sludge, even 4-times higher efficiency of press filtration process was achieved.

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## WPŁYW METODY KONDYCJONOWANIA OSADU POWSTAŁEGO PODCZAS OCZYSZCZANIA WODY NA JEGO MECHANICZNE ODWADNIANIE

Zbyt duża ściśliwość osadów prowadzi do zahamowania procesu ich odwadniania. Uzasadnione więc jest kondycjonowanie osadów przed odwadnianiem nie tylko, aby zmniejszyć określony opór, ale aby też zmniejszyć ściśliwość osadów. Porowatość osadów można zwiększyć, dodając do nich substancje chemiczne, często nazywane budowniczymi szkieletu. Mogą one z osadami tworzyć przepuszczalną i sztywną strukturę przestrzenną (tzw. kratę). Tak powstała struktura wytrzymuje wysokie ciśnienie w procesie mechanicznego odwadniania osadu. Wykorzystując pole ultradźwiękowe jako czynnik intensyfikujący działanie substancji chemicznych, dążymy do zwiększenia efektów odwadniania. Przedstawiono analizę efektywności odwadniania w procesie filtracji ciśnieniowej osadów pokoagulacyjnych, kondycjonowanych polielektrolitami, metodą łączoną (ultradźwięki + polielektrolit) oraz substancjami chemicznie obojętnymi (popiół, gips, cement).