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SETTLING CHARACTERISTICS OF SLUDGE PARTICLES PRODUCED BY WATER TREATMENT PROCESSES

The increasing amounts of sludges and washings produced by water treatment processes pose a number of difficulties for the water treatment plants. So far, the methods for sludge thickening and dewatering either on beds or lagoons are considered to be insufficient, difficult and expensive in exploitation. The sludge particles in a form of flocculent structures bind water in a mechanical way causing a number of difficulties in a process of water removal. In order to intensify the effect of thickening and dewatering processes, the sludges need prior preparation resulting in transformation of the sludge from amorphous into porous structure which facilitates water removal. The application of the ultrasonic field as a factor modifying polyelectrolyte enables us to increase the effect of sludge dewatering. The method proposed is neither dangerous nor detrimental to the environment. The paper deals with the efficiency of thickening of post-coagulated sludge conditioned a polyelectrolyte and sludge conditioned by polyelectrolyte and exposed to the ultrasonic field.

1. INTRODUCTION

Sludges and washings are waste products generated in water treatment processes in water supply plants in order to fulfil the requirements imposed on the quality of potable water [1]. Although the post-coagulated sludges do not need stabilization due to a high degree of sanitary safety, they are not suitable for agricultural applications.

In modern methods of sludge treatment, different types of equipment for thickening and dewatering are used. In the sludge treatment, these unit processes are of a great significance that are associated with relocation of sludge phases. Sludges constitute a three-phase dispersed system with predominant liquid and solid phases. The transformation of the phases takes place when the solid phase is precipitated from liquid or the liquid phase is drained off. These mechanisms occur in the processes of

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sludge thickening, i.e. sedimentation and flotation, as well as the processes of dewatering, i.e. filtration and centrifugation [2].

Sludges generated in water treatment processes are strongly hydrated (even up to 99.8%, depending on the equipment used in a water treatment train) and contain a mixture of aluminium or ferric hydroxides and water impurities in the form of coagulate. The structure and characteristics of these sludges are responsible for their strong abilities to bind water which impairs considerably the process of sludge thickening and dewatering [3], [4]. Time is a critical parameter of the process of sludge thickening by means of sedimentation and therefore the time of settling depends on settling velocity of sludge particles; however, in a final phase of thickening, this velocity is a function of suspension concentration [2].

In order to increase the efficiency of thickening and dewatering, sludges need some preparation resulting in their transformation from amorphous to porous structures which facilitate water removal. The type of sludge preparation depends on dewatering methods. The application of polyelectrolytes as well as ultrasonic field in sludge conditioning results in significant improvement of filtration properties of sludge which, in turn, leads to some changes in its structure. The interaction between ultrasounds and polyelectrolytes improves the dewatering effect, particularly in the case of gravitational thickening. Ultrasounds of high frequency, depending on physical properties of the medium, can lead either to coagulation, i.e. combining small sludge particles into larger agglomerates, or dispergation which results in size reduction of larger sludge particles. The efficiency of sludge thickening is measured by the degree of thickening which is defined as the ratio of dry mass of concentrated sludge to dry mass of non-concentrated sludge.

2. METHODS

The aim of our research was to apply the method combining the ultrasounds and polyelectrolytes in the processes of ultrasound disintegration as well as polymer coagulation. The results of the method applied were estimated based on gravitational thickening of post-coagulated sludges. Our purpose was to determine the most effective physical parameters of the ultrasound field and the optimal dose of polyelectrolyte.

The sludge samples were taken from the horizontal settling tank in the Water Treatment Plant in Dzieckowice. Aluminium sulphate was used as a coagulant. A physicochemical characteristics of the sludges is presented in table 1. PRAESTOL 2530 was used as a chemical reagent in the experiments. The optimal dose of polyelectrolyte was determined based on the test of capillary suction time. The sludge samples were subjected to ultrasonication with the UP 400 S disintegrator of the power output of 400 W, the frequency of 24 kHz and the of amplitude ranging from

12 to 90 μm. This process was carried out at the of amplitude ranging from 45 μm to 90 μm, the time of exposition of sludge to ultrasound field of 1.2 min. The polyelectrolyte was subjected to ultrasonication for 15 s.

Table 1

Physicochemical characteristics of post-coagulated sludges

Parameter	Unit	Value
Initial hydration	%	99.8
Dry matter of sludge	g/dm^3	2.0
Mineral substances	%	69.0
Organic substances	%	31.0
Time of capillary suction	s	34
Colour	–	brown
Odour	–	natural
Reaction	pH	7.2

In order to provide a more detailed background to the results, the experiments were carried out in five stages. They can be itemized as follows:

- gravitational thickening of non-prepared sludges,
- gravitational thickening of sludges treated with polyelectrolyte,
- gravitational thickening of sludges subjected to ultrasonication,
- gravitational thickening of sludges treated with polyelectrolyte and subjected to ultrasonication,
- gravitational thickening of sludges treated with the polyelectrolyte subjected to ultrasonication.

The process of gravitational thickening was carried out in measuring cylinders of 1000 cm^3 volume and the time of gravitational thickening was 120 minutes. The microscope equipped with camera Minolta X-300 was used for examination of the sludge structure.

3. RESULTS

The efficiency of gravitational thickening of post-coagulated sludges is shown in table 2. The average values were calculated based on the results for six samples of sludges representing each preparation method. The final volume of concentrated sludge is considered to be the most essential technological parameter of the thickening process.

Table 2

Characteristics of gravitational thickening of post-coagulated sludges with reference to the preparation method applied

Preparation methods	The volume after thickening [cm^3], time of 120 min
Non-prepared sludge	738
Sludge + UD A = 45, t = 1	920
Sludge + UD A = 45, t = 2	904
Sludge + UD A = 90, t = 1	944
Sludge + UD A = 90, t = 2	916
Sludge + polyelectrolyte d = 1 mg/g d.m.	600
Sludge + polyelectrolyte d = 0.75 mg/g d.m.	608
Sludge + polyelectrolyte d = 0.5 mg/g d.m.	700
Sludge + polyelectrolyte d = 0.25 mg/g d.m.	872
Sludge + UD A = 45, t = 1 + polyelectrolyte d = 1 mg/g d.m.	544
Sludge + UD A = 45, t = 1 + polyelectrolyte d = 0.75 mg/g d.m.	624
Sludge + UD A = 45, t = 2 + polyelectrolyte d = 1 mg/g d.m.	400
Sludge + UD A = 45, t = 2 + polyelectrolyte d = 0.75 mg/g d.m.	410
Sludge + UD A = 90, t = 1 + polyelectrolyte d = 1 mg/g d.m.	420
Sludge + UD A = 90, t = 1 + polyelectrolyte d = 0.75 mg/g d.m.	420
Sludge + UD A = 90, t = 2 + polyelectrolyte d = 1 mg/g d.m.	510
Sludge + UD A = 90, t = 2 + polyelectrolyte d = 0.75 mg/g d.m.	560
Sludge + (polyelectrolyte d = 1 mg/g d.m. + UD A = 45, t =15 s)	460
Sludge + (polyelectrolyte d = 0.75 mg/g d.m. + UD A = 45, t =15 s)	620
Sludge + (polyelectrolyte d = 1 mg/g d.m. + UD A = 90, t =15 s)	590
Sludge + (polyelectrolyte d = 0.75 mg/g d.m. + UD A = 90, t =15 s)	430

d – polyelectrolyte dose [mg/g d.m.], t – time [min], UD – ultrasonic field, A – amplitude [μm].

Taking into account the aforementioned results, ultrasonication of sludges as the only method of their removal seems to be unfavourable due to a significant deterioration of sludge ability to settle in comparison to raw (untreated) sludges. The structure of post-coagulated sludges, which were subjected to ultrasonication, underwent some changes. The application of the amplitude of 45 μm and 90 μm resulted in disintegration of sludge particles. In this case, a content of free water was slightly higher in comparison with non-prepared sludges. It seems that application of ultrasound field leads to generation of fine agglomerates of sludge whose loose structure and insignificant mass impair considerably the process of sedimentation (figure 1b, c). The particles of non-prepared sludges were finely-dispersed and non-uniformly distributed and neither sludge clusters nor free water were observed.

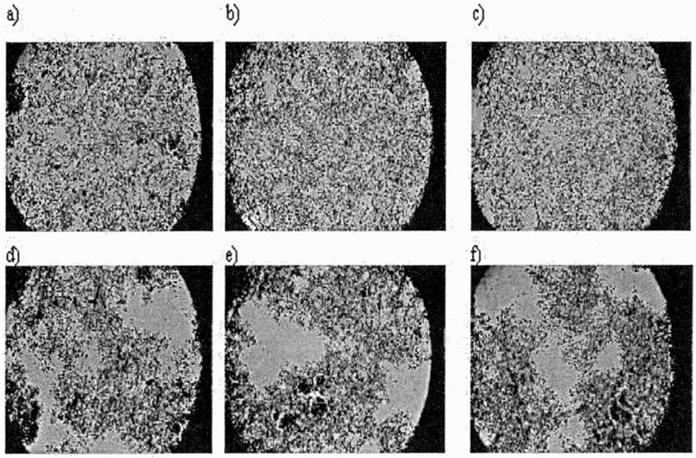

Fig. 1. Microscopic structure of post-coagulated sludges:
a) non-prepared sludge, b) sludge subjected to ultrasonication, $A = 45$ μm, $t = 1$ min,
c) sludge subjected to ultrasonication, $A = 90$ μm, $t = 2$ min,
d) sludge + polyelectrolyte, $d = 0.75$ mg/g d.m.,
e) sludge subjected to ultrasonication, $A = 45$, $t = 1$ min + polyelectrolyte, $d = 0.75$ mg/g d.m.,
f) sludge subjected to ultrasonication, $A = 90$, $t = 2$ min + polyelectrolyte, $d = 0.75$ mg/g d.m.

The sludge treated with polyelectrolyte at almost all doses exhibited a remarkably efficient sedimentation as well as the improvement of the entire process of thickening.

The sludge was concentrated up to 600 cm^3 at the maximum dose of 1 mg of polyelectrolyte/g of dry matter of sludge which is associated with the change in the sludge structure (figure 1d). The dense flocculent agglomerates of sludge, an increased content of free water and few dispersed sludge particles were observed. Such a structure of sludge greatly facilitates its sedimentation, hence improves the process of gravitational thickening.

The most effective thickening (approaching 400 cm^3 at the maximum polyelectrolyte dose of 1 mg/g dry matter of sludge, amplitude of 45 μm and time of 1 min) was achieved for the sludge treated with ultrasounds and polyelectrolyte. The highest intensity of the process was observed for initial 30 minutes and the volume of concentrated sludge reached 480 cm^3. The sludge treated with combined method comprised large, dense agglomerates with a high content of free water (figure 1e, f). If polyelectrolyte was first subjected to ultrasonication and then was used for sludge treatment, the entire process of gravitational thickening was improved in comparison to the process with the same polyelectrolyte which was not subjected to ultrasonication. In figure 2, two processes of sludge thickening carried out using sludge treated with polyelectrolyte and the sludge treated with combined method (ultrasound + polyelectrolyte) were compared. In each case, a combined method of sludge thickening proved to be more efficient in comparison with the method where sludge was treated with polyelectrolyte only. The highest sludge concentration, i.e. 400 cm^3, was obtained using a combined method at the amplitude of ultrasonication of 45 μm, time of 2 min and polyelectrolyte dose of 1 mg/g dry matter of sludge.

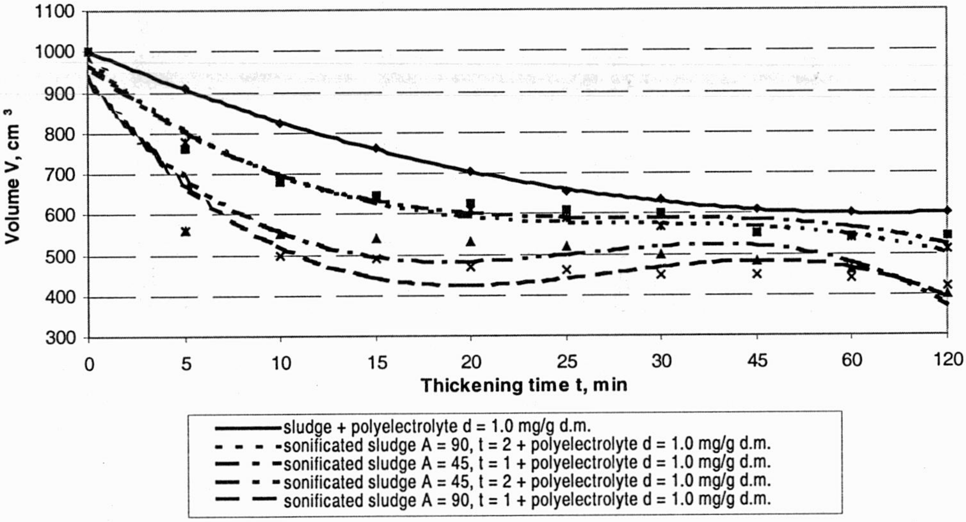

Fig. 2. The process of gravitational thickening of sludge prepared with polyelectrolyte only and ultrasounds + polyelectrolyte

4. CONCLUSIONS

1. The treatment of sludges by means of ultrasound field only impairs the process of their gravitational thickening.

2. The most efficient method of conditioning of post-coagulated sludges in the process of their gravitational thickening is a combined use of ultrasound field and polyelectrolyte.

3. The polyelectrolyte subjected to ultrasonication and used for conditioning a post-coagulated sludge improved its sedimentation in comparison with conditioning the sludge treated with polyelectrolyte alone.

4. The application of the flocculant and ultrasonication leads to formation of stable and compact agglomerates which facilitate removal of free water.

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CHARAKTERYSTYKA OSADZANIA SIĘ CZĄSTEK OSADÓW POWSTAJĄCYCH PODCZAS UZDATNIANIA WODY

Wzrastające ilości osadów i popłuczyn z oczyszczania wody są poważnym problemem w zakładach uzdatniania wody. Metody ich zagęszczania i odwadniania na poletkach czy lagunach stosowane do tej pory są niewystarczające, trudne do przeprowadzenia i kosztowne w eksploatacji. Cząstki osadów tworzące struktury kłaczkowe w sposób mechaniczny wiążą wodę, której usuwanie stwarza trudności. Aby zwiększyć efekt zagęszczania i odwadniania osadów, poddaje się je wcześniej odpowiedniemu przygotowaniu, co pozwala przekształcić strukturę osadów z bezpostaciowej w porowatą, z której łatwiej usunąć wodę. Wykorzystując pole ultradźwiękowe jako czynnik modyfikujący działanie polielektrolitów, dąży się do zwiększenia efektów odwadniania. Taka metoda kondycjonowania nie stanowi zagrożenia dla środowiska. Przedstawiono próbę analizy efektywności zagęszczania osadów pokoagulacyjnych kondycjonowanych za pomocą polielektrolitu oraz skojarzonej metody ultradźwięki + polielektrolit.