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**EFFECT OF POLYELECTROLYTE DOSE
ON THE CHARACTERISTICS OF SEWAGE SLUDGE
IN SEDIMENTATION PROCESSES
IN SMALL-SIZE WASTEWATER TREATMENT PLANTS**

**WPLYW DAWKI POLIELEKTROLITU
NA CHARAKTERYSTYKI OSADÓW ŚCIEKOWYCH
W PROCESACH SEDYMENTACJI
W MAŁYCH OCZYSZCZALNIACH ŚCIEKÓW**

Abstract: The subject of the article are studies on the characteristics of sewage sludge conditioned with the polyelectrolyte Zetag 7631. Sewage sludge was taken at specified time intervals from the same small-size sewage treatment plant. Based on the capillary suction time test, optimal doses of the applied polyelectrolyte were chosen, for which tests were carried out to describe the effects of gravity thickening and dewatering in the process of centrifuging of the sewage sludge examined. The tests determined that untreated sewage sludge in each case underwent thickening and dewatering poorer than the identical sludge conditioned with polyelectrolyte. Based on the obtained test results, relationship curves for selected parameters characterizing the dewatered sludge were plotted. In addition, microscopic observations of sewage sludge conditioned with the polyelectrolyte chosen for the tests were made. On their basis, a relationship of variations in the conditioned sludge structure on the polyelectrolyte dose was determined.

Keywords: sewage sludge, polyelectrolyte, structure change, gravity thickening, centrifuging, final hydration

Sludge management in small-size sewage treatment plants is presently one of the major problems for rural communes. The growing number of external funds, both domestic and foreign, an particularly the European Union's, creates great opportunities for development. It is becoming the priority for local authorities to build sanitary sewage systems and local sewage treatment plants. Along with investing into environmental protection, problems arise in connection with the disposal of generated wastes, including sewage sludge, which properties are very diverse and dependent on many factors.

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The composition and nature of sewage sludge depend on the type of sewage getting to the treatment plant, and on the method of its treatment. Practice shows that there are no two identical sewage sludge [1–3]. Sewage sludge forms a complex multiphase and polydispersion system. It may contain compounds of an organic and mineral nature, in an insoluble, colloidal, and soluble forms. However, the most important characteristics of sewage sludge, which determine their noxiousness, are their amount and hydration [4, 5]. From among the many methods of conditioning, chemical conditioning, including the use of polyelectrolytes, is most often used. So treated sewage sludge more readily undergo sedimentation and thickening in mechanical devices [6, 7]. Recent years have shown an increasing interest in the use of high-molecular weight synthetic polyelectrolytes being regarded as the agents that most effectively aid the processes of sewage sludge pre-treatment before dewatering [8]. Studies carried out so far both home and abroad have shown that polyelectrolytes used in the conditioning of sewage sludge cause an improvement in filtration conditions, thus bringing about changes in their structure. The change of sewage sludge structure results, among other things, in a considerable weakening of the forces bonding water with the surface of solid phase particle, thus facilitating the removal of water in mechanical dewatering processes [9, 10]. An operation which is important for every sewage treatment plant is the proper selection of a polyelectrolyte and its dose, which depends on the type of sewage received by the treatment plant, and the method of sewage treatment. Therefore, the selection of the polyelectrolyte should be made based on experimental tests carried out for each individual sewage treatment plant. An improper selection of the polyelectrolyte dose may result in increased operational costs, and may also impair the result of sewage sludge dewatering [5]. Conditioning agents aid the processes of sewage sludge sedimentation during gravity thickening and dewatering, eg in the processes of sewage sludge centrifuging. Sedimentation is the separation of a suspension into a clear liquid and solid phase particles as a result of particles falling down on the non-porous surface of a tank due to the gravitational force, or other forced motion of particles, caused eg by centrifugal force [11].

Experimental

The experimental part of the study included tests of sewage sludge taken from the sewage sludge stabilization chamber with the aim of describing the physicochemical characteristics of the sewage sludge examined (Table 1), and tests of the same sewage sludge, as conditioned with polyelectrolyte, as well as the monitoring of the conditioning process. The parameters describing the occurring processes were: *capillary suction time* (CST), gravity thickening and hydration in the centrifuging process.

Sewage sludge originating from SBR-type sewage treatment plants of a flow capacity of $Q = 500 \text{ m}^3/\text{day}$ were used for the tests, and were designated with the symbols A, B, C. Sewage sludge were taken at 2.5 months' intervals in 2006, as follows: Sludge A was taken in early January, Sludge B in mid-March, and Sludge C at the end of May. On the sludge sampling day, the percentage of delivered sewage was as follows: for Sludge A, 14 %; for Sludge B, 28 %; and for Sludge C, 5 %.

Table 1

Initial parameters of the examined sludge³

No.	Parameter	Unit	Sludge A	Sludge B	Sludge C
1	Colour	—	brown	brown	brown
2	Odour	—	black	black	specific
3	pH	—	7.00	7.90	6.90
4	Initial hydration	%	98.15	92.76	97.56
5	Dry mass (d.m.)	%	1.85	7.24	2.44
6	The content of organic dry mass	% d.m.	74.36	64.36	72.81
7	The content of mineral dry mass	% d.m.	25.64	35.64	27.19
8	CST	s	398.00	150.00	278.00
9	Final hydration	%	94.10	88.70	90.80
10	Resistivity	$\text{m} \cdot \text{kg}^{-1}$	$14.60 \cdot 10^{12}$	$1.28 \cdot 10^{12}$	$8.93 \cdot 10^{12}$
11	Filtration velocity	$\text{m}^3 \cdot \text{s}^{-1}$	0.02	0.03	0.02
12	Filtration capacity	$\text{kg} \cdot \text{m}^{-2} \cdot \text{h}^{-1}$	0.24	3.20	1.84

For treating the sewage sludge, the Zetag 7631, a very strong cationic type polyelectrolyte, was used [12].

The CST measurement was made on a setup consisting of a measuring adapter and a system automatically controlling the time of blotting-paper absorbing the moisture from the sewage sludge after passing between two rings. Based on the capillary suction time test, the range of optimal polyelectrolyte doses was determined.

The microscopic observations of the structure of the sewage sludge under examination were conducted at a 100-times magnification and with a capability to measure the distance between flocs formed and the sewage sludge agglomerates.

The gravity thickening process was conducted in 1000 cm³ cylinders. The reading of the volume of a separating concentrated sludge layer was taken every 5, 10, 15, 30, 60, 90 and 120 minutes. Based on the measurements of thickened sludge volumes, thickening curves were plotted.

Centrifuging of the sewage sludge was conducted in a periodic-duty laboratory centrifuge with a centrifuging speed and time regulator. The volume of sewage sludge samples subjected to centrifuging was 50 cm³. The tests were carried out for a rotational speed of 4500 rpm and a centrifuging time of 5 minutes. The centrifuged sample volume was 50 cm³.

Results

Based on the capillary suction time test, the properties and efficiency of the Zetag 7631 polyelectrolyte used in the conditioning process, and the selection of optimal doses were determined. From the curves plotted (Fig. 1), the following polyelectrolyte doses were chosen for the tests: 2.0, 2.5 and 3.0. It follows from Fig. 1 that the capillary suction time for each of the sewage sludge tested decreased with increasing dose of the polyelectrolyte used. Further increasing the polyelectrolyte dose resulted in a further

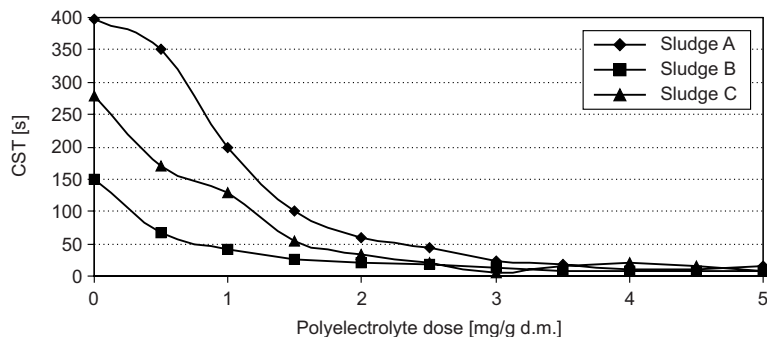


Fig. 1. The influence of polyelectrolyte Zetag 7631 dose on the change of capillary suction time of the examined sludge

decrease in the CST value, but the changes in the sludge structure and the size of flocculi formed, which were observed at the same time, indicated no justification for continuing the increasing of the flocculent quantity (exceeding the break point) [2].

The microscopic photographs of sewage sludge structure (Fig. 2) enable the assessment of the changes occurring in this structure. Observations showed that the polyelectrolyte dose influenced the processes occurring in the sludge. It was found that with the increase in the polyelectrolyte dose, the size of flocculated particles increased.

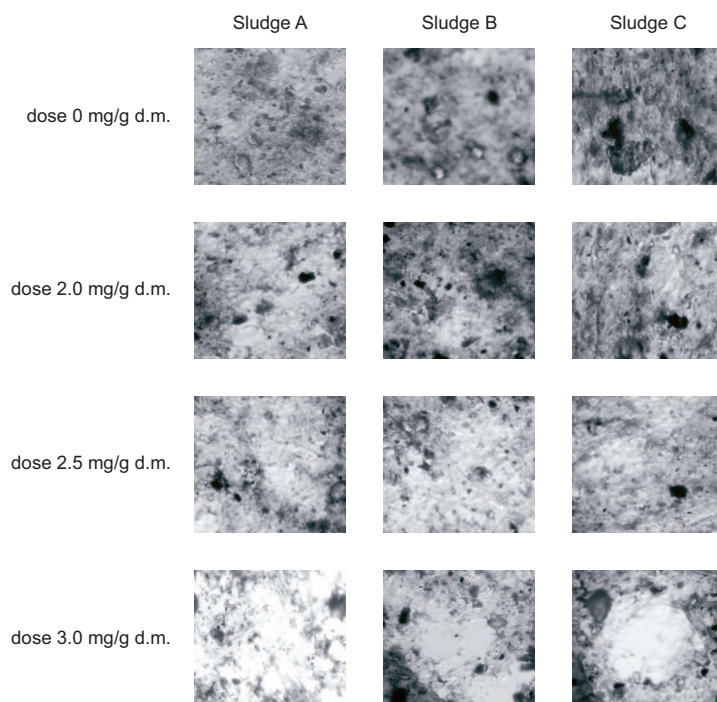


Fig. 2. The structure changes of sludge conditioned by means of Zetag 7631 polyelectrolyte

Untreated sewage sludge showed a finely dispersed structure, and their particles uniformly filled the field of vision. No sludge agglomerates or free water were observed. The conditioning of the sewage sludge with the polyelectrolyte clearly influenced their structure, as compared with untreated sewage sludge. For the dose of 2.0, sludge flocs appeared in the field of vision. The amount of free water present between them increased. The distance between forming floc agglomerates filled with free water was measured. For the dose of 2.0, this value ranged from 8.5 μm to 17 μm ; for the dose of 2.5, from 17 μm to 64 μm ; for the dose of 3.0, from 63 μm to 94 μm (Sludge B) and over 100 μm (Sludge C).

Then, the gravity thickening process was carried out, respectively, for the untreated sludge and for the sludge conditioned with the Zetag 7631 polyelectrolyte in the doses chosen for the tests.

The sewage sludge taken for the tests proved to be very hard to thickening, as during a 2 hours' settling test they underwent sedimentation to a very small extent (the final volume of Sludge A was 995.5 cm^3 ; that of Sludge B was 994 cm^3 ; and of Sludge C, 991.5 cm^3) – Fig. 3.

The settling tests of the sewage sludge for the range of doses determined with the CST test turned out to be more effective for the gravity thickening process. The volume

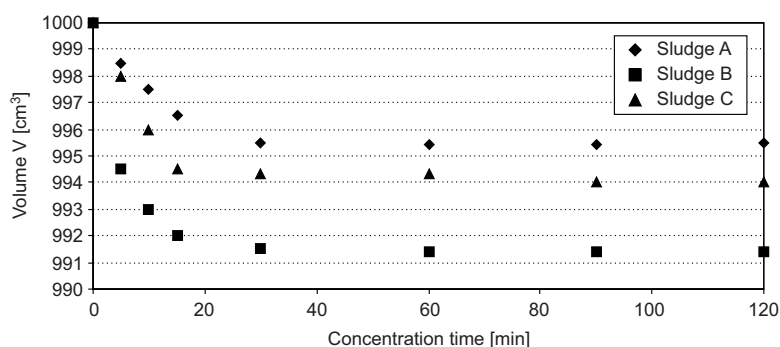


Fig. 3. The course of the gravitational concentration for non-prepared sludge

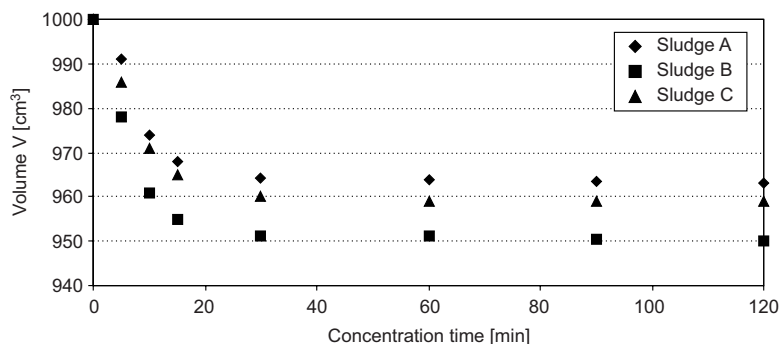


Fig. 4. The course of the gravitational concentration of prepared sludge by means of 2.5 mg/g d.m. dose of polyelectrolyte

of sewage sludge treated with the Zetag 7631 polyelectrolyte in the dose of 2.5 mg/g d.m. after 30 minutes was at a level of 963 cm³ for Sludge A, 950 cm³ for Sludge B, and 959 cm³ for Sludge C.

The course of the sewage sludge thickening test using the dose of 2.5 mg/g d.m. is illustrated in Fig. 4.

The sewage sludge tested were next subjected accelerated sedimentation by centrifuging, and then their final hydration was determined. Variations in the final hydration of sewage sludge in the centrifuging process are shown in Figs. 5 and 6.

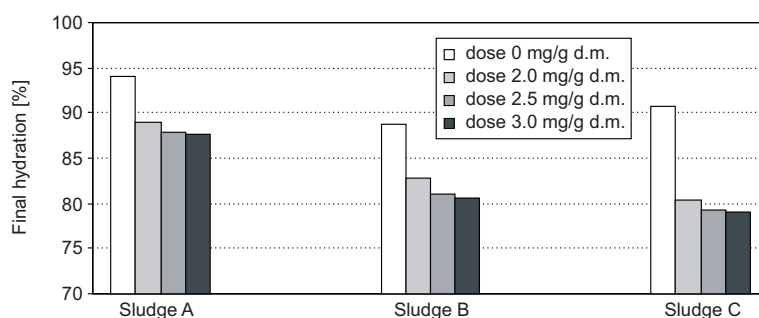


Fig. 5. The final hydration changes of the examined sludge during the centrifuging process

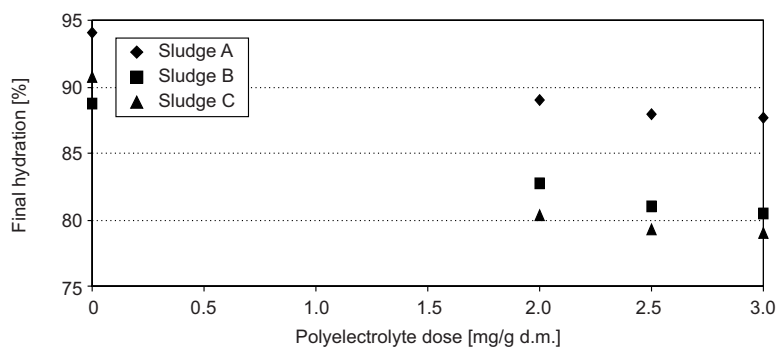


Fig. 6. The comparison of hydration changes of the examined sludge during the centrifuging process

From the obtained test results, an effect of the conditioning agent on the examined parameters was found. The final hydration of untreated sewage sludge in the centrifuging process was, respectively: 94.1 % for Sludge A, 88.7 % for Sludge B, and 90.8 % for Sludge C. The treatment of the sewage sludge with the polyelectrolyte doses caused a reduction in the examined parameter. The final hydration for sewage sludge conditioning with the dose of 2.0 mg/d.m. was, respectively: 89.1 % for Sludge A, 82.8 % for Sludge B, and 80.3 % for Sludge C. The best dewatering effects were obtained for Sludge C. For centrifuged Sludge C, the difference in final hydration between the untreated sludge and the sludge conditioned with the dose of 3.0 mg/g d.m. was 11.8 %.

However, for each of the sewage sludge tested, a dose which definitely influences the effectiveness of dewatering is the dose of 2.5 mg/d.m. The remaining higher doses of the flocculent used reduce the sewage sludge hydration only to a small extent.

Conclusions

From the investigation carried out, the following conclusions have been drawn:

- sewage sludge taken from the same small-size sewage treatment plant at different time intervals differed in their initial parameters and ability to be gravity thickened and dewatered in a centrifuge;
- dewatering of the sewage sludge tested by centrifuging progressed favourably, which was found from the obtained results of final hydration;
- conditioning of sewage sludge before dewatering with fixed doses of polyelectrolyte had the effect of improving the outcome of gravity thickening and dewatering in a centrifuge;
- only one polyelectrolyte dose, the optimal dose, causes the best reduction of the hydration of sewage sludge that exhibit different initial parameter, though originate from the same sewage treatment plant;
- for the sewage sludge investigated, there is a relationship between the floc size and agglomerate formation, and the dewatering and thickening ability of sewage sludge.

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WPLYW DAWKI POLIELEKTROLITU NA CHARAKTERYSTYKI OSADÓW ŚCIEKOWYCH W PROCESACH SEDYMENTACJI W MAŁYCH OCZYSZCZALNIACH ŚCIEKÓW

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Abstrakt: Przedstawiono badania dotyczące charakterystyki osadów ściekowych kondycjonowanych polielektrolitem Zetag 7631. Osady pobierane były w danych odstępach czasu z tej samej małej oczyszczalni ścieków. Na podstawie testu czasu ssania kapilarnego dobrano optymalne dawki zastosowanego polielektrolitu, dla których wykonano badania technologiczne opisujące efekty zagęszczania grawitacyjnego i odwadniania w procesie wirowania analizowanych osadów. Badania wykazały, że w każdym przypadku osad niepreparowany zagęszczał i odwadniał się gorzej niż ten sam kondycjonowany polielektrolitem. Na podstawie uzyskanych wyników badań wykreślono krzywe zależności wybranych parametrów charakteryzujących odwadnianie osady. Dodatkowo wykonano obserwacje mikroskopowe osadów ściekowych kondycjonowanych wybranym do badań polielektrolitem. Na ich podstawie określono zmiany struktury kondycjonowanego osadu od dawki polielektrolitu.

Słowa kluczowe: osady ściekowe, dawka polielektrolitu, zmiana struktury, zagęszczanie grawitacyjne, wirowanie, uwodnienie końcowe