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## The Effect of PIX 123 and Polyelectrolyte Zetag 8160 on the Conditioning and Dewatering of Sewage Sludge

**Wpływ PIX 123 i polielektrolitu Zetag 8160 na kondycjonowanie i odwadnianie osadów ściekowych**

The paper presents the research on the possible use of inorganic coagulant and polyelectrolyte for conditioning of sonicated and non-sonicated digested sewage sludge. The digested sewage sludge from mechanical-biological wastewater treatment was analyzed. The effect of PIX 123 and polyelectrolyte Zetag 8160 and their combined effect on sonicated and non-sonicated sludge was determined. Dosing of coagulant to sludge does not create large and durable flocs that can be effectively separated by thickening or dewatering. Then, a good preconditions for creating strong flocs, obtaining a clear effluent, and improving the degree of sludge dewatering are formed. However, it requires to use a suitable polyelectrolyte after coagulation. For sludge samples the following tests were performed: capillary suction time, vacuum filtration, pressure filtration and sludge structure was observed. The suspension and COD content in the sludge liquids were also analyzed. For non-sonicated sludge prepared with Zetag 8160 or PIX 123 a better effect of the CSK decrease was obtained for Zetag 8160. For sonicated sludge PIX 123 was significantly more effective. Both the dose and the chemical used, as well as the sonication time, have a great impact on sludge structure transformation. The applied doses of PIX 123 and Zetag 8160 increased the degree of sludge dewatering, and the combined effect of ultrasonic field, PIX 123 and Zetag 8160 decreased the suspension and COD content in sludge liquids.

**Keywords:** sewage sludge, coagulants, polyelectrolyte, sonication, conditioning, dewatering

### Introduction

Utilisation of municipal sewage sludge at WWTP is mainly related to the reduction of organic compounds in sludge and sludge dewatering, which results in a decrease of sludge volume. The amount of produced sludge depends on the wastewater composition and methods of wastewater treatment. In Poland, the overall amount of municipal sewage sludge has grown rapidly in recent years due to the expansion of urban sewerage infrastructure [1]. According to Central Statistical Office data there was 568 thousands tons of total solids of sludge

produced in Poland [2]. Most of the municipal sewage sludge are highly hydrated, the content of water in sludge varies from over 99% in the case of raw sludge to 80÷55% for dewatered sludge, and in the case of thermally dried sludge even under 10%. The high degree of water content in sludge determines its difficulty in terms of final disposal.

The process of sludge conditioning affects the change of its structure and properties [3, 4]. Changing of sludge structure [5] leads to a significant weakening of water binding forces with the surface of solid-phase particles and in result to easier removal of water during mechanical dewatering. The commonly used method of sludge conditioning is a polymeric coagulation, which uses a high molecular weight organic polymer (polyelectrolyte) [6-8]. Properly selected polyelectrolyte increases the purity of the effluent and reduces the water content in sludge. An important factor in the process is to add a proper dose of polyelectrolyte. An incorrect dose of polyelectrolyte can lead to increased operating costs and may even deteriorate the effect of water removal.

Dewatering of sewage sludge is one of the more difficult steps in the treatment of sludge at WWTPs, so many drainage techniques have been developed and documented [9]. However, still different sludge conditioning methods are constantly tested to increase the effect of the process of sludge mechanical dewatering [10, 11]. Highly effective dewatering method is very difficult, and despite different techniques used, no final product containing less than 65% dry matter has been achieved [12]. In addition, the properties of sewage sludge change, for example, with the use of ultrasonic disintegration which affects the intensification of the methane fermentation process [13, 14] and has a significant effect on the dispersion of the sludge structure.

The purpose of the study was to determine the influence of inorganic coagulant PIX 123 and polyelectrolyte Zetag 8160 as well as their both use on the efficiency of dewatering process of sonicated and non-sonicated digested sludge. In addition, the influence of selected reagents on the quality of sludge liquids resulting from the dewatering process was also investigated.

## **1. Materials and methods**

### **1.1. Sludge samples**

Samples of digested sludge were obtained from municipal WWTP with an average daily sewage flow of 40 000 m<sup>3</sup>/d. The following symbols were assigned to tested sludge samples: DS - digested sludge; SDS - digested and sonicated sludge.

### **1.2. Analytical methods**

Sonication of sludge was carried out under static conditions. A volume of 300 ml of sludge was prepared each time. For sonication powerful ultrasonic disintegrator with automatic tuning Sonics VC750 was used. The parameters of sonication were

as following: frequency 20 kHz, amplitude 30.5  $\mu\text{m}$ . The time of sonication was a variable parameter. Sludge was sonicated within  $t = 120, 240, 300$  seconds.

For sludge conditioning a coagulant PIX 123 and a polyelectrolyte 8160 Zetag were used. PIX 123 is an inorganic coagulant based on the trivalent iron  $\text{Fe}^{3+}$ . It is an aqueous solution of ferric sulfate, its density at 20°C was about 1.6  $\text{g}/\text{cm}^3$  and a viscosity at 20°C was 60 mPas. PIX 123 was diluted with water in a ratio of 1:9. Mixing of sludge with a coagulant was conducted in two stages. The first stage was carried out with rapid mixing within 60 s. In the second stage a slow mixing within 30 minutes was applied just to ensure a formation of agglomerates. Next polyelectrolyte was used in the form of a dilute solution of 0.1% and the process of mixing was continued within 60 s.

The ability of sludge for dewatering process was measured by CST (capillary suction time). CST and settling properties were used to evaluate sludge dewatering performance. The CST was measured by a PROLAB CST meter equipment. Sludge was poured into the conical tube resting on a piece of Whatman 17 filter paper and the time was recorded automatically. The pressure and vacuum filtration were carried out with laboratory equipment, respectively at 0.5 and 0.05 MPa. For pressure filtration the ET 18 II polyester fiber was used, for vacuum filtration Whatman 1 filter paper was applied.

To observe the changes of sludge structure an image analysis system (Quick Photo Camera) with digital camera Olympus 7070 WZ integrated with an optical microscope Olympus BX41 was used.

The degree of contaminants removal from sludge liquids was estimated by parameters such suspension and COD. COD was performed using a test method with HACH DR4000 spectrophotometer. Determination of suspension was done by a direct weight method.

## 2. Results and discussion

Physico-chemical characteristics of the sewage sludge is presented in Table 1.

Table 1. Physico-chemical characteristics of the sewage sludge

| Parameter         | Unit                   | Value  |
|-------------------|------------------------|--------|
| pH                | –                      | 7.45   |
| Initial hydration | %                      | 98     |
| Total solids      | $\text{g}/\text{dm}^3$ | 20.3   |
| Mineral master    | % TS                   | 36.1   |
| Organic master    | % TS                   | 61.9   |
| CST               | s                      | 1878.5 |

The results of CST show that the process of conditioning with PIX 123 and Zetag 8160 improved the ability of sludge for dewatering process. The value

of CST for non-prepared OP sludge was 1878.5 s. In Figure 1 the relation between CST and a dose of reagents is presented. CST decreases with the increase of coagulant and polyelectrolyte dose. Significant changes of CST are within the dose between 1.0 and 4.0 mg/g TS, the higher doses do not cause significant improvement in CST.

CST of sonicated sludge samples was much higher than CST for non-sonicated sludge, and it was in the range of 3029.4÷3232.8 s (Figs. 2-4). The highest value of CST was achieved for a sample which was sonicated within 300 s (Fig. 4), while the lowest value of CST was obtained for a sample sonicated within 120 s (Fig. 2). When sludge disintegration time lengthens to 300 s it was observed that CST lowered faster when PIX 123 was used for sludge conditioning (Fig. 4). For further research the following doses of PIX were chosen: 2.0, 3.0, 4.0, 5.0 mg/g TS and they were combined with Zetag 8160 of 2.0 mg/g TS dose.

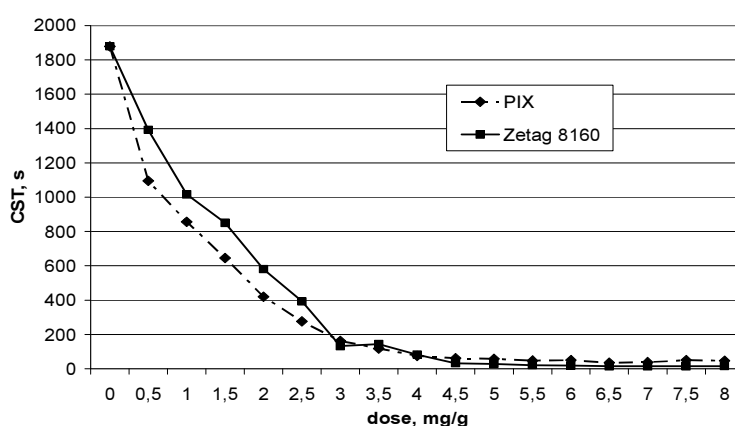


Fig. 1. The effect of PIX 123 and Zetag 8160 dosage on CST for DS sludge

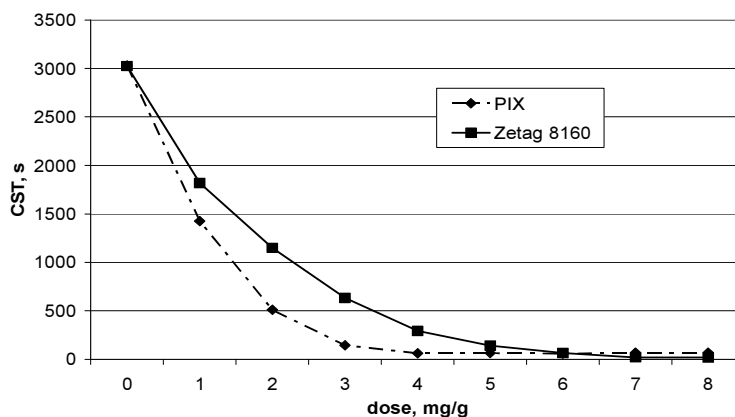


Fig. 2. The effect of PIX 123 and Zetag 8160 dosage on CST for SDS sludge sonicated within 120 s

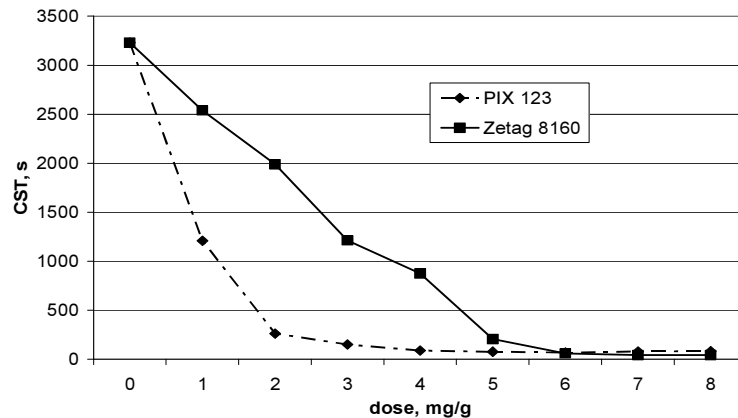


Fig. 3. The effect of PIX 123 and Zetag 8160 dosage on CST for SDS sludge sonicated within 240 s

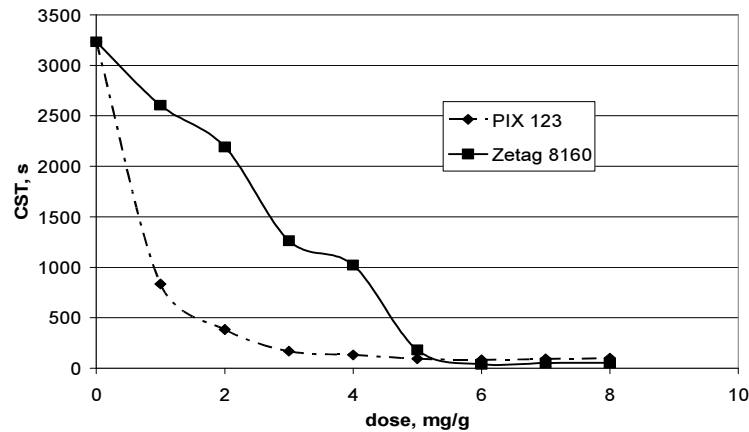


Fig. 4. The effect of PIX 123 and Zetag 8160 dosage on CST for SDS sludge sonicated within 300 s

For determining the susceptibility of sludge during dewatering process in the vacuum and pressure filtration following parameters were tested: final hydration, filtration velocity, sludge resistance and filtration performance. The changes of final hydration for sonicated and prepared sludge during vacuum filtration are shown in Figure 5. The final hydration of non-prepared sludge was 88.8%. For sonicated and prepared with both PIX 123 and Zetag 8610 sludge the final filtration was in the range of 88.2÷84.2%. The higher dose of PIX the lower final filtration was achieved. The highest reduction in final hydration was achieved for sludge which was sonicated within 300 s and prepared by both PIX 123 of 3 mg/g TS dose and Zetag 8160 of 2 mg/g TS dose. Its final hydration was 84.2%. The changes of final hydration in the pressure filtration for sonicated and prepared by coagulant and polyelectrolyte sludge are shown in Figure 6. The final hydration of non-prepared sludge in this case was 86.3%. For sonicated and prepared

with both PIX 123 and Zetag 8610 sludge a final filtration was found in the range of 86.0÷79.7%. The best results in the pressure filtration dewatering process was identified in case when sludge was sonicated within 300 s and prepared by PIX 123 of 5 mg/g TS and Zetag 8160 of 2 mg/g TS. For such sludge a final hydration was 79.7%. The highest value of final hydration was achieved for sonicated sludge. Prolongation of sonication time resulted in an increase of final hydration up to 89.6% (Fig. 6). It could be stated that the combination of chemical conditioning with physical method could be a satisfactory solution resulting in a better process of sludge dewatering.

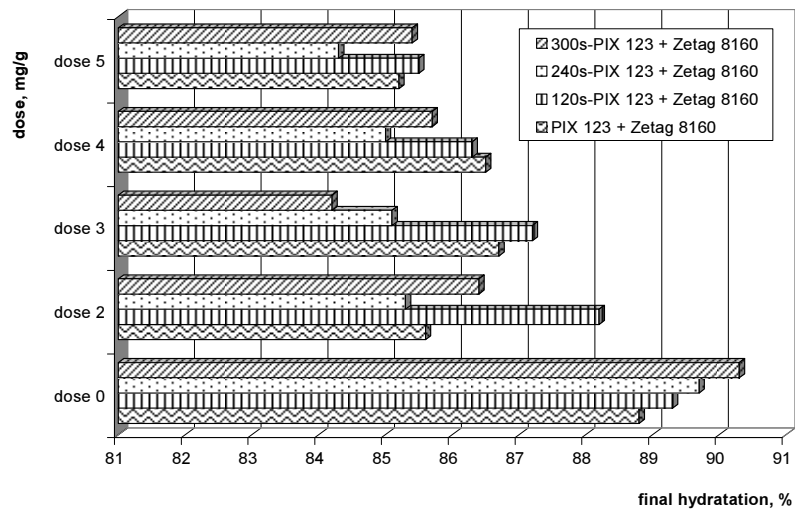


Fig. 5. Changes of sludge final hydration in the process of vacuum filtration

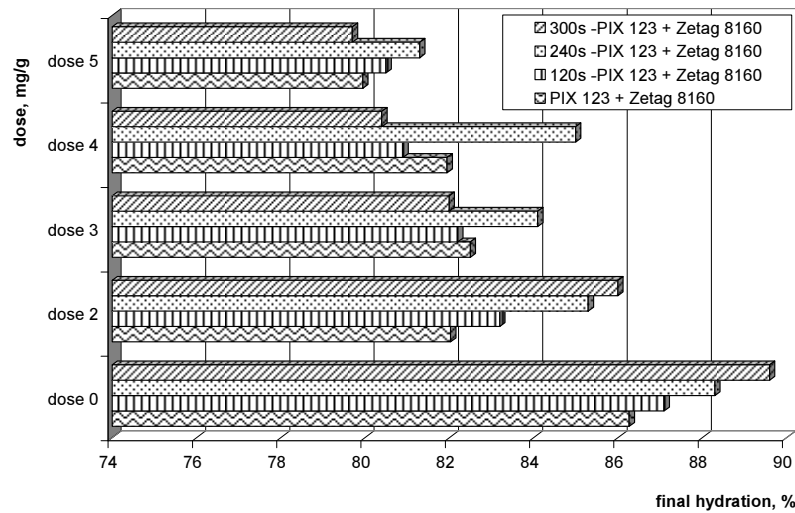


Fig. 6. Changes of sludge final hydration in the process of pressure filtration

The use of ultrasonic technology leads to the destruction of sludge flocs and microbiological cells. During sonication the degree of fragmentation increases with the time of exposure and ultrasonic power. In result sludge flocs break into a fine suspension and the clarity of sludge liquids is worse as well as an increase of COD is observed (Fig. 7). The longer sonication time of an amplitude of  $A = 30.5$  mm the stronger disintegration takes place. However the combined effect of inorganic coagulant and polyelectrolyte allows to reduce the amount of suspended solids and COD (Figs. 8-10).

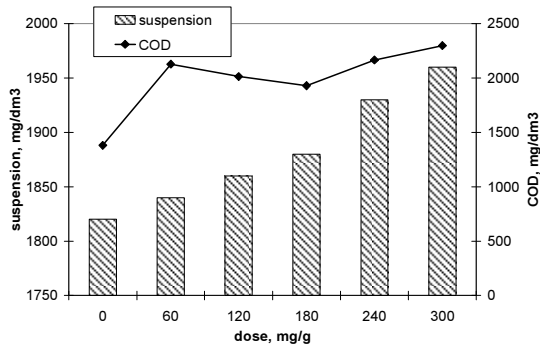


Fig. 7. The influence of sonication time on the quality of supernatant sludge liquor

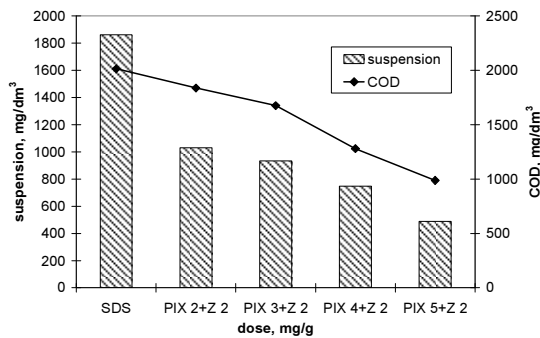


Fig. 8. The influence of sonication and chemical conditioning on the quality of supernatant sludge liquor ( $t = 120$  s, PIX 123 of 2.0, 3.0, 4.0, 5.0 mg/g TS dose, Zetag 8160 of 2 mg/g TS dose)

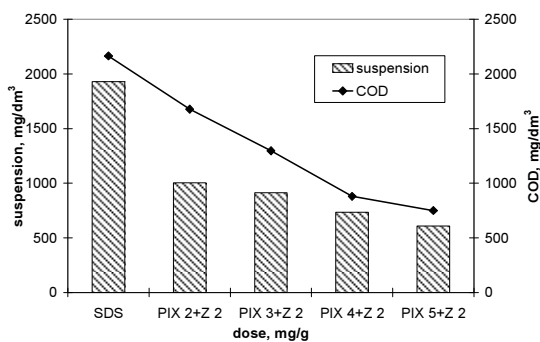


Fig. 9. The influence of sonication and chemical conditioning on the quality of supernatant sludge liquor ( $t = 240$  s, PIX 123 of 2.0, 3.0, 4.0, 5.0 mg/g TS dose, Zetag 8160 of 2 mg/g TS dose)

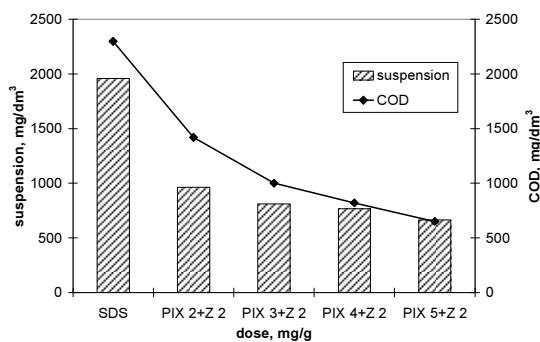
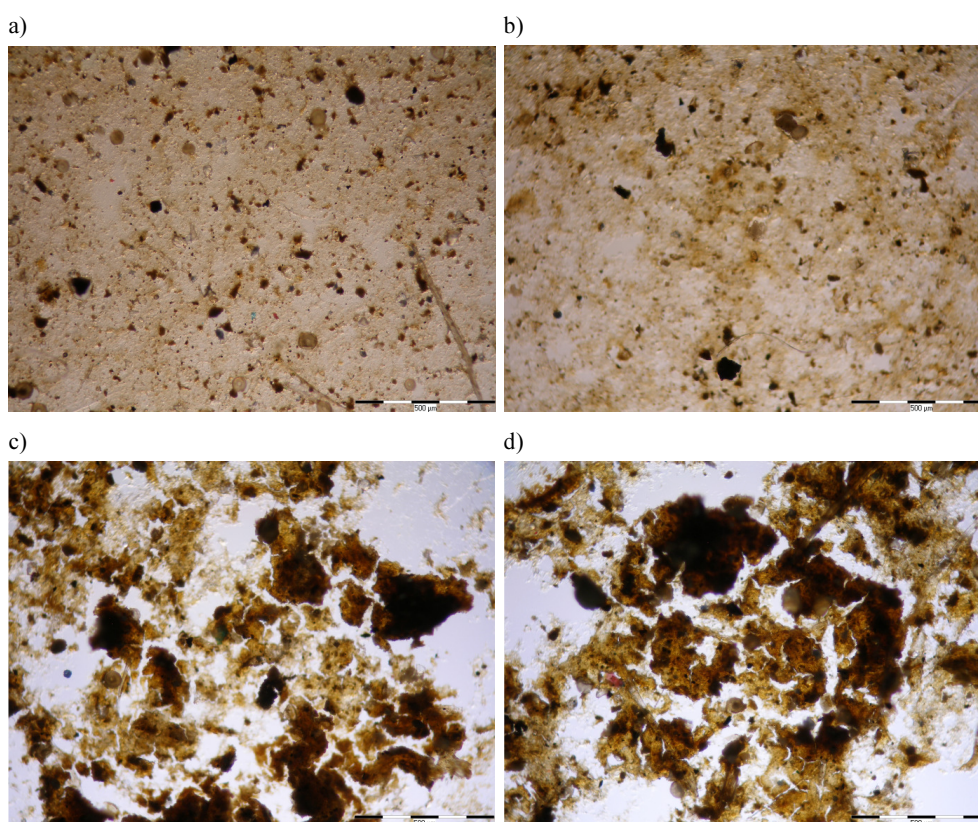


Fig. 10. The influence of sonication and chemical conditioning on the quality of supernatant sludge liquor ( $t = 300$  s, PIX 123 of 2.0, 3.0, 4.0, 5.0 mg/g TS dose, Zetag 8160 of 2 mg/g TS dose)

Microscopic observations of sludge structure allowed to evaluate the changes after conditioning with ultrasonic field, PIX 123 and polyelectrolyte Zetag 8160 use (Fig. 11). They have shown that both the time of sonication and the dose of PIX and polyelectrolyte affect changes in the sludge structure. Sludge after sonication had a uniform structure, flocs were broken down into smaller particles

(Fig. 11a). When doses of PIX 123 and polyelectrolyte 8160 were increased the size of flocculated particles also increased (Fig. 11b-d).



**Fig. 11.** The structure of sludge sonicated within 240 s and prepared by PIX 123 of: a) 0 mg/g; b) 2.0 mg/g; c) 3.0 mg/g; d) 4.0 mg/g dose rate and Zetag 8160 of 2 mg/g dose rate

It was observed that coagulant neutralizes the electrical charges on the surface of solid particles more effectively than polyelectrolyte. Hereby, it creates a better conditions for particle connection. However a coagulant used alone is not in a position to create large and stable flocs, which could be effectively separated in the process of sludge thickening and dewatering. Instead, it gives an excellent prerequisites to create large and strong flocs and to improve the sludge dewaterability. To obtain the total effect the polyelectrolyte has to be applied after coagulant. Polyelectrolyte plays as a bridging and crosslinking agent that allows to form large and stable flocs.

### Summary and conclusions

Sewage sludge is a complex multiphase systems. To achieve better results in a process of sludge dewatering sludge has to be conditioned. For this purpose



the combination of inorganic coagulant PIX 123 and polyelectrolyte Zetag 8160 was used in the experiments. Different dosage of these reagents was applied for non-prepared digested sludge and for sludge that was preliminary sonicated. The idea was to find the optimal range of doses for both reagents. Also the sonication time was analyzed. Using ultrasounds for sludge disintegration causes changes in sludge structure and in result the process of sludge dewatering is changeable.

On the basis of test results the following conclusions are formed:

1. Sonication of digested sludge causes an increase of CST value, the longer time of sonication the higher CST value was achieved.
2. The lowest value of sludge final hydration in the process of vacuum filtration was achieved for sludge preconditioning by sonication within 300 s and then prepared by PIX 123 (3 mg/g TS) and Zetag 8160 (2 mg/g TS).
3. The lowest value of sludge final hydration in the process of pressure filtration was achieved for sludge preconditioning by sonication within 300 s and then prepared by PIX 123 (5 mg/g TS) and Zetag 8160 (2 mg/g TS).
4. The knowledge of sludge structure helps to apply an optimal method of conditioning for improvement of dewatering process.
5. Preconditioning of sludge with ultrasounds helped to obtain a better quality of sludge liquor during dewatering of sludge prepared with inorganic coagulant and polyelectrolyte in comparison to sludge only chemically prepared.

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## Streszczenie

Analizie poddano przefermentowane osady ściekowe pochodzące z mechaniczno-biologicznej oczyszczalni ścieków. W badaniach określono wpływ koagulantu PIX 123 i polielektrolitu Zetag 8160 oraz łącznego działania tych dwóch związków chemicznych na nie-nadźwiękawiane i nadźwiękawiane, przefermentowane osady. Dozowanie koagulantu do osadów ściekowych nie powoduje tworzenia się dużych i trwałych flokuł, które można skutecznie oddzielić w procesach zagęszczania czy odwadniania. Tworzą się za to dobre wstępne warunki do powstania silnych kłaczków, poprawy stopnia odwadniania osadów oraz otrzymania klarownego odcieku. Warunkiem jest zastosowanie po koagulancie odpowiedniego polielektrolitu. Dla osadów ściekowych wykonano następujące badania: czasu ssania kapilarnego, filtracji próżniowej, filtracji ciśnieniowej, a także obserwowano ich strukturę. Analizowano również zawartość zawiesiny i ChZT w wodzie nadosadowej. W przypadku osadów nie-nadźwiękawianych preparowanych Zetagem 8160 lub PIX 123 lepszy efekt spadku wartości CSK uzyskano dla Zetagu 8160. Natomiast w przypadku osadów nadźwiękawianych zdecydowanie skuteczniejszy okazał się PIX 123. Zarówno dawka, jak i rodzaj zastosowanych środków chemicznych, a także czas sonifikacji mają wpływ na procesy zachodzące w badanych osadach. Zastosowane dawki PIX 123 i Zetagu 8160 wpłynęły na zwiększenie stopnia odwodnienia osadów. Ponadto łączne działanie pola ultradźwiękowego, PIX 123 i Zetagu 8160 pozwoliło na zmniejszenie zawartości zawiesin i ChZT w wodach nadosadowych.

**Słowa kluczowe:** osady ściekowe, nadźwiękawianie, kondycjonowanie, odwadnianie, koagulant, polielektrolit