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Rheological parameters of dewatered sewage sludge after conditioning

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Abstract

In the paper, the part of investigation results of sludge conditioning influence on the rheological parameters was presented. The correlation with dewatering parameters of sewage sludge was also determinated.

The tests were conducted on sludge from mechanical and biological wastewater treatment plant after fermentation process with average flow of Q = 57,000 m^3. Investigated sludge was conditioned with polyelectrolyte. To determination of the rheological curves and the liquid limits the rheometer RC 20 was used. The tests were conducted for shear velocity of 0 ÷ 400/s and the measurement time of 120 s. The dose of polyelectrolyte may cause the increase of shear stress in comparison to unprepared sludge.

In the paper the dependencies determining sludge dewatering degree and liquid limit (one of the rheological parameters which is not often tested in the wastewater treatment plants) were noticed. To-date results indicate that there are some dependencies between rheological parameters and dewaterability of tested sludge. Rheological properties may be useful as the control parameter in sludge treatment.

Keywords: Sewage sludge; Conditioning; Dewatering; Rheological parameters

1. Introduction

The increase of solid particles concentration in the liquid leads to arising from the strength of the system, which means that below certain value of shear stress the system will behave like a solid, but above this value will flow with variable viscosity depending on the shear velocity. The variability of viscosity is the result of structure changes proceeding in the sludge during the flow. Thickening of sludge increases its viscosity and causes more difficulties in the pump and hydraulic transport as the result [1]. Because the change of sludge structure is essential to all elementary processes of their treatment and in each process the move of continuous phase in the

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structural system of sludge particle or diverse occurs, the rheological investigations are particularly useful for assessment of sludge structure changes during treatment [2,3].

In the rheology the sewage sludge is treated as continuous medium and its characteristics of flow are determined with the rheological models with the structure features neglected. In the experiments we tend to determine the so-called curves of flow that means dependencies between the shear stress and deformation velocity. Rheological properties of sludge depend on such parameters as shape (size of particles), dispersion degree, solid components content, chemical constitution, temperature and physical features of sludge [4]. The basic rheological parameter of sludge is viscosity, which characterizes the behavior of real substance exposed to deformations. It is related to the flow of substance. The liquid limit, defined as maximal shear stress τ at the shear velocity $\gamma = 0/s$ is the second rheological parameter, which can be practically applied to the quality control and to defining the best properties of products, i.e., maintaining fluidity [5,6].

The literature analysis shows that the up-to-now published research results do not explain fully the influence of conditioning on the changes of rheological parameters. The influence of various conditioning methods on the change of rheological parameters in comparison to the parameters characterizing the sludge dewatering degree also has not been explained properly so far. From the presented analysis of our own investigation results, it follows that strong dependencies between rheological parameters and the parameters describing the sewage sludge dewatering degree exist.

The carried out research was aimed at checking out the possibility of applying the rheological parameters of conditioned sewage sludge in the process of its dewatering. Up to now those parameters were hardly applied in the wastewater and sludge treatment. In the future, they can be used as another control parameter in the proper assessment of wastewater treatment plant operation, which was already mentioned in the literature. That only the scientific purpose was to define the suitability of rheological parameters as another indicator of conditioned sewage sludge dewatering efficiency.

Table 1
Characteristic of investigated sewage sludge

Denotation	Unit	Average value
Dry matter	g/dm^3	21.0
Hydration	%	97.90
Organic matter	%	58.02
Mineral matter	%	41.98
CST	s	523
Resistivity	m/kg	1.98×10^{13}
Zeta potential	mV	–7.64
pH	–	7.56

2. Experimental

The research was carried out on sewage sludge from municipal wastes sampled from separated fermentation tank from the wastewater treatment plant with a daily flow of 57,000 m^3/day. The sewage sludge was characterized with the parameters shown in Table 1.

The sewage sludge was conditioned with two polyelectrolytes (low- and high-cationic). In the

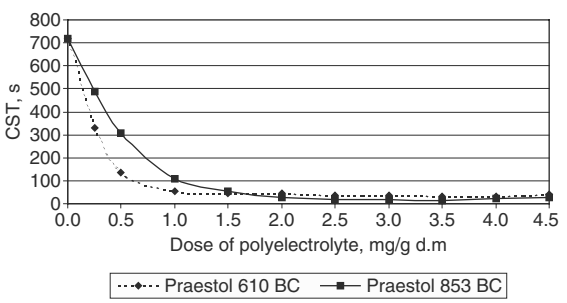

Fig. 1. The influence of polyelectrolyte dose on the CST of tested sewage sludge.

investigation Praestol 610 BC and Praestol 853 BC polyelectrolytes were used, for which, according to the diagram of the dependence of the polyelectrolyte dose on the capillary suction time (CST) the doses of 0.5; 1.0; 1.5 mg/g d.m were selected to the subsequent tests (Fig. 1). The parameters assessed after the dewatering process were final hydration, resistivity of sludge and zeta potential. Simultaneously to the tests determining the degree of sewage sludge dewatering, the values of shear limits were determined. To the flow curves and liquid limits determination the rheometer RC 20 was used. The tests were carried out for the shear velocity of 0 ÷ 400/s at the time of 120 s. The vacuum filtration test was conducted at the negative pressure of 0.066 MPa, on the measurement set consisting of the 9.4 cm diameter Büchner funnel, graduated cylinder, vacuometer and vacuum pump. To the measurement of the electrokinetic potential the automatic analyzer was used.

3. Results

After the analysis of curves of the sewage sludge dewatering on different polyelectrolyte dose, at the steady shear velocity of V = 400/s and the shear limits of conditioned sewage sludge, some regularities were noticed. For the sewage sludge conditioned with various polyelectrolytes the increase of dose caused the decrease of final hydration (of about 6% for 1.5 mg/g d.m dose in comparison to the non-conditioned sewage sludge) and the resistivity of sewage sludge (of about 2×10^{13} m/kg). For the sewage sludge conditioned with Praestol 610 BC in the dose of 1.0 mg/g d.m the values of electrokinetic potential were within the limits of fast coagulation, reaching the value of 0 mV. Along with the increase of polymer dose, also the liquid limit of tested sewage sludge was growing. Such dependence was noticed for the sludge prepared with low-cationic as well as with high-cationic polyelectrolyte.

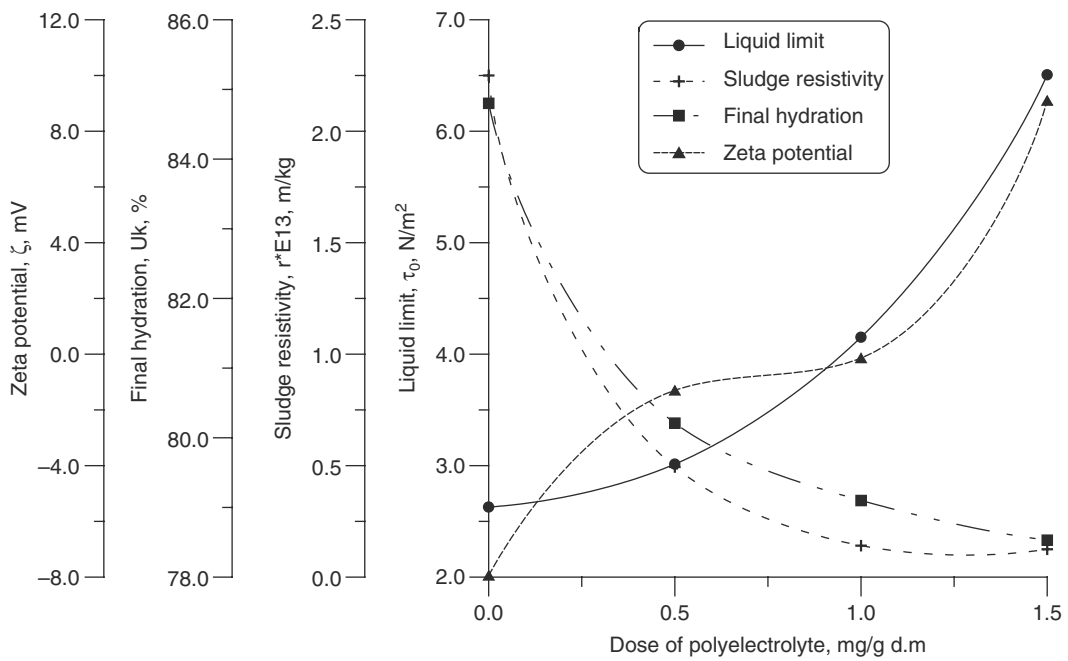

Fig. 2. The liquid limit values and parameters of dewatered sewage sludge for different doses of polyelectrolyte Praestol 610 BC.

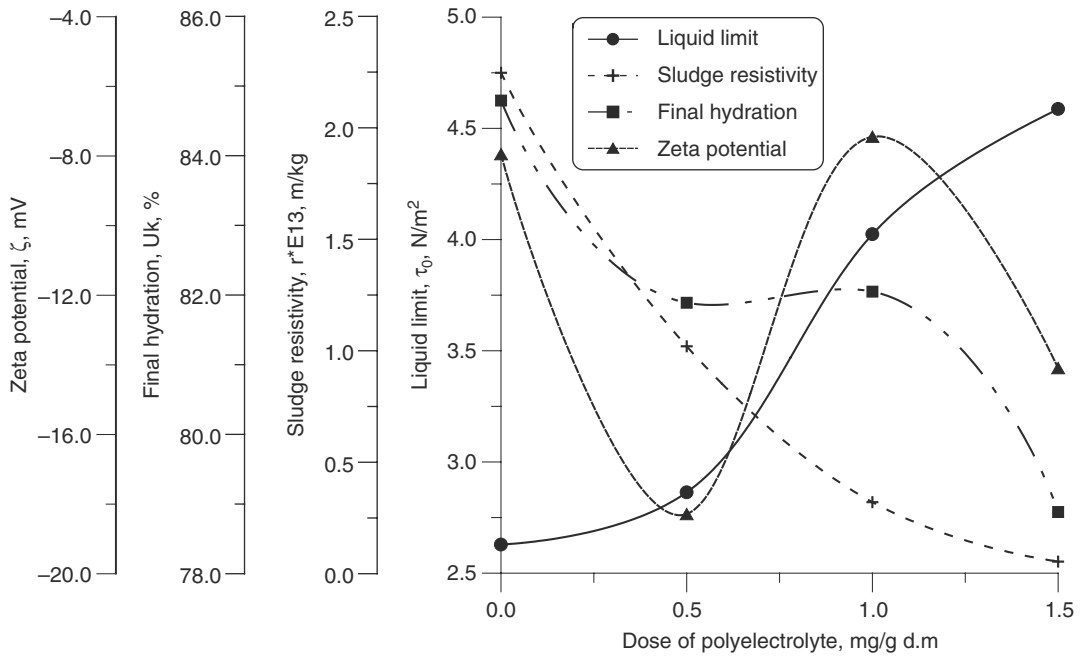

Fig. 3. The liquid limit values and parameters of dewatered sewage sludge for different doses of polyelectrolyte Praestol 853 BC.

Analyzing the diagrams below, certain dependencies between the parameters defining the sewage sludge dewatering degree and its liquid limit were noticed. For the sludge conditioned with Praestol 610 BC polyelectrolyte (dose 1.0 mg/g d.m) the lowest values of sludge resistivity, decreased hydration value, the most advantageous value of electrokinetic potential as well as the liquid limit (4.0 N/m^2) were obtained (Fig. 2). The values for the sludge conditioned with high-cationic polyelectrolyte are analogical (Fig. 3).

While analyzing the flow curves of sewage sludge conditioned with polyelectrolytes, different impact of each polyelectrolyte on the shear stress was noticed. These modifications correspond with the changes of liquid limits. Independently on the conditioning method, the values of shear stress increased along the whole velocity gradient interval. The biggest growth occurred at the lowest shear velocities, but maintained to the very end of the analyzed velocity gradient interval, i.e., to 400/s.

Analyzing the influence of polyelectrolyte dose on the value of shear stress it was stated that conditioning the sewage sludge with the polymers causes shear stress increase in comparison to non-conditioned sewage sludge. The higher polyelectrolyte dose applied, the higher the shear stress values were (Figs. 4 and 5).

4. Conclusion

From the investigation carried out up to now it is known that chemical and physical conditioning influences the course of flow curves and the values of liquid limits of tested sewage sludge [7]. Various polymers (cationic, anionic, non-ionic) have different efficiency of action in the same medium. Along with increasing of their doses the liquid limit of sewage sludge grows, resulting in shifting the field, where it behaves more like a solid than liquid. All these influences the proper run of technological processes, such as pumping, mixing or dewatering.

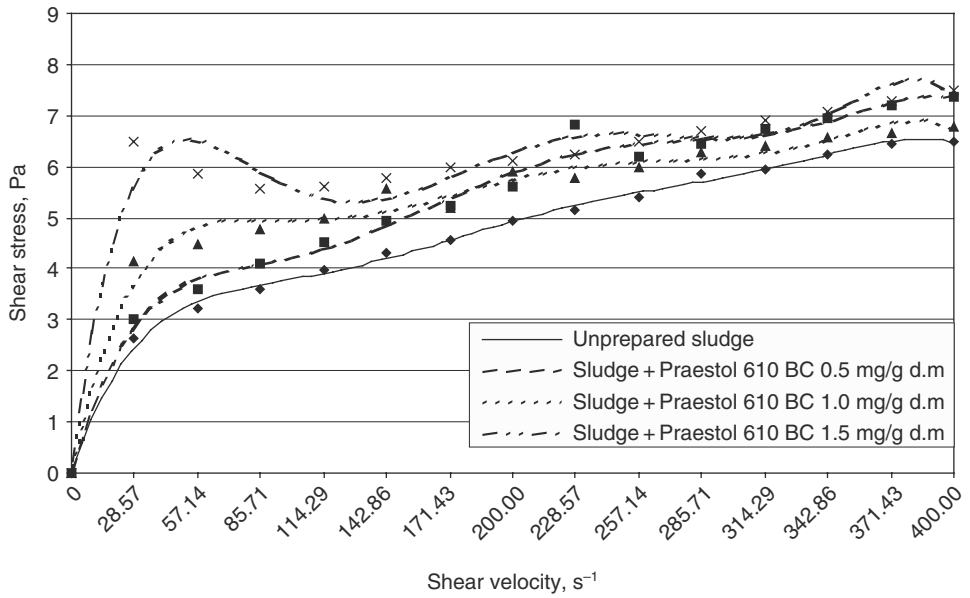

Fig. 4. Flow curves of sludge prepared with polyelectrolyte Praestol 610 BC.

In the paper some dependencies between sewage sludge dewatering degree and the liquid limit – one of the rheological parameters rarely defined in the preliminary tests methodic in wastewater treatment plants were highlighted. Sewage sludge conditioning with chemical factors (polyelectrolytes) increases its dewatering efficiency, which was observed in the investigation by decreasing the final hydration values and resistivity, as well as by obtained values of electrokinetic

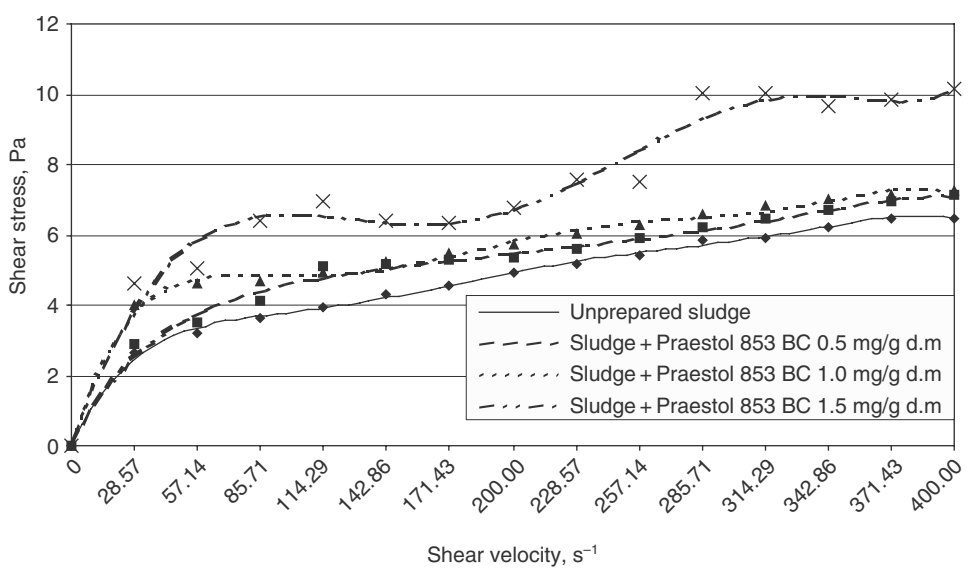

Fig. 5. Flow curves of sludge prepared with polyelectrolyte Praestol 853 BC.

potential remaining within the limits of fast coagulation (±8.0 mV). Each change in sewage sludge structure caused by conditioning influence therefore its rheological parameters. Polyelectrolytes caused the growth of the shear stress and the liquid limits, which resulted in deterioration of their properties in the hydraulic transport.

On the basis of the investigation the following conclusions were formulated:

- some relationships between the rheological parameters and the parameters characterizing the sewage sludge dewatering degree occur. Rheological parameters may serve in the assessment of sewage sludge dewatering for various methods of its conditioning, and therefore can be applied as another control parameter in the sludge treatment;
- increase of the polyelectrolyte dose caused achieving higher values of liquid limits, which was connected with worsening the hydraulic properties of sludge. However, the conditioning caused the improvement of obtained final hydration values, which has a beneficial effect on the sewage sludge disposal;
- for each investigated sewage sludge it is recommended to carry out preliminary tests aiming at defining the rheological characteristics and parameters characterizing the dewatering degree.

Acknowledgment

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