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# DEWATERING OF CONDITIONED SLUDGE IN SMALL WASTEWATER TREATMENT PLANTS

Parameters characterizing the dewatering process of sewage sludge in small wastewater treatment plants (WWTPs) have been analyzed. Two municipal wastewater treatment plants of comparable capacity and similar technology of sewage treatment were selected to the analysis. Comparison of dewaterability of unprepared and conditioned sludge was made. During preliminary tests, the capillary suction time (CST) of sludge conditioned with cationic polyelectrolyte was determined. Next, for the optimal doses of selected polyelectrolyte, more detailed technological experiments were conducted such as vacuum filtration and susceptibility to the gravitational thickening. Tested sludge had very low susceptibility to thickening. The final volume of unprepared tested samples after 2 hour thickening was 977.0 cm$^3$, while the initial volume of thickened sludge was 1000 cm$^3$.The lowest value of final hydration for conditioned sludge was 64.0%.

## 1. INTRODUCTION

Sewage sludge from wastewater treatment plants (WWTPs) demands neutralization not only from the environmental law point of view, but also due to practical and aesthetical causes. For small and medium sized WWTPs, the agricultural application is proposed, but only several percent of sludge is disposed in this way. The reason for this fact is improper physicochemical characteristic of sludge, mainly the excess content of toxic heavy metals (Cd, Zn) [1]. On the other hand, municipal sewage sludge with low heavy metal content may serve as an advantageous agent in the process of phytoremediation of post-industrial soils [2].

The content and characteristic of sludge can be different, depending on the type of sewage and the way of its treatment. However, the most important features which determine the sludge nuisance are its amount and hydration [3]. Pretreatment process-

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es have been developed in order to improve sludge handling and disposal [4]. One of the major problems in the engineering design of a WWTP is to define appropriate conditions for preconditioning of sewage sludge prior to mechanical thickening and dewatering [5]. Among various methods of sludge conditioning, the most frequently used is chemical conditioning, usually including the application of polymers (polyelectrolytes). The proper selection of a polymer improves the purity of the effluent and has positive impact on the sludge dewaterability [6, 7].

Sequencing batch reactor (SBR) is a sewage treatment technology aimed to meet the growing standards required for its environmentally friendly disposal. Conventional SBR technology is a batch process based on an activated sludge treatment technology [8]. This treatment method has been gaining considerable popularity in recent years because of its high efficiency and flexibility [9]. The SBR operation is based on the principle of four steps, i.e. fill, react, settle and draw – all steps being operated sequentially in a single reactor [10]. Sewage sludge from municipal WWTPs is generated as a result of treating mainly sewage inflowing through sewerage but also sewage supplied to the treatment plant by waste removal vehicles. Two local WWTPs of comparable capacity and similar technology of sewage treatment were selected to evaluate the parameters characterizing sewage sludge dewatering process. The research, which was made up to date, has shown that the usage of polyelectrolytes as conditioning agents causes the improvement of filtration properties. The change of sludge structure improves the removal of free water during the mechanical dewatering process [11, 12].

The aim of the tests was to analyze the parameters describing the dewatering process of sewage sludge in small WWTPs. The most advantageous agents of sludge conditioning were determined and the most efficient method of sludge dewatering was indicated. Finally, the comparison of dewaterability of unprepared and conditioned sewage sludge was made.

## 2. EXPERIMENTAL

The tested sludge, labeled sludge I, was obtained from the mechanical-biological sequencing batch reactor (SBR). The reactor was designed for the medium daily input of 500 $m^3$ (450 $m^3$ of sewage supplied through sewage system and 50 $m^3$ supplied through waste removal vehicles). The WWTP's technological system comprises: sewage reception site, basket grate, sewage pumping station, sieve, equalization tank, biological sequencing batch reactor (SBR), treated sludge outflow chambers, aerobic stabilization and thickening chamber. Sludge labeled sludge II was obtained from the ecolo-chief-type WWTP with daily input of 350 $m^3$, including 12 $m^3$ of sewage supplied by waste removal vehicles. The technological system comprises: sewage reception site, grate with sewage pumping station, primary sedimentation tank, anoxic chamber, aeration chamber, secondary settlement tank, aerobic stabilization chamber of excess and primary sludge. In both cases, the excess sludge after the aerobic stabilization process and before thickening was used for the analysis. The physicochemical characteristics of sludge I and II used for the analysis is presented in the Table 1.

Table 1

Physicochemical characteristics of the tested sludge

| Property | Sludge I | Sludge II |
|---|---|---|
| Smell | Putrid | Soily |
| Initial hydration, % | 98.15 | 95.22 |
| Dry matter content, % | 1.85 | 4.78 |
| Mineral matter content, % | 74.36 | 72.38 |
| Organic matter content, % | 25.64 | 27.62 |
| Capillary suction time, s | 337.12 | 205.20 |
| Specific resistance to filtration (SRF), m/kg | $14.60\times10^{12}$ | $7.56\times10^{12}$ |
| Final hydration, % | 94.12 | 91.40 |
| Filtration rate, $cm^3/s$ | 0.01 | 0.15 |
| Filtration output, $kg/(m^2\cdot h)$ | 1.05 | 9.87 |
| pH | 6.47 | 6.11 |

The chemical analysis included determination of dry matter content, mineral and organic matter content as well as hydration according to the PN-EN 12880 and PN-EN 12879. Technological investigation, observing the methods outlined above consisted of capillary suction time (CST) PN-EN 14701-1 measurement, gravitational thickening, dewatering in the vacuum filtration process and microscopic analysis. Vacuum filtration test was conducted at the negative pressure of 0.06 MPa. The tests were carried out at constant temperature (of 291 K in triplication. After preliminary tests of some types of polyelectrolytes (Praestol 650BC, Praestol 852 BC and Praestol 658BC of low, medium and high cationic charge, respectively) and Zetag 7631 (cationic polyacrylamide), only Zetag 7631 was selected for further investigations. The most advantageous doses of polyelectrolyte Zetag 7631 (1.5, 2.0, 2.5, 3.0 mg/g d.m.) were determined based on the capillary suction time. Sludge dewatering was carried out using a laboratory vacuum filter, whereas the gravitational thickening of sludge was done in a 1 $dm^3$ measuring cylinder. In order to evaluate the impact of the polyelectrolyte on the changes of the sludge structure, microscopic photographs were made using a microscope Olympus BX41 at a magnification of 100×.

## 3. RESULTS AND DISCUSSION

The both tested sludge I and II had low dewaterability. The final hydration of filtered sludge prior to treatment process was 94.12% for sludge I and 91.40% for sludge II. The initial values of hydration were 98.15% and 95.22% for the untreated sludge I and II, respectively. The SRF value was 14.6×$10^{12}$ m/kg and 7.56×$10^{12}$ m/kg and CST value 337.12 s and 205.20 s for sludge I and II. The most beneficial parameters of tested sludge were determined by observations of changes of its structure and CST (Figs. 1, 2).

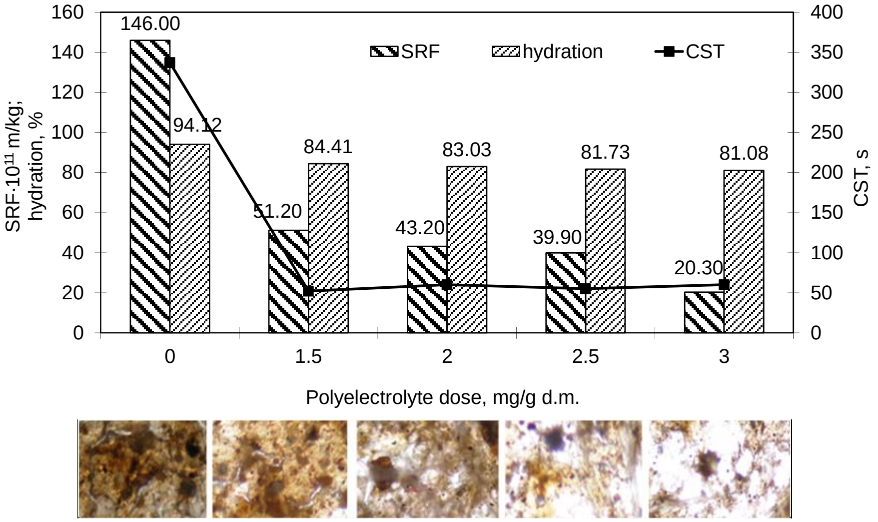

Fig. 1. Changes of parameters and microscopic structure of the conditioned sludge I

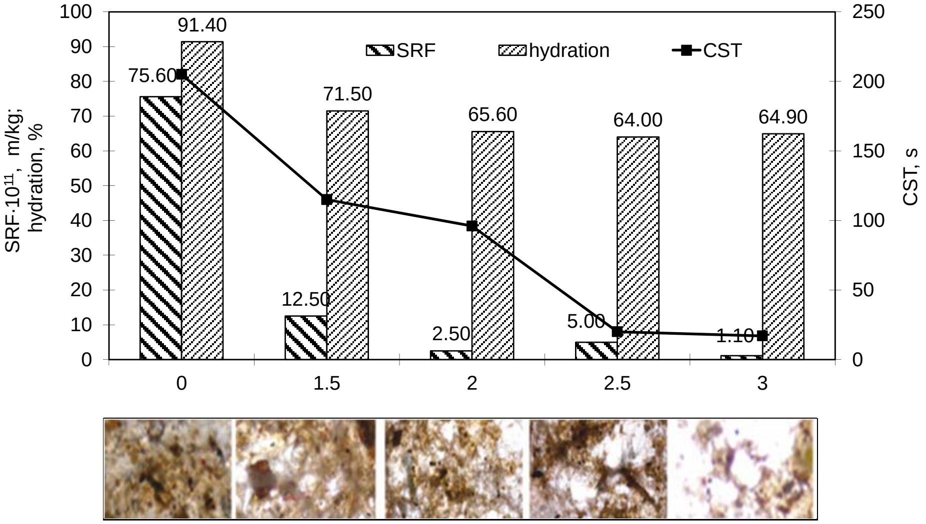

Fig. 2. Changes of parameters and microscopic structure of the conditioned sludge II

For the tested sludge, the increase of polyelectrolyte dose reduced significantly the CST. Remarkable reduction of CST for sludge II was observed at the Zetag dose as low as 1.5 mg/g d.m. in comparison to unconditioned sludge, whereas the lowest CST of 15 s was obtained at the dose of 3.0 mg/g d.m. The trend of CST reduction obtained for sludge I was similar to that for sludge II but the highest decrease of CST (to 56.42 s, which meant about 87.0% reduction in comparison to unconditioned sludge) was observed at the Zetag dose of 1.5 mg/g d.m. Conditioning of sludge I with increasing doses of polyelectrolyte had no impact on the changes of CST (Fig. 1). Confirmation of the results obtained was the microscopic analysis of sludge structure. For the most effective doses of polyelectrolyte, sludge conglomerates had more advantageous shapes and the spaces between the solid particles were bigger, which may contribute to better dewatering. The lowest values of final hydration of tested sludge after filtration process were 64.0% (sludge II) for the dose of polyelectrolyte 2.5 mg/g d.m. and 81.1% (sludge I) for the dose of 3.0 mg/g d.m. (Figs. 1, 2). General characteristics of tested sludge (Table 1) was different. In the case of sludge II (Fig. 2) the dose of polyelectrolyte 3.0 mg/g d.m. resulted in increasing hydration value because flocs of sludge structure had an apparently larger size and it could markedly inhibit dewaterability of sludge. This “floc water” (or colloidal water) may be removed after damage of the structure of sludge flocs, mainly in the centrifugation process. On the other hand, the optimum parameters for conditioning vary with sludge characteristics. Resistance to filtration of sludge I in this conditions of treatment was $20.3\times10^{11}$ m/kg and in comparison to unconditioned sludge there was 86.0% reduction. Better result was obtained for sludge II at the Zetag dose of 3.0 mg/g d.m. and it was $1.1\times10^{11}$ m/kg. In relation to unconditioned sludge, the absolute reduction was about 98.0%.

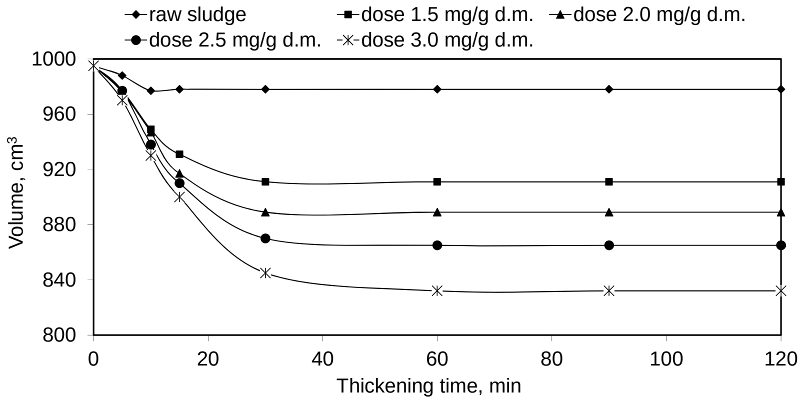

Fig. 3. The course of gravitational thickening of sludge I
conditioned with selected doses of polyelectrolyte

Significant and favorable correlation between tested indicators and parameters of conditioned sludge was observed. The results of thickening process of sludge I are shown in Fig. 3. The final volume of conditioned sludge I with the Zetag dose of 3.0 mg/g d.m. was 833.0 cm$^3$. The susceptibility to thickening of unprepared sludge was very low and the final volume was 977.00 cm$^3$. In the case of both sludge I and II, application of cationic polyelectrolyte resulted in decrease of the CST and SRF value, as well as hydration, which is shown in Figs. 1 and 2. The microscopic analyses of the conditioned sludge revealed clusters of solid flocs and clearly separated liquid phase which might confirm the obtained results.

Since the issue of conditioning of activated sludge with low- and high-molecular polyelectrolytes is well recognized [13], there is still limited evidence on the application of such agents for the treatment of excess sludge after the process of aerobic stabilization. Up to date there, in spite of accessibility of a few methods of minimization of excess sludge volume, none of these methods is efficient enough to eliminate the production of excess sludge [14]. It is the reason for the need of developing new ways of thickening of excess sludge. Some research was made in the field of optimization of the existing methods of gravitational thickening of sludge [15].

Additional difficulty in the assessment of the sludge conditioning process are the physicochemical parameters of the sludge which vary according to the source of the raw sewage. This might explain the differences in results obtained for sludge I and II. Similarly to the results of other authors [7], the susceptibility to thickening of tested sludge was very low.

Beneficial changes in the sludge structure following conditioning process are often regarded as a confirmation of treatment efficiency. Generally, differences in sludge dewatering performance may be attributed to a combination of sludge composition and polyelectrolyte characteristics.

## 4. CONCLUSIONS

The presented research deals with the problem of dewatering of excess sludge in small WWTPs. Each of tested sludge had different properties although small WWTPs of similar capacity and sewage treatment technology were compared. The characteristics of sludge strongly depend on variable amount and quality of raw sewage. Polyelectrolyte Zetag appeared to be properly selected to the tested sludge and the optimal dose was of 2.5 and 3.0 mg/g d.m. The lowest value of final hydration of filtered sludge II was 64.0%. Both sludge I and sludge II had very low susceptibility to thickening. In spite of conditioning process, the final volume of prepared sludge I was 833.0 cm$^3$ (dose of 3.0 mg/g d.m.). It was noticed that technology of sewage treatment which is designed not always met the requirements of real conditions in small

WWTPs. It mainly concerns the variability of sewage input, the way of exploitation, and, last but not least, looking for savings in the whole sewage treatment technology.

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