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Influence of Thermo-Chemical Disintegration of Digested Sewage Sludge on its Dewaterability

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Several options for «sludge-to-energy» utilization in sludge treatment sections of wastewater treatment plants (WWTP) can be considered. Among key factors influencing the choice of sludge treatment technology is sludge heating value, its composition and specifically, the fraction of organic compounds. A crucial parameter in evaluation of mass and energy fluxes is the level of attainable dewatering, which, beside the type of sludge, also depends on the treatment technology.
In literature, the treatment technology influencing the dewaterability is referred to as disintegration. The three most important methods of disintegration are mechanical, chemical and thermal disintegration.
Nowadays, disintegration of sewage sludge is used in the field of anaerobic sludge treatment to increase biogas production or in case of operational problems. Disintegration is usually applied on waste activated sludge, where preferably mechanical methods (e.g. agitator ball mill, lysate centrifuge, ultrasound) are used (Dohányos, 2006, Nickel, 2007 and Group of authors ATV/DVWK, 2000).
This contribution shows the results of research in the influence of thermo-chemical disintegration of digested sludge on its dewaterability. The influence on dewaterability was assessed tracking the total solids content of dewatered sludge in a laboratory centrifuge. Further, the change of rheological characteristics (measuring viscosity using the rheometer RheolabQC) and change in sludge structure (microscopically) were assessed.

1. Introduction

Disintegration aims at rupturing sludge flakes and, respectively cells of microorganisms contained in sewage sludge. The purpose of disintegration is the damage of waste activated sludge structure. Disintegration is applied e.g. to prevent operational inconvenience caused by filamentous bacteria (Group of authors ATV/DVWK, 2001). Another aim of its current application is the significant increase of biogas production in anaerobic digestion, which can have a positive impact on the energy demand of the sludge handling section while simultaneous reducing the amount of sludge solids for disposal. In case of convenient placement as well as choosing of disintegration method,

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another advantage can be gained: The rupture of sludge flakes, which can result in improved dewaterability of sewage sludge.

Technically, disintegration can be done by several methods (Leschber, 1996 and group of authors ATV/DVWK, 2003):

- Mechanical methods - these methods comprise disintegration and milling of solids contained in the substrate using different types of mills, high pressure homogenizer, ultrasonic sound, lysate centrifuge et al.,
- Thermal methods - thermal disintegration usually consists of thermal hydrolysis, another theoretical possibility would be freezing - unfreezing,
- Chemical methods - these methods comprise of hydrolysis using acids or lye as well as wet oxidation using oxidation agents (ozone, hydrogen peroxide, oxygen)

By thermal treatment of sewage sludge, components of solid cells becomes hydrolyzed. The high temperature disturbs the cells and causes hydrolysis of protein, hydrocarbons, fats and the release of other macromolecules from the cells. However, the advantages of thermal treatment can be counterbalanced if compounds are formed which are not biodegradable.

Table 1 shows the results of experiments, which studied the dewatering properties of thermally disintegrated sludge. Dewaterability was assessed by centrifugation of the sludge samples in a laboratory centrifuge. During experiments of thermal disintegration, measurements were carried out at sludge temperatures ranging from 70 to 160 °C. From the measurements follows that temperatures under 100 °C do not have a considerable influence on the increase of sludge solids content after centrifugation. The dry solids content increased not until temperatures above 100 °C were selected.

Table 1 Dry solids content of sludge samples after centrifugation for various disintegration temperatures

temperature [°C]	*treated sludge dry solids content [%]*	*original sludge dry solids content [%]*
70	8.8	8.5
100	8.5	7.8
130	12.4	8.4
160	15.5	8.2

2. Methods and Material

Besides stand-alone thermal disintegration, a combination of thermal and chemical methods can be used. Chemical hydrolysis can be attained using appropriate chemical agents (acid, lye). By chemical hydrolysis, the cell walls of microorganisms are damaged and the sludge structure breaks up. The outcome is a higher content of biological degradable matter in the liquid phase and change of sludge structure leading to better dewaterability of sludge. The combination of thermal and chemical hydrolysis allows reducing the operational temperature of the disintegration process. Thereby, the energy demand of the sludge handling section can be reduced.

Measurements were carried out in the laboratory of the Institute of Process and Environmental Engineering, Brno University of Technology. Digested sludge from the wastewater treatment plant in Modřice (Czech Republic) was used for experiments. Disintegration of sludge was done in a pressurized stirred tank reactor which was connected to a oil thermostat for heating and a compressor to increase the operational pressure to its required value.

The following devices were used during laboratory measurements:

- centrifuge MPW-340 with a maximum acceleration of 2 600 × g,
- pH-meter WHW-3210,
- rheometer RheolabQC,
- optical microscope with digital image capture.

Centrifugation of sludge was done at an acceleration of 2 600 × g over 10 minutes. The amount of centrifuged sample was 80 g. After centrifugation, the centrate was poured off and used to determine the total amount of solids at 105 °C and pH. The dry solids content in the sludge cake was determined as total amount of solids according to ČSN EN 12880.

For comparison of results from centrifuged sludge it was necessary to use a reference measurement. The method of direct comparison was chosen due to different conditions during particular measurements. Samples of disintegrated and original (non-disintegrated) sludge were processes simultaneously measuring dewaterability of sludge by means of centrifugation.

Thermo-chemical experiments were conducted adding sodium hydroxide (NaOH) and citric acid respectively. The disintegration temperature was chosen 110 °C based on former measurements. The amount of agent was increased from zero to 200 g/kg of sludge dry solids using equal conditions of thermal disintegration (temperature, pressure and time). A detailed overview of conducted measurements and used ratio of agents is shown in Table 2.

Table 2 Overview of measurements and used agents

sample code	*agent and treatment method*	*agent per sludge dry solids [g/kg]*
XT-01	30 min at 110 °C	0
LT-01	NaOH + 30 min at 110 °C	35
LT-02	NaOH + 30 min at 110 °C	120
LT-03	NaOH + 30 min at 110 °C	200
KT-01	citric acid + 30 min at 110 °C	43
KT-02	citric acid + 30 min at 110 °C	112
KT-03	citric acid + 30 min at 110 °C	200

The tank reactor was filled up with the sample of digested sludge (approx. 2 kg) and agent and after closing pressurized to 0.5 MPa. The course of measurements can be subdivided into following stages: heating, holding and cooling. Holding time was selected 30 minutes at a temperature of 110 °C for thermo-chemical measurements, which corresponds to 130 °C in heating medium. The samples contained in the stirred tank were cooled to a temperature of approx. 80 °C after the required holding time has run out. After the sample was discharged from the tank reactor, it was cooled to ambient, laboratory temperature. The next day centrifugation of the treated and original sludge took place at room temperature, dynamic viscosity at 30 °C was determined and a sludge sample was studied under the microscope.

3. Measurement Results

3.1 Dry solids content of cake

The content of dry solids in reference samples was relative constant and amounted to (11.8 ± 0.3) %. From the measurements of dry solids content follows, that thermo-chemical disintegration improves the attainable solids content in sludge cake compared to stand-alone thermal disintegration. The lowest values of solids content 15.0 and 15.5 % in thermo-chemically treated samples were obtained for the lowest agent dosage. The highest value of solids content 19.1 % was obtained using 200g NaOH /kg of sludge dry solids. Using 200 g citric acid/ kg of sludge dry solids (KT-03) it came to an irregularity in the dry solids content of the centrifuged samples. The result can be considered to be exceptional and will be verified in repetitive measurements.

Table 3 Measured dry solids content of sludge cake at 2 600 × g

sample code	*treated sample [%]*	*original sample [%]*
XT-01	14.4	11.6
LT-01	15.0	12.1
LT-02	15.7	11.7
LT-03	19.1	11.5
KT-01	15.5	11.5
KT-02	16.7	11.8
KT-03	15.7	12.1

3.2 Analysis of centrate

As a result of thermo--chemical treatment, the total amount of solids in centrate increased (see table 4). The values ranged from 7 800 to 22 500 mg/kg of centrate in treated samples, whilst the total amount of solids in original samples accounted for approx. 3 000 mg/kg. Using stand-alone thermal disintegration (XT-01), approx. 16 % of the overall solids content in sludge sample remained in centrate. Using sodium hydroxide in sludge treatment, the content increased up to 41 % and ranged from 23 to 31 % using citric acid. After centrifugation of original sludge samples only 6 % of the total amount of solids contained in sludge samples remained in centrate. This phenomenon can be traced back to the decreased in sludge particle size. Measured values of pH in reference samples showed only a small deviation from the average value 7.4. Measured values of pH in centrate are shown in Table 4.

Table 4 Measured total amount of solids in centrate at 2 600 × g and pH value

sample code	treated sample [%]	original sample [%]	pH in centrate of treated samples [-]
XT-01	7 800	2 800	-
LT-01	10 100	2 800	-
LT-02	17 900	2 800	9.4 at 22.7 °C
LT-03	22 500	2 900	10.1 at 23.7 °C
KT-01	11 500	2 900	7.8 at 23.1 °C
KT-02	14 400	3 200	7.4 at 23.1 °C
KT-03	17 500	3 100	6.6 at 21.4 °C

3.3 Structural change of samples

From the rheograms shown in Figure 1 emerges, that thermal disintegration degreases the dynamic viscosity. Thermo-chemical disintegration, leads to the most considerable decrease of viscosity, which is not only influenced by the dosage but also by the type of agent. From figure 1 emerges, that using the lowest dosage of NaOH (LT-01) results approximately in the same dynamic viscosity as stand-alone thermal disintegration (XT-01). Here, only a small change in structure was observed. The highest decrease in viscosity was observed at a dosage of 200 g/kg NaOH (LT-03).

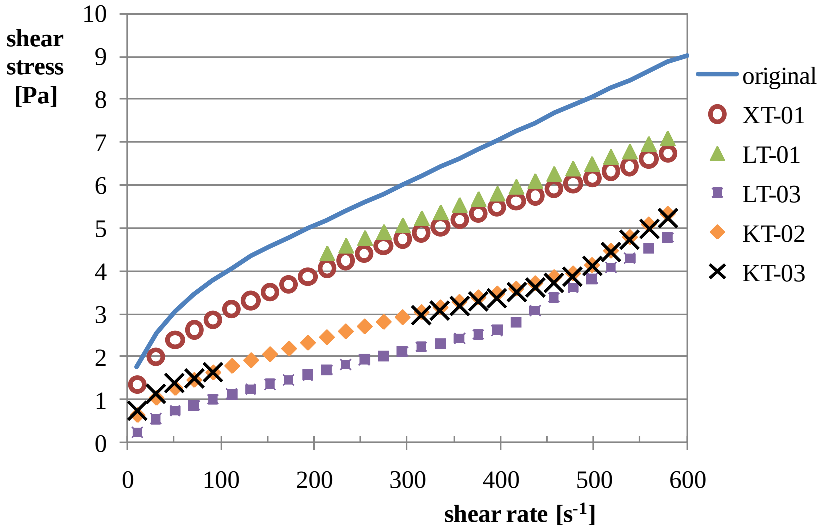

Figure 1 Rheograms of measured sludge samples

From the microscopic images of sludge (Figure 2 KT-02) emerges clearly a rather considerable change in sludge structure after its thermo-chemical treatment using higher dosage of agents (irrelevant if lye or acid). The structural change of samples treated by thermal disintegration (Figure 2 XT-01) and for low agent dosage (LT-01, KT-01) is hardly noticeable.

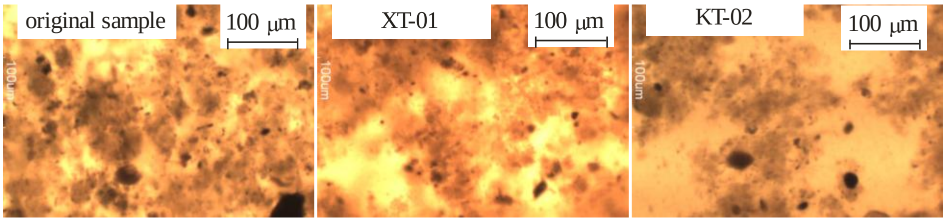

Figure 2 Image of untreated, thermally and thermo-chemically treated sludge (from the left to the right)

4. Conclusion

Dosage of acids or bases deepens the effect of the process compared to stand-alone thermal disintegration. The increased content of dry solids in sludge cake, which can be attained by centrifugation, counts to the advantages of this process. The outcome is a reduction of sludge amount for disposal and reduction of the disposal costs of dewatered sludge. Another advantage of the combined process is the reduction of its energy demands. This can significantly reduce the amount of required heat. A disadvantage is the increased concentration of total solids in centrate, which increases the return load of the biological wastewater treatment stage by solids and chemical oxygen demand.

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