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Processing of sewage sludge: Dependence of sludge dewatering efficiency on amount of flocculant

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ABSTRACT

Paper presents results of experimental dewatering of stabilized sludge analysis and study. The experiments were carried out at a small waste water treatment plant (15,000 population equivalent). Experiment focused on impact of consumption of flocculant and centrifuge load on quality of dewatered sludge and centrate. Dry solids in dewatered sludge and content of undissolved particles in the centrate were observed in particular for proper evaluation of the experiment. It was proven that specific consumption of flocculant has greater impact on centrate quality than on dry solids content in dewatered sludge. It was possible to increase dry solids content in dewatered sludge only by 10% at most. However, amount of undissolved particles dropped more than ten-fold. Regarding quality of dewatered sludge and centrate, optimum specific consumption of flocculant during the experiment amounts to 8 g/kg of dry solids of sludge with flocculant concentration being 0.16% and centrifuge load reaching 110 kg/h of dry solids. Specific consumption of flocculant amounting to 5.4 g/kg of dry solids of sludge (calculated value) under identical operational conditions proves to be the best economical option.

1. Introduction

Sludge represents only 1% or 2% of treated waste water but contains from 50% to 80% of pollution. Operating cost for sludge treatment can amount to approximately 50% of the total operating cost of the whole waste water treatment plant (Appels et al., 2008). Thus it is appropriate to optimize sludge management so that the cost of sludge (waste) processing is as low as possible (Sikos and Klemeš, 2009).

Sludge produced at various stages of waste water cleaning may contain only 0.25% of dry solids (DS) (Werther and Ogada, 1999). It has to be further thickened so that the amount of water is lowered which results in lower economic demands (Thapa et al., 2009). Thickening is usually carried out in gravitation or flotation units. Thickened sludge may contain up to 7% of DS (Houdková et al., 2008) and is appropriately stabilized, which may mean anaerobic or aerobic stabilization (Demirer and Othman, 2008; Pérez-Elvira et al., 2006). Stabilized sludge is then dewatered at sludge press, belt press or at a centrifuge (Lee et al., 2005). Sludge dewatering by centrifuge enables increase in DS content up to 20–40%; sludge press dewatering enables increase of 24% up to 42% of DS (Werther and Ogada, 1999). Sludge processing line layout is shown in Fig. 1.

Flocculants are used to increase sludge dewatering efficiency (Nguyena et al., 2008; Vaxelaire and Cézac, 2004), which is useful especially in sludge separating based on different particle weight. Reaction of flocculant and sludge results in clusters of sludge particles and formation of flakes. Amount of dosed flocculant significantly influences the amount of dry solids content in dewatered sludge as well as the amount of DS which are brought back into the cleaning process in the centrate. This has an enormous impact on the cost of sludge management operations (Chu et al., 2005). Degree of DS content after dewatering plays a key role in subsequent thermal processing of sewage sludge. Higher amount of sludge dry solids content after dewatering reduces energy demands of sludge drying prior to its thermal utilization, e.g. in cement works (Fytili and Zabaniotou, 2008; Šťasta et al., 2006), municipal waste incinerators (Murphy and McKeogh, 2006; Pavlas et al., 2008). It is also possible to incinerate sludge in sewage sludge incinerators (Horttanainena et al., 2009; Murakami et al., 2009; Park et al., 2009; Stehlík, 2009).

2. Methods and materials

The experimental part was focused on operational experiment carried out at small-scale waste water treatment plant (WWTP). There the impact of flocculant specific consumption on the dry solids (DS) content in the dewatered sludge was assessed. Apart

Abbreviations: DS, dry solids; PE, population equivalent; TSS, thickened stabilized sludge; UP, undissolved particles; WWTP, waste water treatment plant.

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Nomenclature

$c_{disposal}$	dewatered sludge disposal cost (€/t)
c_F	dry polymer organic flocculant cost (€/kg)
c_{power}	power cost (€/kWh)
$C_{tot,d}$	total cost (€/d)
c_{water}	water cost (€/m^3)
$m_{DS,TSS}$	average production thickened stabilized sludge dry solids (kg/d of DS)
m_F	specific consumption of flocculant (g/kg DS)
m_{UP}	amount of undissolved particles (mg/L)
P	power input of the decant centrifuge (kW)

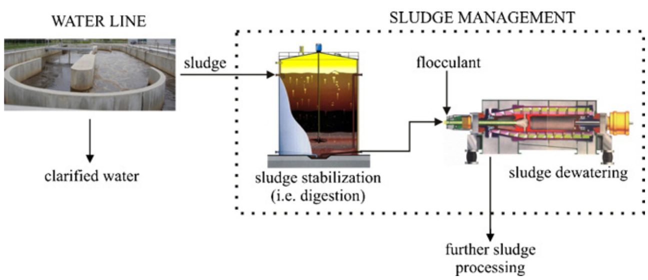

Fig. 1. Sludge processing line layout.

from the DS in the dewatered sludge, DS in the thickened stabilized sludge (TSS) entering the centrifuge was observed. Concurrently the amount of undissolved particles (UP) in the centrate outgoing from centrifuge was measured.

Selected WWTP is designed as a low-load mechanical–biological waste water treatment plant with the maximum load of 15,000 population equivalents (PEs). Sludge management is assumed to use the capacity of up to 18,000 PE because of the possibility to obtain a partially treated sludge from nearby small WWTPs. There is a rainwater basin and an inlet structure with rotary screen and a catch basin at the inlet into the WWTP. There are also two tanks with circulatory activation and two final settling tanks. In order to remove phosphor, a ferric-sulphate solution is dosed into the activation. An excess sludge is taken to the flotation unit immediately from the activation for thickening. Thickened sludge goes through a stabilization processes which are completed in two tanks with an autothermal thermophilic stabilization and aeration with pure oxygen. Thickened stabilized sludge is dewatered in the decanting centrifuge (see Fig. 2) with hydraulic capacity of 1.5–3.0 m^3/h and material capacity of 100–120 kg DS/h, and is stored on a dump. Flocculant solution is prepared in a mixing tank using dry polymer organic flocculant.

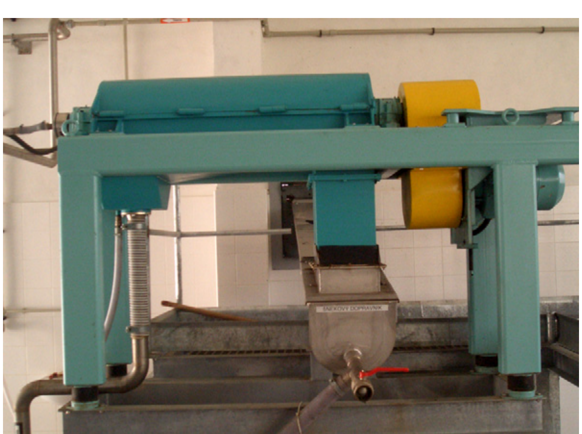

Fig. 2. Experimental facility.

2.1. Measurement

Measuring at the WWTP took 5 days. On the first day only several test samples were taken. The second day of measurement was intended for monitoring of common operations without any intervention (flow rate of TSS of 90 kg DS/h, concentration of flocculation solution of 0.16% and flocculant specific consumption of 5.4 g/kg of DS). All samples were taken in regular intervals.

In following days, different operating modes were gradually tested with concentration of the flocculant solution of 0.12%, 0.16% and 0.20% and with different combinations of flow rates of TSS and flocculation solution. TSS was dosed with the flow rate of 70, 90 and 110 kg DS/h. Specific consumption of the flocculant was selected as 3.5, 5.0, 6.5 and 8.0 g/kg of DS. Flow rate was controlled using frequency converters of the corresponding screw pumps, and it was measured by induction flow meters.

2.2. Sampling and analysis of samples

Throughout the sampling, a TSS sample was taken as well as a sample of dewatered sludge and centrate. There was a time lag between the change of operating mode and individual sampling that was set at 20 min as a minimum due to the need of stabilizing the flow rate of TSS and the flocculant solution.

Samples of TSS were collected from the centrifuge inflow. Dewatered sludge was collected from a spiral conveyer immediately beyond the centrifuge. Since content of DS is one of sludge main characteristic DS (as well as temperature) of all samples of TSS and dewatered sludge were measured. Halogen moisture analyzer Kern MLS-50 was used to DS measuring. Samples were dried at 105 °C temperature following the technical standard.

Centrate was collected from centrifuge outflow. Temperature and UP were measured and colour of centrate was observed. Vacuum filtration and the glass fibre filters with pore size 2.5 μm were used to the UP measuring (following the technical standards).

3. Results of experiment

Average value of DS in the stabilized sludge before entering the centrifuge was 2.78%. Temperature of TSS entering the centrifuge ranged between 19 and 24 °C. An average value of DS in the dewatered sludge under common operating conditions was 24.26%, while the measured values range from 24.0% to 24.5%.

The operational experiment proved the following:

- DS in dewatered sludge increase with the rise in flocculant specific consumption. This dependence could be in some cases considered linear.
- The highest amount of DS in dewatered sludge with the given flocculant specific consumption was reached with maximum load of the centrifuge of 110 kg of DS/h.
- The highest amount of DS in dewatered sludge was 26.04% with the flocculant solution concentration of 0.16%, flocculant specific consumption of 8 g/kg of DS and TSS flow rate of 110 kg of DS/h.
- The lowest amount of dry solids in dewatered sludge was 22.32% with the flocculant solution concentration of 0.20%, flocculant specific consumption of 3.5 g/kg of DS and TSS flow rate of 70 kg of DS/h.

The content of the DS was obvious from the visual appearance of the sludge. Lower content of DS was demonstrated in the form of