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Sludge conditioning prior to dewatering: Introducing drainage index as a new parameter

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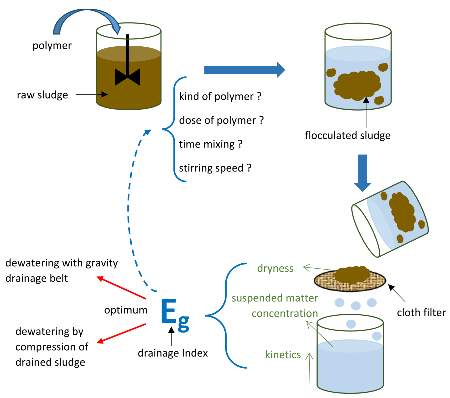
HIGHLIGHTS

- A new index is introduced for sludge dewatering optimization.
- Drainage index allows optimization of flocculation parameters for gravity drainage.
- The index allows optimization of dose, mixing time and speed for sludge compression.

GRAPHICAL ABSTRACT



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ABSTRACT

The conditioning stage is a key parameter for enhancing the efficiency of sludge dewatering. However, the choice of the conditioning procedure (type of flocculant, dosage, mixing conditions) remains a current difficulty. A new index (called drainage index) was introduced to optimize conditioning parameters specifically for sludge thickening on draining table and by extension for sludge dewatering in belt filter press. This easy and quick to measure index was tested via lab-scale drainage experiments. Drainage performance was measured in terms of particles capture rate, final sludge dryness and drainage kinetics. The drainage index allowed to select optimal flocculation conditions prior to gravity drainage. Its relevance to select flocculation conditions insuring a good sludge compression was also demonstrated (except for the polymer selection) from tests carried out in lab-scale filtration–compression device.

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1. Introduction

Over the last decades the increase in municipal and industrial wastewater treatment activities has resulted in a significant increase of sewage sludge amount. A reduction of sludge volume is usually required before handling and disposal (or valorization). Due to their relatively low power consumption, mechanical processes (filters or centrifuges) are commonly used to carry out sludge dewatering. Depending on the dewatering strategy used, a thickening stage can sometimes be carried out as a preliminary step. Using thickening, a dry solid content of around 5 to 8% can be reached. Several processes can be used to carry out sludge thickening, mainly gravity thickeners, flotation units or draining belts. Belt filter presses may also have their own gravity drainage area prior to the compression step. Although the gravity drainage (notably on drainage belt) of wastewater sludge is a technique often used, it has been little studied in the scientific literature (Severin et al., 1999; Olivier et al., 2004; Christensen et al., 2010a,b; Christensen and Keiding, 2011; Dominiak et al., 2011).

In the gravity belt thickening process, the sludge is deposited on a moving filter cloth (the belt) and water is extracted by gravity. Thus, it is necessary to work with filter cloths of high permeability, i.e. with pore diameters that exceed the size of the initial suspended solids in the sludge. That is the reason why the sludge must be flocculated (conditioned) before drainage. Conditioning allows to form larger aggregates called "flocs" that may be retained on the filter cloth. Chemical conditioning of wastewater sludge usually uses organic polymers, commercially available with different degrees of cross-linkage, various average molecular weights and charge densities. The ability of the sludge to thick depends not only on the type and dosage of polymers but also on mixing conditions between sludge and chemicals (Sanin et al., 2011). Flocculation is a key step in dewatering processes (thickening, filtration and compression). It can have a major impact on final sludge dryness and operating cost. Very few studies on the impact of conditioning factors on dewatering performance have been published in the scientific literature. The selection, the dosage and the way of adding the polymers currently remain based on very empiric procedures, there is little correlation between fundamental understanding and industrial practices.

In many papers, measurement of capillary suction time (CST) is used as a criterion of sludge dewaterability (To et al., 2016a,b). The CST method uses the capillary suction force generated by filter paper to mimic filtration (Wu, 2013). It is commonly used to find the optimum amount of flocculants needed to condition the sludge (Wu, 2013). The dose of flocculants corresponding to the lowest CST is considered as the optimum dosage. However, as it was highlighted by several authors (Peng et al., 2011; Raynaud et al., 2012; Skinner et al., 2015; To et al., 2016a; Lu et al., 2017), CST measurements cannot really be used to predict the performances of dewatering under pressure. Moreover, the small size of the samples used for CST tests is generally not well adapted to suspensions conditioned with cationic polymers (non-homogeneous suspensions containing large flocs).

Specific resistance of filtration (SRF) is another criterion used to characterize sludge dewaterability (To et al., 2016a). Its measurement requires recording the amount of filtrate removed over time during a filtration at constant pressure. This measurement can be carried out with a Buchner funnel under vacuum or with a filtration/compression cell (FCC). The optimal dose of flocculant is the one which leads to the lowest SRF. The SRF is an index which is measured only in relation to the filtration phenomenon, it is not suitable for characterizing the expression (or compression) stage occurring during mechanical dewatering of wastewater sludge. For example, Pan et al. (2003) showed that SRF should not be used in the case of belt filter presses. Indeed, in this case the sludge is commonly drained in the first section of the system. Then the dewatering under pressure (occurring in the second section) concerns a partially consolidated sludge. It is consequently achieved only by compression. In addition, for very compressible sludge (such as flocculated activated sludge), the filtration phase is very fast (very short), so it is generally not possible to properly determine SRF with filtration /compression cells (FCC).

In the industrial field, companies also develop their own procedures. For example the parameters of flocculation (such as the choice of the polymer and the amount to be added) are usually determined from tests directly carried out on the industrial device and knowledge of the technicians (mainly visual observation). Consequently, it is important to find additional criteria for optimizing sludge conditioning for thickening by drainage (and in a more global perspective, for pressurized dewatering). Tests carried out at laboratory scale to characterize the drainage of wastewater sludge are highly reproducible (Olivier et al., 2004; Ginisty and Peuchot, 2011). Standard BS EN 14701-4 (2010) presents the procedure set up to conduct these tests. It consists of two steps: flocculation of sludge under reproducible and comparable conditions and gravity drainage on a filter cloth similar to those used in belt thickeners. Since the results obtained with lab-scale gravity drainage devices give a good description of the industrial behavior, they could be used to design industrial belt thickeners (Olivier et al., 2004; Christensen et al., 2010a). This kind of laboratory tests can also be considered as an interesting tool to evaluate the quality of the flocculation with regards to sludge thickening by gravity drainage. For this purpose, a drainage index has been developed to characterize and quantify good and bad gravity drainage, respectively. This index has been added very recently in the European standard BS EN 14701-4. The aim of the present work is to study the relevance of the drainage index to select the flocculation parameters (type of polymer, dosage, mixing time and stirring speed) leading to the best gravity drainage. In addition, some compression experiments were also carried out to study how the drainage index might also be useful for optimizing the dewatering under pressure.