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Relationship between physicochemical properties and dewaterability of hydrothermal sludge derived from different source

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ABSTRACT

Sewage sludge (SS) and deinking sludge (DS) were used to comparatively study the hydrothermal dewatering of sludge with different components. For a better overview, an insight into the relationship between physicochemical properties and dewaterability of hydrothermal sludge was provided. Results found that not all kinds of sludge were suitably conditioned by hydrothermal treatment (HT) in term of the elevation of dewaterability. Higher hydrothermal temperature tended to enhance the dewaterability of SS rather than DS, which was supported by the variation of their physicochemical properties (including water distribution, bonding energy, extracellular polymeric substance (EPS), particles size, acid functional groups and zeta potential in this study). In addition, the changes in surface morphology suggested that the reverse effect of HT on sludge dewaterability was mainly due to their dewatering behavior. For SS, the destruction of EPS structure leaded to the release of bound water, thereby strengthening sludge dewatering. Conversely, “Bridging effect” generated by lignocellulose in DS was beneficial for sludge dewatering; however, the increasing hydrothermal temperature degraded part of lignocellulose and weakened “bridging effect”, finally resulting in worse dewaterability of DS.

Introduction

Since the growing population and raising requirement for human activities, large amounts of sludge with high moisture content (>99%) were generated from wastewater treatment plants. In China, over 30 million tons dewatered sewage sludge (SS) were produced in 2015 (Zhao et al., 2014), leading to considerable transportation and disposal cost. Besides that, the high moisture and huge volume of sludge limited its effective treatment as the disposal standard for sludge became increasingly restricted nowadays. Thus, sludge dewatering has recognized to be an effective method to overcome above difficulty on account of its distinguished advantages; for instance, the reduction of sludge volumes and being much convenient to dispose. However, just dewatering sludge by established mechanical methods *via* filter presses, centrifuges or belt presses could hardly reduce moisture content to a satisfied extent. For this reason, thermal drying of mechanically

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dewatered sludge was unavoidable for further decreasing moisture content, which would absolutely consume extra power and operating cost. Therefore, several pretreatments so far have been intensively investigated for the purpose of improving sludge dewatering and saving energy. Among these technologies, hydrothermal treatment (HT) is one of the effective pretreatments for sludge due to its advantages of direct utilization of wet sludge, improvement of sludge dewaterability and low energy consumption (Escala et al., 2013; Wang et al., 2014; Zhu et al., 2013).

In HT, wet sludge inside a closed vessel was heated to temperature ranged from 120°C to 250°C for several hours, thus allowing for saturated pressure to build up (Peng et al., 2016; Zhai et al., 2014, 2017). A series of reactions including hydrolysis, dehydration, decarboxylation, polymerization and aromatization occurred during hydrothermal process. These reactions changed the surface structure of sludge and then improved their dewatering properties. Zhu et al. (2013) used SS as feedstock and found that the moisture of sludge samples decreased to less than half of its initial levels after hydrothermal dewatering, which was consistent with the observation from Escala et al. (2013) and Saveyn et al. (2009). Moreover, Bougrier et al. (2008) studied the effects of HT on different SS, suggesting that both dewaterability and settleability of all hydrothermal sludge gained a great improvement. In fact, it was commonly known that the elevation of sludge dewaterability was principally caused by the conversion of bound water to free water during hydrothermal process. But Sponza (2003) pointed out that the redistribution of water in sludge related to their extracellular polymeric substance (EPS) structure and other physicochemical properties. EPS in SS mainly comprised of vulnerable protein and polysaccharide, so the bound water adhered by this organic matter was easily escaped from sludge particle under hydrothermal conditions. However, EPS structure of sludge varied with species, environment and type of organics in wastewater certainly affected dewatering characteristic to different extent. Deinking sludge (DS) was another main type of sludge from paper mills. This kind of sludge was mainly made up of lignocellulose which was more thermal-stable than protein and polysaccharide in SS (Mäkelä et al., 2016). Unfortunately, the influence of HT on DS was rarely considered and studied. Knowledge of evolution in physicochemical properties of hydrothermal sludge derived from different source was essential for further understanding the mechanism of hydrothermal process on sludge dewatering performance.

Therefore, the specific objectives of this study were to (1) determine the effects of HT on the dewaterability and physicochemical properties of two kinds of sludge; (2) investigate the dewatering behavior of hydrothermal sludge and (3) construct the relationship between the variation of physicochemical properties and sludge dewaterability.

1. Materials and methods

1.1. Sludge sample

SS and DS were sampled from Guangzhou wastewater treatment plant and Nansha paper mill, respectively. After collecting, sludge samples were directly stored in refrigerator at 4°C and all tests were finished within three weeks in order to avoid the degradation of microbe. Pre-analysis of materials found that SS possessed higher moisture content (97%) than DS (93.3%), and the pH for SS and DS was 7.7 and 7.8 respectively.

1.2. Experimental procedure

1.2.1. Hydrothermal treatment

A 400 mL, type 316 stainless steel tubular reactor with heater in an electric heating jacket was used to carry out the HT of sludge in laboratory scale. The hydrothermal temperature was set at several points (between 120°C and 240°C with interval of 30°C) for 60 min. A 200 mL of original sludge was used for each run. Additionally, magnetic stirrer was rotated at a constant speed of 300 r/min throughout the whole hydrothermal process so as to assure that the sludge inside reactor was evenly heated. Once the reaction was finished, the reactor was cooled down to ambient temperature. The treated sludge was immediately collected and stored in 4°C prior to analyze. The samples were designed as SS-120 or DS-120, as 120 represent the hydrothermal temperature.

1.2.2. Extraction of extracellular polymeric substances (EPS)

Heat method was used for EPS extraction in this work and the detail procedure was shown in Fig. 1. Briefly, a 40 mL of sludge

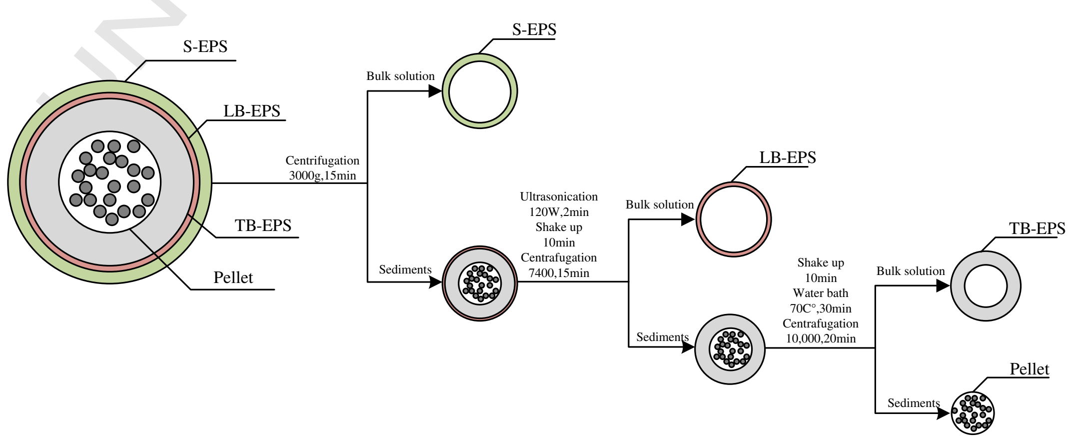

Fig. 1 – The extraction procedure of extracellular polymeric substances (EPS).