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Short Communication

Bioflocculant from pre-treated sludge and its applications in sludge dewatering and swine wastewater pretreatment

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HIGHLIGHTS

- A bioflocculant was produced by using alkaline-thermal (ALT) pre-treated sludge.
- Sludge dewatering by this bioflocculant was discussed compared with chemicals.
- The application of this bioflocculant in real wastewater treatment was investigated.
- Flocculating mechanisms were detected by using kaolin suspension in present of Ca^{2+}.

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ABSTRACT

Potentials of alkaline-thermal (ALT) pre-treated sludge as a bioflocculant were studied in sludge dewatering and swine wastewater pretreatment. When incubated with this ALT pre-treated sludge, dry solids (DS) and specific resistance to filtration (SRF) of typical wastewater activated sludge reached 22.5% and 3.4×10^{12} m/kg, respectively, which were much better than that obtained with conventional chemical flocculants. Sludge dewatering was further improved when both the bioflocculant and conventional polyaluminum chloride (PAC) were used simultaneously. Charge neutralization and inter-particle bridging were proposed as the reasons for the enhanced performance in the case of the combined use. With swine wastewater, the bioflocculant could remove COD, ammonium and turbidity by 45.2%, 41.8% and 74.6% when incubated with 20 mg/L at pH 8.0. This study suggested that the ALT pre-treated sludge has a great potential as an alternative bioflocculant to conventional flocculants in sludge dewatering and swine wastewater pretreatment.

1. Introduction

Sludge, by-products at various stages of wastewater treatment process, typically contains more than 90% of water, thus, it must to be further thickened to reduce its volume, which can result in lower economic demands for sludge disposal (Thapa et al., 2009). Chemical conditioning is often applied in sludge separation based on different particle weights by adding flocculants (Zhai et al., 2012). Although the inorganic flocculants and organic synthetic polymers, such as $FeCl_3$, $Al_2(SO_4)_3$, polyaluminum chloride (PAC), and polyacrylamide (PAM), have been widely used, more and more negative reports about their toxic and non-readily degradable were known to people.

Microbial bioflocculant (MBF), secreted by microorganisms during their active secretion and cell-lysis, was a kind of environment-friendly material with the characteristics of harmless and biodegradable. Currently, bioflocculant has been regarded efficiently in removing pollutants (like suspended solids, organic pollutants, and heavy metal ions) from wastewaters on laboratory scale (Guo et al., 2013), but there is hardly report on its application in sludge dewatering (Yang et al., 2012). Further, the knowledge about the performance of bioflocculant in actual project is lacking, and the parameters relating with pollutant removal, such as COD, ammonium, and turbidity were not determined (Li et al., 2009).

In present study, the bioflocculant harvested from alkaline-thermal (ALT) pre-treated sludge in our previous study was selected as a conditioner for sludge dewatering and swine wastewater pretreatment (Guo et al., 2014). Dewater-ability of the sludge treated by various conditioners, including this bioflocculant, $FeCl_3$, $Al_2(SO_4)_3$, PAC, and PAM was compared with each other, and the feasibility of the compound uses of this bioflocculant and PAC in sludge dewatering was investigated. For swine wastewater pretreatment, effectiveness of this bioflocculant in reducing COD,

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ammonium, and turbidity were investigated. Furthermore, based on the performance in flocculation of kaolin clay suspension (4.0 g/L), the flocculating mechanisms of this bioflocculant were discussed.

2. Methods

2.1. Bacteria strain and its bioflocculant

Bioflocculant was produced by *Rhodococcus erythropolis* using alkaline-thermal (ALT) pre-treated sludge which the concentration of suspended solids (SS) was 25 g/L, and was extracted using the methods in our previous study (Guo et al., 2014). In ALT treatment, pH value of the sludge sample was first adjusted to 10 by using 1.0 mol/L NaOH at room temperature (25 °C), and then autoclaved at 121 °C for 30 min.

Thermal stability of biological products depends on their activity ingredients, as known to all, bioflocculant with sugars were thermostable, while those made of protein were generally sensitive to heat (Guo et al., 2013). In this study, while the flocculating activity of the bioflocculant produced by using ALT sludge can be maintained at 90.6% or more after being heated at a relatively low temperature (<60 °C) for 30 min, it was decreased by about 59% after being heated at 80 °C for 30 min and by about 86% after being heated at 120 °C for 30 min. The poor heat stability indicated that the main backbone of this bioflocculant was a protein rather than a polysaccharide.

Chemical analysis of the bioflocculant revealed that the molecular weight of the bioflocculant was appeared as 4.21×10^5 Da. Infrared spectrum of the bioflocculant displayed a broad stretching peak in the range from 3400 to 3500 cm^{-1} which can be assigned to –OH and NH groups, and the peak at around 3430 cm^{-1} is an indication of –OH stretching from hydroxyl group (Liu et al., 2010). The peak around 1640 cm^{-1} is an indication of $-COO^-$ asymmetric stretching vibration (Lian et al., 2008). The peaks around 1080 cm^{-1} were characteristic of C–O groups (Ahmad et al., 2013).

2.2. Sludge dewatering by the bioflocculant

Sludge for dewatering tests was obtained from the secondary settling tank at Tuanjie Wastewater Treatment Co., Ltd., Sichuan province, China. Dry solids (DS), specific resistance to filtration (SRF), and pH value of this sludge are 13.2%, 11.3×10^{12} m/kg, and 6.5, respectively. Dewater-ability of the sludge was expressed in terms of DS and SRF. Flocculants, including the bioflocculant, $FeCl_3$, $Al_2(SO_4)_3$, PAC, and PAM were separately added into a 200 mL mixing chamber with 100 mL sludge, and the mixtures were stirred at 200 rpm for 10 min using a six–breaker jar tester (SY.36-ZR4–6, Shenzhen Zhongrun Company, China). After agitation, all the samples were allowed to stand for 30 min, and then were poured into the funnel fitted with a filter paper separately. After 2 min of gravitational drainage, a vacuum of 0.04 MPa was applied. The volume of the filtrate collected every 15 s was recorded.

The DS of dewatered sludge was determined according to the following equation:

$$DS = \frac{W_2}{W_1} \times 100\% \qquad (1)$$

where W_1 is the weight of wet filter cake and W_2 is the weight of filter cake after drying at 105 °C for 8 h.

The SRF was calculated by the following equation:

$$\frac{dt}{dV} = \frac{\mu}{A(\Delta p)}\left(\frac{\alpha c V}{A} + R_m\right) \qquad (2)$$

where t is the time (s), V is the filtrate volume (m), μ is the filtrate viscosity (N s/m^2), A is the filter area (m^2), Δp is the pressure drop across filter (N/m^2), c is the slurry concentration (kg/m^3), α is the SRF and R_m is the resistance of filter medium (neglected).

2.3. Swine wastewater pretreatment by the bioflocculant

Swine wastewater, taken from Jiancha pig farm, Sichuan Province, China, was chosen as a representative suspended sample. The concentrations of COD, ammonium, and turbidity of this solution were 1064 mg/L, 828 mg/L, and 157 NTU, respectively. In the experiments for discussing the potential of the bioflocculant in reducing COD, ammonium, and turbidity from swine wastewater, 100 mL of wastewater sample was firstly poured into a 300 mL beaker and its pH value was adjusted by using 1.0 mol/L NaOH or HCl if necessary. Then the bioflocculant was added into the sample, and the mixture was stirred at 200 rpm for 10 min using a six–breaker jar tester (SY.36-ZR4-6, Shenzhen Zhongrun Company, China). After agitation, the sample was allowed to stand 30 min, and the supernatant was collected to determine the residual COD, ammonium, and turbidity according to the APHA Standard Methods (APHA, 2005).

2.4. Assay of flocculating activity

Flocculating activity of the bioflocculant was conducted in jar testers by measuring turbidity of 4.0 g/L kaolin suspension (Guo et al., 2014). After adjusting the pH value using 1.0 mol/L NaOH or HCl, 50 mg of $CaCl_2$ and 2.0 mg of bioflocculant were added into the 100 mL of kaolin suspension in a 300 mL beaker. The mixture was vigorously stirred (180 rpm) for 1.0 min and slowly stirred (80 rpm) for 4.0 min, and then allowed to stand 10 min. The optical density (OD) of the clarifying solution was measured with a spectrophotometer (Unic-7230, Shanghai Lianhua Company, China) at 550 nm. A control experiment was conducted in the same manner without adding bioflocculant. All the measurements were carried out in triplicates and the average values were presented (with standard error less than 5% of the mean). The flocculating activity was calculated by the following equation:

$$FR = \frac{(B - A)}{B} \times 100\% \qquad (3)$$

where FR is the flocculating activity; A and B are the OD values of the sample and control.

3. Results and discussion

3.1. Application of this bioflocculant in sludge dewatering

3.1.1. Sludge dewatering by the bioflocculant

The potential of the bioflocculant from ALT pre-treated sludge in sludge dewatering was studied by the following investigations. From Fig. 1, the DS was increased by 8.4–70.4% and the SRF was decreased by 9.2–69.9% when the bioflocculant dose was adjusted in the range of 0.4–1.6 g/L, meaning that the dewater-ability of the sludge was improved. The optimal values of DS and SRF reached 22.5% and 3.4×10^{12} m/kg, respectively, when the bioflocculant dose was 1.6 g/L. These conclusions were similar with the results of Guo et al. (2015), in which the DS was increased to 21.7% and SRF decreased to 3.6×10^{12} m/kg when 1.5 g/L MBFGA1 was added at pH value of 7.5.

Based on the above results, the bioflocculant was demonstrated to be an effective conditioner in enhancing the dewater-ability of the sludge. Due to the high molar weight of 4.21×10^5 Da and polar groups of hydroxyl, carboxyl, and amino groups, the bioflocculant can supply ample binding sites and strong van der Waals

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