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Physical and chemical characteristics of waste activated sludge treated with electric field

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ABSTRACT

This study investigates the physical and chemical characteristics of sludge treated with controlled levels of electric field. The results indicated that the potential gradient and contact time strongly influenced the physical and chemical characteristics of sludge. Based on the settling velocity measurements, a potential gradient of 6 V/cm with a treatment time of 10 min is recommended as an optimal condition for improving sludge settling. For sludge disintegration, applying a higher potential gradient and a longer treatment time to the sludge are more efficient than applying lower levels. The results of the experiments presented here show that an electric field not only disintegrates sludge and destroys microbial cells but also removes and solubilizes organic substances. Possible mechanisms of electric field treatment are also discussed.

Keywords: Potential gradient; Settleability; Treatment time; Physical–chemical characteristics; Waste activated sludge

1. Introduction

The method of activated sludge has been widely used in wastewater treatment processes, which produce large amounts of waste activated sludge (WAS). Many technical problems arise from treating and disposing of the excess sludge, which can cause secondary environmental pollution. Reducing the amount of sludge and improving sludge characteristics are beneficial to the subsequent treatment. Various physical and chemical methods, such as thermal hydrolysis (Bougrier et al., 2006; Climent et al., 2007; Paul et al., 2006), ultrasonic treatment (Feng et al., 2009), mechanical disintegration (Baier and Schmidheiny, 1997; Raynaud et al., 2010), microwave irradiation (Yu et al., 2010), hydrolysis and acidification (Liu et al., 2008), have been examined, and their influence on sludge has been evaluated.

Recent years have seen growing interest in electro-kinetic remediation, a promising technique for sludge treatment. The word electro-kinetic implies the combined effects of motion and an electrical field (Mahmoud et al., 2010). Electro-kinetic remediation is a controlled application of electrical migration and electro-osmosis, together with the electrolysis reactions at the electrodes. Electric currents are used to extract radionuclides, heavy metals, certain organic compounds, mixed inorganic species and organic wastes from soils and slurries (Acar et al., 1995). Electrolysis is thought to be a novel and efficient tool for sludge disintegration and for improving sludge biodegradability (Yuan et al., 2010). As a result of the more stringent environmental regulations on the discharge of industrial and municipal wastewater, electrochemical technology is considered to be a powerful means of pollution control and has been widely used (Song et al., 2010). In some situations, the technology may be the indispensable step for the effluents that are refractory using conventional treatments (Lei et al., 2010).

The literature on the treatment of activated sludge using an electrical field has focused on the extraction of heavy metals from dewatered sludge (Gent et al., 2004; Jakobsen et al., 2004). Prior studies have shown that applying an electrical field may induce a series of physicochemical changes in the applied media, which would lead to a change of sludge characteristics. However, only a few of these approaches have been examined.

The present study therefore focuses on the effect of different electric field intensities and treatment time on the

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Table 1 – Characteristics of the initial sludge sample (mean ± S.E.).

Parameter	Value
pH	6.65
VS (mg/L)	9732 ± 214
TDM (mg/L)	504.50 ± 12
TSCOD (mg/L)	4062.4 ± 115
SCOD (mg/L)	159.20 ± 6.31
EC (μS/cm)	692 ± 5
Water content (%)	98.17 ± 0.01

physical and chemical characteristics of WAS to determine the specific situations that are most effective for its disintegration. The physical properties that were examined in this study include settleability, electrical conductivity (EC), and mass composition. The chemical properties measured are soluble chemical oxygen demand (SCOD), ammoniacal nitrogen content (NH_4^+–N), and protein and polysaccharide content of the supernatant. The possible mechanisms by which treatment under an electric field alters these characteristics of sludge are also discussed.

2. Materials and methods

2.1. Materials

Samples of WAS were collected from LiJiao Municipal Wastewater Treatment Plant (WWTP) in Guangzhou, China, which utilizes an anaerobic–anoxic–oxic process at a flow rate of 200,000 t daily. The collected sludge was immediately transferred to the lab and stored in a plastic box not beyond 24 h at 4 °C prior to use. Sludge characteristics are presented in Table 1.

2.2. Experimental equipment and methods

A rectangular plexiglas column was used as a sludge specimen chamber, and the cell dimensions were 100 mm × 100 mm × 80 mm. A Ti/IrO_2 anode and a Ti cathode, with a working area of 80 cm^2, were installed at each side of the sludge chamber. The sludge samples (800 mL) were put into the reactor and treated with an array of 2, 4, and 6 V/cm for various durations, e.g., 0, 5, 10, 15, 20, 25 and 30 min.

Sludge samples with and without electric field were analyzed for settling velocity (SV), volatile solids (VS), and total dissolved matter (TDM). Samples were centrifuged at 4000 rpm for 30 min at 25 °C (Universal 32 R centrifuge, Hettich, Germany), and the supernatant was filtered through a 0.45-μm filter and then analyzed for SCOD, ammoniacal nitrogen content, and the presence of extracellular polymeric substances (EPS). Each experiment was performed in triplicate, an average values were then obtained. Statistical correlations were analyzed using Sigmaplot software (version 10.0).

2.3. Measurement of physical characteristics

Water content, VS and TDM were determined according to standard methods (APHA, 1998). SV is one of sludge's most important settling parameters in routine process control, and was obtained using the method described by Feng et al. (2009). SV was measured as follows. Sludge samples (100 mL) with and without electric field were mixed well and transferred into a glass cylinder with a diameter of 27 mm. SV was then determined from the height of the sludge that had settled after a certain fixed interval of time. Sludge samples with and without electric field were allowed to settle freely for 24 h (Feng et al., 2009; Yu et al., 2010), after which the turbidity of the supernatant was measured using standard methods (APHA, 1998). The EC of the sludge sample supernatant was determined using conductivity meter (DDS-307, Rex, China).

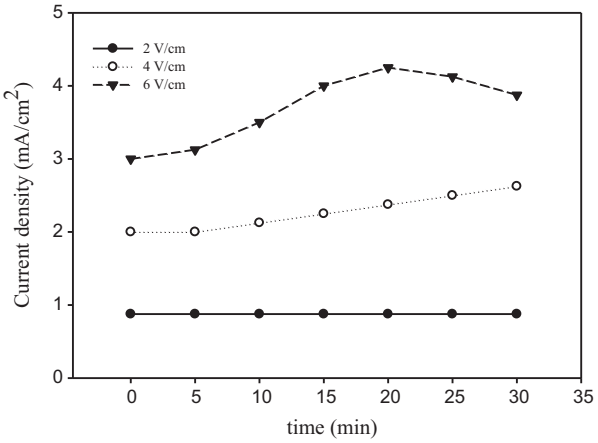

Fig. 1 – Variation of current density during the process.

2.4. Measurement of chemical characteristics

COD and NH_4^+–N were measured following standard methods (APHA, 1998). Total SCOD (TSCOD) was obtained via an alkaline hydrolysis procedure in which the initial sludge sample was mixed with 0.5 M NaOH at room temperature for 24 h (Feng et al., 2009).

The EPS content of the sludge supernatant was determined spectrophotometrically using a T6 UV/vis spectrophotometer (PGeneral, China). Proteins were determined using the Coomassie Brilliant Blue G-250 method with absorbance at 595 nm (Bradford, 1976), using casein as the standard. Polysaccharide was measured by the anthrone method with absorbance at 625 nm (Riesz et al., 1985), using glucose as the standard.

The increase in NH_4^+–N ($I_{NH_4^+}$–N, Eq. (1)) was calculated as the difference between the NH_4^+–N content after electric field treatment and the initial NH_4^+–N ($NH_4^+(0)$) content of the supernatant:

$$I_{NH_4^+-N}(\%) = \frac{NH_4^+ - NH_4^+(0)}{NH_4^+(0)} \times 100 \quad (1)$$

3. Results and discussion

3.1. Current density

Current density is a vital parameter that has a significant influence on electrolysis. Fig. 1 shows current density as a function of time. At the beginning of the test, the current density was low for each system, and then it increased thereafter. As shown, the change was inconspicuous at a potential gradient of 2 V/cm and was maintained at 0.88 mA/cm^2. The current density increased slowly with time at 4 V/cm, from 2.00 mA/cm^2 to 2.63 mA/cm^2. However, there were some differences in the 6 V/cm system; the highest current density was 4.25 mA/cm^2 with a treatment time of 20 min, and then decreased to 3.88 mA/cm^2.