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Feasibility of bioleaching combined with Fenton oxidation to improve sewage sludge dewaterability

Changgeng Liu[1,2,3], *Panyue Zhang*[2,3,*], *Chenghua Zeng*[1,*], *Guangming Zeng*[2,3], *Guoyin Xu*[1], *Yi Huang*[1]

1. *School of Resources and Environmental Engineering, Panzhihua University, Panzhihua 617000, China. E-mail:* changwyx@163.com
2. *Key Laboratory of Environmental Biology and Pollution Control (Hunan University), Ministry of Education, Changsha 410082, China*
3. *College of Environmental Science and Engineering, Hunan University, Changsha 410082, China*

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ABSTRACT

A novel joint method of bioleaching with Fenton oxidation was applied to condition sewage sludge. The specific resistance to filtration (SRF) and moisture of sludge cake (MSC) were adopted to evaluate the improvement of sludge dewaterability. After 2-day bioleaching, the sludge pH dropped to about 2.5 which satisfied the acidic condition for Fenton oxidation. Meanwhile, the SRF declined from 6.45×10^{10} to 2.07×10^{10} s^2/g, and MSC decreased from 91.42% to 87.66%. The bioleached sludge was further conditioned with Fenton oxidation. From an economical point of view, the optimal dosages of H_2O_2 and Fe^{2+} were 0.12 and 0.036 mol/L, respectively, and the optimal reaction time was 60 min. Under optimal conditions, SRF, volatile solids reduction, and MSC were 3.43×10^8 s^2/g, 36.93%, and 79.58%, respectively. The stability and settleability of sewage sludge were both improved significantly. Besides, the results indicated that bioleaching-Fenton oxidation was more efficient in dewatering the sewage sludge than traditional Fenton oxidation. The sludge conditioning mechanisms by bioleaching-Fenton oxidation might mainly include the flocculation effects and the releases of extracellular polymeric substances–bound water and intercellular water.

Introduction

Activated sludge process plays an important role in worldwide wastewater treatment (Chang et al., 2001), but it has a serious drawback of producing huge amounts of excess sludge (Feng et al., 2009). The water content of excess sludge is generally over 98%, which leads to the difficult dewatering (Vaxelaire and Cezac, 2004). Therefore, the treatment of excess sludge has already become a serious environmental problem in wastewater treatment plants. It has been reported that the performance of sludge dewatering significantly depends on sludge properties, such as particle size, extracellular polymeric substances (EPS), water content, etc. (Karr and Keinath, 1978; Mikkelsen and Keiding, 2002; Neyens and Baeyens, 2003; Novak et al., 1998). Sludge dewatering has been pointed out as the most expensive and the least understood process (Bruus et al., 1992), and the cost of sludge treatment and disposal nearly accounts for as high as 50%–60% of the entire operating cost of wastewater treatment plants (Egemen et al., 2001). With the development of stringent environmental regulations, more efficient sludge treatment technologies are demanded.

Advanced oxidation processes for sludge conditioning have gained the worldwide attention in recent years (Tony et al., 2009). Fenton oxidation as one of the advanced oxidation processes has

* *Corresponding authors.* E-mails: zhangpanyue@hnu.edu.cn (Panyue Zhang); zch1963111@sina.com (Chenghua Zeng).

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been proved to be a promising technology for conditioning sludge. During the last decade, many efforts have been made to explore the possibility of sludge dewatering by Fenton oxidation, and the experimental results indicated that Fenton oxidation had a positive effect on sludge dewatering (Buyukkamaci, 2004; Debowski et al., 2008; Erden and Filibeli, 2010; Kaynak and Filibeli, 2008; Lu et al., 2003). In addition, it was reported that Fenton pretreatment played a positive role in sludge minimization (Kaynak and Filibeli, 2008). Through Fenton pretreatment, the anaerobic biodegradability of biological sludge was also improved significantly (Erden and Filibeli, 2010; Kaynak and Filibeli, 2008). As a result, the higher volatile solid (VS) reduction and higher biogas production were achieved (Kaynak and Filibeli, 2008).

Traditionally, inorganic acid is always needed in Fenton reaction to reduce sludge pH to achieve the desired efficiency. In that case, large amounts of inorganic acid for sludge conditioning and further alkali for neutralizing are required, which leads to high operation cost of Fenton treatment. Bioleaching as one of the microbial technologies for sludge treatment may serve as a substitution method of conventional chemical acidification, because the sludge pH can decline to the optimal pH range for Fenton reaction through bioleaching. In addition, it is widely accepted that bioleaching is superior in leaching heavy metals (Benmoussa et al., 1997; Couillard and Mercier, 1991; Kim et al., 2005), destroying and destructing pathogens (Benmoussa et al., 1997; Couillard and Mercier, 1991), controlling odor (Filali-Meknassi et al., 2000), reducing volume and improving stability (Benmoussa et al., 1997). Therefore, bioleaching has gained increasing attention to sludge conditioning in recent years.

In our previous studies, bioleaching combined with Fenton-like oxidation was proved to be efficient in removing heavy metals from sewage sludge (Zhu et al., 2013). In this study, we continuously investigated the possibility of bioleaching combined with Fenton oxidation to improve sludge dewaterability. The specific resistance to filtration (SRF), moisture of sludge cake (MSC), supernatant volume, and VS reduction were adopted to characterize the treated sludge. Bioleaching provides a suitable reaction condition for Fenton oxidation, which has been scarcely reported. The main objective of this study was to evaluate the feasibility and efficiency of the combined process for sludge conditioning and dewatering.

1. Materials and methods

1.1. Sewage sludge

Sewage sludge was collected from sludge thickener of a full-scale wastewater treatment plant in Changsha, China. After gravity settling for 12 hr, the supernatant was removed, and then the sludge as experimental sample was stored at 4°C in a refrigerator. Before conditioning experiments, the sludge sample was kept in a water bath at 20°C for 30 min. Some properties of raw sludge are given in Table 1.

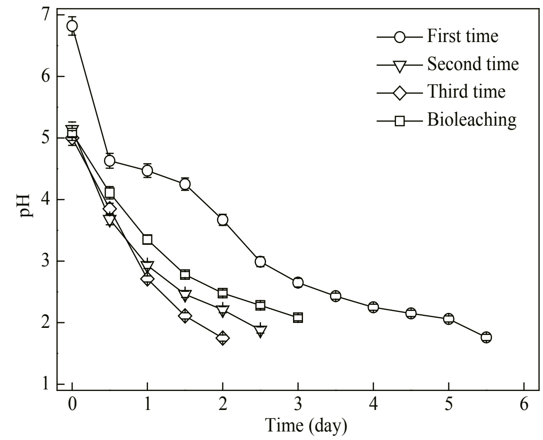

Fig. 1 – pH change during inocula preparation and sludge bioleaching process. Experimental condition: sulfur powder dosage = 0.31 mol/L for inocula preparation, sulfur powder dosage = 0.09 mol/L for sludge bioleaching.

All chemicals used in this study were of analytic grade, and purchased from Sinopharm Chemical Reagent Co. Ltd.

1.2. Inocula preparation

It has been reported that pure *Thiobacillus* for bioleaching could be isolated from sewage sludge or acid wastewater (Wong et al., 2004). Thus, fresh sewage sludge as the seed sludge was applied to enrich and culture the indigenous acidophilic *Thiobacillus*, which was collected from the sludge thickener in the same wastewater treatment plant. All experiments were performed at ambient temperature of 28°C. Inocula preparation was described in detail as follows. Firstly, sulfur powders of 0.31 mol/L as the energy substance were added into a 250 mL Erlenmeyer flask (Zhengzhou Zhongtian Chemical Instrument Co., Ltd., Zhengzhou, China) filled with feed sludge of 100 mL. Then the flask was agitated in an orbital shaker (ZHWY-1102, Shanghai Zhicheng Analytical Instrument Co., Ltd., Shanghai, China) at a shaking speed of 180 r/min until the pH of seed sludge dropped to below 2.0. Subsequently, the acidified sludge of 10 mL was transferred into a 250 mL Erlenmeyer flask filled with 90 mL feed sludge, under the same conditions the *Thiobacillus* were enriched and cultured twice again. After being cultured and enriched

Table 1 – Properties of raw sludge and bioleached sludge.

Sludge	pH	TS (mg/L)	VS (mg/L)	Supernatant volume (mL)	MSC (%)	SRF (s^2/g)
Sludge sample	6.83	15461	10248	2.0	91.42	6.45×10^{10}
Bioleached sludge	2.23	14,503	9449	3.0	87.66	2.07×10^{10}

TS, VS, MSC, and SRF denote total solids, volatile solids, moisture of sludge cake, and specific resistance to filtration, respectively.