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Research article

Controlling odors from sewage sludge using ultrasound coupled with Fenton oxidation

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ABSTRACT

We examined the effects of ultrasound (U), Fenton oxidation (F), and ultrasound coupled with Fenton oxidation (U + F) pre-treatments (prior to anaerobic digestion) on the elimination of odorous compounds. The results demonstrated that U promoted odor release, while the coupled treatment and F alone decreased odor release. After 20-min treatments, the concentration of dissolved sulfide (S^{2-}) under the coupled U + F treatment declined from 17.4 mg/L to 8.1 mg/L, decreasing by more than 50% and 34%, respectively, for U alone and F alone. In addition, the dissolved sulfate (SO_4^{2-}) concentration under couple U + F treatment significantly increased in sewage sludge from 200 mg/L to 390.6 mg/L, up 95.3% compared to U alone and 5% compared to F alone. This illustrates the oxidation process from S^{2-} to SO_4^{2-}. Throughout experimentation, SO_4^{2-} was odorless and stable, highlighting the mechanism of odor control. Thus, combining U and F into a single coupled treatment proved to be a better alternative pretreatment for controlling sludge odor compared to the U and F alone and can effectively decrease potential odor release.

1. Introduction

The common use of activated sludge in the wastewater treatment process is always accompanied by large amounts of sludge waste (Ruffino et al., 2015). Characterized by instability and odor release, large amounts of untreated sludge waste pose a high risk to both environmental and human health (Mahanty et al., 2014; Mowla et al., 2013). As a result, methods to properly dispose of sludge waste are critical (Easter et al., 2005). At the same time, sludge waste contains elements such as nitrogen and phosphorus that could be used as fertilizer and thus various technologies (including chemical, physical, and thermal treatments) have been applied to sludge disposal. In fact, the primary objectives of sludge waste treatment include improvement of sewage sludge dewaterability and the recovery of usable organic/inorganic matter (Hurst et al., 2005; Jiang et al., 2014; Mowla et al., 2013).

Unfortunately, existing technologies are relatively ineffective at controlling and eliminating odors, primarily due to the complexity of pretreatment methods and toxicity. As a result, more efforts must focus on odor control (Kim et al., 2014; Lebrero et al., 2012). It is clear that sources of odor emissions are the first priority in odor control (Batistella et al., 2015). Many studies have focused on the control or elimination of odors released from sewage sludge (Charnnok et al., 2013; Lebrero et al., 2012), and several authors have described the characteristics of emissions from sewage sludge treatment. This includes the fact that sulfur-containing compounds and ammonia constitute the major components of odors (Kim et al., 2014; Vega et al., 2015). Thus, we focused on typical odor components including H_2S, methyl mercaptan (CH_3SH), dimethyl sulfide (CH_3SCH_3), dimethyl disulfide (CH_3SSCH_3), and ammonia. Others have demonstrated the effectiveness of single ultrasonic and other chemical oxidation technologies, such as hydrogen peroxide and activated carbon, in controlling or eliminating odors (Chestnutt et al., 2007; Fraikin et al., 2011). For example, ultrasonic pretreatment enhances odor release caused by the cavitation effect (Ruiz-Hernando et al., 2014); hydrogen peroxide has been applied to oxidize H_2S, mercaptans, and thiosulfate in wastewater sludge and thickened sewage sludge (Lebrero et al., 2013); and activated carbon has been used to eliminate odor compounds (Chen et al., 1997; Sioukri and Bandosz, 2005). However, these odor control

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technologies overlook the effects of sewage sludge dewaterability and material release. Moreover, their practical application is limited by their low efficiency and high cost. Thus, alternatives like coupled treatments including combine the ultrasonic and alkali, combine microwave and hydrogen peroxide (H_2O_2), bio-trickling filtration coupled with activated carbon have recently been studied to determine their effectiveness relative to single odor control technologies (Milenković et al., 2013; Park et al., 2012; Pham et al., 2010; Pilli et al., 2015). However, more effort is required to comprehensively evaluate the effects of coupled treatments.

Here, we submit a new approach for both sewage sludge integration and odor control: ultrasound coupled with Fenton treatment. Our objective was to evaluate the efficiency of sewage sludge dewaterability via U, F, and U + F treatments, and to pay particular attention to sulfur-containing odor elimination from sewage sludge. Our previous research has already confirmed that the U + F treatment increased the soluble chemical oxygen demand (SCOD) of sewage sludge by 2.1 times and 1.4 times compared to separate U and F treatments, respectively, as well as improving sludge solubility on the basis of our group research (Gong et al., 2015). Here, we focused on odor control under the above treatments. The maximum decrement of dissolved sulfide (S^{2-}) and maximum increment of dissolved sulfate (SO_4^{2-}) after coupled treatments displayed higher efficiency than separate U and F. Consequently, we suggest that coupled U + F is an effective new approach for both enhancing sewage sludge dewaterability and eliminating odor.

2. Materials and methods

2.1. Anaerobic digestion sludge

Anaerobic digestion sludge was obtained from the Xiao Hongmen Wastewater Treatment Plant in Beijing, China, which has a sewage treatment capacity of 6.0 × 10^7 m^3 per day. The sewage treatment plant uses the anaerobic-anoxic-oxic (A^2/O) processing system for municipal wastewater treatment. Sludge was obtained from the anaerobic digester, after gravity thickening. The characteristics were analyzed before experimentation and are presented in Table 1. All the data presented in Table 1 and Figs. 1–4 of the manuscript were assayed in triplicate. Error bars (SE) have been added in Table 1 and Figs. 1–4.

2.2. Sampling method

Experiments were conducted in a system comprising several parts, including a quartz reaction tube, a gas inlet, a tap water inlet, a sampling outlet, a supernatant outlet, and an odor collection device. The sewage sludge was treated respectively by U, F, and U + F prior to transfer in the quartz reaction tank, and was then purged with nitrogen gas for several minutes to ensure an anaerobic incubation environment. After predetermined sampling intervals (24, 48, and 72 h), odor samples were collected by injecting tap water at the bottom to force the odors out. Gas chromatography was then used to analyze sample composition. Supernatant samples were collected from the liquid outlet by purging gas through the system. All experiments were conducted at room temperature and under atmospheric pressure conditions.

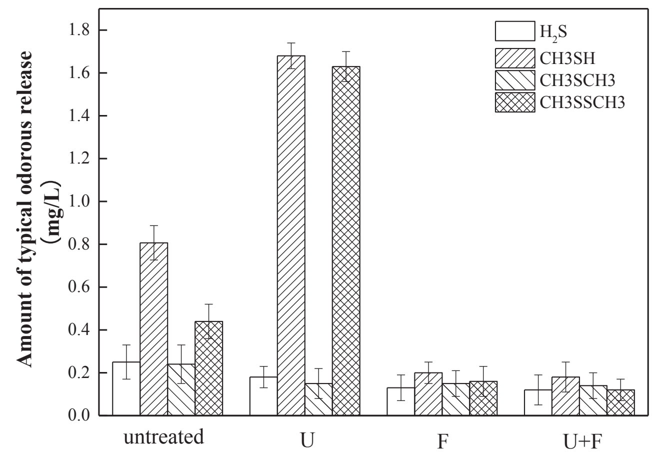

Fig. 1. Various pretreatment effects on odor release from sewage sludge (U: ultrasonic energy density 720 W/L; F: concentration of Fe^{2+} 0.2 g/L; H_2O_2 0.5 g/L; U + F: ultrasonic energy density 720 W/L, concentration of Fe^{2+} 0.2 g/L; H_2O_2 0.5 g/L).

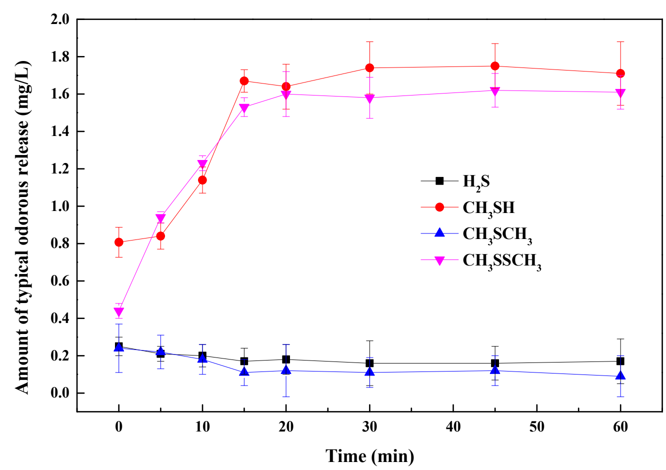

Fig. 2. Effects of treatment time on four kinds of typical odor releases from sewage sludge after ultrasound treatment (ultrasonic energy density 720 W/L).

2.3. Experimental set-up

For the U treatment: We used a probe-type ultrasound generator (model FS1200, Shanghai Sonxi Ultrasonic Instrument Co.,

Table 1
Basic properties of the anaerobic digestion sludge.

No.	pH	Moisture %	COD[a] mg O_2/L	SCOD[b] mg O_2/L	TS[c] mg/L	VS[d] mg/L	S[e] g/Kg	N[f] g/Kg
Average	6.67	98.5	13679.5	142.0	9418.6	4968.5	4.31	19.6
SE	0.04	0.2	1219.3	9.8	961.7	277.5	0.27	1.5

[a] Chemical oxygen demand.
[b] Soluble chemical oxygen demand.
[c] Total Solid.
[d] Volatile Solid.
[e] Sulfur.
[f] Nitrogen.