Original Article

Treatment of Compost Leachate By Ferro-sonication Process: Effect of Some Operational Variables

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Abstract

Aim: Application of composting process for the management of organic solid waste led to the production of leachate, which causes many problems to environment. This study was aimed at investigation of ferro-sonication (FS) process in composting leachate degradation. **Materials and Methods:** Leachate samples were collected in composting factory located in Isfahan. In each run, 400 ml of leachate was sonicationed through an ultrasonic homogenizer in a cylindrical glass reactor. Ferrous sulfate was added to the reactor as accelerator agent. The effect of various parameters including pH, ferrous sulfate doses, sonication times, and ultrasonic intensity was studied in the removal of chemical oxygen demand (COD) and biological oxygen demand (BOD) from composting leachate. **Results:** The results showed that the COD and BOD removal rate was increased by increasing ferrous sulfate dosages, sonication time, and ultrasonic intensity. In addition, lower pH was favored for leachate degradation. In general, the optimum conditions for pH, ferrous sulfate dosage, irradiation time, and ultrasonic intensity were 3, 8 mmol, 180 min, and 150 W, respectively. Approximately 46% of COD and 33% of BOD were removed in optimum condition. **Conclusion:** These results revealed that FS can be effective in degradation of compost leachate and can be presented as a good choice for pretreatment of leachate.

Keywords: Biological oxygen demand, chemical oxygen demand, compost leachate, ferro-sonication, ultrasonic

Introduction

Solid waste management has become one of the most important problems in developed countries.[1] Several methods such as incineration, sanitary landfill, composting, grinding and discharging to sewer, compaction, dumping, milling, reduction, and anaerobic digestion have been implemented for solid waste disposal.[2] Nowadays, the global strategy on management of organic wastes has been aimed at recycling. Among different technologies for recycling of organic wastes, composting is often presented as a low-technology and low-investment process to transforming the wastes into stable products known as compost.[3] In this process, leachate is produced which has a variable and complex chemical and microbial composition.[4] Due to high loading, complex chemical composition, and variable seasonally volume, the leachate treatment processes are very difficult and expensive.[5] Common leachate treatment systems, such as air stripping, coagulation, flocculation, and settling, are often expensive regarding initial outlay of plant equipment, energy necessities, and regular use of additional chemicals. Coagulation–flocculation systems, for example, have some drawbacks, such as sludge production and increasing of aluminum or iron concentrations in the liquid phase.[6] Other techniques such as reverse osmosis or active carbon adsorption only change pollutant phase from wastewater to biomass or sludge[7] which subsequently creates other environmental problems. Thus, different combinations of physicochemical treatments have been used.[8] Recently, advanced oxidation processes (AOPs) have been suggested as an effective alternative for degradation of persistent organics in leachate. There are several types of

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AOPs including ozonation, Fenton process, ultrasonication, heterogeneous photocatalysis, ferro-sonication (FS), electrochemical oxidation, or even the combination of some of them that can be used in the treatment of leachate.[9] FS is a combination of ultrasonic irradiation and addition of $FeSO_4 \cdot 7H_2O$. During ultrasonication, the formation, growth, and implosive collapse of bubbles in a liquid generates unusual chemical and physical environments, which subsequently induced chemical effects.[10] The collapse of bubbles produced high temperature which decomposes water (H_2O) into highly reactive hydrogen atoms (H^+) and hydroxyl radicals ($OH^·$). The generated radical species can also recombine to form hydrogen peroxide and molecular hydrogen or react with other molecules to initiate sonochemical degradations.[11]

Application of FS in the removal of persistent compounds has been reported previously. For example, Mohapatra *et al*.[12] applied FS as pretreatment for bisphenol A (BA). Result of their study showed that FS has positive effect in degradation of BA. Moreover, Pourzamani *et al*.[13] showed that combination of ultrasonic irradiation and H_2O_2 has positive effect in degradation of natural organic matter. It seems that application of FS can be useful in reduction of organic matter in compost leachate. Although many studies related to leachate treatment have been conducted previously, to the best of our knowledge, there has been no study regarding FS in the treatment of leachate. Given this hypothesis, the present work was performed to investigate the effect of FS in leachate degradation. Effect of parameters such as ferrous sulfate dosage, time of sonication, and input power in the removal of chemical oxygen demand (COD) and biological oxygen demand (BOD) was outlined.

Materials and Methods

Leachate characteristics

The samples were taken from the Isfahan composting factory (ICF). ICF is located at the eastern parts of Isfahan city. About, 1000 tons of source-separated organic MSW deliver to the facility daily.[14] Untreated leachate was stored in refrigerator at 4 C for the duration of experiment. Before being used in the system, leachate was diluted using municipal wastewater. The brief characteristics of raw and diluted leachate are summarized in Table 1.

Chemicals and instruments

All the chemicals used in this study (H_2SO_4, NaOH, and $FeSO_4 \cdot 7H_2O$) were in analytical grade and were purchased from Merck Co (Germany).

Sonication was done by ultrasonic homogenizer (SONOPLUS HD, 3200, Bandelin, Germany) operating at 20 kHz equipped with a titanium probe transducer, 8 mm in diameter.

Procedures

The degradation of leachate compost was performed in a batch reactor. The reactor used for the experiments involving the sonication was consisted of a glass cylindrical reactor with the cooling jacket and the maximum working volume of 1L. In each run, 400 ml of diluted leachate [Table 1] was poured in the reactor. Thereafter, solution pH was adjusted by 10 N NaOH and H_2SO_4 in desired ranges of 3, 5, 7, and 9. Ferrous sulfate in specified dosages was added to the reactor simultaneously with sonication. The introduced powers to the diluted leachate were 100, 120, and 150 W. For degradation of composting leachate, sonication was performed at times of 60, 150, 200, and 250 min and sampling was done at the end of each run, respectively. Measurements of pH, BOD_5, and COD were done according to the standard methods for water and wastewater examination.[15] All experiments were performed in duplicate and the result was taken as the average value of the experiment. The obtained data were analyzed by Excel software.

Results

In this study, the performance of FS for leachate degradation was evaluated. In addition, the effect of variables such as pH, ferrous sulfate dosages, input powers, and times of sonication was discussed.

Effect of pH

Influence of pH on COD removal is given in Figure 1. It can be seen that COD removal rate has an increasing trend by decrease of pH. The maximum removal of COD (43%) was achived in pH 3. Hence, pH of 3 considered optimum in the following.

Effect of ferrous sulfate dosage

The added ferrous sulfate dosages in FS process were 2, 4, 8, and 12 mmol. In Figure 2, it was observed that by increasing of ferrous sulfate dosages, the removal of COD and BOD increased. The maximum removal of COD and BOD was occurred in 8 mmol ferrous sulfate.

Influence of sonication time on chemical oxygen demand and biological oxygen demand removal

Figure 3 illustrates the effect of sonication time (60, 120, 180, and 250 min) on the removal of COD and BOD. The

Table 1: Some of the leachate sample characteristics

Parameter	Unit	Raw leachate concentrated (average)	Diluted leachate concentrated
COD	mg/L	93000	4500
BOD_5	mg/L	57000	2100
pH	-	4.8	5

COD: Chemical oxygen demand, BOD: Biological oxygen demand experiments in this stage were carried out in the optimum ferrous sulfate dosage 8 mmol, power of 120 W, and pH of 9. It is clear that the COD and BOD removal increased as the time of sonication increased. Approximately 41% removal of COD was achieved by FS in 250 min.

Effect of ultrasonic power

Degradation of compost leachate was investigated at different ultrasonic powers (100, 120, and 150 w), solution pH 9, ferrous sulfate dosage of 8 mmol, and 180 min sonication time. As shown in Figure 4, COD and BOD removal increased by increasing of input powers. Approximately 46% of COD was removed at the power of 150 w.

Discussion

Solution pH has an important effect on chemical process. This study was conducted to evaluate the effect of FS on COD and BOD removal of leachate compost. In this regard, the effect of pH was evaluated. FS process is combination of ultrasonic irradiation and addition of $FeSO_4.7H_2O$. Ultrasonication led to decomposition of water into reactive H^+, and $OH^\bullet$ in zones have higher temperature and hydrogen peroxide in the cooling phase.[16] It is expected higher production of OH• radicals can occur due to the reaction between hydrogen peroxide and Fe_2^+ (equation 1).

$$Fe_2^+ + H_2O_2 \rightarrow Fe_3^+ + OH^\bullet + OH^{-[17]} \quad (1)$$

The COD removal rates were higher in low pH solution [Figure 1]. In pH 3, approximately 33% of COD was removed. This is in accordance with the results reported by Vilar *et al*.[18] who evaluated Fenton process in the treatment of landfill leachate. The result of their study showed that about 65% of COD removed at pH of 3. As shown in Figure 1 by increasing of pH, removal rate decreased, and in pH 9, about 9% of COD was removed. In alkaline environment, precipitation of Fe_{2+} can occur which in turn decreased the required amount for effective production of OH radicals. Generation of $OH^\bullet$ radicals in FS process led to degradation of leachate and therefore removal of COD and BOD.

Increasing of ferrous sulfate dosage led to increase of COD and BOD removal. As shown in Figure 2 by increase of ferrous

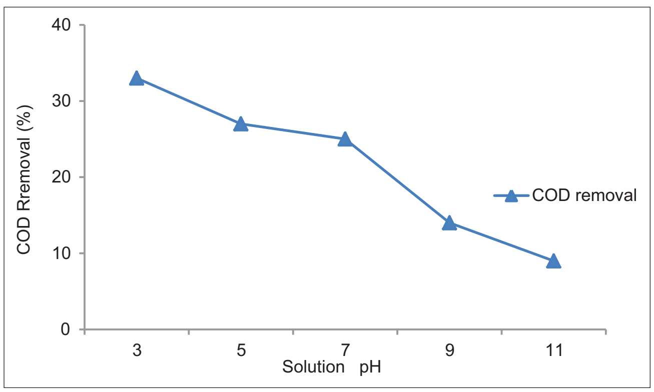

Figure 1: Effect of solution pH on chemical oxygen demand removal in the ferro-sonication process (reaction time: 60 min, input power: 120 W, and ferrous sulfate dosage 4 mmol)

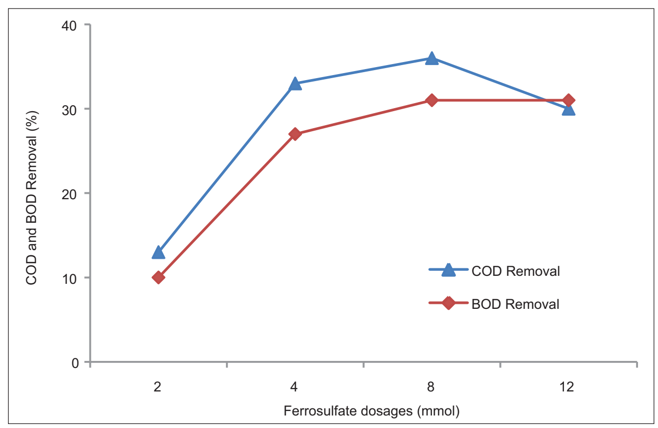

Figure 2: Effect of on chemical oxygen demand and biological oxygen demand removal in the ferro-sonication process (reaction time: 120 min, input power: 120 W, and solution pH of 3)

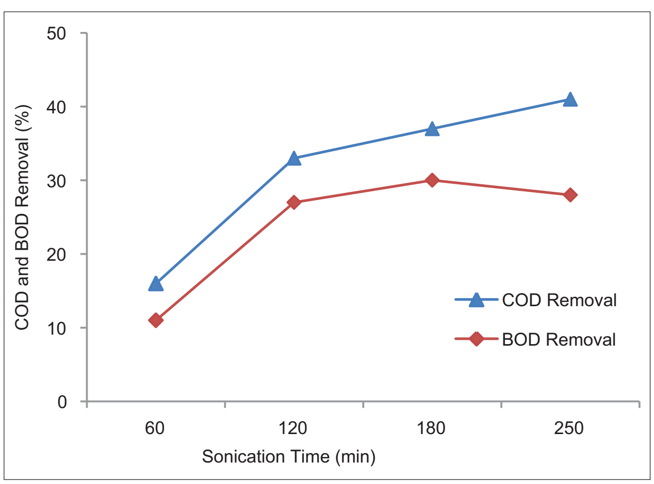

Figure 3: Effect of sonication times on chemical oxygen demand and biological oxygen demand removal in the ferro-sonication process (ferrous sulfate dosage: 8 mmol, input power: 120 W, and solution pH of 3)

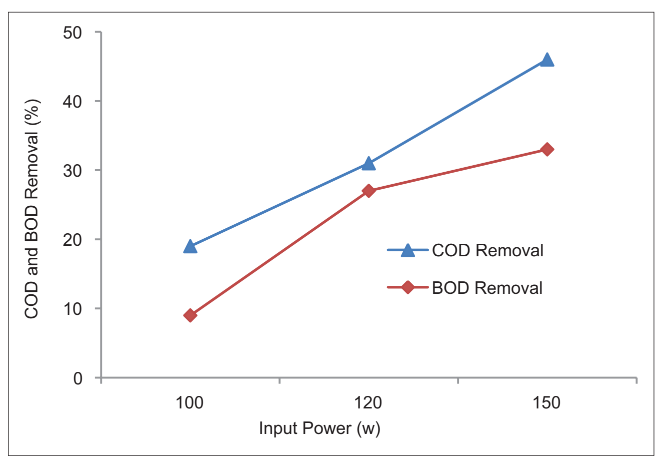

Figure 4: Effect of input powers on chemical oxygen demand and biological oxygen demand removal in the ferro-sonication process (ferrous sulfate dosage: 8 mmol, sonication time: 180 min, and solution pH of 3)

sulfate dosage from 2 to 8 mmol, the removal of COD and BOD increased from 13% to 36% and 10% to 31%, respectively. Increase of ferrous sulfate dosage from 8 to 12 mmol causes a slightly decrease in removal rate. The optimum ferrous sulfate concentration for maximum COD and BOD removal was 8 mmol. In general, the removal of organic matters improves with increasing concentration of iron salt. Many studies have shown that usage of a much higher concentration of Fe_{2+} can lead to the self-inhibition of OH radical by Fe_{2+} ions and decrease the degradation rate of pollutants: $OH^{\cdot} + Fe_2^{+} \rightarrow Fe_3^{+} + OH^{-}$.[19]

The effect of reaction time on COD and BOD removal through FS process was survived. As shown in Figure 3, the removal of COD and BOD increases with the increasing of the ultrasonic irradiation time. Approximately 37% and 30% of COD and BOD removal rate was obtained at a time of 180 min, respectively. This time was determined as equilibrium time for COD and BOD removal. After that time, a considerable change did not observed in COD and BOD removal. Reaction time is a key factor in Fenton process. By increasing of sonication times, formation both of $OH^{\cdot}$ and $O_2^{\cdot}$ may be promoted.[20] The results of this study are in line with the results obtained by others[21-23] who stated that by increasing of sonication time, removal rate was increased.

Influence of ultrasonic intensity on COD and BOD removal was evaluated. Figure 4 shows the effect of different ultrasonic irradiation intensity on COD and BOD removal. It is clear that degradation efficiency increased with ultrasonic intensity. The percentage removal was 19%, 31%, and 46% for COD and 9%, 27%, and 33% for BOD in sonication powers of 100, 120, and 150 W, respectively. Increasing of ultrasonic intensity increased the COD and BOD removal. It can be assumed that higher intensity results in more turbulence of the solution, which in turn, increases the reactive radicals.[20] This result is in good agreement with the results obtained by others.[10,20]

Conclusion

In this study, the degradation of compost leachate by FS process was investigated under a variety of operating conditions. The results show that COD and BOD removal intensified with increasing ferrous sulfate addition, ultrasonic intensity, and decrease in solution pH. The optimum conditions for FS including ultrasonic irradiation time, solution pH, ultrasonic intensity, and ferrous sulfate dosage were 180 min, 3, 150 W, and 8 mmol. Application of this method can be a good choice for pretreatment of wastewater and leachate before conducting of biological treatment. However, it must be consider in economical aspect.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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