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LANDFILL LEACHATE TREATMENT WITH COMBINED UASB AND FENTON COAGULATION

Key Words: Leachate, UASB, Fenton reagent, coagulation

Peng Wang[1*], Ivan W. C. Lau[2], Herbert H. P. Fang[2], and Ding Zhou[1]

[1]Department of Environmental Engineering, Harbin Institute of Technology, Harbin 150001, P. R. China
[2]Department of Civil Engineering, The University of Hong Kong, Hong Kong

ABSTRACT

A two-stage process was developed for the treatment of landfill leachate in Hong Kong. The leachate contained 15700 mg/L of chemical oxygen demand (COD) and 2300 mg/L of ammonia-nitrogen (NH_3-N). In the first stage, it was treated in a UASB (upflow anaerobic sludge blanket) reactor at 37 °C. The process removed 89%-91% COD on average within a 6.6 days hydraulic retention period. The UASB effluent, containing 1500 mg/L COD, was then treated in the second stage using a Fenton coagulation process with H_2O_2 and excess Fe^{2+}. In this process, organic substances were oxidized and precipitated through the Fenton reaction and coagulation. 70% COD of the UASB effluent

* Corresponding author; e-mail: pwang73@yahoo.com

was further removed. The optimal parameters of the Fenton coagulation process were determined as an initial pH between 4 and 6, mixing for 5-10 min, a Fe^{2+} concentration of 300 mg/L, and a H_2O_2 concentration of 200 mg/L. The final effluent contained a 447 mg/L COD, which was acceptable sewer system level according to the present Hong Kong regulations.

INTRODUCTION

At present, about 9000 tons of municipal solid wastes were collected and disposed of daily at three landfill sites in Hong Kong. The leachate from the landfill sites contained both readily biodegradable and refractory organics. The existing leachate treatment used an activated sludge process with extended aeration, operating in sequencing batch mode. An HRT (hydraulic retention time) of 30 days was required for the degradation of organic pollutants (Chen, et al., 1997). Due to extremely high aeration and land costs, it was necessary to develop a more efficient treatment processes.

This study was conducted to develop a two-stage process for the effective treatment of Hong Kong landfill leachate. At first, organics in the raw leachate were degraded using an upflow anaerobic sludge blanket (UASB) process, and then the residual organics in the UASB effluent were further treated by Fenton coagulation. The UASB process has been successfully commercialized in the past decade for the treatment of various types of industrial wastewaters. The process was effective in degrading various organic chemicals, including fatty acids (Fang et al., 1995), starch (Fang and Kwong, 1995), refractory proteins (Fang et al., 1994) and aromatics (Li et al., 1995).

Advanced oxidation processes have proven to be an effective technology in treating the non-biodegradable organic pollutants. In advanced oxidation process, organic pollutants were oxidized by free radicals and oxygen, even mineralized completely to carbon dioxide and water. The hydroxyl radicals (·OH) generated were of particular interest in this context, on account of their high oxidation potential (E^0=2.80V). When H_2O_2 was added to wastewater containing ferrous ions, it reacted with organic compounds in a series of redox reactions. The reaction of H_2O_2 and ferrous ions to yield free radicals was commonly referred to as Fenton's process. When the molar ratio of Fe^{2+}/H_2O_2 increased, the excess Fe^{2+} would act as a coagulant. The simultaneous processes involved oxidation and coagulation which provided an effective means to remove the complex organic matter from the wastewater. In this study, the extent of organic removal from UASB effluent by Fenton coagulation process was quantified.

MATERIALS AND METHODS

UASB Process

The UASB reactor had a capacity of 2.8 L with a 84 mm internal diameter and was 250 mm high (Fang and Li, 1995). On top of the reactor was a gas-liquid-solid separator with an internal diameter of 114 mm and a height of 250 mm. The reactor was water-jacketed and was operated at a constant temperature of 37°C for 150 days. In this study, the UASB reactor was seeded with one litre each of UASB sludge (26.7 g/L) and deposit sludge (10.8 g/L), which were obtained separately from a previous UASB reactor and from an oxidation pond in a landfill site. A peristaltic pump (Cole-Parmer, Masterflex) was used to feed raw leachate into the reactor system, forcing an equal volume of supernatant to come out as effluent.

Fenton Coagulation

An aqueous H_2O_2 stock solution (40 g H_2O_2/L) was prepared by diluting a 30% H_2O_2 solution (Merck Chemical Co.). A ferrous solution (20 g Fe^{2+}/L) was prepared by dissolving $FeSO_4.7H_2O$ (Aldrich Chemical Co.) in 0.1 mol/L H_2SO_4. In conducting the Fenton coagulation process, the pH of the UASB effluent was first adjusted. Then the Fe^{2+} and H_2O_2 solutions were mixed, followed by 30 seconds of rapid mixing. The sample was then immediately put on a Jar Tester (Phipps and Bird, model PB-700). Stirring speed was fixed at 80 rpm. After 10 minutes of coagulation, the sample was transferred into an Imhoff cone for settling. The supernatant and settled sludge were sampled for analysis after 30 minutes.

Analysis

The measurements of COD (chemical oxygen demand), BOD_5 (5-day biochemical oxygen demand), NH_3-N and volatile suspended solids (VSS) followed the procedures of the Standard Methods (APHA, 1985). Since residual H_2O_2 would interfere with the COD measurement, the total organic carbon (TOC) content was determined by the combustion-infrared method using a TOC analyzer (Shimadzu, TOC-5000A).

RESULTS AND DISCUSSION

UASB Performance

Raw leachate was continuously treated using the UASB reactor for 150 days. Steady state was reached after 120 days of operation. Between days 120-150, raw leachate containing 15700 mg COD/L and 2300 mg NH_3-N/L was feed in as a substrate. The COD removal efficiency was maintained at 89%-91%

at an organic loading rate of 2.37 g COD/L-day and HRT of 6.6 days, which was much shorter than the minimum HRT of 30 days required by the current aerobic treatment method used at the landfill site in Hong Kong. The UASB effluent containing 1500 mg COD/L was collected for the subsequent experiments. The composition of raw leachate and UASB effluent was summarized in Table 1.

Fenton Coagulation

A series of experiments were conducted in parallel to determine the effect of pH at 300 mg/L Fe^{2+} and 200 mg/L H_2O_2. Results in Figure 1 showed that the optimal initial pH for the Fenton coagulation of the UASB effluent was a pH between 4 and 6, at which about 60% of TOC was removed. At pH < 4, it was found that flocculation of colloidal matter was severely suppressed, resulting in the deterioration of organic matter removal. Based upon the results in Figure 1, an initial pH of 6 was chosen for all the subsequent experiments.

The effect of the Fe^{2+} dosage was investigated on the removal of organic residues in the UASB effluent. The initial H_2O_2 concentration and pH were kept at 200 mg/L and 6 separately. Figure 2 illustrates the experimental results. Obviously, without the addition of Fe^{2+}, H_2O_2 oxidized only 24% of the organics. The TOC removal efficiency was enhanced with the addition of Fe^{2+}, and leveled off at 60% when the Fe^{2+} dosage was 300 mg/L. The dosage of Fe^{2+} was fixed at 300 mg/l for the subsequent experiments.

The effect of the H_2O_2 dosage on the removal of organic pollutants is illustrated in Figure 3. It shows that the TOC removal efficiency increased as the H_2O_2 dosage was increased, and leveled off at 66% when the H_2O_2 dosage was 200 mg/L. Further increases of the H_2O_2 dosage did little to enhance the TOC removal efficiency. On the contrary, 800 mg/L or more resulted in sludge flotation, probably due to the release of O_2 from the H_2O_2 decomposition.

TABLE 1
Characteristics of Raw Leachate and UASB Effluent

	Raw leachate	UASB effluent
pH	7.7±0.3	8.5±0.2
COD (mg/L)	15700±1700	1500±160
BOD_5 (mg/L)	4200±230	75±20
TOC (mg/L)	4600±150	470±140
NH_3-N (mg/L)	2260±230	2540±250

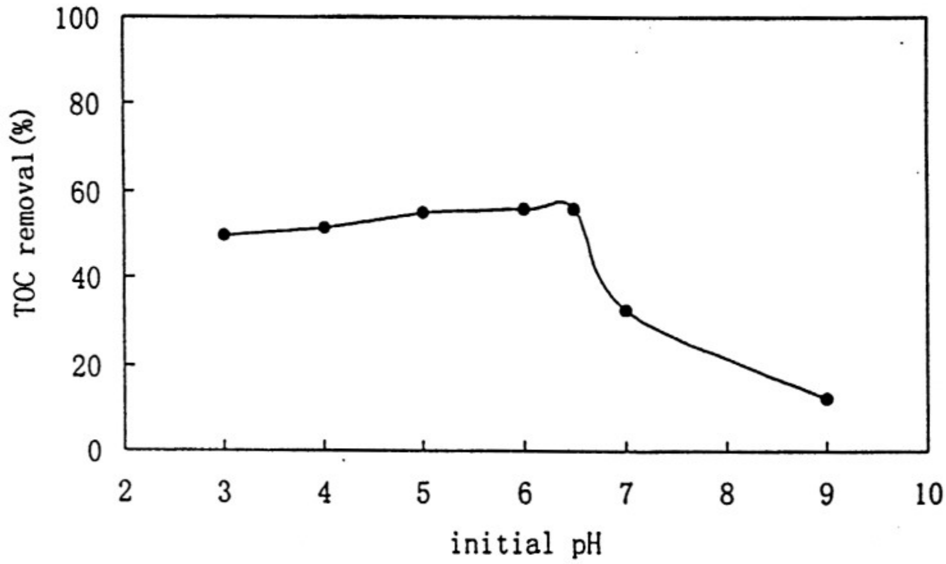

FIGURE 1
Effect of initial pH on TOC removal from UASB effluent.

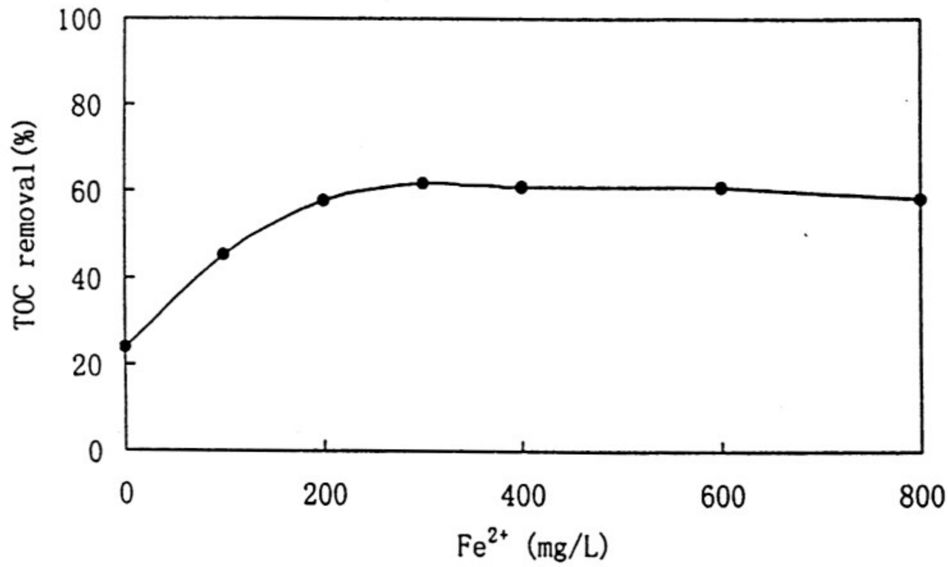

FIGURE 2
Effect of Fe^{2+} dosage on TOC removal from UASB effluent.

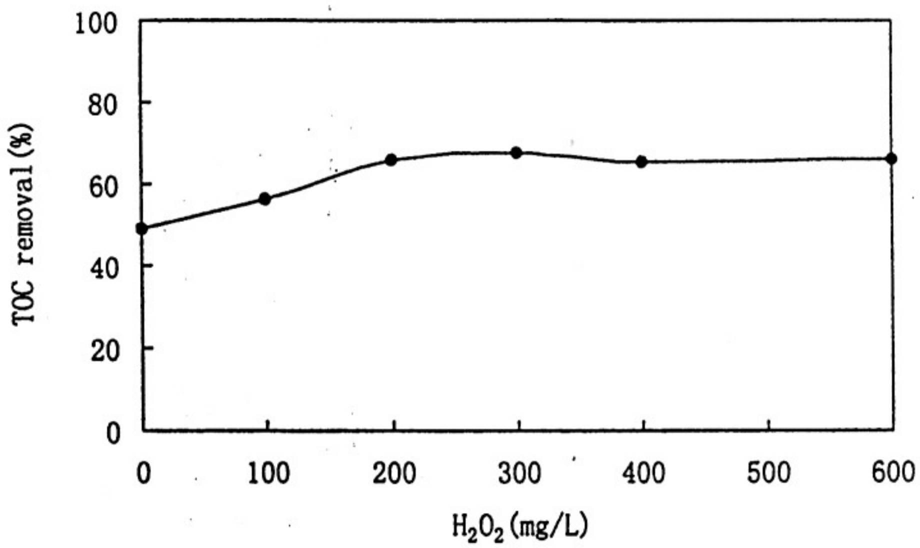

FIGURE 3
Effect of H_2O_2 dosage on TOC removal from UASB effluent.

Fenton Reagent Consumption and COD Removal

Based on the above results, the optimal dosages for the organic removal of UASB effluent at an initial pH of 6 were identified as 300 mg/l Fe^{2+} and 200 mg/l of H_2O_2. Then four experiments were conducted to verify the optimal dosages. The final effluent contained 447 mg/l of COD, with a removal efficiency of 70%.

It should be noticed that most of the COD removed by the Fenton coagulation process was still in the settled sludge phase. Only 13.7%, i.e. 200 mg/l of COD, was oxidized. 200 mg/l of H_2O_2 only provided 83.3 mg/l of O_2 when fully utilized, which was less than half of the amount needed to remove 200 mg/l of COD.

CONCLUSION

The UASB process was able to remove 90.4% COD on average in the Hong Kong landfill leachate at 37°C, with 6.6 days HRT and a loading rate of

2.37 g-COD/L-day. Then 70% COD left in the UASB effluent was removed by Fenton coagulation. The optimal parameters of the Fenton coagulation process were identified as Fe^{2+} 300 mg/L, H_2O_2 200mg/L, an initial pH between 4-6, and a mixing time between 5-10 min. Removing one gram COD required 0.28 g Fe^{2+} and 0.18 g H_2O_2. The average COD in the final effluent was 447 mg/L.

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