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Influence of landfill structures on stabilization of fully recycled leachate①

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Abstract: The experiment was conducted to treat the leachate from two simulating columns by recycling to the columns themselves without being discharged into the enviroment. The columns were employed to simulate anaerobic and semi-aerobic landfills separately. The influence of landfill structure on stabilization of fully recycled leachate was studied. The results show that semi-aerobic landfill structure accelerates the stabilization of leachate recycled. The full recycle of leachate in semi-aerobic landfill is a very feasible and effective technology for leachate treatment with low cost and energy saving especially in arid and rare rainfall regions. Meanwhile, the environmental impact of landfill can be greatly minimized.

Key words: landfill structure; full recycle; stabilization of leachate; environmental impact
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1 INTRODUCTION

With rapid development of urbanization and population growth, solid waste disposal has become extremely important to improve the urban environment[1]. Nowadays, sanitary landfill is the most popularly adopted to dispose municipal solid waste. However, there exist some problems, such as large area of land occupied, pollution from the leachate and landfill gas, of which the leachate is one of the main reasons for the environmental pollution of the landfill[2]. Due to being complex and variable in quantity and quality, the leachate treatment by traditional biological or physic-chemical methods either cannot satisfy the discharge requirement by the norm or needs a high operation cost[3], and at present its treatment is still a worldwide unsolved problem[4]. Today, increasing attention is paid to landfill leachate recirculation in leachate treatment and landfill stabilization[5]. Leachate recirculation has been shown in lysimeter, pilot-scale and full-scale investigations to reduce the time required for waste stabilization, improve leachate quality, provide the opportunity for leachate volume reduction, and to enhance the rate of gas production[6]. In this study, in order to research the impact of landfill structures on fully recycled leachate degradation, two landfill-simulating columns, one with anaerobic structure and the other with semi-aerobic structure were constructed and placed at a constant temperature of 15 ℃. A feasible and effective technology for leachate treatment with low cost and energy saving was developed.

2 MATERIALS AND METHODS

2.1 Structure of simulating columns

The simulation setting consisting of 2 PVC columns with external diameter of 400 mm and height of 1 600 mm is shown in Fig. 1, where valves 1, 2 and 4 bores on the top of the anaerobic column were all closed and valves 1 and 4 bores on the top of the semi-aerobic column were fully open with valve 2 half open. The other structures were the same for both columns. To avoid the influence of external conditions such as environmental temperature, etc, the experiment was carried out without simulating rainfall.

2.2 Solid waste filling

Both columns were filled with a municipal solid waste mixture representing the typical solid waste composition in Shapingba district, Chongqing City. The solid waste for experiment was taken from Yanggongqiao and Chenjiawan Garbage Transfer Stations in Shapingba District, Chongqing City and crushed into pieces with size less than 50 mm after removing the foreign substance such as fibers, rubber and plastics, brick and stone, metal pieces, glass, etc. In order to increase the inorganic ingredient and air-permeability of the waste and accelerate its degradation, stone grains and coal ash were added into both columns,

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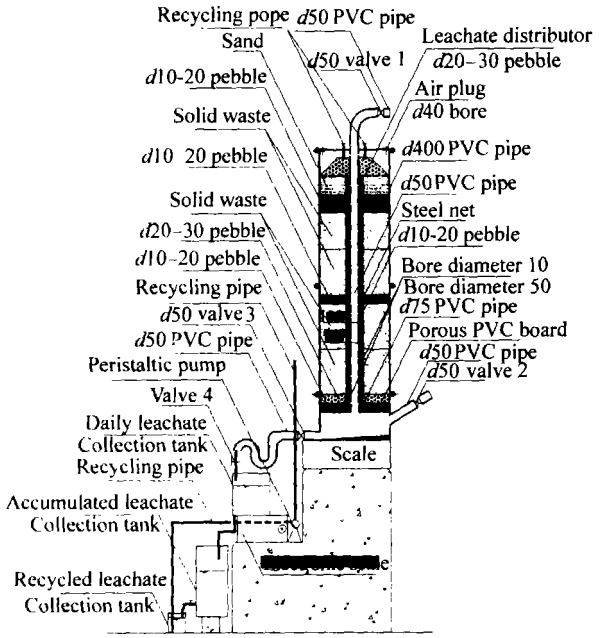

Fig. 1 Structure of simulating column (mm)

and 7.3 kg and 3.0 kg anaerobic active sludge was added into anaerobic column and anaerobic zone of semi-aerobic column respectively, and 4.3 kg aerobic active sludge was added into the aerobic zone of semi-aerobic column. Above mentioned additives were mixed with waste homogeneously and fed into the column in four layers with being weighed, filled and compacted. The compositions of the solid waste sample for experiment are given in Table 1. And the characteristics of solid waste sample are as follows: density, 731.3 kg/m^3; mass of filling, 68.9 kg; water content, 59.8%; anaerobic column BDM, 274.6; semi-aerobic column BDM, 236.6.

Table 1 Composition of solid waste sample (mass fraction, %)

Kitchen refuse	Tree leaves	Paper and plastics	Metal pieces	Stone grains	Coal ash
21.3	47.7	1.2	1.8	0.1	27.9

2.3 Experiment method

During the experiment, before the first refilling of leachate in the morning each day, the volume and mass of the leachate from the daily leachate collection tank of each column were measured; then, the leachate was poured into accumulated leachate collection tank where all the leachate produced from the column was stored and mixed homogeneously with the former one, after 600 mL was taken for refilling (hydraulic load 15.9 L/(m^2·d), if the volume of leachate was inadequate, the tap water was added). The accumulated leachate was refilled to the columns three times a day, namely at the time of 6∶00, 13∶00 and 18∶00. Once a week, the accumulated leachate was taken to analyse COD_{cr}, BOD_5 and NH_3-N to study the treatment effect of the two different columns. The indexes, experiment methods and instrument are shown in Table 2.

Table 2 Testing indexes and methods

Index	Method	Instrument
COD_{cr}	Potassium bichromate colorimetry	HAC, 2010 spectrophotometer
BOD_5	Dilution inoculation	
NH_3-N	Ammonium-Nesster's reagent colorimetry	721 spectrophotometer

3 RESULTS AND DISCUSSION

3.1 Daily output of leachate

For both simulating columns, the leachate was generated at the day of solid waste being filled. Necessary regulations were made so that the columns had the same experiment condition and the leachate refilling started at the 8th day. The variation of volume of leachate generated daily from each column is shown in Fig. 2, which was obtained after 82 d of the experiment. It can be seen from Fig. 2 that under the same condition of operation and external environment, the volume of daily leachate from anaerobic column is much greater than that from semi-aerobic column. The maximum daily leachate output of the anaerobic and semi-aerobic columns is 2.91 L and 1.18 L, and the minimum is 269 mL and 0 mL, respectively; the former trends to be increased and the later to be decreased. The leachate of landfill derives itself from precipitation, degradation of solid waste and original water content in solid waste[7]. In this case, the major causes of the above experimental results are that the solid waste degrades thoroughly and rapidly in semi-aerobic landfill with improving the structure for natural air penetration without oxygen supply by power, especially around and inside the collection pipe and most of the organic substance being transferred into gas.

3.2 Concentration of NH_3-N

The changes of NH_3-N concentration of full recycled leachate from anaerobic and semi-aerobic simulating columns are shown in Fig. 3.

It can be seen from Fig. 3 that the NH_3-N concentration of leachate from both simulating columns increases rapidly after leachate is refilled and the concentration in anaerobic column is much higher than that in semi-aerobic column, this is

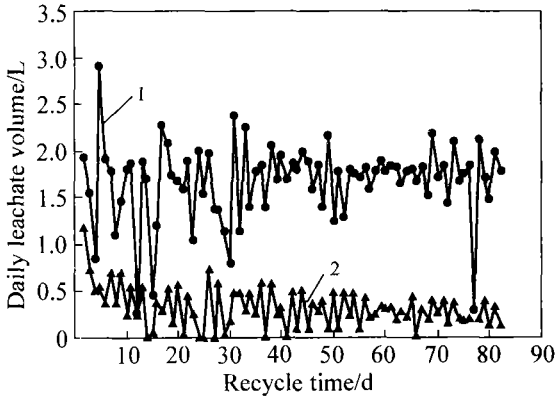

Fig. 2 Daily change in leachate volume
1 —Anaerobic colum; 2 —Semi-aerobic colum

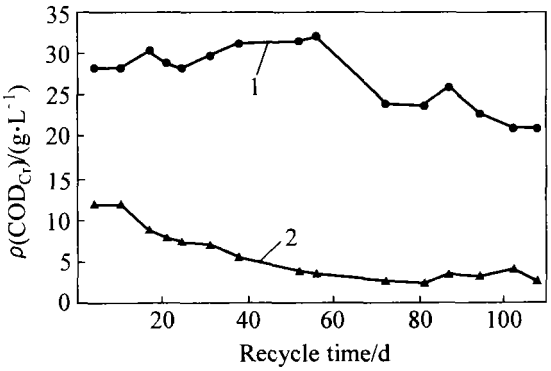

Fig. 4 Weekly change in COD_{cr} concentration in accumulated leachate from two simulating columns
1 —Anaerobic column; 2 —Semi-aerobic column

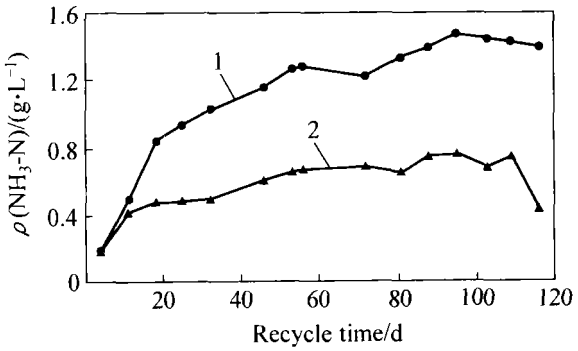

Fig. 3 Weekly change in NH_3-N concentration in accumulated leachate from two simulating columns
1 —Anaerobic column; 2 —Semi-aerobic column

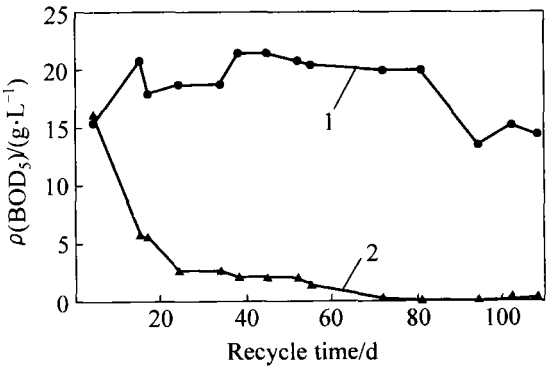

Fig. 5 Weekly change in BOD_5 concentration in accumulated leachate from two simulating columns
1 —Anaerobic column; 2 —Semi-aerobic column

because there are aerobic, anoxic and anaerobic zones in semi-aerobic column to create condition for amination, nitrification and denitrification of ammonia and nitrogen in leachate. However, only anaerobic zone exists in the anaerobic column. The ammonia and nitrogen are dissolved continuously, leading to the increase of ammonia and nitrogen in leachate to great extent.

3.3 Concentration of COD_{cr} and BOD_5

There is a large difference in quality of leachate from simulating columns with different landfill structures. The changes in COD_{cr} and BOD_5 concentration in two kinds of accumulated leachates are shown in Figs. 4 and 5.

From Figs. 4 and 5, It can be seen that COD_{cr} and BOD_5 concentrations of each column have the same trend of variation, that is, COD_{cr} and BOD_5 concentrations of semi-aerobic column drop quickly at the initial stage of leachate being refilled and down to 2.730 g/L and 0.121 4 g/L respectively at 108th day. As for anaerobic column, they increase slowly and COD_{cr} drops only at the 56th day but still maintains over 21 g/L and BOD_5 drops only at the 81th day but still maintains over 13 g/L. This is because the organic substance with large molecules in semi-aerobic column is decomposed into organic substance with small molecules under the action of exo-enzymes generated from microbes, then it is further oxidized and decomposed by aerobic microbes and enters into tricarboxylic acid (TCA) circulation through different ways and is decomposed finally into CO_2, H_2O, nitrate and sulfate, and results in the COD_{cr} and BOD_5 dropping quickly[8]. In anaerobic column, there is mainly the anaerobic degradation of organic substance. The organic solid waste is decomposed into soluble organic substance with small molecules under the action of exo-enzymes generated from anaerobic microbes and enters into leachate, leading to the increase of COD_{cr} and BOD_5[9,10]. In addition, there is large accumulation of ammonia in anaerobic column, the high concentration of ammonia and nitrogen inhibits the activity of microbe in solid

waste, consequently inhibits the degradation of COD_{cr} and BOD_5 in leachate.

4 CONCLUSIONS

1) Landfills with its leachate being recycled to itself may be operated as municipal solid waste bioreactor treatment system rather than as a conventional waste dumping sites. The technology of semi-aerobic landfill has the advantage of decomposing the organic substance thoroughly and transferring most of them into gas with energy saving and without forced ventilation. So the adoption of semi-aerobic landfill structure can reduce the volume of leachate to great extent and accelerate the stabilization of full recycled leachate, not only reducing the difficulty and the expenses of leachate treatment, but also reducing the CH_4 and H_2S output. All of these effectively diminish the environmental pollution caused by solid waste landfill.

2) The semi-aerobic landfill structure provides beneficial conditions for degradation of solid waste, by which solid waste can be stable quickly and results in saving the cost for management and environment monitoring of landfill site caused by long duration of its stabilization. So the environmental impact of landfill is greatly minimized.

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