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Nitrogen removal in the bioreactor landfill system with intermittent aeration at the top of landfilled waste

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Abstract

High ammonia concentration of recycled landfill leachate makes it very difficult to treat. In this work, a vertical aerobic/anoxic/anaerobic lab-scale bioreactor landfill system, which was constructed by intermittent aeration at the top of landfilled waste, as a bioreactor for in situ nitrogen removal was investigated during waste stabilization. Intermittent aeration at the top of landfilled waste might stimulate the growth of nitrifying bacteria and denitrifying bacteria in the top and middle layers of waste. The nitrifying bacteria population for the landfill bioreactor with intermittent aeration system reached between10^6 and 10^8 cells/dry g waste, although it decreased 2 orders of magnitude on day 30, due to the inhibitory effect of the acid environment and high organic matter in the landfilled waste. The denitrifying bacteria population increased by between 4 and 13 orders of magnitude compared with conventional anaerobic landfilled waste layers. Leachate NO_3^-–N concentration was very low in both two experimental landfill reactors. After 105 days operation, leachate NH_4^+–N and TN concentrations for the landfill reactor with intermittent aeration system dropped to 186 and 289 mg/l, respectively, while they were still kept above 1000 mg/l for the landfill reactor without intermittent aerobic system. In addition, there is an increase in the rate of waste stabilization as well as an increase of 12% in the total waste settlement for the landfill reactor with intermittent aeration system.

Keywords: Bioreactor landfill; Biological nitrogen removal; Intermittent aeration; Nitrifying bacteria; Denitrifying bacteria

1. Introduction

Recycled landfill leachate is often characterized by its high ammonia concentration, which is even higher than during conventional single pass leaching [1]. In addition, the C/N ratio is lower in stabilized leachate, thereby causing serious challenges to treatment systems [2]. There are many different landfill leachate treatment options, include complex and expensive events of ex situ physical–chemical and biological processes for the treatment of high strength ammonia. Of these, biological treatment is the most common method for ammonia removal in leachate, due to the lower cost [3,4].

Conventional systems for the biological treatment of ammonia-rich wastewater involve both nitrification and denitrification. In the nitrification step, NH_4^+ is firstly oxidized to nitrite by bacteria such as *Nitrosomonas*, and then the nitrite produced is oxidized to nitrate by microoganisms such as *Nitrobacter*. There is a need of a great of oxygen during the nitrification process. When the degradable organic carbon level is high in the environment, heterotrophic microorganisms would outcompete nitrifiers for oxygen and nutrients. However, the most denitrifying bacteria exist in the environment in which organic compounds are presents, and use organic matter as carbon resources and electron donors. Denitrification is inhibited by the presence of oxygen, and limited to anoxic environments. Therefore, ex situ treatment of ammonia commonly need spatial separation of nitrifying and denitrifying units, or temporal separation of each step by alternating aeration and no aeration in the same unit. Furthermore, for the high ammonia/low carbon leachate, the method of biological nitrogen removal usually needs air-stripping pretreatment and external carbon sources such as methanol to adjust C/N ratio [5,6]. This not only increases importantly in costs, but also enhances the difficulty of management.

The landfill environment is a complex heterogeneous system in which different types of microorganisms coexist. The predominant microorganisms vary with the prevailing conditions

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and the organisms-substrate specificity during waste stabilization [7]. Normally, the conditions prevalent in a landfill body are anaerobic/anoxic thus enabling methanogenesis and, potentially, denitrification. The feasibility of waste materials, such as crushed brick, bulking agent of compost, as filter media for nitrification and denitrification in an anoxic/anaerobic column filled with landfilled waste has been shown in laboratory and on-site pilot [4]. Onay and Pohland [8] utilized compost as the waste matrix, and adopted the air inlet at the bottom of the reactor to develop a three-component simulated landfill system, including anoxic, anaerobic and aerobic zones, for in situ attenuation of high residual leachate ammonia nitrogen concentrations. Since oxygen penetrates in the interstices of landfilled waste, vertical aerobic/anoxic/anerobic biological zones are formed naturally in landfill ecosystems. Many wastewater treatment facilities, such as rotating biological contactors, oxidation ditchs and sequencing batch reactors, indicate the aerobic/anoxic/anaerobic treatment processes reduce ammonia concentration [9,10]. In the last few years, some new processes and operational strategies by limiting the oxygen supply for a nitrification reactor, such as SHARON and OLAND, have arisen to reduce operational costs of the biological nitrogen removal process in wastewater. However, few studies have reported on landfilled waste bed for nitrogen removal during waste stabilization.

In a typical landfill, waste stabilization progresses through the initial adjustment phase, transition phase, acid formation phase, methane fermentation and maturation phase. The rate and characteristics of leachate produced from a landfill vary from one phase to another, and reflect the microbially mediated processes taking place inside the landfill. The initial adjustment phase is associated with initial placement of solid waste and accumulation of moisture within landfills. In the transition phase, field capacity is exceeded and leachate is generated. Measurable concentrations of chemical oxygen demand (COD) and intermediates such as volatile fatty acids (VFA) appear and increase in leachate. With the continuous hydrolysis and fermentation of waste, a decrease in pH occurs with VFA becoming dominant in leachate during the acid formation phase. In the methane fermentation phase, leachate organic strength is decreased dramatically with intermediate acids consumed by methane-forming consortia (methanogenic bacteria) and converted into methane and carbon dioxide. And leachate pH is elevated to the level of biocarbonate buffering system. During the final maturation phase, leachate remains constant at low concentrations [11]. Pohland and Al-Yousfi [12] reported that leachate recycle led to the accumulation of fermentation products, consisting primarily of volatile organic acids and alcohols, in the first phases of waste decomposition. As a result, bacterial activity was inhibited. When applying in situ nitrogen removal, leachate COD and ammonia concentrations and their changes need to be taken into account, especially in landfills containing leachate with varying characteristics and age [4].

Leachate with high concentrations of volatile organic acids from new landfill cells can be treated in a separate anaerobic reactor that has established methanogenic microflora [13]. In addition, circulating leachate between a landfill cell and an anaerobic reactor (mature landfill cell) takes advantage of high alkalinity of effluent in the anaerobic reactor to buffer low pH in landfilled waste [14,15].

The objective of this research was to evaluate the performance of nitrogen removal in an vertical aerobic/anoxic/anaerobic lab-scale bioreactor landfill system, which was constructed by intermittent aeration at the top of landfilled waste, and an upflow anaerobic sludge blanket (UASB) reactor was introducted into leachate recirculation to elimiate the inhibitory effect of high organic matter in leachate on bacteria activity, especially in nitrification. The nitrifying bacteria, denitrifying bacateria and chemical changes were characterized in the bioreactor landfill system during waste stabilization as well as in the bioreactor landfill system without intermittent aeration system.

2. Materials and methods

2.1. Municpal solid waste (MSW) composition

MSW was synthesized by mixing 10 different components shredded into 2–4 cm pieces in the experiment. The physical composition of the synthetic MSW mixture, according to the investigation made in the city of Ningbo, was as follows (by weight): vegetables, 45.95%; fish, 2.55%; meat, 1.02%; fruit, 8.12%; cooked rice, 1.02%; paper, 7.66%; plastics and leather rubber, 12.18%; cellulose textile, 3.68%; brick sand and soil, 8.63%; metals and glasses, 6.38%; wood, 2.81%. The readily and moderately decomposable organic waste constituents (RMDOWC), i.e. vegetables, fish, meat, fruit and cooked rice, accounted for 58.66%. Total nitrogen (TN) was 4.338 ± 0.763 mg/dry g RMDOWC. The moisture content of the mixture was about 56% (w/w).

2.2. Experimental set-up

The experimental set-up used in this research is illustrated in Fig. 1. The simulated landfill reactor consisted of a 42-l cylinder made of PVC (28.7 cm i.d., 65 cm height). A polyethylene male adapter (about 0.8 cm) was installed at the bottom of each landfill reactor as a leachate drainage port. Two such adapters were installed in the lid of each landfill reactor for leachate recirculation and gas collection. Adapters were held in place with wax to provide a gas-tight system. The anaerobic reactor was operated in an UASB reactor made of PVC (10 cm i.d., 80 cm height) with working volume of 5.50 l. Collection tanks with

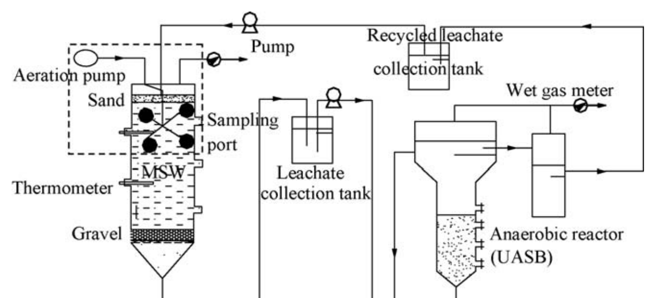

Fig. 1. Schematic diagram of the bioreactor landfill systems in the experiment.

total volume of about 3 l were attached to landfill and anaerobic reactors for collections of leachate and recycled leachate.

2.3. Experimental design and operation

Two bioreactor landfill systems, R1 and R2, were used in the experiment. Both systems used were identical except that system R1 contained intermittent aeration at the top of landfilled waste by an aeration pump. The schematic diagram of the experimental bioreactor landfill systems is illustrated in Fig. 1, of which the broken line part denotes the intermittent aeration system.

The anaerobic reactors were seeded with raw sludge procured from the Hangzhou citric acid factory and Hangzhou Shibao sewage treatment plant. The volume of sludge inoculum was 82% v/v in each anaerobic reactor. The sludge was incubated with the synthetic wastewater with a chemical oxygen demand (COD) of 3000 mg/l for 10 days to activate the sludge activity. The synthetic wastewater contained (g/l): saccharose, 2.75; NH_4Cl, 0.03; KH_2PO_4, 0.73; $KHPO_4$, 0.25; $NaHCO_3$, 3.30. Then it was acclimated by leachate with COD concentration of 1743–2436 mg/l and NH_4^+–N concentration of 242–359 mg/l from Hangzhou Tianzhiling landfill. The start-up of anaerobic reactors was accomplished when the COD removal efficiency reached stability at above 70% under organic loading rate (OLR) of about 1.0 kg COD/m^3 d and hydraulic retention time of 2.2 d. The acclimated sludge in anaerobic reactors R1 and R2 contained total solids (TS) content of 90.8 g/l and 96.5 g/l and volatile solids (VS) content of 33.0 g/l and 34.5 g/l, respectively.

Prior to filling, a 5 cm thickness of gravel was placed at the bottom of each landfill reactor to retain refuse and stop small particles from leaching out. Then about 23.4 kg synthetic MSW mixture, which was added with deionized water to 75% moisture content, was filled into each landfill reactor and a specific height of 50 cm was attained. Finally, the waste mixture was covered with a 5 cm depth of sand. On the basis of the above filling, air injection pipes were laid on the landfilled waste at a specific height of 40 cm in landfill reactor R1. An aeration pump was run at a flow rate approximately of 0.5 l/min between hours 8 and 10 and between hours 19 and 21 every day, to provide oxygen to waste mass. Leachate was collected and stored in leachate collection tank. After treated in the anaerobic reactor, the effluent, namely recycled lechate, was collected and stored in recycled leachate collection tank. Leachate was continuously circulated between the landfill and anaerobic reactors by using pumps with adjusted flow rates varying with leachate volume, except for the first two days when no recycled lechate was fed to the landfill reactor. The recycled leachate volume, i.e. the effluent volume, nearly amounted to the influent leachate volume every day. The simulated landfill reactors were operated at room temperature and the anaerobic reactors were carried out in a temperature-controlled room at 30 ± 1 °C.

2.4. Microbial enumeration

Approximately 50 g of the MSW mixture was withdrawn periodically from three sampling ports of each landfill reactor. After mixed by hand manipulation, 25 g of the MSW sample was used to form an inoculum for microbial enumeration. Experiments were performed to develop and validate the inoculum as reported previously [16]. The remaining MSW sample was used to monitor for moisture content.

Nitrifying bacteria and denitrifying bacteria in the MSW sample were enumerated by the most probable number (MPN) technique with three tubes per dilution. The culture medium for nitrifying bacteria contained (g/l): $(NH_4)_2SO_4$, 2.0; $FeSO_4$, 0.2; K_2HPO_4, 1.0; $MgSO_4$, 0.5; NaCl, 2.0; $CaCO_3$, 5.0; pH, 7.0–7.2. The culture medium for denitrifying bacteria contained (g/l): $KNaC_4H_4O_6\cdot 4H_2O$, 20; KNO_3, 2.0; K_2HPO_4, 0.5; $MgSO_4\cdot 7H_2O$, 0.2; pH, 7.2. All MPN tubes were incubated at 30 °C and checked for denitrifying bacteria growth after 14 days and nitrifying bacteria growth after 28 days. MPN analyses for nitrifying bacteria and denitrifying bacteria were based on product formation [17]. MPN values were calculated from standard MPN tables.

2.5. Analytical methods

Leachate and recycled leachate samples were taken from collection tanks weekly, and analyzed for COD, VFA, TN, NH_4^+–N, NO_3^-–N and pH. COD, TN, NH_4^+–N, NO_3^-–N and pH in leachate were determined by conventional methods [18]. VFA was analyzed by acidified ethylene glycol colorimetric method [19]. Dry weight of waste and moisture content were measured by drying the sample in an oven at 105 °C. VS was measured by ashing the dried waste in a furnace at 550 °C.

3. Results and discussions

3.1. Characteristics of recycled leachate and leachate in landfill reactors

After treated in anaerobic reactors, COD concentrations and pH values in recycled leachate were relatively steady during waste stabilization (Fig. 2). There was no significant difference in the COD concentrations and pH values in recycled leachate for both two landfill reactors, except that a sharp increase in the COD concentrations were observed in landfill reactor R2 between days 28 and 35, due to a high OLR for the anaerobic reactor (data not shown).

The leachate COD and VFA concentrations for landfill reactor R1 varied more gently than for landfill reactor R2 (Fig. 3). With the degradation of landfilled waste, leachate COD and VFA concentrations for landfill reactor R1 reached the maximum value of 28.5 and 8.3 g/l on day 14, when leachate pH dropped from 6.6 to 5.6. This demonstrated that waste stabilization progressed the acid formation phase, which was characterized by the accumulation of acidic fermentation intermediates and a decrease in pH [7], for landfill reactor R1 on day 14. Similar trends were also observed in landfill reactor R2 on day 28, which was 14 days later compared with landfill reactor R1. This suggested that interimment aeration might accelerate waste stabilization. The leachate pH value of above 6.5 was achieved in landfill reactor R1 on day 35, while it was attained in landfill reactor R2 on day 49. Along with the increase in pH value, a

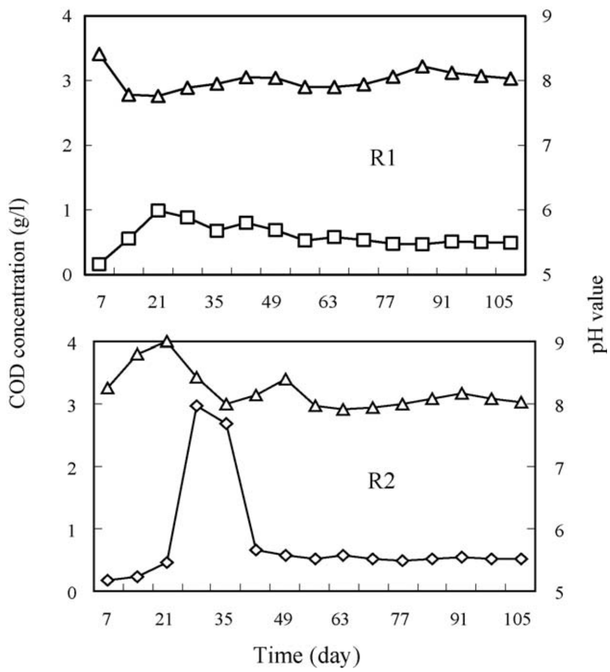

Fig. 2. COD concentrations and pH values in recycled leachate. COD (◊); pH (△).

more gradual decrease in leachate COD and VFA concentrations for landfill reactor R1 was indicative of more active conversion of organics in leachate to carbon dioxide and methane by intermittent aeration at the top of landfilled waste.

Leachate volume increased sharply with waste decomposition in the first 56 days, and then kept 2200 ml/d or so till the end of the experiment (Fig. 4). As compared with landfill reactor R2, there was more leahcate volume in landfill reactor R1 prior

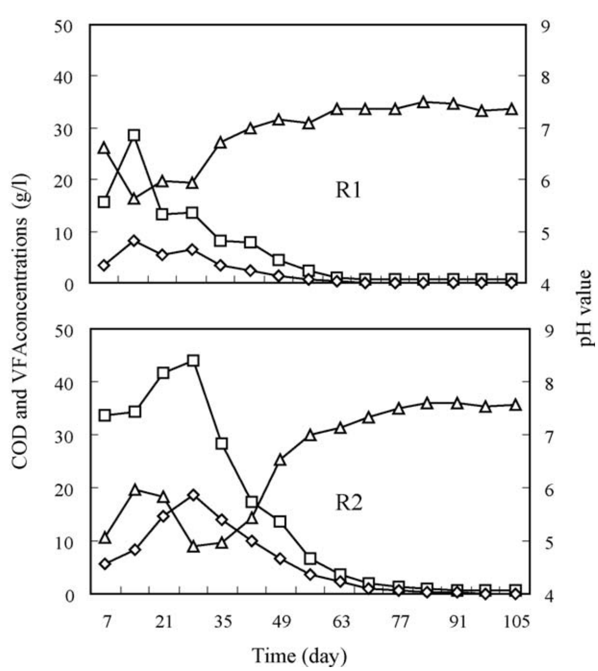

Fig. 3. Variation of COD, VFA concentrations and pH values in leachate during waste decomposition. COD (□); VFA (◊); pH (△).

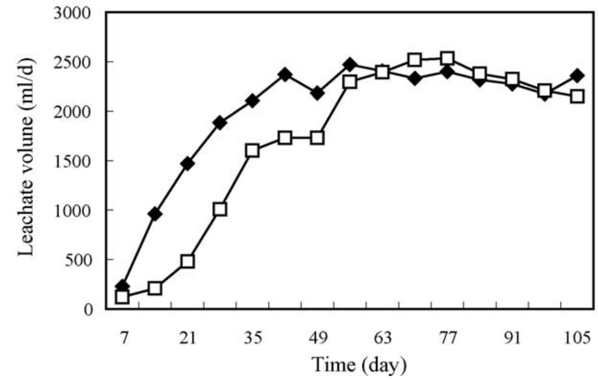

Fig. 4. Variation of leachate volume during waste decomposition. Landfill reactor R1 (⧫); Landfill reactor R2 (□).

to day 56. This showed that a rapid biodegradation occurred in the landfill reactor R1 with interimmtent aeration system.

3.2. Distribution of nitrifying bacteria and denitrifying bacteria in landfill reactors

MPN results for the nitrifying bacteria population in landfill reactors are shown in Fig. 5. Nitrifying bacteria were not detected in the simulated MSW mixture. After landfilled, nitrifying bacteria were presented in landfilled waste layers. This might be attributed to the oxygen entrained in refuse at burial, which had allowed the growth of aerobic bacteria during the early stage of refuse decomposition [20]. With the depletion of oxygen present initially (anaerobic condition prevailing in refuse ecosystem), the growth of aerobic microorganisms would be inhibited. As a result, a decrease in the nitrifying bacteria population was observed on day 30, and thereafter it was a near depletion of the nitrifying bacteria for landfill bioreactor R2. The nitrifying bacteria population in landfill bioreactor R1 was high, and reached 10^6 cells/dry g waste on day 15, which exceeded that in landfill bioreactor R2 by 3 orders of magnitude. However, after 30 days, the nitrifying bacteria population

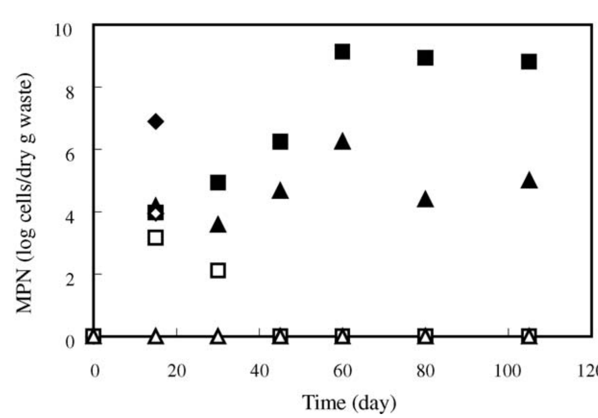

Fig. 5. Variation of nitrifying bacteria population during waste decomposition. The points (MPN = 0) showed where no nitrifying bacteria were detected. After 30 days operation, there are not samples from top layers due to the landfilled waste in top layers subsiding to middle layers. Top layer of R1 (⧫); middle layer of R1 (■); bottom layer of R1 (▲); top layer of R2 (◊); middle layer of R2 (□); bottom layer of R2 (△).

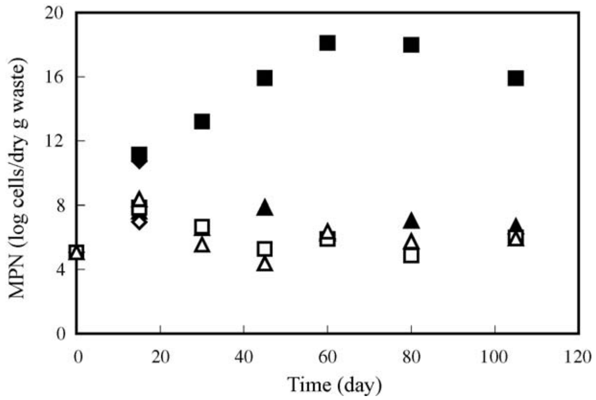

Fig. 6. Variation of denitrifying bacteria population during waste decomposition. After 30 days operation, there are not samples from top layers due to the landfilled waste in top layers subsiding to middle layers. Top layer of R1 (♦); middle layer of R1 (■); bottom layer of R1 (▲); top layer of R2 (◇); middle layer of R2 (□); bottom layer of R2 (△).

decreased 2 orders of magnitude in the top layer, i.e. the middle layer, owing to the landfilled waste in the top layer subsiding to the middle layer with waste decompostion. The reason for this decrease was the inhibitory effect of the acid environment and high organic mass effluent from the landfilled waste. The half saturation constants for nitrification may alter with changing pH, with apparent values decreasing at lower pHs, because that the pH optimum for mono-oxygenase, which catalyses the oxidation of ammonia to nitrite, is 7 [21]. The recovery of the nitrifying bacteria population was observed on day 45, when the pH increased from 5.9 to 7.2, and the COD and VFA concentration decreased from 13.7 g/l and 6.7 g/l to 4.34 g/l and 1.27 g/l, respectively. Most notably, the nitrifying bacteria population increased to10^8 cells/dry g waste in the maturation phase of waste decomposition.

The denitrifying bacteria were presented in the simulated MSW mixture (Fig. 6). The denitrifying bacteria population for landfill bioreactor R2 increased 2 and 1 orders of magnitude after waste landfilled. This was also observed in the conventional landfilled waste layers [22]. Intermittent aeration at the top of landfilled waste might stimulate the growth of denitrifying bacteria. As compared with landfill bioreactor R2, the denitrifying bacteria population in landfill reactor R1 increased by between 4 and 13 orders of magnitude in landfilled waste layers.

As seen from the MPN results in Figs. 5 and 6, the nitrifying bacteria and denitrifying bacteria in landfill bioreactor R1 distributed mainly in the top or middle layers. A potential explanation was that intermittent aeration boosted oxygen diffusion in the landfilled waste. As compared with the bottom layer, there was relatively much oxygen in the top layer, i.e. the middle layer, due to waste settlement after 30 days operation. Thus, there was also a high nitrate content in the top or middle layer, owing to nitrifying bacteria mustering mainly in these layers. Nitrate was the main factor in well decomposed refuse served as an electron donor for denitrification [23]. In addition, the landfill environment is a complex heterogenous system in which aerobic and anoxic conditions coexist in the top or middle layer, in despite of intermittent aeration at the top of landfilled waste. So, a high

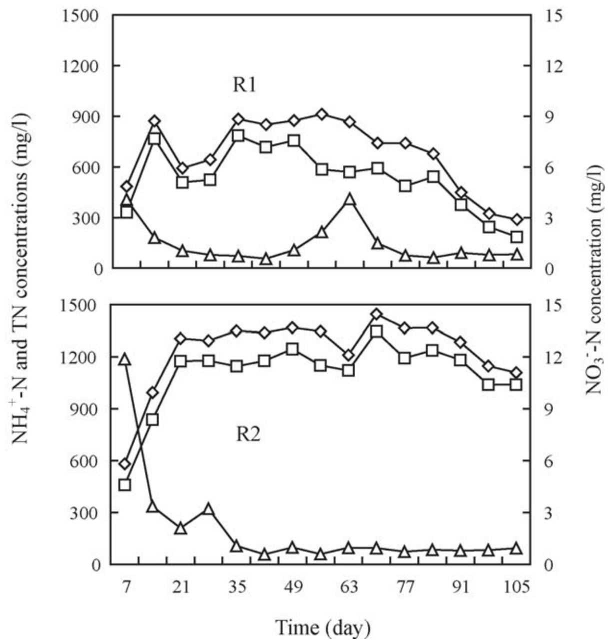

Fig. 7. Variation of NH_4^+–N, NO_3^-–N and TN concentrations in leachate during waste decomposition. NH_4^+–N (□); TN (◇); NO_3^-–N (△).

denitrifying bacteria population was also found in the top or middle layer where a supply of nitrite or nitrate (produced from nitrification) and anoxic conditions. This suggested that intermittent aeration at the top of landfilled waste might establish an aerobic/anoxic/anaerobic condition in landfills, which resulted in the function for nitrogen removal in landfill bioreactors. A similar result was found by Onay et al. [8] in a three-reactor system by the air inlet at the bottom of the reactor to maintain aerobic conditions.

3.3. Performance of nitrogen removal in bioreactor landfill systems

NH_4^+–N, NO_3^-–N and TN concentrations in leachate are presented in Fig. 7. Although the nitrifying bacteria population in landfill reactor R1 was high, leachate NO_3^-–N concentration was still low. In addition, the leachate NO_3^-–N concentration for landfill reactor R1 was less than that for landfill reactor R2 on day 7, which may be attributed to the increase in denitrifying bacteria population by intermittent aeration at the top of landfilled waste (Fig. 6). An increase in the leachate NO_3^-–N concentration was observed in landfill reactor R1 between days 56 and 70. This was consistent with the increase in nitrifying bacteria population on day 60 (Fig. 5). The NO_3^-–N data indicated that the landfilled waste ecosystem had a capability to consume NO_3^-–N.

Leachate NH_4^+–N and TN concentrations had a similar value in both two landfill reactors in the first 14 days. After 14 days operation, the leachate NH_4^+–N and TN concentrations for landfill reactor R2 increased dramatically to above 1000 mg/l on day 21, and remained the high NH_4^+–N concentration till the end of the experiment. However, the leachate NH_4^+–N and TN concentrations for landfill reactor R1 decreased a little between days 21 and 28, due to the increase in leachate volume (Fig. 4). As compared with landfill reactor R2, the leachate NH_4^+–N and TN concentrations for landfill reactor R1 were lower during the whole experiment. Especially from day 56, leachate NH_4^+–N and TN concentrations for landfill reactor R1 dropped gradually, and reached 186 and 289 mg/l, respectively, at the end of the experiment.

In order to examine the possibility of ammonia air stripping in the experiment, the effluent gas from landfill reactor R1 was absorbed by 200 ml of 0.1 mol/l H_2SO_4 for 105 days. The analysis showed that little NH_4^+–N was presented in the absorbent (NH_4^+–N was not detected in the analytical method, in which the minimum NH_4^+–N concentration is 0.02 mg/l). This might be due to the pH of 8 or so in the waste bed (Figs. 2 and 3), which made little possibility to remove nitrogen from leachate by air stripping, because that the pH optimum for ammonia air stripping is between 10.8 and 11.3 [24]. Thus, the nitrogen removal in landfill reactor R1 was mainly caused by biological conversion. As many wastewater treatment facilities, such as rotating biological contactors, oxidation ditchs and sequencing batch reactors, the aerobic/anoxic/anaerobic landfill system also promoted the ammonia removal from leachate in a similar manner, whereby air, moisture and nutrients are combined together by leachate recirculation and intermittent aeration at the top of landfilled waste. Since the concentrations of these compounds are reduced, the need for ex situ leachate treatment could also be reduced, depending on applicable regulations.

Intermittent aeration at the top of landfilled waste not only enhanced nitrification and denitrification in the landfilled waste bed, but also stimulated the metabolic activity of aerobes, which brought a rapid degradation of waste into CO_2 and H_2O. With an anaerobic reactor using treated leachate recirculation, the degradation of landfilled waste and organic pollutants in leachate was a two-phase degradation process, where the hydrolysis–acidification of organic waste occurred mainly in the landfill reactor, and methanogenesis occurred chiefly in the anaerobic reactor. The gas production from the following anaerobic reactor accounted for nearly 88% of the overall gas volume in the bioreactor landfill system with an anaerobic reactor using treated leachate recirculation [25]. In the experimental bioreactor landfill system, methane produced from the landfiled waste might be oxidized to CO_2 by methanotrophic bacteria in the top and middle layers, which need be further investigated to reduce methane emission because methane is one of the most important greenhouse gases.

3.4. MSW stabilization

The rate and magnitude of landfill settlement depends primarily on the waste composition, operational practices and factors affecting biodegradation of landfill waste [26]. The cumulative settlement for landfill reactor R1 was more rapid than that for landfill reactor R2 throughout the experimental period (Fig. 8). The total settlement for landfill reactor R1 reached 34% of the original thickness after 105 days operation, which exceeded that for landfill reactor R2 by 12%. At the initial and final time, the wet weight, dry weight and VS of landfilled waste demonstrated a higher degree of MSW stabilization in landfill reactor R1 (Table 1). Dry weight and VS of landfilled waste for landfill reactor R1 had a statistically significant decrease compared with landfill reactor R2 (Table 1; $P < 0.05$). This suggested that more rapid and complete degradation of waste might be achieved (than under anaerobic conditions) by adding the proper proportions of air to the waste mass.

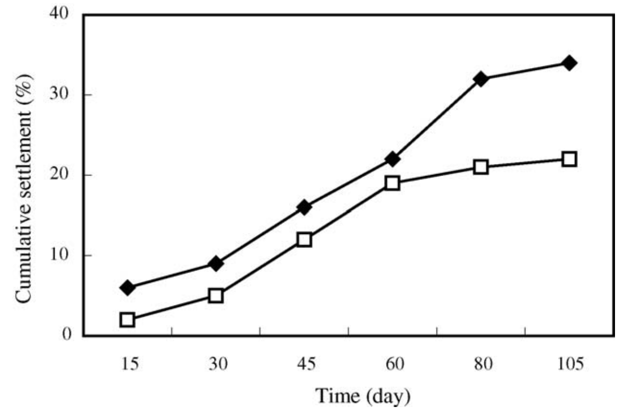

Fig. 8. Cumulative settlements for landfill reactors during waste decomposition. Landfill reactor R1 (♦); landfill reactor R2 (□).

Table 1
Physical and chemical properties of different landfill reactors

Time (days)	Reactor	Landfilled waste (kg)		
		Wet weight	Dry weight	VS
Initial ($t = 0$)		23.4	10.23 ± 1.23	5.91 ± 0.52
Final ($t = 105$)	R1	13.8	6.89 ± 0.65*	3.21 ± 0.41*
	R2	15.1	7.89 ± 0.79	4.18 ± 0.61

* $P < 0.05$.

4. Conclusion

The present study showed that intermittent aeration at the top of landfilled waste might establish an aerobic/anoxic/anaerobic condition in landfills, which stimulated the growth of nitrifying bacteria and denitrifying bacteria in the top and middle layers of waste. This provided the potential for in situ nitrogen removal from recycled leachate in the landfill bioreactor. After 105 days operation, leachate NH_4^+–N and TN concentrations for the landfill reactor with intermittent aeration system dropped to 186 and 289 mg/l, respectively, while they were still kept above 1000 mg/l for the landfill reactor without intermittent aerobic system. And the biodegradable portion of waste could be stabilized in a significantly shorter time frame than under anaerobic conditions. A higher degree of MSW stabilization and an increase of 12% in the total waste settlement were achieved by intermittent aeration at the top of landfilled waste. In conclusion, with an anaerobic aerobic using treated leachate recirculation to elimiate the inhibitory effect of high organic matter in leachate on nitrification, intermittent aeration at the top of landfilled waste not only might develop the landfilled waste as a bioreactor bed to remove organic and ammonia from leachate, but also increased waste decomposition, stabilization, and settlement.

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