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Microbiological indication of municipal solid waste landfill non-stabilization

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Abstract: Accidental collapse resulted from unstable factors is an important technological problem to be solved in sanitary landfill. Microbiological degradation of organic matters in landfilled solid waste are an important unstable factor. A landfill reactor was thus manufactured and installed to examine quantitative and population dynamics of microorganisms during degradation of landfilled solid waste. It was showed that unstable landfill can be reflected and indicated by microbiological features such as rapidly decreased growth amount of microorganisms, no detection of fungi and actinomyces, and changing the dominant population into methanogenic bacteria and *Acinotobacter*.

Keywords: municipal solid waste; sanitary landfill; unstable factor; microbiological indication

Introduction

Landfilling is the oldest and popular approach to municipal solid waste treatment in the world (Zhou, 1997; Hu, 1998). In China about 95% of domestic solid waste and 90% of commercial solid waste are directly dispatched to landfill. However, most concern has been felt over leachate, landfill gases and a variety of trace organic pollutants from landfill sites all the time (Harmsen, 1983; Sylvestre, 1999). In recent years, more and more attention has been paid to accidental collapse resulted from unstable landfilled municipal solid waste during its decomposition, because serious environmental pollution and extensive damage to people and domestic animals took place in a lot of landfill sites (Zhou, 2003).

In general, the decomposition of municipal solid waste in landfills can be divided into 4 phases (Barlaz, 1988; Sylvestre, 1999): (1) the aerobic decomposition phase—solid waste is converted into carbohydrates and water due to the limited amount of oxygen in landfills, thus having resulting in wastewater, and the growth of anaerobic microorganisms especially bacteria is promoted in the phase; (2) the anaerobic decomposition but nonmethanogenic phase; (3) the methanogenesis phase—initial methane formation begins in this phase as methanogenic bacteria anaerobically convert acids to methane and carbon dioxide, and pH decreases, methanogen population increases and methane can be detected in the landfill; and (4) the stead methane generation phase—the generation of methane is becoming steady and the rate of methanogenesis increases rapidly to a maximum value, usually occurring much later, and the pH increases at the neutral level and an increase in the methanogenic bacteria occurs. This increase occurs concurrently and declines later (Senior, 1990). At the final stage, landfilled solid waste is said to be gradually stable. In order to decrease the risk of landfill accidents, we did a research aimed at identifying the biodiversity of microorganisms degrading organic matters and their totality in leachate, especially those that are directly related to methane gas production influencing landfill stability.

1 Materials and methods

1.1 A landfill reactor

According to experimental needs, a cylindrical landfill reactor with a volume of 0.327 m^3 was manufactured and installed in the Tianziling Landfill Center in Hangzhou, Zhejiang Province. The medium-sized cosmic reactor can be closely sealed using a secure cover with three orifices used for adding water, inserting a thermometer, and a pressure gauge (Fig. 1). At the bottom of the reactor was assembled with a leachate collector. Landfill gases were collected using the diversion water method. To avoid rainwater flow into the landfill reactor, it was also covered with a plastic sheet.

1.2 Sample collection

Fresh samples of municipal solid waste were systematically collected from the six districts (Shangcheng District, Xiacheng District, West-Lake District, Jiagang District, Linan District, and Gongshu District) of Hangzhou City. After the collection, the fresh municipal solid waste samples were well mixed each other. Using the quartering method, a quarter of the mixed sample was selected. The selected municipal solid waste was sorted. Organic matters including animal and plant residues, inorganic matters including furnace dust, ash drop and brickbat tiles, plastics and scrap materials including glass, ferrous and tin cans and old batteries were respectively weighed. The weighed results

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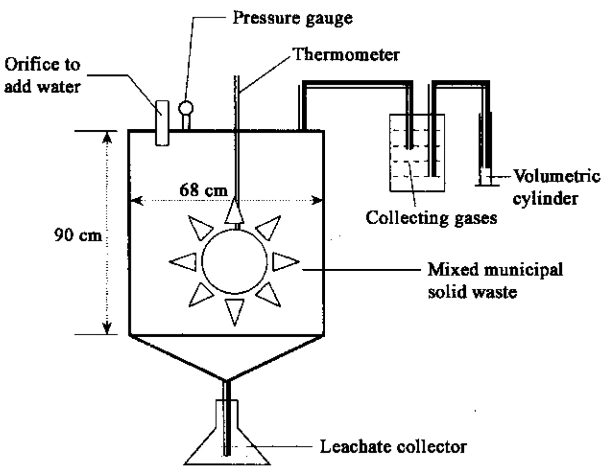

Fig.1 The experimental landfill reactor

are listed in Table 1.

Table 1 Composition of the tested municipal solid waste

Composition	Weight before landfilling, kg	Relative content before landfilling, %	Weight after landfilling, kg	Relative content after landfilling, %
Plastic	23.9	11.0	24.2	15.2
Scrap material	11.2	5.2	10.8	6.5
Organic matter	84.7	39.3	49.5	29.9
Inorganic matter	95.7	44.4	80.1	48.4
Water content		60.0		30.5
Total weight	215.5		165.5	

1.3 Decomposition simulation

After having weighed, the sorted samples were fully mixed together and put into the landfill reactor. Then 8 ml of tap water was weekly added to the landfill reactor based on the annual average precipitation in Hangzhou. Internal and surrounding temperatures, internal pressure, and amount of gases produced were determined and the leachate sample was taken in each time before the addition of tap water to the reactor. Colony quantity of microorganisms in the leachate sample was analysed, including the identification of the diversity of microorganisms and their totality in the leachate.

1.4 Analytical methods

Internal temperature in the reactor and its ambient temperature were measured using a thermometer. Leachate pH was determined using a pH meter. The volume of produced gases was measured using the water-removing method(Zhejiang Agricultural University, 1988).

Microorganisms including bacteria, fungi and actinomycetes were counted using the diluted plating method which is also known as the colony-counting method and the Most Probable Number(MPN) method(Fang, 1992; Ming, 1999). Counting of methanogenic bacteria was made by the roll tube technique(Bookter, 1986).

Isolation and identification of microorganisms was carried out according to the procedures suggested by the Nanjing Institute of Soil Science (Nanjing Institute of Soil Science, 1985) and Fielding *et al*.(Fielding, 1988).

2 Results and discussion

2.1 Quantitative dynamics of microorganisms

During the decomposition of municipal solid waste, the population and amount of microorganisms in the landfill reactor changed with time endlessly. The growth of bacteria, fungi and actinomycetes can be divided into two phases: (1) growth and development—the amount of microorganisms increased with time; (2) inhibition and death—the amount of microorganisms decreased with time(Fig. 2). However, the amount of methanogenic bacteria in the landfill reactor was an increasing process all the while.

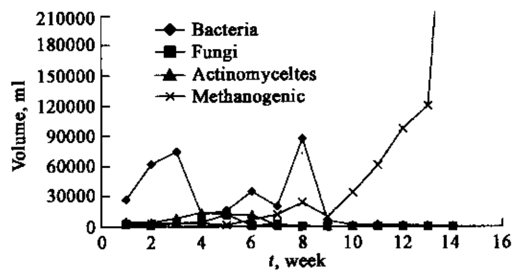

Fig.2 Changes in the growth amount of microorganisms in the reactor with time

It was observed according to the leachate collected from the reactor that the amount of bacteria in per ml of leachate was first increased from 2.7×10^4 (March 4) to 3.5×10^5 (April 8), and then decreased to 5.2×10^2 (June 4) gradually after three months of degradation(Table 2). The highest amount of bacteria in leachate was observed at the first five weeks after the solid waste samples were added to the reactor. The growth amount of fungi in per milliliter of leachate generally increased from 2.7×10^3 (March 4) to 1.2×10^4 (April 1) during 4 weeks after the solid waste was added. After the highest value, it gradually and steadily declined to zero (no detection). The growth amount of actinomycetes in per milliliter of leachate also gradually increased from 4.9×10^3 (March 4) to the maximum growth (1.8×10^4)(April 14) at the first 6 weeks after the reactor test started. After the highest value, it gradually declined to zero levels.

During the growth and development phase, microorganisms occurred in municipal solid waste reproduced so rapidly, due to the abundance of nutrient elements such as nitrogen, carbon, phosphorus and some trace elements. In particular, the presence of cellulose, pectin substances, carbohydrates, fats and proteins in solid waste can provide a natural basic substrate media for the growth of microorganisms. In the process of solid waste degradation, oxygen in the landfill reactor was rapidly depleted as a result of microbiological activity. After oxygen depletion, the subsequent degradation reactions took place under anaerobic conditions, thus having encouraging the growth of anaerobic microorganisms, especially methanogenic bacteria.

Table 2 Variation of microorganism populations in the landfill reactor

Tested date (Month/day)	Bacteria, ml	Fungi, ml	Actinomycetes, ml	Methanogenic bacteria, ml
March 4	2.7×10^4	2.7×10^3	4.9×10^3	2.5×10^3
11	6.2×10^4	1.0×10^3	4×10^3	3.5×10^3
18	7.4×10^4	3.6×10^3	8.6×10^3	3.0×10^3
25	1.2×10^5	4.2×10^3	1.4×10^4	3.5×10^3
April 1	1.6×10^5	1.2×10^4	1.2×10^4	1.6×10^3
8	3.5×10^5	1.0×10^3	1.2×10^4	6.8×10^3
14	2.0×10^4	2.7×10^3	1.8×10^4	1.2×10^4
22	8.7×10^4	2.0×10^2	8×10^2	2.4×10^4
28	6×10^4	50	40	1.0×10^4
May 5	1.6×10^3	20	8	3.4×10^4
13	2.0×10^3	7	5	6.1×10^4
20	1.5×10^3	4	3	9.7×10^4
27	1.0×10^3	0	0	1.2×10^5
June 2	5.6×10^2	0	0	4.5×10^5

In this study, it has been revealed that bacteria, fungi and actinomycetes are very important populations to degrade organic components of solid waste under aerobic and facultative anaerobic conditions. Methanoganic bacteria are ideal microorganisms for anaerobic degradation processes.

2.2 Population dynamics of microorganisms

The biodiversity of microorganisms in the landfill reactor changed with time. At the growth and development phase, the diversity of microorganisms including bacteria, fungi and actinomycetes was increased with time. However, the diversity of microorganisms excepting methanogenic bacteria was decreased with time at the inhibition and death phase.

It has shown that bacteria were the dominant population throughout the whole experiment. At the beginning of the experiment, aerobic bacteria were the dominant population. After 2 weeks when solid waste was added to the reactor, anaerobic microorganisms gradually became the dominant population. At the latter phase, methanogenic bacteria were the dominant population.

A lot of bacteria such as *Aerococcus*, *Staphylococcus*, *Bacillus*, *Derxia*, and *Acinotobacter* could be detected in the landfill reactor. Changes in dominant populations of bacteria in the landfill reactor are listed in Table 3. During the 1st—2nd week of soild waste decomposition, the dominant population of bacteria was balloon bacteria(*Aerococcus*) and staphylococcal bacteria(*Staphylococcus*). At the third week, *Bacillus* and methanogenic bacteria became the dominant population. During the 3rd-7th week, the dominant population was Delburkii species(Derxia) and methanogenic bacteria. After the 8th week, mobile coli(*Acinotobacter*) and methanogenic bacteria were the dominant population.

2.3 Analysis of unstable landfill factors

Results of solid waste composition analysis before the landfill and 3 months after the landfill are presented in Table 1. It was revealed that plastic weight increased by 1.25% after the landfill and its relative content increased by 37.5%. Scrap material decreased by 3.57% after the landfill, but its relative content increased by 25%. Organic matters were declined in both bulk weight and relative content by 41.6% and 23.9% respectively. In other words, the degradation of organic matters is an unstable factor due to a rapid decrease in landfill volume when organic materials are broken down into small particles by microorganisms, transformed into soluble matters, and ultimately discharged as leachate or converted to gaseous methane. In particular, biodegradable matters in solid waste landfill can invariably lead to the generation of gases and an increase in internal temperature and pressure with a series of complex physical, chemical, and biological reactions.

Table 3 Changes in dominant populations of bacteria in the landfill reactor

Date (Month/ Day)	Dominant population	Amount of bacterial species
March 4	*Aerococcus*, *Staphylococcus*, and methanogenic bacteria	20—30
11	*Aerococcus*, *Staphylococcus*, *Bacillus*, and methanogenic bacteria	30—40
18	*Bacillus*, and methanogenic bacteria	22
25	*Derxia*, and methanogenic bacteria	16
April 1	*Derxia*, and methanogenic bacteria	14
8	*Derxia*, and methanogenic bacteria	12
15	*Derxia*, and methanogenic bacteria	12
22	*Derxia*, and methanogenic bacteria	11
28	*Acinotobacter*, methanogenic bacteria	10
May 5	*Acinotobacter*, methanogenic bacteria	8
13	Methanogenic bacteria, *Acinotobacter*	6
20	Methanogenic bacteria, *Acinotobacter*	6
27	Methanogenic bacteria, *Acinotobacter*	3
June 2	Methanogenic bacteria, *Acinotobacter*	3

High temperature, acidic pH and gas generation are unstable indexes of solid waste landfill. At the phase with the highest amount of bacteria, surrounding temperature was 14.9—17.5℃, internal temperature was 16℃, and there was a moderately acid condition(pH = 5.6)(Table 4). At the phase with the highest growth amount of fungi, surrounding temperature was 6.9—16.8℃, internal temperature was 12℃, and there was also a moderately acid conditions(pH = 5.5). At the phase with the highest growth amount of actinomycetes, the surrounding temperature was 15.2—26.3℃, the internal temperature was 18℃, and the pH value in the reactor was also moderately acid (pH = 5.6).

However, the amount of methanogenic bacteria in per ml of leachate increased with time, even under high internal temperature (34℃) and high surrounding temperature (19.7—28.4℃), unstable landfill conditions. There was no gas production occurred in the landfill reactor till the tenth week with a substantial increase in methanogenic bacteria (9.7×10^4/ml). In other words, unstable situation of solid waste landfill became obvious with the generation of gases after the 12th week when solid waste was added, although pH values approached the neutral level (pH = 6.3—6.5), a stable landfill condition.

Table 4 Changes of temperature, pH and gas production in the reactor with time

Tested time (Month/day)	Surrounding temperature, ℃	Inner temperature, ℃	pH value	Quantity of gases produced, ml
March 4	8.0—9.6	16	5.4	0
11	7.0—12.9	18	5.4	0
18	7.9—14.8	18	5.4	0
25	6.5—7.8	18	5.4	0
April 1	6.9—16.8	12	5.5	0
8	14.9—17.5	16	5.7	0
14	15.2—26.3	18	5.6	0
22	22.2—27.4	18	5.8	0
28	17.0—30.4	24	5.8	0
May 5	17.2—19.2	24	6.0	0
13	16.1—17.9	24	6.1	0
20	21.7—30.9	25	6.3	13
27	15.7—28.4	30	6.3	14
June 2	19.7—28.4	34	6.5	17

3 Conclusions

Microbiological indication of unstable solid waste landfill should include 3 aspects: (1) the growth amount of microorganisms is decreased with time, only 10^3/ml; (2) the growth amount of fungi and actinomyces is approaching zero; (3) methanogenic bacteria and *Acinotobacter* become the dominant population of microorganisms degrading organic components of landfilled solid waste.

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