LABORATORY EXPERIMENT BASED ON IN-SITU LANDFILL ANAEROBIC-AEROBIC CHANGEOVER CONTROL AND WATER SUPPLYING FOR METHANE GAS COLLECTION AND WASTE STABILIZATION

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SUMMARY: The realization toward a sustainable loop-style exploitation society has involved various processes all over the world, one of which is how to effectively use the waste that had been piled up at final landfill disposal sites. So many researches on this problem have been reported. However, they were often uniquely and separately conducted by country to country. From a point of view of international contribution, it would be much better if the results of those researches are mutually shared and effectively extended for use under international research cooperation for making potentially new achievements.

For international cooperation and contribution, a research on the dumping waste of final landfill site is carried out at the Research Institute The landfill systems and technologies research association of Japan(NPOLSA) in cooperation with Sudokwon Landfill site management Corporation (SLC) of South Korea in 2006. The research title is "Final disposal landfill of anaerobic-aerobic changeover style for collecting methane gas as well as early stabilizing dumping waste". According to this research, it is considered that collecting methane gas generated from landfill dumping waste and rationally using it for producing electric energy, and promoting discharge of decomposed organic components and heavy metals from dumping waste in early stabilization should be designed as a definite landfill control method. It is explained that, depending on the waste's characteristics at voluntarily phase (stage), periodically alternating the created atmosphere inside the dumping waste layer from anaerobic to aerobic condition, as well as sprinkling the dumping waste with water to change its water quality and amount will force the waste to generate methane gas and be stabilized in suitable landfill condition.

Keywords: methane gas, stabilization, anaerobic-aerobic, landfill

1. INTRODUCTION

The realization toward a sustainable loop-style exploitation society has involved various processes all over the world, one of which is how to effectively use the waste that had been piled up at final landfill disposal sites. So many researches on this problem have been reported. However, they were often uniquely and separately conducted by country to country. From a point of view of international contribution, it would be much better if the results of those researches are mutually shared and effectively extended for use under international research cooperation for making potential new achievements.

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A series of column tests was carried out. In this paper, column test layout, dumping waste characteristics and results of various data analysis for a testing period from beginning to present are reported.

2. PURPOSES OF STUDY

The two main purposes of this study are:

1) To confirm the method of effectively generating methane gas from the landfill dumping waste;

2) To examine the method of promoting stabilization of landfill dumping waste.

In this experimental study, 6 column tests are conducted, all of which have been set up with anaerobic condition at the beginning. The anaerobic condition that is purposely set for collecting methane gas, is also expected to be good for follow up stabilizing because difficultly decomposed raw materials would be gasified and hence easily stabilized under this condition.

3. EXPERIMENTAL OUTLINES:

3.1 Purposes of the column tests

In this experiment, 6 column tests were carried out, among which 5 columns used general municipal waste and the other one used incineration ash from South Korea. For each column test, depending on alteration of air supplying pattern and water supplying amount, differences in amount, speed and composition of the generated gas were measured. At the same time, the inside temperature of the column, the amount and properties of exuded water were analyzed to clarify the column condition.

3.2 The used dumping waste

Material for filling up the columns 1 to 5 were relatively composed of dumping waste from the 2005 bring-in waste (general living activity waste) in 2005 of South Korea metropolitan landfill. This bring-in waste material was cut by scissors in to pieces of 20 ~ 30mm for making test samples. The compositions of the general dumping waste used for the column tests 1 to 5 are summarized in Table 1, which indicates that about 97% of the waste is combustible.

On the other hand, compositions of three components of the used general dumping waste and incineration ash are shown in Table 2, while the component element analysis and the amount of generated heat are shown in Table 3. The physical properties of the used materials such initial weight, density and dry weight, initial weight of water, initial water ratio and initial content are presented in Table 4 for all tested columns.

As seen from Table 2, when the combustible component is of about 65%, the incineration reduction weight is about 2%. From Table 3, up to 53% of the general dumping waste was carbon (C).Next, decomposing potentials (such as easy, difficult or unable decomposition) of the general dumping waste used in filling up columns of cases 1~ 5 are established in Table 5. Actually, in South Korea, directly dumping of raw waste to the landfill has been prohibited since 2005. Therefore, by thoroughly management of separately collecting raw waste, at present the percentage of the raw waste is about 12% lower than in the past. In 1gram of the tested material, the ratio C/N was 48, which is out of the suitable range (C/N = 10 ~20) for methane generation. This is considered due to the fact that the used dumping waste was relatively less material rich in N such as raw waste.

Photos 1 and 2 illustrate the tested general dumping waste and incineration ash, respectively.

Table 1. General dumping waste compositions

Combustible					Incombustible		
Vinyl	Paper	Fiber	Wood	Raw material	Glass	Metal	Other
39.42	38.07	5.2	2.04	11.96	2.15	1.13	0.03
96.69					3.31		
100							

Table 2. Compositions of three components of general dumping waste and incineration ash (percentage)

Classification		Water	Ash	Combustible
General dumping waste	Vinyl/Plastic	6.65	11.73	81.62
	Paper	25.05	15.66	59.29
	Fiber	4.20	14.94	80.86
	Wood	12.75	9.46	77.79
	Raw material	43.47	19.75	36.78
	Incombustible	0.0	3.31	0.0
	Weighted average efficiency	17.83	17.23	64.94
Incineration ash		3.38	94.66	1.96 (incinerated volume reduction)

Table 3. Component element analysis and amount of heat generation from general dumping waste and incineration ash

Classification		Element analysis (%)					Generated heat (cal/kg)	
		C	H	O	N	S	Low position	High position
General dumping waste	Vinyl/Plastic	79.1	7.0	8.9	0.9	ND	8849.1	9,267
	Paper	34.6	4.6	42.3	0.3	ND	2226.3	2,625
	Fiber	54.7	5.2	36.7	0.7	ND	5203	5,509
	Wood	47.6	5.7	43.8	0.5	ND	4632.7	5,017
	Raw material	39.0	5.0	34.9	2.7	ND	3394.18	3,925
		52.8	5.50	26.6	0.84	ND	5106.9	5,510.6
Incineration ash			ND	ND	ND	ND	—	—

Table 4 General dumping waste types

Type	General dumping waste			
	Decomposable		Non-decomposable	Total
	Easily decomposable	Difficultly decomposable		
Component	Raw waste Paper	Fiber Wood	Vinyl Non-combustible (glass, metal, others)	
Percentage by weight (%)	50.03	7.24	42.83	100
	57.17			
Organic dry weight DS (g/kg)	353	68	401	822
	421			
Organic Concentration (g/kg)	270	58	—	—
	328			
Ratio C/N	41	82	—	—
	48			


Photo 1 general dumping waste


Photo 2 incineration ash

5. COLUMN TEST DEVICE INSTALLATION

Installation of column test device is outlined hereafter.

1) On the assumption that the filling material sample inside the column may break (smash) at about 20mm, the device is made of clear acrylic for enabling observation of inside.
2) The column test device consists of 3 equal column parts, each of which is 50cm in length and 15cm in diameter, able to be connected together into a 3-stage column of 1.5m high. The test material will be filled in each part of the column before connecting.
3) The column was designed strong enough with thickness of 10mm, a flat cover on the top and 3 measurement holes for sampling on the side of the column (each at the middle height of the upper, middle and lower column parts).
4) The joint between the 2 column parts is about 20mm thick, sealed up by O-ring and sealing material, and fixed by bolts at 12 positions.
5) At each measurement hole in the middle height of each column part, hygrometer is inserted for measurement.
6) A pipe of 10mm diameter is inserted from top to bottom of the column for sucking in the generated gas from all dumping waste layers, as well as supplying air to them.
7) A gas pack is equipped in order to collect the generated gas from the waste layer, as well as for the gas phase from the waste's pores to escape when sprinkling water.
8) To be able respond necessarily, the gas phase adjustment hose is set in close condition by ordinary valve.
9) Waste monitoring holes (diameter of 10mm) are set at 3 locations around the column so that measurement of temperature, water, gas etc… can be done.

10) The bottom cover of the column is designed in funnel shape so that the water extraction device can be easily clung to.

11) The bottom of the column is filled with gravel and unwoven textile on its top for good water drainage.

12) The column is wrapped from outside with paper and then with heat insulation material. When taking off these wrapping layers, the inside stabilizing condition can be observed.

The outline of column test equipment is presented in Figure 1. Photo 3 illustrates the set up of column test.

After the test system was set up once and the test was performed, it was disassembled and then reassembled because generation of the gas was slower than expected. The second test was named "2nd stage test". The picture of the system is shown by Photo 4.

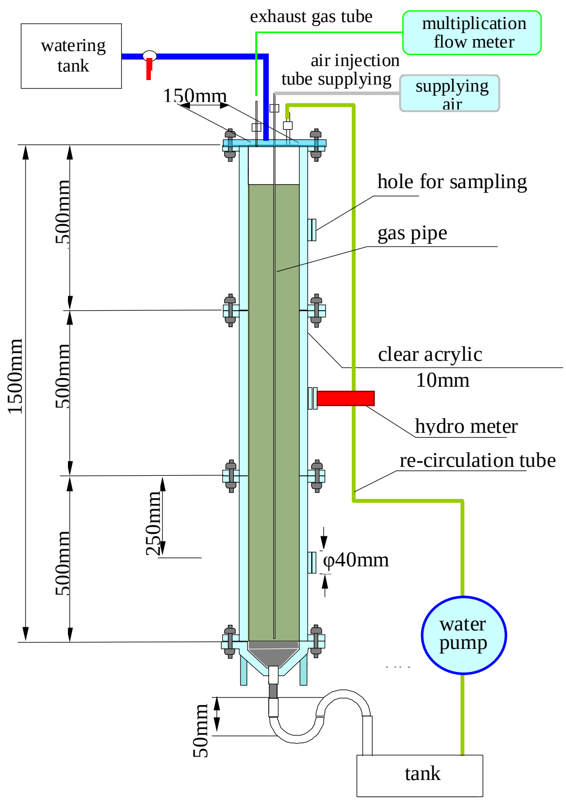

Fig 1. Column test setup

Photo 3. Column test setup

Photo 4. Column test setup(second stage)

6. EXPERIMENTAL RESULTS

This chapter discusses the results of the second stage experiment.

6.1 Temperature in the column

To know the state of biological decomposition in the column, intraformational temperatures were measured. At the same time, room temperature of the laboratory (exterior of column) was also measured. Figure 6.1-1 shows temporal change of temperatures inside the column measured by using temperature sensor placed in the column and temperature outside of the column.

Temperature of the experimental columns were maintained at 20 to 30℃ during the experiment

by using warm air from room air conditioner. The temperature inside the column was around 10℃ at the beginning of the test (December 14, 2006), went up to 25 to 30℃ during the following 20 days, went up to nearly 40℃ during the following 100 to 150 days, and then, wend down gradually and stayed in the range from 20 to 30℃ (The temperature was low at 15th, 63rd and 110th days from the beginning of the experiment due to malfunction of the heater).
For the temperature in the column at nearly 150th day from the beginning of the experiment, columns 4 and 5 showed noticeable rise of temperature, and a little later, columns 1 to 3 showed rise of temperature. These phenomena indicate that some kind of chemical reaction(s) occur in the columns.

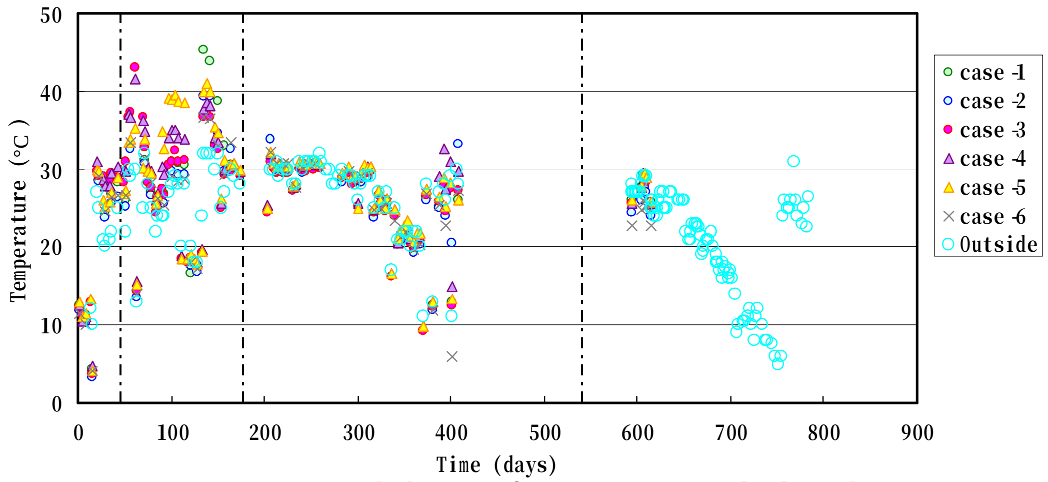

Figure6.1-1 Temperal change of temperature inside the columns

6.2 Generation of gas

Measurement of the gas generated in the column is made for the purpose of finding conditions the most suitable for production of gas that can be used for power generation. The measurement of gas components allows confirmation that interior of the column is anaerobic. The gas was generated first in the second stage test. The amount of gas generated was the highest in the column 2, and then 5 and 6 in this order, and columns 4 and 1 produced little gas. We did not expect column 6 to produce gas from the beginning. The column 2 showed obvious increasing tendency of the gas production.

The components of the gas are CH4, CO2, O2 and N2, among which the amount of CH4 is the highest, possibly indicating that the gas is anaerobic. The column 3 produced N2 more than other columns though the amount is very low.

Figure 6.2-1 shows temporal change of gas yield and Figure 6.2-2 shows accumulated total of gas yield.

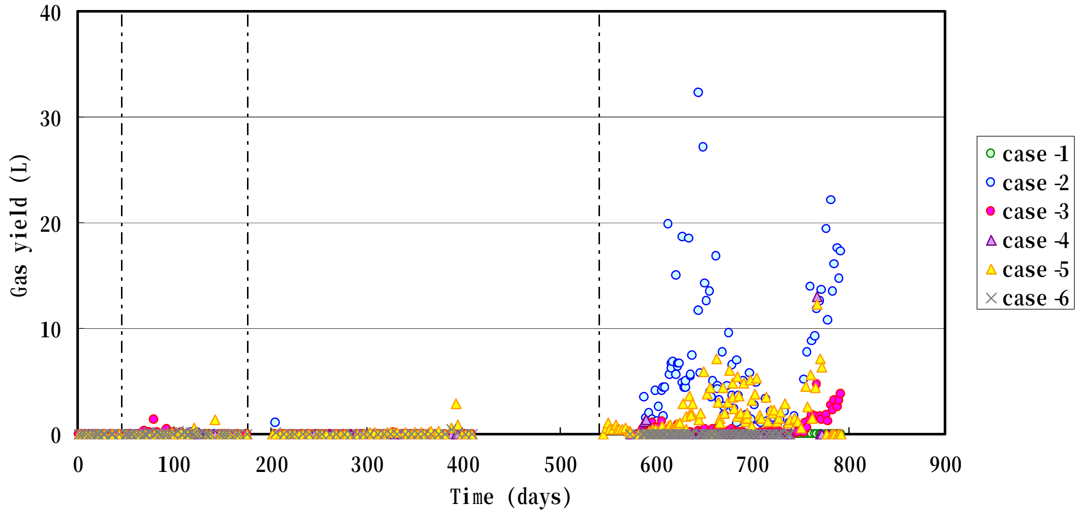

Figure 6.2-1 Temporal change of gas yield

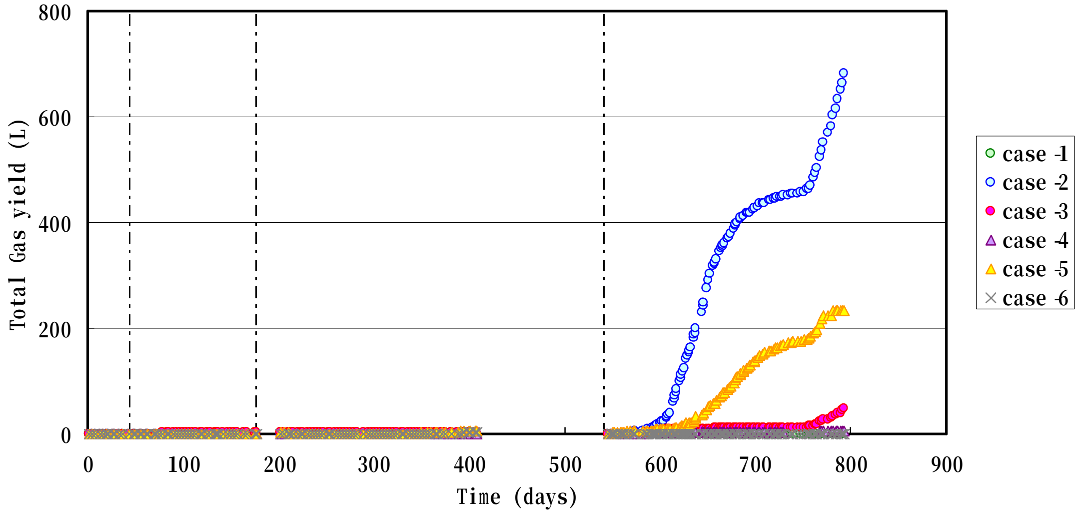

Figure 6.2-2 Temporal change of accumulated total of gas yield

6.3 Chemical components of leachate

The leachate was analysed on the chemical components to understand the state of washing out of the components and decomposition in the columns. The analysis was made on the items including pH, COD, BOD, alkalinity, NH4+, NO3- and NO2-. For the column 6 that is filled with incineration ash, the leachate was analysed on heavy metals additionally. From nearly 140th day from the beginning of the experiment, the items including ORP, T-N, Cl and SO42- were added for the analysis.

The following sections describe some of the analysis results.

a) pH

Figure 6.3-1 shows temporal change of pH of the leachate. The measurement of PH is made for the purpose of evaluating if it is in the range that biological reaction is possible in the liquid. The columns 1 to 5 that are filled with general municipal waste show pH value ranging from 6 to 8. The column 6 that is filled with incineration ash shows pH value ranging from 11 to 12 during initial stage, and then around 10 at 400th day from the beginning of the experiment.

The columns 3 to 5 show mild acidity up to 300th day. This may be due to generation of volatile organic acid (such as acetic acid) caused by acid fermentation. However, the cause should be examined some more because, under normal conditions, reasonable pH value is a little lower than this. They show nearly neutral after 300th day.

The columns 1 and 2 stay nearly neutral, possibly indicating that no acid fermentation occurs yet.

The column 6 shows typical feature of incineration ash landfill, indicating weak alkali (pH value of around 10). However, because no neutralization by carbon dioxide gas occurred here, indication of strong alkali, even if it occurs, is not abnormal.

After the second stage, column 1 showed weak alkali, and all other columns except 6 are in the neutral range.

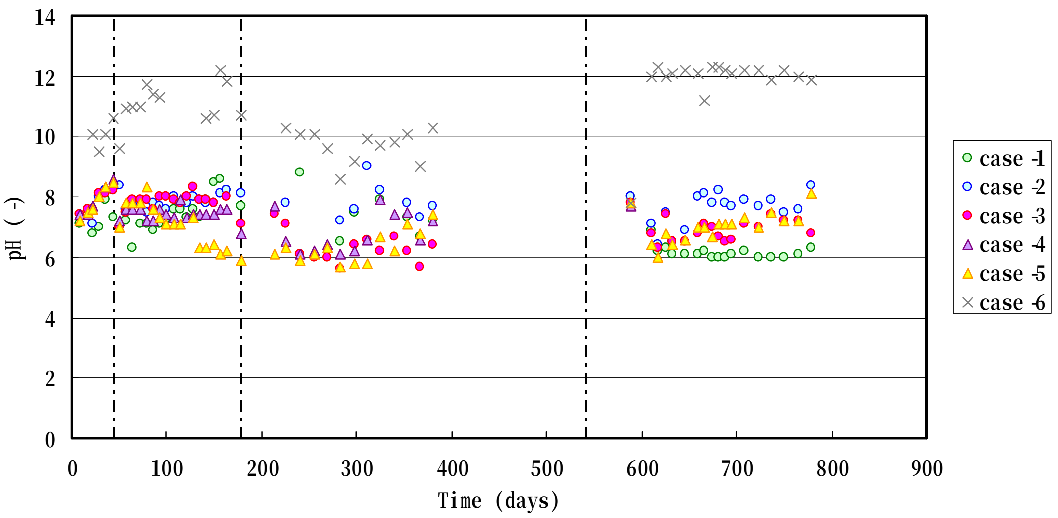

Figure 6.3-1 Temporal change of PH values

b) Organic properties (COD, BOD and TOC)

Figures 6.3-2, 6.3-3 and 6.3-4 show temporal change of COD, BOD and TOC respectively. COD and BOD show proportional relationship, where COD：BOD is nearly equal to 1.5：1

The columns 3 to 5 show high COD and BOD from approximately 100 days from the beginning, and after this, COD shows reducing tendency in all columns. The column 3 shows a little delaying movement as compared with the columns 4 and 5.

For the column 1, COD and BOD are reducing monotonously in initial period. This may be because degradable components are flushed away by the water supplied from tap, not circulating the leachate. However, from 300th day, both COD and BOD of the column 1 increase to the level equal to those of the columns 3 to 5.

The column 6 does not show big change of COD and BOD.

The increase of BOD might have been caused by production of volatile organic acid or alcohol from acid fermentation. The columns 3 to 5 show increase of BOD in the period from 100th day to 250th day, and then, show decrease. This might have been caused by consumption of BOD component (volatile organic acid) contained in the leachate by the production of methane gas.

After the second stage, COD and BOD of the column 2 reduce. This indicates that the amount of organic components that is put out of leachate decreases as the gas production increases.

Measurement of TOC was begun from the second stage. The temporal change of TOC is nearly the same as that of COD and BOD for all columns.

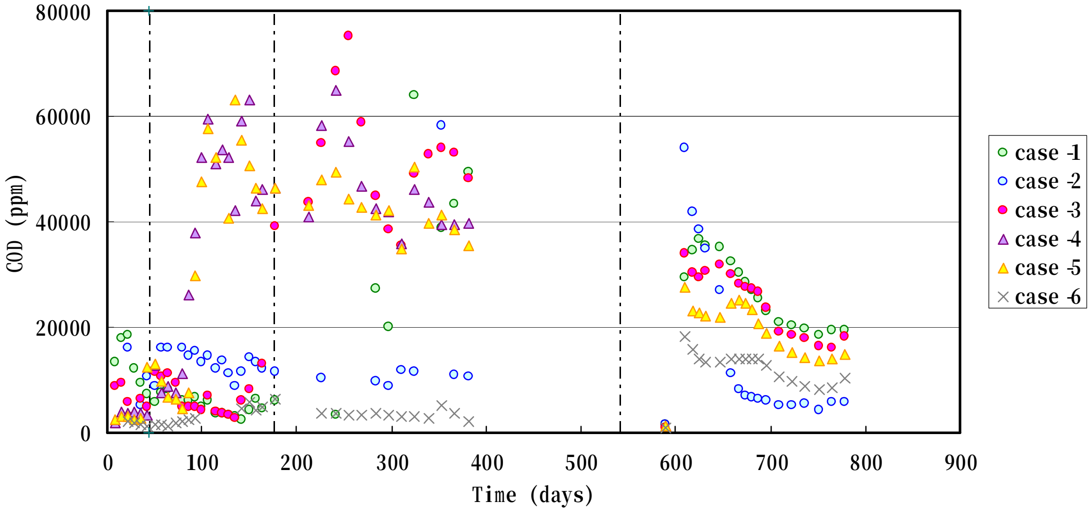

Figure 6.3-2 Temporal change of COD

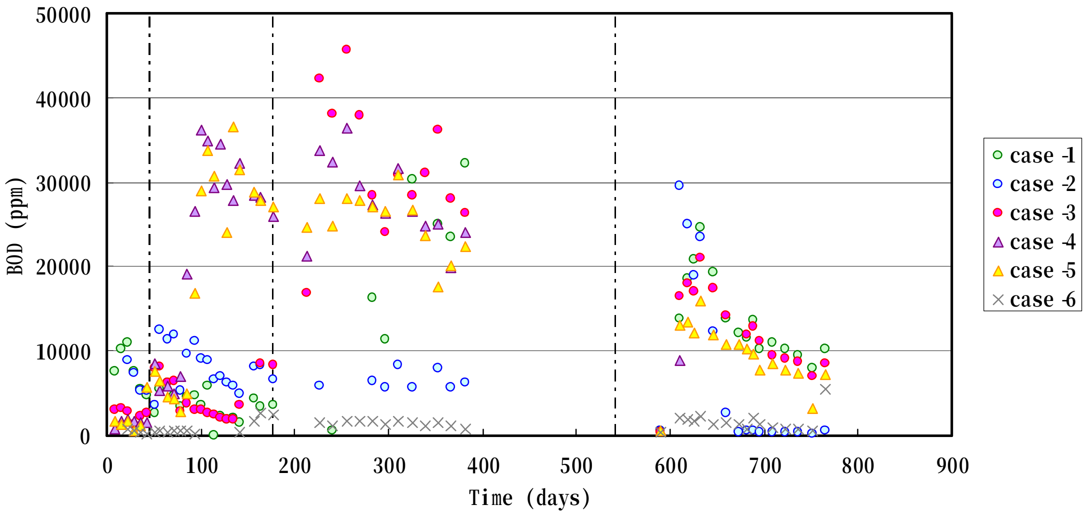

Figure6.3-3 Temporal change of BOD

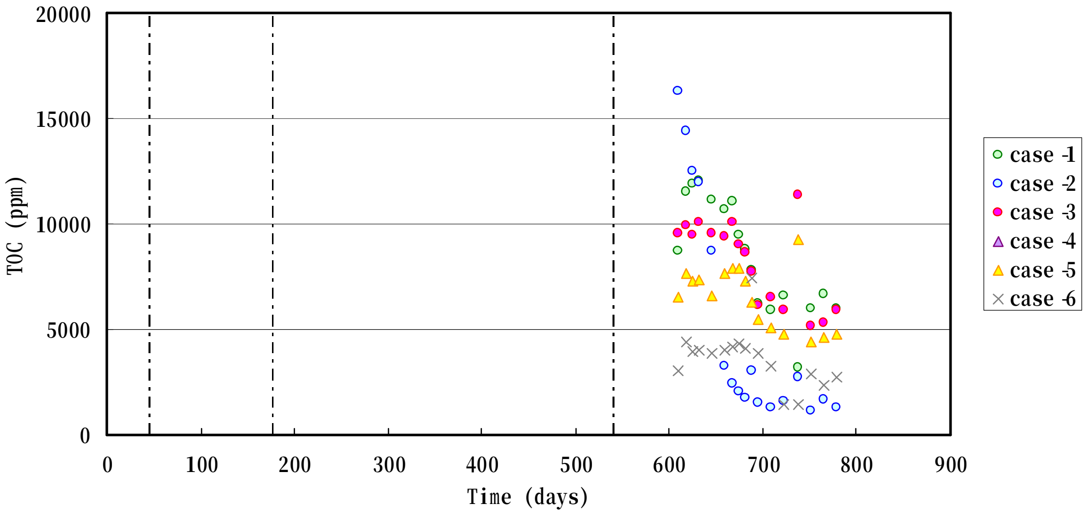

Figure 6.3-4 Temporal change of TOC

7. Gas production potential of experimental columns

To estimate the amount of production of gas in this experiment, we obtained total methane gas production per 1 column of the filling waste used for this experiment based on the amount of methane gas production per loss of ignition (VS : Volatile Solid,%) in SLC.

Table 5 Methane gas production potential and prediction of amount of methane gas production by waste component

Waste			VS(%)	Weight of VS(%)	mL CH4 /g VS※	CH4(L)
Component	Weight % Compo-sition(%)	Weight (kg, dry)				
Plastic	40.8	1.97	95.90	1.89	75.7	142.71
Paper	39.3	1.90	81.80	1.56	284.9	443.61
Textile	5.4	0.26	97.30	0.25	230.8	58.39
Wood	2.1	0.10	97.60	0.10	213.1	21.21
Food	12.4	0.60	81.60	0.49	419.9	204.90
Total	100	4.83	-	4.29	-	870.82

※：From data owned by SLC

From the above data, the amount of methane gas production per column is estimated to be 870 liters, and the methane gas production potential per unit weight of waste obtained from the filling waste 4.83kg is approximately 180L-CH4/kg＝ 180m3-CH4/t-waste.

When converting this value into the gas production, the predicted gas production ranging from 1450L(when CH4 concentration is 60%) to 1760L(when CH4 concentration is 50%) is obtained depending on the methane concentration.

8. Examinations on anaerobic-aerobic changeover index

We are planning to perform anaerobic-aerobic changeover when the concentration of nitrogen contained in the leachate has reached 1000mg/L. The reason why the concentration of nitrogen is used as a measure for the decision is that the nitrogen in high concentration disturbs degradation of organic substances contained in the waste, and thus, causes troubles if the leachate is released into the environment.

In this study, as another index, we examine to use the lower limit of concentration of methane gas that is not suitable for power generation, because, as an anaerobic degradation of waste continues, concentration of methane contained in the produced gas is reduced gradually.

The type of power generation equipment varies according to the generation capacity required. For general landfills, gas engine is used for collection of methane gas and power generation. If larger capacity is required, several gas engine power generators ranging from 1000 to 2000 kW are generally used because of easier maintenance and overhauling, and based on the risk management viewpoint.

In recent years, high efficiency gas engines that are able to provide power with low concentration methane gas have been developed, and for collection of methane gas from landfills and power generation, many of the engines require methane gas concentration of 50% or over for performance guarantee.The gas engine released from GE Jenbacher, on of the leading gas engine manufacturers, require methane gas concentration over 40%. It is reported that some of other engines lose the efficiency if the methane gas concentration is reduced to 35%. Therefore, when assuming the use of methane gas for power generation, it is possible to continuously monitor the measurements of methane gas concentration to use the methane gas concentration of around 35% where the generation efficiency reduces as one of anaerobic-aerobic changeover indices.

9. RECOMMENDATIONS

The fundamental purpose of this study is to produce methane gas efficiently first in anaerobic condition, and then, changing the state to aerobic to stabilize the property. Therefore, we are planning to collect data after changing to the aerobic state and examine them.