B–16.1.3 Study on the Recovery and Utilization of Methane from Solid Waste Landfill

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INTRODUCTION

Solid wastes and wastewater from municipal and industrial human activities emit global warming gases (greenhouse effect gases). This problem is originated from carbon recirculation through human system and natural global environment. Solid wastes which are collected and treated intermediately are finally dumped at waste disposal sites such as solid waste landfill (SWL). After dumping the wastes, bacterial degradation of organic substances in the SWL emits methane and carbon dioxide which are major global warming gases.

Methane is high energy content gas and it is able to be recovered and utilized as one of alternative energy resources. However, methane recovery from landfill needs evaluation of potential gas production, contribution percentage for global warming, appropriate collection system and management, decreasing efficacy of global warming by energy utilization of methane, and so on. The technology development for methane recovery from SWL requires fundamental studies on biological gas emission from unit amount of solid wastes, total amount of solid wastes in the world, energy conversion system for recovered methane and its efficiency, and capability evaluation of reduction of global warming.

In this study, affecting factors to the anaerobic bacterial gas emission from synthetic solid wastes were cleared. Potential gas production from SWL was investigated by using bench-scale experimental landfill column modules of SWL. Global warming gas emission from waste was simulated by using the experimental data and by assuming practical-scale SWL. The net energy recovery with methane gas engine and electricity generators from landfill gas was calculated and evaluated. The efficacy of SWL gas recovery and use as energy resources to relieve the global warming was also evaluated in this study.

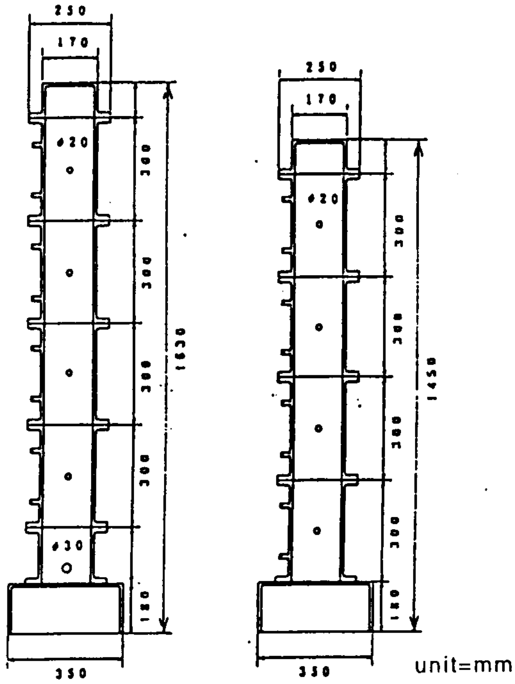
STUDIES ON THE SWL SYSTEM AND MANAGEMENT METHOD OF FOR METHANE RECOVERY AND UTILIZATION

The model solid waste was synthesized with powdered paper, special soil, dried yeast, fermented droppings of fowls, fish meal, slacklime, digested sewage sludge, and water. In the first experiment, the amount of produced gases and the production rate was measured under following conditions. 1) the synthetic solid waste (SSW) was fermented in the pure water anaerobically, 2) the SSW was fermented in phosphate buffered water (pH7.3) anaerobically, 3) the SSW was fermented in yeast extract (500mg/l) solution anaerobically, 4) the SSW was fermented in phosphate buffered yeast extract solution anaerobically. Temperature conditions of 15°C, 20°C, 25°C, 30°C, and 35°C were adapted for the each fermentation condition.

The experimental data showed that gas production rates of total gas and methane were increased by adding yeast extract as nutrient supplier. The data also showed that prevention of dropping pH value of fermenting liquid was important for anaerobic gas production from SSW. The gas production at 15°C was very slow and negligible methane was produced. The amount of gas evolved was increased with increasing fermentation temperature. The maximum gas production was observed at 35°C.

Based on the experimental data described above, potential gas emission from SWL was investigated by using bench-scale experimental landfill column modules of SWL. The experimental SWL equipments were shown in Fig.1. One of the SWL column modules was operated aerobically with an air pump aeration from the bottom of the column through the SSW bed. Other three SWL column modules were provided for anaerobic SSW stabilization. One anaerobic SWL module column was operated without any extra water supply, and other two anaerobic systems were operated with water supply from outside, and in one of them leachate cycling through the SSW bed was adapted.

In the aerobic column module, methane was not detected from the exhausted gas from the column. In this column, grew rapidly and many fruiting bodies were formed in the SSW column. After that small insects appeared in large number. The SSW bed volume of this aerobic column decreased to almost half of that originally packed within 100 days. In this anaerobic bio-degradation, organic matter was mineralized rapidly, and the carbon was converted to carbon dioxide and discharged into atmosphere.



(Column module No.1) (Column module No.2,3and4)

Fig. 1. Experimental SWL Column Module.

In the SWL column module in which rain fall water was removed through the surface drainage and almost no rain water came into the SSW bed, semi-dried condition resulted in very low emission of anaerobic gases especially methane. In this case, almost no methane can be recovered and utilized.

In the SWL column module in which rain water was penetrated into the SSW bed, carbon dioxide was evolved after 20 days and methane was actively emitted 60 days after the module operation was started. Therefore, it is considered that acid fermentation of SSW preceded the final methane fermentation in this water supplied column module. However, the gas emission decreased rapidly when the penetrated water was reached to the 4/5 of the SSW bed height. After discharging penetrated waster from the column module to 1/2 of the SSW bed height, the gas emission was recovered and more active production of methane was observed stablely. This shows that appropriate level control of penetrated water in the SWL is important operational factor for stable and utilizable energy gas production.

In the case of the SWL column module experiment in which the penetrated water pooled at the bottom of the column was pumped up and circulated through the SSW bed, higher gas production and higher methane content of the emitted gas (average 47%) were observed. The penetrated water circulation ratio was set at 1/5 (1/day) of total pooled water in the column. This result shows that water circulation through the SWL is very effective to produce gases anaerobically and to stabilize organics matter in solid waste. It can be considered that the water circulation also effective to treat the penetrated water from SWL.

EVALUATION OF GLOBAL WARMING BY THE EMITTED GASES FROM SWL

The statistic data of the total amount of solid wastes collected in the world has not been sufficiently provided. It, however, can be roughly presumed as 0.5 kg/human•day by estimating it from the data collected in developed countries (0.75 - 1.0 kg/human•day). The total amount can be calculated as 2.8×10^{12} g/day and as 1.02×10^{14} g/year under the condition that the present human population is 5.6 billion. The data of average organic matter content in solid wastes is also not available. However, it is considered that the organic content is ranged from 30% to 70%, and it is not unlikely that the average content can be assumed as around 50%.

Assuming carbon content of organic matters of solid wastes as 40%, the total amount of carbon dioxide production is calculated 2.04×10^{14}g as carbon per year, if all of the solid waste was burned. This amount consists almost 3.4% of total global carbon dioxide emission if the value of 6×10^{15}g as carbon per year is adopted as the totally emitted carbon dioxide per year in the world.

Methane is another important global warming gas and is emitted vigorously from SWL. Under the conditions of strictly anaerobic and completed anaerobic biodegradation, carbon dioxide and methane production ratio is almost 50 to 50%. Therefore, the amount of methane from SWL is estimated about 1.3×10^{14}g per year. Many researchers reported different estimation values of global methane emission, and average value of those is around 5×10^{14}g per year. This means that the estimated amount of methane from SWL consists about 26% of total methane emission in the world, if all of the organic matter in solid wastes was fermented anaerobically.

It is reported that the contribution of methane to the global warming is around 20% and the contribution of carbon dioxide is around 60%. The half volume of emitted gas from SWL consists with carbon dioxide and residual half volume consist with methane. Therefore, the total warming effect of emitted gas from SWL can be estimated as follows:

$$(0.034 \times 1/2) \times 60\% + 0.26 \times 20\% = 6.22\%$$

This estimation result is showing that, in the worst case, the contribution of emission gas from SWL to the global warming is over than 6% of total warming.

ESTIMATION OF COLLECTABLE METHANE, USAGE AS ENERGY RESOURCES OF IT, AND REDUCTION OF WARMING EFFECT.

As mentioned above, gas emission from SWL is not negligible and methane affects mainly to this environmental problem. If the methane is recovered, however, the methane is usable as energy resource. Not only this, methane is converted to carbon dioxide by combustion, and its estimated contribution for total global warming can be reduced from over 6% to almost 2%. This reduction provides large effect for the prevention of global warming.

In this study, simulation analysis for the energy recovery from SWL methane and its efficacy for saving fossil fuel was done by assuming model SWL of actual scale. The assumed SWL for the simulation is shown in Fig.2. The gas production rate and carbon dioxide and methane contents of produced gas were assumed from the data of the bench-scale column module experiments described previously. In this simulation, it is assumed that methane is used as fuel for a gas-engine which is connected to an electricity generator. Other detailed assumptions are omitted here.

The total volume of emission gas from the assumed SWL was estimated as 27.9 Mm^3 ($1Mm^3 = 10^6 m^3$). The total available gas volume which was collected after the gas emission reached to stable state was almost 27 Mm3. The methane content of the emission gas was assumed 47% and 44% of anaerobic SWL with penetrated water circulation and without it, respectively. In the case with penetrated water

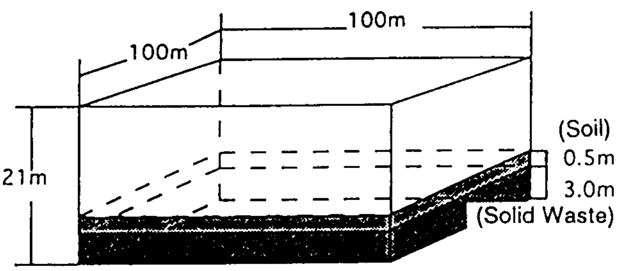


Fig. 2. Assumed Practical-Scale SWL for Simulation Analysis.

circulation, the period of the effective gas recovery was 27.2 years, 8.6 years and 5.0 years under the conditions of the gas emission rate was 1/10, 3/10 and 5/10 of ideal gas production rate which was observed in the ideally controlled bench-scale SWL column module, respectively. The same calculation for the model SWL without penetrated water circulation showed that the period was 39.3 years, 12.5 years and 7.1 years under the conditions of the gas emission rate was 1/10, 3/10 and 5/10 of ideal gas production rate which was observed in the ideally controlled bench-scale SWL column module, respectively.

The calculated electric power which can be utilized in this simulation is shown in Table 1.(a) and (b).

Table 1. Calculated Electric power by gas-engine generator using emitted gas from SWL.

(a) Electric power generation and available electric power from SWL with penetrated water ciculation.

Assumed Emission Rate (m^3/day)		Electrilc Power Generation per day (kwh)	Avairable Electric Power per day (kwh)	Avairable Total Electric Power (kwh)
(1/10)	2750	1550	1260	12600000
(3/10)	8250	4650	4370	13800000
(5/10)	13700	7754	7470	13500000

(b) Electric power generation and available power from SWL without penetrated water ciculation.

Assumed Emission Rate (m^3/day)		Electrilc Power Generation per day (kwh)	Avairable Electric Power per day (kwh)	Avairable Total Electric Power (kwh)
(1/10)	1900	1000	1000	14400000
(2/10)	5710	3020	3020	13600000
(5/10)	9520	5030	5030	13100000

Value of fossil fuel which can be saved since the recovered electric power by the methane gas-generator is substituted as energy resources was also calculated. The calorific value of crude petroleum (CP) and methane is about 10 Mcal per 1 litter and 8.6 Mcal per 1 Nm^3, respectively. The available methane from a model SWL is 12 Mm^3 and this is equivalent to 10.5 ML of CP. Assuming that efficiency of the commercial electric generation is 1.5 times higher (45%) than that of the methane gas-engine electricity generation(30%), the equivalent quantity of CP is estimated as 6900 m^3. This is net saving of fossil fuel.