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Recycling Possibility of Waste Using BMP and AT_4 Test†

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This study analyzed the physical and chemical properties of waste and the biodegradability to present a plan for the re-use of landfills as a basic study on the reuse of landfills. As an analysis result of physical and chemical properties, there were lots of combustible contents (50 %) compared with the analysis result of the existing landfill (30 %). The biodegradability of buried anaerobic (BMP Test) waste was analyzed to be within 11 %. As a result of the aerobic evaluation(AT_4 test), the oxygen consumption of buried waste was 5.45 to 19.76 mg O_2/g DM and was measured less than 2525 mg O_2/g DM, a pre-stabilization evaluation standard at all the places where the sample had been collected. It seemed to be necessary to seek a plan for the reuse at landfill A by lowering the content of organic foreign materials less than 1 % through the secondary selection using the incineration treatment after drying for combustibles, the reburial for incombustibles and cleaning and wind power for sorting soil.

Keywords: Biodegradability, Aerobic evaluation, Anaerbic evaluation, Oxygen consumptiom.

INTRODUCTION

A landfill site can be divided into a sanitary landfill and a unsanitary landfill according to the installation and management of environment facilities such as a leachate transfer and a leachate treatment facility[1]. A sanitary landfill does not seriously influence its surrounding environment, especially ground water. But, an unsanitary landfill seriously pollutes its surrounding water and the connected water system below the earth's surface due to the inflow of leachate continuously occurring when it is in use or after it closed.

The Ministry of Environment had carried out a project for reorganizing unsanitary landfills with the selective/transfer treatment and stabilization method[2,3]. The selective/transfer treatment method is a kind of method that combustible or economic waste is selected and buried again after an unsanitary landfill is dug out. Even though ground water is not polluted any more through this method, it is not possible to restore the ground water system exposed to pollutants for a long time. The local stabilization method that has currently attracted people's attention has also the problem that pollutants have continuously been flown in the surrounding ground water system while the stabilization of a landfill site are proceeding. An unsanitary landfill can give big constraints on the use of land as it has caused pollution and made ground subsidence for too long due to the construction with neither plan nor design. A long time is also required to achieve a sufficient condition for stabilization due to the continuous occurrence of bad smell and the risks of fire and explosion. Therefore, it is feared that the problem occurs in case of the early use. Moreover, it is difficult to select a proper method according to a small scale of temporary landfills and the construction unit cost comes to increase. Therefore, there is no other method but to select an excavation/transfer/reburial method when a treatment method is actually applied.

This study did a basic research on the physical-chemical properties of the buried waste in Sindong Landfill, Asan-si, Chungchengnam-do, where its closing day came closer and a plan for reusing the landfill site through a biological pre-stabilization evaluation (BMP, AT_4). This study aimed to present the strategy direction that could handle landfill sites where the closing day came closer according to a rapid change in the paradigm of modern society.

EXPERIMENTAL

The study divided the landfill site in The Environmental Sanitation Management Center in Gochang-gun, Chellabuk-do into two places, the upper and lower part by the burial year to select samples. The study used an excavator and an auger crane to collect samples. The study analyzed the physical and

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chemical properties and the biodegradability of samples collected by place and location.

Physical component analysis: The study analyzed the apparent density, the physical composition and ternary mixtures according to the waste process testing method as the most important data useful to estimate the types and properties of buried waste through the calculation of heat value. The study made an elemental analysis on chemical components such as carbon, hydrogen, oxygen, sulphur and chlorine with an automatic elemental analyzer.

Theoretical amount of gas generation and accumulated gas generation: The study biologically analyzed elements of the composable organic waste and drew chemical formulas[4,5]. The study estimated the amount of the total digestion gas that could occur under an assumption that all organic matters might convert into carbon dioxide and methane, using the following formula (Buswell's equation).

$$C_nH_aO_bNCS_d + (n\text{-}a/4\text{-}b/2 + 7c/4 + d/2)H_2O \longrightarrow (n/2\text{-}a/8\text{+}b/4\text{-}3c/8\text{+}d/4)CO_2 + (n/2 + a/8\text{-}b/4\text{-}3c/8\text{-}d/4)CH_4 + cNH_4 + dH_2S$$

here, a, b, c and d have the following meaning: a = C content (%)/12, b =H content (%)/1, c = O content (%)/16 and d = S content (%)/32.

This formula is one that presents the correlation between the chemical composition of organic matters and the methane yield. The study substituted the data obtained after the elemental analysis of samples into the formula to calculate the theoretical gas generation. The methane yield is comparatively evaluated greatly in organic matters with the high mole content of carbon and hydrogen. It is known that there is a close relation between the oxygen and nitrogen component and the generation fraction of carbon dioxide among the chemical composition of organic matters. In term of the measurement of accumulated CH_4 gas generation, it is general that methane gas generation is marked as mL CH_4/gVS after the amount of methane gas that occurs per volatile solids (VS) of input waste.

Methane gas generation:

$$VCH_4\text{-}M_1(V_1+V_0)\text{-}M_0V_0$$

here, VCH_4: produced methane volume (mL), M_1: methane content (%) at sample time, M_0: methane content (%) at previous sampling time, V_1: biogas volumeme asured by syringe (mL), V_0: gas phasc volume of the reactor (mL).

Accumulated methane gas generation: VCH_4[STP L/g VS] = VCH_4 (measured at 35 ºC) * {273/(273 + 35} * {760-42.2)/760}

here, 42.2 is saturation vapour pressure (mmHg).

Culture media and seeding sludge: The study made up a medium for microorganisms for a BMP (Biochemical Methane Potential) test according to the method used by Shelton and Tiedje[6]. The study first made up 1 N NaOH, melted NaOH 40 g in distilled water and put it in a 1000 mL volume flask to fill it up to the marked line. The study melted 1 N HCl filled-HCl 36.5 g in distilled water and put it in a 1000 mL volume flask to fill it up to the marked line. Next, the study prepared culture media. Components and amounts used in preparation are shown in Table-1. The study concentrated a phosphate buffer solution and mineral nutriment 10 times to 1000 mL and micro-elements 1,000 times. As samples were not completely melted in making a medium, the study collected samples with a pipette to make a medium. The study mixed 1 mL micro-element in 100 mL phosphate buffer solution and mineral nutriment and put it in a 1000 mL volume flask to fill it up to the marked line with distilled water. Next, the study put a sterilized medium in a sample bottle to pressurize and sterilize it in a sterilizer for 10 min. The study collected seeding sludge needed to inoculate anaerobic microorganisms from an anaerobic bank installed at Asan-si Environmental Management Center and used filtrates filtered with a strainer several times.

TABLE-1
CHARACTERISTICS OF ANAEROBIC MEDIA FOR BIOCHEMICAL METHANE POTENTIAL TEST

Compound		Concentration (g/L)
Phosphate buffer	KH_2PO_4	0.27
	K_2HPO_4	0.35
Mineral salts	NH_4Cl	0.53
	$CaCl_2{\cdot}2H_2O$	0.075
	$MgCl_2{\cdot}6H_2O$	0.1
	$FeCl_2{\cdot}4H_2O$	0.02
Construction	$MnCl_2{\cdot}4H_2O$	0.0005
	H_3BO_3	0.00005
	$ZnCl_2$	0.00005
	$CuCl_2$	0.00003
	$NaMoO_4{\cdot}2H_2O$	0.00001
	$CoCl2{\cdot}6H_2O$	0.0005
	$NiCl_2{\cdot}6H_2O$	0.00005
	Na_2SeO_3	0.00005

Evaluation of the biodegradability of waste (Anaerobic BMP TEST): In the BMP test, the study injected anaerobic microorganisms and nutrients needed for the decomposition process in a serum bottle and identified gas generation and composition, keeping the optimal conditions such as temperature and pH. The study collected the samples of the buried waste at w-1 (upper and lower), w-2 (upper and lower) and w-3 (upper and lower) by place (within 2 m upper and 7 m lower part), autoclaved them at 105 ºC, chilled them and crushed them blow 10 mm. The study put nitrogen gas to remove oxygen in a sample bottle, made it in an anaerobic condition and put microorganisms and sludge at the rate of 1:10. The study first put 300 mL media, filled nitrogen gas and put 30 mL seeding sludge. After filling nitrogen gas again, the study put substrates (sample: 1.5 g VS/L). After filling nitrogen gas, the study adjusted pH with 1 N NaOH and 1 N HCl to set pH at 7. The study filled nitrogen gas again, put bicarbonate and capped it to supplement sufficiently in order to prevent the fall of pH. After capping, the study stuck a glass syringe into the sample bottle, using a three way cock. The study set up the temperature of the incubator at 35 ºC and cultivated them in the sample bottle. The study identified the gas generation with the glass syringe connected to the three way cock. The study collected 50 μL gas for a gas analysis, using a GC syringe and directly injected it into GC (GC : Agilent 7890 A GC Chemstation) to make a gas analysis. The analysis conditions of GC are shown in Table-2. Furthermore, the study confirm the result of each analysis, using 2.5, 5 and 10 % CH_4 standard gas (Fig. 1).

Evaluation of the biodegradability of waste (aerobic AT_4 test): The principle of AT_4 is to absorb carbon dioxide generated by aerobic microorganisms with soda lime and then to measure oxygen consumed by reduced pressure. Based on

TABLE-2
CONDITIONS OF GAS CHROMATOGRAPHY ANALYSIS

Component	Analysis method
Gas chromatography	Agilent 7890 A GC Chemstation
Detector	FID (Flame ionization detector)
Columns	HP capillary columns 30 m
Temperature	250 ºC
Pressure	10.3 Pa
Oven temperature	30 ºC
Quantity	50 µL

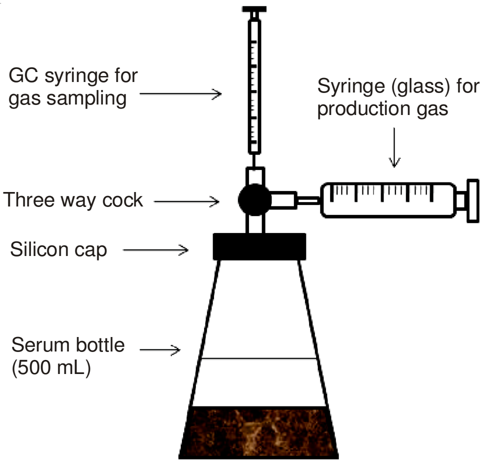

Fig. 1. Schematics of BMP test apparatus

this principle, the study carried out a test with Oxitop control OC110 of WTW in Germany and calculated the oxygen based on the respiratory quotient provided by WTW[7] (Fig. 2).

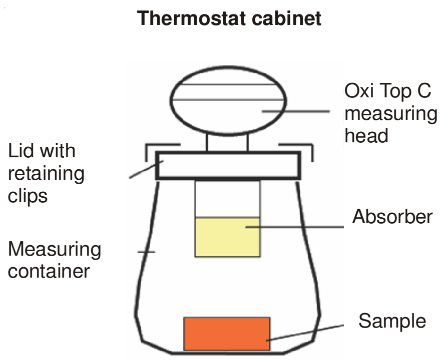

Fig. 2. Schematics of AT_4 test apparatus

The study dried collected samples at 105 ºC, crushed them into less than 10 mm pieces and saturated the water of 40 g samples up to 50-70 % of the maximum water holding capacity in an analysis instrument (1000 mL). The study put NaOH with an absorber, cultivated it in an incubator at 20 ºC and absorbed carbon dioxide generated by aerobic microorganisms for 4 days (96 h) to calculated the consumption rate of oxygen, caused by the pressure difference inside the bottle[8].

RESULTS AND DISCUSSION

Physical composition and ternary mixtures: The study measured the apparent density of waste with samples collected at a total of two places (upper and lower), using a 20 L container. The apparent density of waste is different according to the components, water, shape, or size of waste. It changes in accordance with the source or the season. Table-3 showed that the density is higher on the upper than on the lower part of Place A, whereas it is the same on the upper and lower part of Place B. The average apparent density is 0.47 kg/L.

TABLE-3
COMPARISON OF DENSITY CHARACTERISTICS
OF EXCAVATED WASTE IN S LANDFILL

	A Upper	A Lower	B Upper	B Lower	Average
Buil density (kg/L)	0.49	0.46	0.47	0.47	0.47

The physical composition is shown in Table-4. The plastic material was the highest among combustibles, followed by papers. The composition that exerted the biggest effect on the carbon content was plastic materials among elementary compositions[9]. Since they have difficulties in decomposition, plastic materials have the highest carbon content in spite of the waste buried for a long time. This is shown in Table-5. The content of food was considerably low compared with the food contend (20-30 %) of the general waste brought in. It was detected only at place lower A and there was no food at place upper A and place upper and lower B. This meant that the decomposition speed of food was much faster than one of organic matters. Moreover, the content of combustibles was considerably high. It was assumed that the content of plastics with slow decomposition speed was high in the composition of the existing waster brought into landfill S. The results of a ternary mixture analysis are shown in Table-6. Water is the highest at place upper A as 38.72 %, whereas it is the lowest at place lower B as 29.82 %. The reason was assumed that it had rained a few days before samples were collected.

Considering that combustibles were more than at other landfills, there might also be an effect caused by the sample collection method. This study collected samples by using an excavator and auger crane for this test. This study was able to collect buried waste evenly. But, the study identified that there was a low possibility of collecting buried waste intactly and lots of cover materials were come along when only an auger crane was used in collecting samples. At this part, it was considered that there had to be definite standards for sample collection.

BMP test: As shown in Table-7, the biodegradability of buried waste shows a low figure of 11 % on the whole. In particular, the biodegradability is 3.23 % at place lower B. The reason was that lots of organic matters decomposed by burial. It was judged that the organic matters in buried waste did not still reach a stabilized state, considering that methane occurred. It was judged that the stabilization method had to be preceded to reuse a landfill site. In general, if the biodegradability is less than 5-7 %, it is considered that the decomposition of organic matters is almost done. But, there is no clear standard.

AT_4 test: As a result of an AT_4 analysis, an evaluation method of the biodegradability in an aerobic condition, the oxygen consumption of buried waste was 5.45-19.76 mg O_2/g DM. The oxygen consumption rate at place lower A was the highest as 19.76 mg O_2/g DM. It was judged that this resulted from effects of the homogeneity of samples and the content of organic matters inside as in a BMP test. In consideration of the whole data trend, the oxygen consumption of the buried

TABLE-4
COMPARISON OF PHYSICAL CHARACTERISTICS OF EXCAVATED WASTE IN S LANDFILL

	Food	Paper	Wood	Plastic	Rubber/leather	Fiber	Metal	Glass	Gravel	Sand	Other	Total
A Upper	0.00	8.37	4.57	20.24	0.00	0.92	0.36	1.59	17.74	47.41	1.80	100
A Lower	0.38	2.55	1.95	21.61	0.81	4.23	0.27	1.47	6.84	57.22	2.66	100
B Upper	0.00	8.08	0.59	24.79	0.00	4.98	0.16	0.11	4.98	53.43	2.89	100
B Lower	0.00	2.96	1.67	26.94	0.05	2.26	0.16	0.32	4.41	60.75	0.48	100
Average	0.10	5.49	2.20	23.39	0.22	3.10	0.24	0.87	7.74	54.70	1.96	100

TABLE-5
COMPARISON OF CHEMICAL CHARACTERISTICS OF EXCAVATED WASTE IN S LANDFILL

	Chemical composition (weight ratio, %)						
	C	H	O	N	S	Cl	Ash
A Upper	43.89	5.81	33.54	0.02	0.15	0.24	16.36
A Lower	47.75	6.02	30.83	0.02	0.16	0.11	15.10
B Upper	45.24	5.59	32.39	0.01	0.10	0.10	16.58
B Lower	43.86	5.48	29.29	0.01	1.60	0.01	19.74
Average	45.05	6.06	32.99	0.44	0.01	0.42	16.95

TABLE-6
THREE COMPONENT ANALYSIS FOR EXCAVATED WASTE IN S LANDFILL

	Moisture	Combustible	Ash	Total
A Upper	38.72	51.26	10.02	100
A Lower	29.39	59.94	10.67	100
B Upper	32.51	56.30	11.19	100
B Lower	29.82	56.33	13.85	100
Average	32.61	55.96	11.43	100

TABLE-7
CUMULATIVE METHANE PRODUCTION FOR EXCAVATED WASTE IN S LANDFILL

	A Upper	A Lower	B Upper	B Lower
Cumulative gas (mL) (CH_4/g VS)	10.01	4.57	5.38	3.23
Biodegradability (%)	13.7	4.8	6.66	4.59

TABLE-8
CUMULATIVE O_2 UPTAKE (AT_4) OF WASTE IN S LANDFILL

	A Upper	A Lower	B Upper	B Lower
Waste	16.03	19.76	17.31	5.45

waste with less burial time was high and the oxygen consumption rate was measured a little higher on the lower part than on the upper part by place. But, the oxygen consumption rate was measured low at place lower B. The reason resulted from the activities of microorganisms and the homogeneity of samples. The oxygen consumption rate was measured to be less than 25 mg O_2/g DM, a pre-stabilization evaluation standard.

Conclusion

• As an analysis result of physical and chemical properties, there were lots of combustible contents (50 %) compared with the analysis result of the existing landfill (30 %). As an analysis result of ternary mixtures. The water content appeared to be higher on the upper part than on the lower part. The reason was considered that it had rained a few days before a sample was collected.

• The biodegradability of buried anaerobic (BMP TEST) waste was analyzed to be within 11 %. The generation of gas from samples stopped within 10 days. As a result of the aerobic evaluation (AT_4 test), the oxygen consumption of buried waste was 5.45-19.76 mg O_2/g DM and was measured less than 2525 mg O_2/g DM, a pre-stabilization evaluation standard at all the places where the sample had been collected.

• It seemed to be necessary to seek a plan for the reuse at landfill A by lowering the content of organic foreign materials less than 1 % through the secondary selection using the incineration treatment after drying for combustibles, the reburial for incombustibles and cleaning and wind power for sorting soil.

• This study secured basic data related to the reuse of landfill A. It was judged that the basic data secured through this study could be used as the basic data not only in a process design for the reuse of landfill A in the future and but also for an application and maintenance plan for landfills where the closing day would come closer.

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