Recycling of Greenhouse Gas and Odor Management in Landfills Near Urban Area

Eun Ji Woo, Ji Ye Yoo, and Chan Jin Park

***Abstract*—This study is to identify the greenhouse gases from landfill facilities and the characteristic of odor emission near urban area by selecting a representative landfill site that conforms with the conditions and by looking into related references, and aimed to seek for measures for conducting further research on the efficient management of landfill gas and odor control. Through the analysis of statistical data of landfill gas in recent years, the trend in generation and collection of landfill gas and current state of odor could be identified. Thus, this paper aims to find the relation between the landfill gas and odor as well as generation characteristic and then to be utilized for the research about efficient management method.**

***Index Terms*—Greenhouse gas, landfill, landfill gas, odor.**

I. Introduction

Wastes coming from many fields in contemporary world are being treated in various ways. Landfill takes high percentage among them and is responsible for numerous environmental issues. Landfill gas produced during anaerobic decomposition process mainly consists of methane and carbon dioxide. It is important in terms of not only environment management inside and outside the landfill but also global greenhouse gas. On the other hand, landfill gas is receiving more attention as the new renewable energy [1]. South Korea declared to reduce 30% of greenhouse gas emission compared to BAU until year 2020, in the Climate Change Convention 15th Conference of the Parties in 2009. Since 30% of total domestic greenhouse gas emission comes from landfills, it is increasingly important to manage landfill gas [2]. In addition, civil complaints from nearby region are constantly brought up due to the stench emitted during the incineration of landfill and from landfill gas. Thus, it is highly crucial to efficiently manage landfill including landfill gas and stench. Many researchers have conducted related studies, but the problem has not yet been solved. The difficulty seems to be due to the lack of related references, and because the exact cause cannot be discovered with the disclosed data. This research aims to complement these problems and utilize it for further research and the monitoring of landfill gas and stench from landfill.

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II. Methods and Contents

First, this study has selected it as a representative landfill area for investigation and research, occurrence characteristic of landfill gas and odor and condition of recycling of greenhouse gases in landfill gas investigation used the research with.

A. Condition of Present Domestic Landfill

There are 288 landfills in terms of domestic general waste treatment facility as in year 2012. Total landfill area is 46,968,000m^2, total landfill volume 587,066,000m^2, existing landfill volume 313,129,000m^2, and remaining landfill capacity 273,937,000m^2 [3]. It is estimated that the remaining landfill capacity has been decreased when putting into account the closed and to-be closed landfills.

Domestic general wastes amount was 382,009ton per day as in 2012 standard. Among them, landfill was 33,699ton per day, which is 9% of total wastes. The landfill amount has decreased compared to 42% ten years ago, in year 2002 [3], possibly due to reasons such as the implementation of volume-rate garbage disposal system, waste recycling, and reinforcement of allowed waste standard.

B. Current State of Landfill

Fig. 1. Location of Landfill Area.

K landfill is the biggest domestic landfill, of which waste from 58(city/district/borough) is carried in. Especially, it locates near the ocean and residential area, thus causing many civil complaints due to various problems shown in Fig. 1. Thus, this study has selected it as a representative landfill area for investigation and research. Currently, K landfill site consists of total four landfills. Total area including other landfill sites is 161,830,000m^2 [3]. Among these, landfill site 1 has started in 1992, and ended its operation in 2000, and ex post facto management is underway, constructing various sports facilities and botanic park. Since the close of first landfill site in October 2000, waste is buried in second landfill site, which is expected to be closed in this year.

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C. Occurrence Characteristic of Landfill Gas

Landfill gas generally occurs as landfilled waste goes under anaerobic decomposition. In general, the occurrence of landfill gas can be divided into five stages as in Fig. 2. The first stage is the anaerobic state of the first decomposition, which doesn't generate much methane. The second stage is the anaerobic state where most carbon dioxide is generated. The third stage is the anaerobic state during which carbon dioxide decreases and methane begins to be produced. The fourth stage is the normal condition with the highest methane concentration. In the last stage, anaerobic decomposition gradually decreases, and the landfill stabilizes. In this fifth stage, nitrogen concentration slowly increases. Most landfill becomes the methane-generating stage within two years of waste landfill. Elements such as waste composition, moisture content, temperature, pH, and nutriments affect the generation amount and pace of landfill gas [4]. Generated landfill gas mainly consists of methane and carbon dioxide which are the main components of greenhouse gas, thus needs proper management. Meanwhile, methane is receiving attention as bio-gas [1], thus is being collected and withdrew for the use of recycled resource. On the other hand, carbon dioxide is not being used, since while it is generated the most among the greenhouse gases, greenhouse index is very low compared to methane, and is easy to be circulated and reutilized in nature. However, in the time when the greenhouse gas problem is becoming an issue, measures to reduce and recycle carbon dioxide is needed.

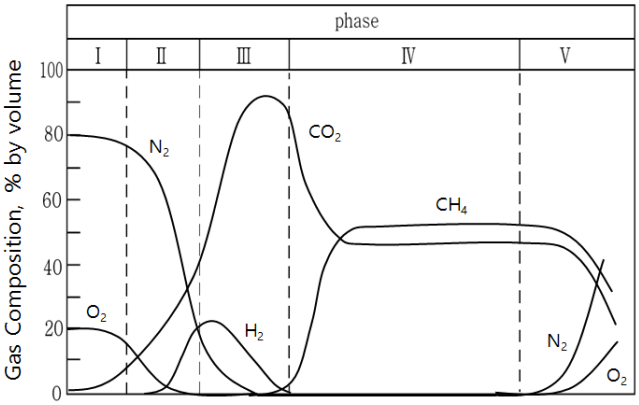

Fig. 2. The change in composition of Landfill gas due to phase decomposition of waste. (Source: Tchobanoglous *et al*, *Integrated Solid Waste Management*, McGraw-Hill Inc., 1993, p. 385).

D. Current State of Landfill Gas Amount

This study researched the state of the amount of landfill gas of the biggest domestic landfill K according to the main emission route. The collected landfill gas amount of landfill site 1 was 58,991,940m^3 per year in year 1997, 213,506,030 m^3 per year in year 2000 when the landfill was closed, and tended to decrease constantly afterwards [5]. This seems to show the stabilizing state after ten years of the close of the landfill.

Progress of collected landfill gas in landfill site 2 was 33,276,650m^2 per year in 2002, and tended to steadily increase since then. Since 2007, the collected amount has increased due to the expansion of landfill amount and collected region. In addition, there is a tendency to decrease after the big increase of collected amount in 2012 due to the replacement from landfill collection and transferring pipe [5], [6]. This seems to be related to the overall decrease of the amount of the brought-in waste. [Fig. 3]

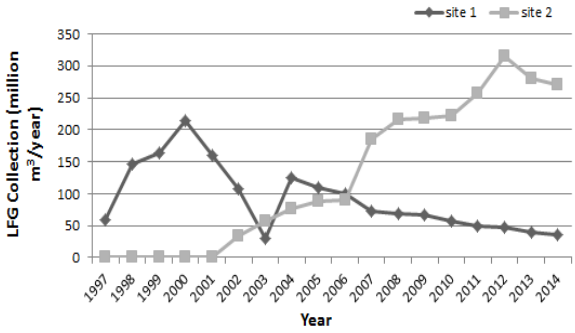

Fig. 3 Trend in LFG collection of Landfill Site.

E. Characteristic of Landfill Gas Classified by Waste Description

Landfill Site 1 of K landfill site has started since 1992. In the early phase, food waste, among household waste, accounted for 30% of total waste. Meanwhile, landfill site 2 had high rate of paper and plastic waste [6]. The reason behind it was that the direct-landfill of food waste was prohibited after the need of the solution to improve the problem caused during treatment of food waste in other landfill facility was brought up. Moreover, it seems that the landfill of food waste has decreased due to the effort to recycle food waste using its properties.

According to what have been describe above, it seems that the generated amount of landfill gas of landfill site 1 and landfill site 2 would be different according to the different waste description between the both. Food waste has different description and content according to discharged source, and has high possibility of decomposition for the high moisture content [7], thus contributed more in generating more landfill gas and odor. However, upon examination of years of data, the description of landfill gas of the two landfills showed natural results of methane (CH_4) > Carbon Dioxide (CO_2). The generated amount did not showed big difference as well. [Fig. 4], [Fig. 5].

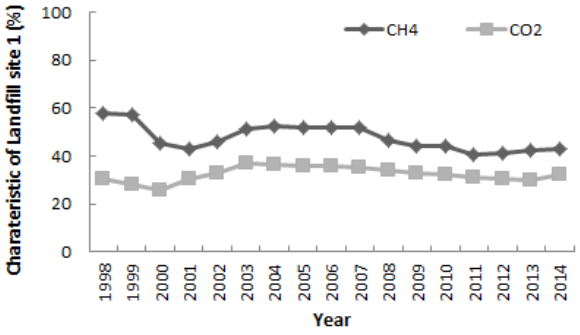

Fig. 4. Trend LFG characteristics of Landfill site 1.

It is estimated that methane (CH_4) generation is different according to waste description, but it is difficult to calculate it in this country. There is not enough landfill data according to waste description, and it is hard to estimate due to the long period of operation over 10 years and high cost, taking the half-period of description into account [8]. In this aspect, no definite conclusion of the relation between landfill rate

according to waste description and the generated amount of landfill gas was drawn. Therefore, further research and investigation is required in order to confirm the relation between the two factors.

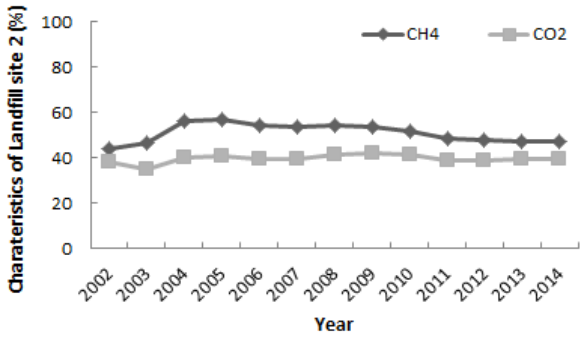

Fig. 5. Trend LFG characteristics of Landfill site 2. (Source*: SL Corp, Landfill gas generation monitoring and characteristic analysis of SUDOKWON Landfill Site*, SUDOKWON-Landfill Site Management Corporation, 2014).

F. Current State of Odor Occurrence in Landfills

It is inevitable that odor comes out from landfill as the waste goes under anaerobic decomposition. Meanwhile, odor management is needed due to increasing related civil complaints as residential area near landfill K is expanding. There are various reasons behind why odor is being emitted. In case where gas is being generated due to waste landfill, landfill gas is collected and incinerated, or is recycled to be used in electricity generation and fuel. During this process, gas escaped to the air due to insufficient sealing function could be the cause of stench. In addition, gas released from surface area and from cracked parts, and odor emitted from leachate treatment facility, drumming room, and sludge recycling facility could be the cause [9]. Moreover, there are all sorts of industrial complex and basic environment treatment facility near landfill which could affect the emittance of odor.

In fact, according to a report, facilities near landfill were emitting stench, and particularly mixed odor from landfill site 2 which is now under operation has exceeded 1.4 times the legal standard, and hydrogen sulfide, which is the main odor-emitting substance, has exceeded 16 times the standard. Moreover, some of other landfill facilities have exceeded the legal standard as well [10]. Generally, landfills are covered up in the middle of and at the last stage of landfill due to reasons such as reduction of odor emittance, prevention of leachate and various pathogenic bacteria. In this aspect, land covering rule is highly important. However, it has been reported occasionally that untreated landfill gas with highly concentrated odor had released into the air because of cracks or holes made due to improper covering of land [11]. For the time being, carrying out optimum covering of land could solve the problem, but rule improvement regarding ways of covering, and development and supplementation of land-covering material is also required.

In addition, there is a research stating that during the process of collecting and recycling the landfill gas, gas composed of odorous constituent also gets collected, thus leading to the odor reduction effect [12].

As residential and industrial area near landfills are increasing, civil complaints regarding stench are also on the rise, and effort to surveil and control this is continuously on its way. Furthermore, local governments are measuring real-time stench, but monthly, yearly data other than real-time data lack, thus it is hard to check on the amount and description of odor. According to some material disclosed from landfill K and other research papers, concentration of odor-inducing substance was on the tendency to decrease. Although the exact cause cannot be known due to the absence of detailed data, the fact that the collection of landfill gas efficiency has risen from 7% to 30% thanks to the improvement gas-collecting facility is considered as one of the reason behind the decrease of odor.

For the management of landfill gas and odor from landfill henceforth, constant monitoring for building precise data is needed. Moreover, plan to research to control odor from various cause other than landfill is underway.

G. Ex Post Facto Management and Utilization of Domestic and Overseas Landfills

Waste treatment from various fields is still a problem around the world. Landfill is one of them, and the need to efficiently manage it is being raised. Thus, this paper attempts to find proper management measures by comparing ex post facto management and utilization of landfills in developed countries and domestic landfills.

Closed landfills could sufficiently be reused if ex post facto management is properly implemented, therefore in most countries lands which were once landfills are used as parks for its citizens. Developed countries utilization of closed landfills includes golf course, park, living space, and sports complex [13]. Domestically, the whole landfill N has turned into park, and landfill site 1 of landfill K site is under construction of sports facility [Table I].

TABLE I: CASE OF LANDFILL USE IN EACH COUNTRY

Country	***Title of Landfill***	***Case***
America and Canada	A Landfill etc.	Golf course, Park, living space
The United Kingdom	B Landfill	Park, Business space
	E Area	Eco-friendly city
Germany	D Landfill etc.	Indoor skiing park, living space
Australia	H Area	Sports facility
Japan	J Landfill etc.	Golf course, youth training center, park etc.
Korea	K Landfill (Site 1)	Sports facility
	S Landfill	Park

Closed landfills are being utilized in similar ways inside and outside the country. On the other hand, due to the differing aspect of the amount and characteristic of landfill gas, there was a difference in ex post facto management ways. Odor was rarely emitted in country D, and the collection rate of landfill gas in country C was extremely low. Reasons behind this are estimated to be the differing characteristic of odor emittance according to different waste description rate and landfill measures from country to country.

Although domestic landfills are under good management, more efficient management of landfill by implementing other countries' excellent cases could be effective in decreasing

greenhouse gases and civil complaints from odor.

H. CDM Business of Landfills

CDM business refers to Clean Development Mechanism, which is one of the mechanisms of Kyoto Protocol adopted in the third Conference of the Parties of Climatic Change Convention, and is an institution carried by both the developed and developing countries to alleviate global warming by reducing greenhouse gas.

It is to include to the reduction goal of developed countries the reduced amount of greenhouse gas, of which is achieved in result of greenhouse gas reduction business the developed countries with reduction goals has run by investing capital and technology in developing countries with no reduction goal. The target is subdivided into 15 fields which discharge 6 kinds of greenhouse gas including carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFC), perfluorocarbon (PFC), and sulfur hexafluoride (SF_6).

TABLE II: DOMESTIC LANDFILLS CDM PROJECT

Landfill	Capacity	type	Start date
S	6.5MW	Gas Engine	'01. Dec
	3.38MW	Gas Engine	'03. Mar
	50MW	Steam Turbine	'06. Dec
B	5MW	Gas Engine	'01. Jul
P	2MW	Gas Engine	'02. May
D1	1.5MW 130Nm3/min Middle grade gas production	Gas Engine	'05
D2	3.4MW	Gas Engine	'03. Jul
K	1MW	Gas Engine	'02. Dec
G	2MW	Gas Engine	'03. Dec
J	2MW	Gas Engine	'03. Apr
C	1MW	Gas engine	'04. Feb
Y	1MW	Gas Engine	'04. Aug
M	1.5MW	Gas Engine	'05

<Source: *UNFCCC*>

Domestic greenhouse gas emission consists of total 688.3 million ton of CO_2eq, among which waste consists of 14.8 million ton of CO_2eq by 2012 level, thus the need for a measure to decrease greenhouse gas from landfill was brought up. CDM business centered in landfill mainly aims to recycle landfill gas. Existing landfill gas treatment only focused in the simple incineration. As the business for utilizing landfill gas from landfill N, which had closed in 1990s, was propelled, research activities regarding the utilization of landfill gas have been actively underway since the mid1990s, with the Ministry of Environment on its lead [14]. As a result, plan to enhance the efficiency of collecting landfill gas generated from landfill site 1, 2 of landfill site K, and to reduce greenhouse gas by recycling and appropriately handling the collected landfill gas was established. It was carried forward with two stages in total; the first business was finished as business registration to UNFCCC was completed by planning CDM business of recycling landfill gas in 2005. Currently, second stage business is underway, of which the name of the business is 'development business of landfill gas from landfill K. Period of business is from April 30th 2007 to April 29th 2017, total time span of ten years [14], [15].

In landfill where landfill gas is being recycled, collected landfill gas is transferred to landfill gas control center and needless gas is incinerated, and reusable landfill gas is used as electric generator fuel in power plant of 50MW or as boiler fuel for leachate treatment plant administration building [15]. Following is the chart of CDM business being implemented in other domestic landfills as in Table II.

Currently in the capital area, there is one power production facility of 50MW to recycle landfill gas as a part of CDM business, which started to operate since 2007 until now in collecting and generating from landfill gas. Looking into landfill gas collection and utilization state classified by landfills from 1997 to 2014 [15], all collected landfill gas was incinerated from 1997 to 2000, but since then with the installation of power production facility, the rate of power generation from collected landfill gas has been on the steady increase. Meanwhile, the progress of the last 5 years of power generation from landfill gas is on the decrease, which seems to because of the change in the incineration and generation amount by the overall decrease in landfill gas, due to the reduction of collected landfill gas of stabilized landfill site 1, and the reduction of waste brought in because of various waste treatment policies. [Table III].

TABLE III: STATUS OF LFG POWER GENERATION

Year	*Generation*	*Sale*	*Use*
2007	222,229	197,354	24,875
2008	397,862	357,529	40,333
2009	402,967	363,259	39,708
2010	380,959	343,570	37,389
2011	397,795	358,673	39,122
2012	382,131	344,467	37,664
2013	290,839	256,835	34,004
2014	243,246	205,961	37,285

(Source: SL Corp, *SUDOKWON Landfill Statistics Yearbook*, Vol.13, 2015, SUDOKWON Landfill Site Management Corporation, Resource Recovery Business Division)

III. RESULTS

When looking into the research which is about the landfill gas and the odor characteristics of a landfill selected as a representative, ended landfill site1 showed a tendency to reduce the amount of landfill gas capture more and more. And landfill site2 showed a steady increase in the amount of collected landfill gas which is being used. On the other hand, reclamation is ongoing in the landfill site 2, and it is shown that the landfill gas will be collected continuously from the point when the reclamation ends to the point of the stage of stabilization. In addition, the components of captured landfill gas mostly consist of methane and carbon dioxide, in which the amount of methane was more than that of carbon dioxide. However, there were no significant difference in the emissions of methane and carbon dioxide of site 1 and site 2.

The odors from the landfill were caused by a number of complex factors such as leachate treatment plants, sludge recycling facilities, waste incineration process and the surrounding industrial areas. Through lots of investigation, it is shown that odor problems has been decreased than in the past, but there is no accurate data demonstrating the cause of the decrease. Therefore, the research about this area will be conducted more and more.

Since Methane and carbon dioxide of landfill gas are

greenhouse gas, they are recycled through resource recovery plants.

CDM projects are a major recycling business. In particular, the selected landfill has a 50MW generation facility which is the largest in the country. In particular, the selected landfill has a 50MW generation facility which is the largest in the country. In addition to this, there are other 10 places installed that have 1~5MW of generation facility. Through these facilities, landfill gases are recycled.

IV. Conclusions

This study wanted to investigate the current state of landfill gas and odor characteristics that occur in urban areas and landfills. Also, it wanted the occurrence characteristics and trends of greenhouse gases, methane and carbon dioxide, which are the main components of landfill gas. Therefore, based on previous research it conducted a. Although the investigation as representative selected the landfill's reclamation Characteristics and is available for easy data capture and emissions are steadily since the start of the measurement of landfill gas from showed with respect to the generation and collection capacity trends, Characteristics of landfill gas. We investigated the landfill which is selected for the research. Through the investigation, it was easy to find the trend and the type of the landfill gas because the type, the collection and the emission of the landfill gas were measured steadily. However, this data was so deficient that it was difficult to study the characteristics of the type of the landfill gas. And the data about the cause of the odor was comparatively deficient. There will be some difficulties on managing and studying odors because there are lots of things to be considered such as the state of the weather and the difference of the degree how people feel the odors. Therefore, future studies of the odor characteristics will be focused on managing and reducing the odors, and also focused on providing alternatives.

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