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Enhanced methane recovery by food waste leachate injection into a landfill in Korea

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ABSTRACT

The current food waste leachate (FWL) disposal practice in Korea warrants urgent attention and necessary action to develop an innovative and sustainable disposal strategy, which is both environmentally friendly and economically beneficial. In this study, methane production by FWL injection into a municipal solid waste landfill with landfill gas (LFG) recovery facility was evaluated for a period of more than 4 months. With the target of recovering LFG with methane content ~50%, optimum LFG extraction rate was decided by a trial and error approach during the field investigation in five different phases. The results showed that, upon FWL injection, LFG extraction rate of ~20 m^3/h was reasonable to recover LFG with methane content ~58%. Considering the estimated methane production potential of 31.7 m^3 CH_4 per ton of FWL, methane recovery from the landfill was enhanced by 14%. The scientific findings of this short-term investigation indicates that FWL can be injected into the existing sanitary landfills to tackle the present issue and such landfills with efficient liner and gas collection facility can be utilized as absolute and sustainable environmental infrastructures.

1. Introduction

Consequent upon the adoption of strict food waste management policies in Korea in 1997 and prohibition of direct disposal in landfills from 2005, food waste recycling facilities were installed throughout the country to produce various useful resources such as feedstock for animals, fertilizer to be used on agricultural lands etc. In reality, however, 70–90% of the food waste treated in such facilities is resulting in a dense, malodorous liquid called food waste leachate (FWL), which is eventually discharged to the ocean (Behera et al., 2010). Additional details pertaining to FWL is mentioned elsewhere (Lee et al., 2009). According to the London dumping convention and inter-governmental treaties, the marine disposal of organic sludge including FWL will be prohibited in Korea from 2012 (Ohm et al., 2009). Thus, the present situation warrants finding an environmentally friendly yet economically beneficial approach to address the problem from a sustainability view point.

The conventional 'dry tomb' approach of dumping the municipal solid wastes (MSW) in landfill sites is primarily aimed at reducing the environmental risks by minimizing landfill leachate (LFL) generation and landfill gas (LFG) emission. Though the liner system, LFL collection and treatment systems and LFG collection and management systems have been strengthened in the recent years, the inertial 'dry tomb' approach still appears to be a global trend. On the other hand, due to low water content of MSW inside landfill, biological activity decreases and stabilization of wastes is extended. Consequently, monitoring of LFG emission and leachate generation is required for a very long period of time even after closure of the site, which is against the concept of sustainability (Zhao et al., 2008; Benson et al., 2007; Valencia et al., 2009; Benbelkacem et al., 2010).

Table 1 shows that the disposal of wastes in the city of Ulsan, South Korea has started reducing from the year 2000 due to the integrated solid waste management measures taken toward vigorous recycling of wastes. Particularly, due to the installation and operation of food waste recycling facility in 2004, landfilling of food wastes came to an end resulting in the reduction of LFG production (Fig. 1). This could be the reason why over 50% of landfills with LFG recovery facility in Korea are suffering from reduced LFG production (Lee et al., 2009). The development of this adverse situation might be attributed to the waste management policy adopted in Korea that was not harmonized with the technological advancement in the area of landfill management.

In order to accelerate the stabilization of wastes, landfills should be designed and operated in a different manner which can establish favorable conditions for biodegradation. In this

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Table 1
MSW types and their quantities during filling in landfill site.[a]

Year	MSW (ton/yr)							
	Organic						Inorganic	Total
	Food and vegetable	Paper	Wood	Rubber and leather	Plastics	Miscellaneous		
1997	73,535	44,899	13,053	6727	14,935	27,526	40,442	221,117
1998	71,066	38,362	18,834	8213	13,104	23,652	59,532	232,761
1999	67,270	50,699	25,550	11,607	14,454	30,697	56,466	256,741
2000	37,267	22,594	15,586	7264	10,111	11,206	100,120	204,145
2001	21,703	18,250	15,175	2168	5546	10,158	40,880	113,880
2002	16,412	12,534	9617	1228	5720	9348	59,860	114,720
2003	8963	10,288	8241	2047	3836	20,645	55,480	109,500
2004	0	16,646	11,219	3132	7904	13,623	50,735	103,259
2005	0	13,213	6607	3249	10,585	13,432	55,298	102,383
2006	0	7348	2475	2707	8778	10,557	39,822	71,686
2007	1,716[b]	12,118	2847	2555	9563	6169	30,624	65,591
2008	0	12,739	694	1570	5913	11,388	19,090	51,392

[a] Environment white book, Ulsan Metropolitan city, 2009.
[b] Illegal food waste disposal along with other wastes.

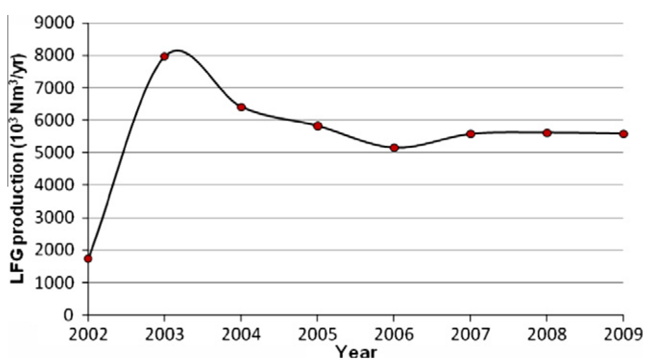

Fig. 1. LFG production profile of the selected landfill site.

context, the bioreactor landfill approach insists on controlling the moisture mostly through the recirculation of the landfill leachate (LFL) generated. Increasing the moisture content and flux through the landfill creates favorable environment for microbiological processes and organic matter decomposition (Leckie et al., 1979; Ham and Booker, 1982). The recirculation of LFL or liquid addition not only decreases the life of landfill by accelerated decomposition of MSW, resulting in enhanced LFG production and quicker waste stabilization (see for example, Warith et al., 2001; Khire and Mukherjee, 2007), but also reduces the long-term aftercare burden on future generations. Though this idea was conveyed long time back, the 'dry tomb' concept is still preferred and promoted by the regulations in many of the developed and developing countries. Nevertheless, in the past few years the idea of utilizing non-hazardous liquid organic wastes in the landfills, to be used as bioreactors, for accelerated biodegradation and enhanced LFG production has again resurfaced for the development of landfill sustainability (Behera et al., 2010).

Our previous works (Lee et al., 2009; Behera et al., 2010) shows that FWL, being a mechanically treated food waste, is highly biodegradable. Hence, injection of FWL to the existing landfill sites, with efficient LFG recovery and LFL collection facilities, may supplement the required organics and other nutrients to accelerate biological decomposition of wastes and maintain a continual biogas production. Besides, the landfill sites with efficient LFL collection systems and LFG recovery facilities can represent a perfect low-cost solution for liquid organic waste generators. Anew, liquid organic wastes with similar characteristics as that of FWL may also be accepted at landfills and put to beneficial use. Furthermore, the recent concerns of global warming related to methane have led to considerable interest in controlling LFG emission into the atmosphere (Perera et al., 2002). Thus, introduction of active LFG recovery systems would enable high methane recovery rate that would ultimately limit the environmental impact of landfills by reduced greenhouse gas emissions.

This paper presents results from the field study carried out for more than 4 months investigating the performance of the landfill with regard to methane recovery enhancement through FWL injection. Field investigation results are compared with our previous work in a simulated laboratory-scale landfill and percentage enhanced methane recovery was estimated as a result of FWL injection to the landfill. Given the relatively short time period over which this field study was performed, the findings from this study do not necessarily reflect long-term conditions and deserves further investigation in the field.

2. Materials and methods

2.1. Landfill site

The city of Ulsan is located in the south-eastern part (35°28′13″ N and 129°33′36″ E) of South Korea. The landfill site under study in Ulsan was opened in 1994 and has a surface area of approximately 135,000 m^2. It is expected to be filled up in the year 2014 with a total amount of 4070,000 ton of waste. The different types of waste and their quantities in each year are shown in Table 1. The biogas recovery system installed in the landfill site is composed of 49 gas wells. A total of five test wells (Nos. 3, 12, 17, 23, and 46) are used in this investigation for LFG extraction (Fig. 2). LFL collected on site is treated in the leachate treatment facility and subsequently passed onto the municipal waste water treatment facility for further treatment. The average temperature at Ulsan is 14.6 °C. Total annual precipitation is 1342.2 mm including a total snowfall of 35 mm. The average temperatures are 4.0, 13.8, 23.2, and 16 °C for winter, spring, summer, and fall, respectively. The average low temperature in winter is −4.0 °C and the high temperature in summer is 28.4 °C.

2.2. FWL injection

As liquid waste disposal in landfill sites is prohibited in Korea, this particular field-scale investigation of FWL injection into landfill was carried out upon special permission from the Ministry of Environment, Korea. FWL was collected from Sung-am food waste resource recovery plant in Ulsan, Korea. It had average total solid