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# Suggestions for the Estimation of the Methane Emission from a Landfill Site

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**Abstract** : Sudokwon landfill("Sudokwon" means regions of Seoul, Kyunggi and Incheon metropolitan cities in Korea), the world's largest sanitary landfill, has been systematically managing statistics on the incoming and dumping wastes and satisfactorily controlling pollutants including leachate and LFG. According to our long time experience of LFG field monitoring, the emission of GHG from landfill estimated by the IPCC Guideline showed much difference with our results. C&D waste has high concentration of sulfate compared to other wastes. Increased C&D waste of dumping waste had changed the COD/sulfate ratio in the landfill, which caused the increase of $H_2S$ gas and the decrease of $CH_4$ gas. But the IPCC estimation method does not consider the effects of sulfate. In addition to that, the oxidation factor of the cover soil is set to the default values of 0.1 but the measured values by the field monitoring, are showing much higher than that, especially in the closed landfill.

**Key Words**: Landfill, methane emission, IPCC guideline, oidation factor

## 1. Introduction

### 1.1 Research Background and Purpose

For the reduction of Green House Gas(GHG), Korean government are operating Emission Trading System(ETS). One of the features in Korea unlike EU is that the ETS includes Solid Waste Disposal Sites(SWDS). The estimation of the GHG emission from SWDS has high an uncertainty, which could cause disturbance in operating the ETS. But, Korean government might have thought that there should be no exception for the soft landing of ETS in Korea. The estimation of GHG emission from landfill is based on the 2006 IPCC Guideline and 1 $tCO_2$ has been exchanging at about 19 ~ 20$ in the ETS market.

Sudokwon landfill is one of the world largest and has been managed well. It also has been running 50MW generator for the proper use and reduction of GHG. Recently, managing odor has become a main issue as the residence facilities are approaching to the landfill site. But, according to the estimation method based on 2006 IPCC guideline, about 50% of LFG generated from Sudokwon landfill is being released into the air. If it is true, there should be enormous complaints from residences against odor but there is no. On the contrary, Sudokwon landfill has been monitoring GHG emission using flux chamber since 2005. According to the results, much less is being emitted from landfill, indicating some default values of IPCC Guideline is not appropriate to apply for wastes in Korea. The amount of GHG emission from landfill should be accurate for the proper managing landfill as a source of GHG. In this study, we would like to suggest some findings to advance the IPCC method for the better estimation from our long experiences and accumulated data on field monitoring.

## 2. Estimation Method for $CH_4$ emission from SWDS

The $CH_4$ emissions from solid waste disposal for a single year are estimated using Equation 1(IPCC, 2006). $CH_4$ is generated as a result of

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degradation of organic material under anaerobic conditions. Part of the $CH_4$ generated can be recovered for energy or flaring and oxidized in the cover of the SWDS.

$$CH_4 \text{ Emissions} = [\Sigma CH_{4\ \text{generated}\ T} - R_T] \cdot (1-OX_T) \quad (1)$$

$$CH_{4\ \text{generated}\ T} = DDOC_m \cdot F \cdot 16/12 \quad (2)$$

Where, T = inventory year,

$R_T$ = recovered $CH_4$ in year T

$OX_T$=oxidation factor in year T

$DDOC_m$=$DDOC_m$ decomposed in year T

The $CH_4$ generation from the waste will decrease gradually by the First Order Decay(FOD) equation. FOD equation is built on an exponential factor that describes the fraction of degradable material is degraded into $CH_4$ in each year. Generation potential and the fraction of degradable material of waste are different in types of waste and regions. Values of generation potential($L_0$) and generation rate(k) regarding wastes are usually got from Biological Methane Potential(BMP) tests.

## 3. Problems of estimation method

According to the results and long experiences of the field monitoring by Sudokwon landfill, the above estimation method based on IPCC guideline has following problems.

### 3.1 Uncertainty of emission factor($L_0$, k)

Fig. 1 and 2 are showing the results of BMP test for food and paper(SLC, 2004). As shown in the figures, results have shown different values though they used same waste and followed same method. This means that biological reactions are very sensitive to its decomposition conditions. IPCC guideline suggested default values of generation potential($L_0$) and generation rate(k) if there are no country or site specific data. But the default values are showing much differences compared to values of field monitorings.

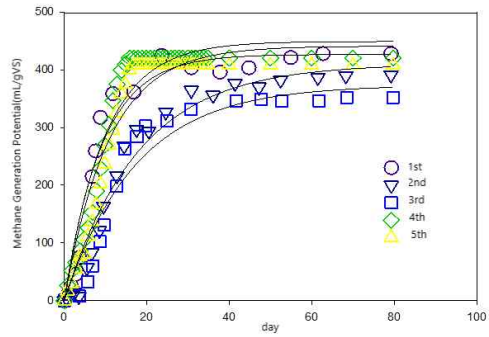


Figure 2. BMP results of foods

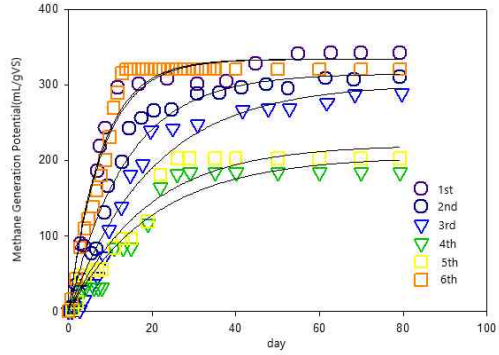


Figure 3. BMP results of papers

As mentioned above, the key parameters for $CH_4$ generation, such as $L_o$ and k, are theoretic values, representing the generation potential and rate obtained from the optimal degradation condition. But, landfill site is not optimal condition for degradation and not all the waste is decomposed. Fig. 3 shows non-decomposed wastes over 20 years after dumping. Some wastes in the landfill are not decomposed under certain conditions though it is anaerobic. The method overestimates $CH_4$ generation when the site have these conditions shown in Fig. 3.

Figure 4. Non-degraded waste

The amounts of $CH_4$ generation had been measured using 5 large scale lysimeters, which their diameter and height are 1m and 3m, respectively, and their waste composition and decomposition conditions were set same over 4 years(Lee, 2009). Fig. 4 is showing the generations of estimated and measured CH4 from 5 lysimeters. All the measured generations were much lower than the estimated one though they were under similar conditions.

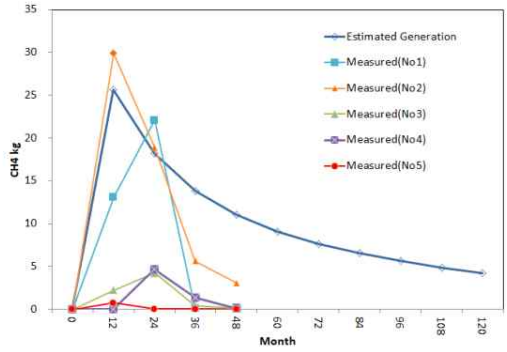


Figure 5. CH4 amounts from similar conditions

### 3.2 Influence of sulfate

There have been many reports(EREF, 2010) of odors in Construction & Demolition(C&D) waste landfills. C&D wastes contain much sulfate compared to Municipal Solid Waste (Jang 2001), which consumes organics in anaerobic condition and produces H2S, a major source of odor. Microbes associated with the production of $H_2S$, called Sulfate Reduction Bacteria(SRB), compete with Methane Production Bacteria(MPB) for organic matter as substrates in the presence of sulfate. In this process, the ratio of COD/Sulfate is very important. When the ratio is high, the decomposition rate of the organic matter and sulfate to the gas phase increases. Conversely, when the ratio is low, the gas phase ratio decreases and the ratio of the two leached liquid phases increases(Isa 1986; Hu 2015)).

High concentration of sulfate could lower the activity of MPB(Speece 1983). $H_2S$ has strong toxicity and its low concentration could interfere the activity of MPB and SRB(Kroiss 1983). From the above reasons, IPCC guideline on agriculture stated that sulfate containing amendments can significantly influence $CH_4$ emission(Bachelet 1992).

Fig. 5~7 are statistics data of Sudokwon landfill(SLC 2018). In Fig. 5, the amounts of C&D waste has been increased compared to MSW. C&D waste contains much sulfate than MSW, causing the change of leachate characteristics shown in Fig. 6 and LFG compositons in Fig. 7. These results indicate that the estimation of CH4 from SWDS needs to consider sulfate effects as did agriculture(IPCC 2006).

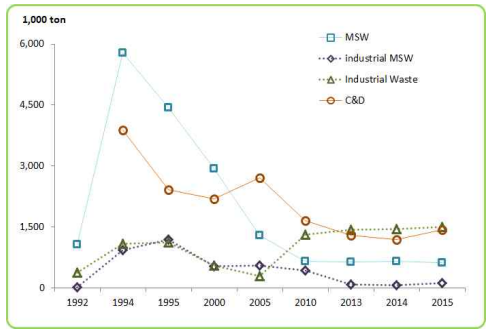


Figure 5. Increase of C&D waste ratio

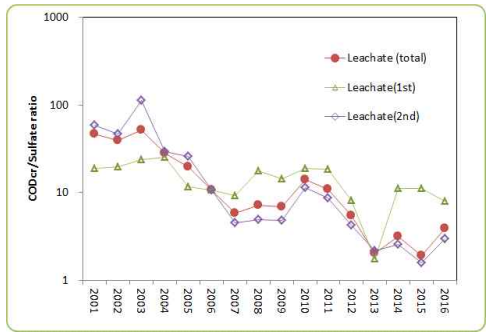


Figure 6. COD/sulfate ratio in leachate


Figure 7. Increase in H2S ratio in LFG

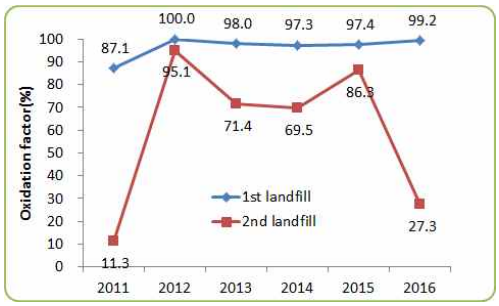


Figure 8. Oxidation factor measured

### 3.3 Oxidation factor(OX)

The oxidation factor of cover soil is different from sites and can be measured by experiment. IPCC guideline indicates that direct measurement of SWDS is undesirable for reasons of high uncertainty of monitoring method. And the oxidation factor is set to a default value of 0.1.

Sudokwon landfill has two sites. The 1st landfill had been completed in 2000 and has been used as a golf course after the final cover. The final cover layer consists of barrier layer 0.45 m, vegetation layer 0.6 m, and gulf course mounding. The 2nd landfill has been used since 2000 and is divided into 24 cells. Except for 3 or 4 operating cells, the middle layer has 0.5 m thickness. $CH_4$ emissions using flux chamber method have been monitored since 2005. Fig. 8 shows oxidation factor(%) measured by flux chamber method. Though there were much fluctuation in the 2nd landfill, the oxidation factor of the 1st and the 2nd landfill, are showing about 99% and 20% in 2016, respectively, much higher than the default value of 0.1. When the default value is applied to the oxidation factor, the emission would be overestimated

## 4. Conclusions

Sudokwon landfill has been systematically managing with waste, leachate and landfill gas and has long and reliable data on GHG emission obtained from the field monitoring. According to our reliable data and long experiences, the followings should be reflected in the IPCC guideline for the better estimation of emission.

There is big uncertainty of GHG generation by the biological reaction of landfill, In addition to that, $H_2S$ generation also affects $CH_4$ generation by consuming the organic matter and $H_2S$ gas and high concentration of sulfate are reported to be toxic to microorganisms and inhibit methane production. But it still is difficult to quantify these effects, there should be more research for that.

The oxidation factor of cover layer in the IPCC guideline, is given as a default value of 0.1. But the measured values of the Sudokwon landfill were much higher than the default value, indicating that there should be more options for the factor according to the types of landfill.

In case of Sudokwon landfill, much fluctuation of the oxidation factor were seen in the 2nd landfill, which is the uncertainty of the monitoring method using the chamber showing in most landfill. So, there should be technological advances on direct measurement method as the current estimation method has limitation.

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