

# Discuss on the design of MSW landfill gas collection project

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## Abstract

Landfill gas (LFG) is the gas generated by waste anaerobic process in landfill, LFG consists of  $\text{CH}_4$  ,  $\text{CO}_2$  (more than 98% in volume ) and other gases (little bit). LFG is a pollutant and dangers gas for a landfill, and also is a energy. Effectively leading, collecting and using the landfill gas not only can avoid the pollution and explosion, but also can get benefit from gas utilization. The way of LFG quantity estimating and engineering design of collecting facilities will be discussed in this paper. Some suggestion and conclusion that should be considered on design are submitted.

**Key word:** landfill landfill gas(LFG) emission rate collection and guide

## 1 Summary

Landfill gas is the one of the main contamination and explosive danger for a MSW landfill, and it also is an energy. Effectively leading, collecting and using the landfill gas not only can avoid the pollution and explosion, but also can get benefit from gas utilization. About 80% of waste is treated by landfill in China now, but LFG facilities are very simple and not accord with the criterion. The LFG system and facilities with optimized design is required.

## 2 The stages of LFG produced

According to the process of organic's anaerobic, LFG generation can be divided to 4 stages (or 4 phases):

Phases I is called aerobic phase, this stage occurs in early days of waste being filled.  $\text{O}_2$  reduces and  $\text{CO}_2$  increases gradually with time in this stage. When  $\text{O}_2$  is used up, The Phase II starts, this stage is called anaerobic phase. In this stage, Concentration of  $\text{CO}_2$  increases gradually to peak and some  $\text{H}_2$  is created, but  $\text{CH}_4$  has not generated. The Phase III begin with  $\text{CH}_4$  start to created. In this stage, methane bacterium's activity is increase, concentration of  $\text{CH}_4$  increase also. Concentration of

CO<sub>2</sub> reduces to a stable level and H<sub>2</sub> reduces to 0. When concentration of CH<sub>4</sub> reaches peak value and CO<sub>2</sub> down to a stable level, the phase IV is start. Components of LFG reach a balance level in this phase.

Actually the four stages of LFG generation in landfill is not followed stage by stage because waste is filled in landfill every day. Each day's waste has it's four stages of LFG generation. For a landfill cell that it is operating , there are four stages in the same time, and for a landfill cell that it has been closed, stage IV is formed about several months to one year after the landfill is closed. Generally, the time that the former three stages ( I, II and III) last is 6-12 months for Chinese landfill, and the time that stage IV lasts will be 10 years to decades .

### 3. Estimating of LFG

It is difficult to calculate exactly volume of LFG generated from landfill because anaerobic digestion in landfill is very complex process. Some estimate method can be used for LFG quantity forecast in engineering design.

#### 3.1 Calculating model selecting

There are several models for estimate the LFG emission, one of them is called Scholl Canyon model (called LFG model following ), the model is simple and convenient to use for LFG engineering.

The LFG model bases on following supposes: The LFG emission rate reaches the peak in a short time(not longer than one year) after waste is putted in landfill compare with the whole period (several decades) of anaerobic process of waste. The emission rate will go down with exponent curve. The math expression of LFG emission rate can be expressed as follows:

$$l_t = kL_0e^{-kt}$$

Thereinto:  $L_t$ —LFG emission rate m<sup>3</sup>/t.a ;

$k$ — Constant 1/year;

$t$ —time years;

$L_0$ — Max quantity of LFG generated in the whole period of anaerobic process of waste.

#### 3.2 Utilization of LFG model in estimate of LFG emission rate in a landfill

As anaerobic process of waste will last a long time, time the LFG emission rate reaches the peak is only several months, so the time before emission rate peak can be ignored. It is very convenience to get the curve of the LFG emission rate with time.

Commonly LFG volume in every year is needed for engineering design. The LFG volume in some year is summation of LFG volume emitted in this year from the waste putted in each year before. The LFG volume in some year can be expressed as follows:

$$L_t = kL_0 \sum_{t=1}^n R_t e^{-kT_t}$$

Thereinto:  $L_t$ —Total LFG emission volume in year  $t$  ( $m^3/a$ );

$k$ —LFG emission rate constant (1/year);

$T_t$ —time (years);

$L_0$ — Max quantity of LFG generated in the whole period of anaerobic process of waste. ( $m^3/t$ )

$R_t$ —The waste quantity is filled in year  $t$  from landfill start to operation

The above expression also can be shown by figure 1:

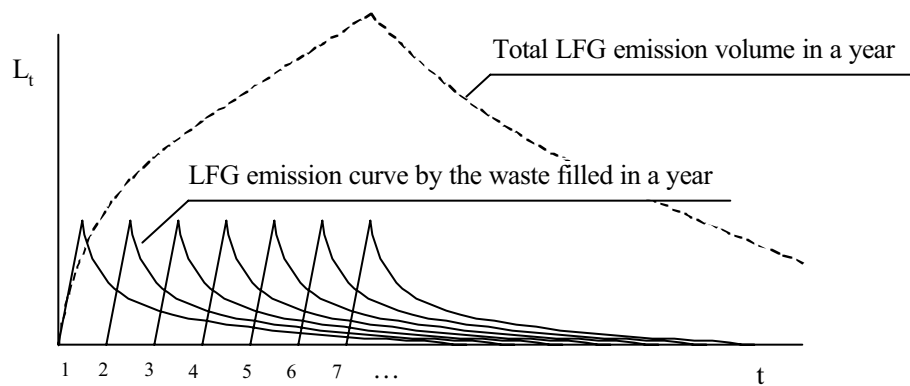


Figure 1 Relation of LFG emission rate with landfill age

Max quantity of LFG generated in the whole period of anaerobic process of waste ( $L_0$ ) and LFG emission rate constant ( $k$ ) is needed for estimated the  $L_t$ .  $L_0$  related to waste component,  $L_0$  is larger for the waste with higher organic portion,  $L_0$  is smaller for the waste with lower organic portion.  $k$  related to waste component, landfill condition and local weather etc. Therefore there are different  $L_0$  and  $k$  value with different landfill, It is needed to get  $L_0$  and  $k$  value according to waste component and site test before project design, then the  $L_t$  can be calculated by the expression above with the waste quantity filled in landfill in each year.

### 3.3 Estimate of $L_0$

$L_0$  is total LFG volume generated by all organic element during the anaerobic process in landfill. Due to the volume of  $\text{CH}_4$  and  $\text{CO}_2$  is larger than 95% of the total volume of LFG, it can be close to consider that  $L_0$  is the volume of  $\text{CH}_4$  and  $\text{CO}_2$  generated by all organic carbon of waste. The volume of  $\text{CH}_4$  and  $\text{CO}_2$  can be estimated by organic carbon quantity of waste, so  $L_0$  can be expressed as:

$$L_0 = 1/2V_{oc} \cdot 22.4/M_1 + 1/2V_{oc} \cdot 22.4/M_2 = 11.2 V_{oc}(1/M_1 + 1/M_2) \quad \text{m}^3/\text{t}$$

Thereinto:  $V_{oc}$ —Organic carbon quantity of waste;

$M_1$ —The molecular weight of  $\text{CH}_4$ ;

$M_2$ —The molecular weight of  $\text{CO}_2$ .

Organic carbon quantity of waste can be obtained through element analyses of waste.

### 3.4 Estimate of $k$

$k$  is a parameter to reflect the LFG emission rate. A larger  $k$  expresses a larger LFG emission rate, a higher speed of waste digestion, and a shorter time of waste anaerobic process. A smaller  $k$  expresses a smaller LFG emission rate, a lower speed of waste digestion, and a longer time of waste anaerobic process.

The  $k$  relates to waste component, landfill condition and local weather etc. Commonly, if easy-digest organic waste has a higher proportion, landfill is under the warmer season (or warmer place), waste has a good press by compactor, the  $k$  will be larger, waste easy to digest, the time of digestion will be shorter. if easy-digest organic waste has a lower proportion, landfill is under the colder season (or colder place), waste has a not good press, the  $k$  will be smaller, waste difficult comparatively to digest, the time of digestion will be longer.

For a landfill, the  $k$  can be obtained through site test. The test way will not introduce here.

## 4. Design of LFG collection way and facility

There are two LFG collection way. The one is collect by horizontal trenches, the another is collect by vertical wells. Horizontal trenches are layed between two waste layers, this way is convenience to collect LFG during landfill operation. The vertical wells can be layed from bottom of landfill, also can be built after landfill close.

### 4.1 Design of horizontal trenches

For design of horizontal trenches, it is mainly consider to prevent trenches broken with settlement of waste. The trenches can be designed as figure 2.

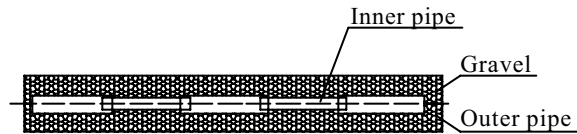


Figure 2 horizontal trench for LFG collection

The pipe in the trench showed in figure 2 use the structure of pipe in pipe. The pipe will bend instead of broken when waste settlement, LFG still can through the trench.

## 4.2 Design of vertical wells

### 4.2.1 Structure design of vertical wells

Vertical well consists of perforated pipe and grave. Perforated pipe use HDPE pipe with diameter of 100-125mm, is put in center of the well. Grave is filled outside the perforated pipe. The outside diameter of the well is about 1000mm. The structure of vertical well is showed in figure 3.

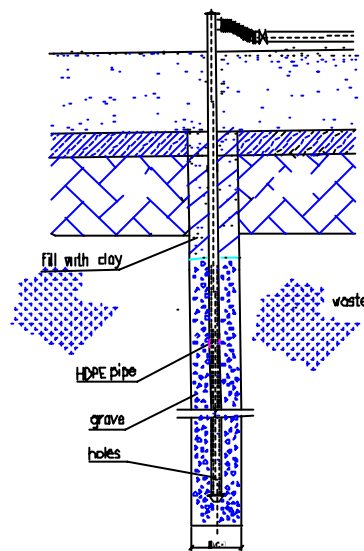


Figure 3 structure of vertical well

### 4.2.2 Confirmation of effect area of the vertical well

Effect area of the vertical well related to the press extent of waste, inner condition of waste pile and LFG emission rate etc. For a landfill, the effect area of the vertical well for collection of LFG can be obtained by site test. The effect diameter of a vertical well is 15-25m.

### 4.2.3 Collocation of the vertical wells

In order to get larger collection ratio, control emigration of LFG, collocation of the vertical wells should make the effect area of the wells cover the whole area of

landfill. Therefore the vertical wells should be located by intersecting. See figure 4.

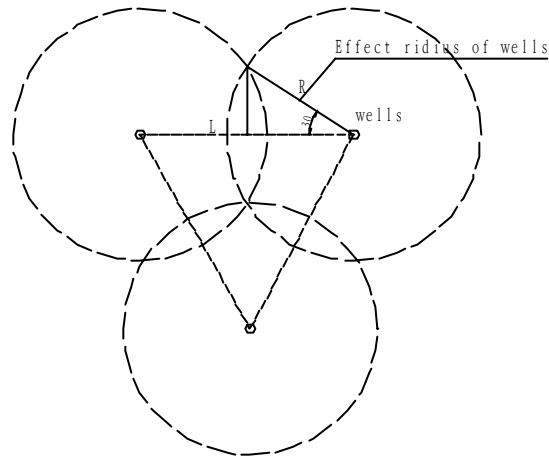


Figure 4 Collocation of the vertical wells

According to figure 4, the distance  $L$  between two wells should be expressed as:

$$L = 2R \cdot \cos 30^\circ = 1.73R$$

## 5. Conclusion

The important thing is estimate the quantity of LFG for a LFG collection project design. It is needed some parameter of waste and landfill for LFG quantity estimating. Through above discussion, following viewpoints and conclusions are obtained:

- 1) The process of anaerobic (LFG generation ) in landfill can be divided to 4 stages , the time took by the first 3 stages is not more than 1 year, but LFG emission rate has reached to peak in the 3 stages. The stage 4 will last 10 years to decades;
- 2) The suppose for Scholl Canyon model is close to the LFG generating condition in landfill, so it is reasonable to use the Scholl Canyon model for LFG collection project design;
- 3) The LFG volume in some year is summation of LFG volume emitted in this year from the waste putted in each year before;
- 4) It can be consider that  $L_0$  is close to the volume of  $\text{CH}_4$  and  $\text{CO}_2$  produced by all organic carbon of waste. The volume of  $\text{CH}_4$  and  $\text{CO}_2$  can be estimated by organic carbon quantity of waste;
- 5) The  $k$  relates to waste component, landfill condition and local weather etc. The  $k$  can be obtained through site test;
- 6) The horizontal trench for LFG collection can use the structure of pipe

in pipe in order to prevent waste settlement;

- 7) the relation of distance  $L$  between two wells and effect radius is  
 $L = 1.73R..$

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