Recovery of landfill gas under the conditions of landfills in developing countries

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The problem

- The prediction of the landfill gas production is normally done by using the quite common first order model.
- This model includes several factors to consider waste and side specific conditions.
- But when a gas collection plant had been built it happened very often that the collected gas did not reach the predicted values.
- Especially in landfills with poor conditions this happened often. Therefore it is very important to find out those conditions which influence most the efficiency of a gas collection system.

Possible causes

Landfill conditions which may influence the gas recovery rate:

- The composition of the waste is other then assumed,
- Loss of carbon because of fires and aerobic conditions,
- Bad conditions for gas collection f.e. water in the landfill body, air intrusion, no cover, no compaction

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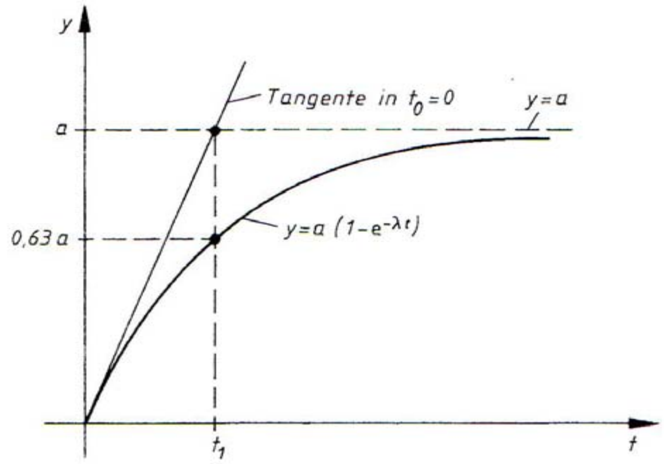
G_{t1}= (1.868.C.f_1.(0,014.T +0,28) . (1 – 10^{-kt})).f_2 . M_1

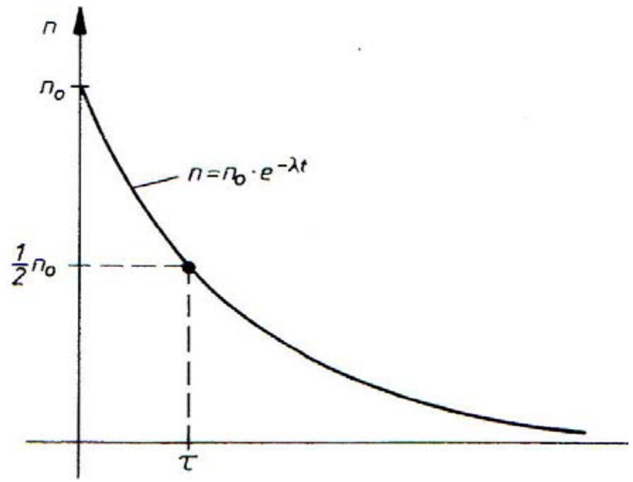


With:

- G_{t1}: Gasproduction until the year t of the waste from year 1
- f_1: correction factor for carbon loss
- f_2: correction factor for less exploitation, approx. 40 – 60 %
- M_1: waste from year one

Or:

G_{vt1}= (1.868.C.f_1.(0,014.T +0,28) (k . $10^{-k.t}$) .f_2 . M_1



With:

- G_{vt1}: Gasflow in the year t of the waste from year 1 in m³/year

Estimation of biodegradable carbon

Common values for the biodegradable amount of carbon are the followings:

• Household waste:	200 kg C_{org}/Mg wet waste
• Commercial waste:	130 kg C_{org}/Mg wet waste
• Bulky waste:	70 kg C_{org}/Mg wet waste
• Sewage sludge:	100 kg C_{org}/Mg wet waste
• Demolition waste:	70 kg C_{org}/Mg wet waste
• Inert materials:	0 kg C_{org}/Mg wet waste
• Garden waste	150 kg C_{org}/Mg wet waste
• Inert material from sorting plants	130 kg C_{org}/Mg wet waste

$$\mathbf{C = 3.75 \cdot AT_4 - 7.5}$$

Unfccc model and default values as correction factor

„Tool to determine methane emissions from dumping waste at a solid waste disposal site“

$$BE_{CH4,SWDS,y} = \varphi \cdot (1-f) \cdot GWP_{CH4} \cdot (1-OX) \cdot \frac{16}{12} \cdot F \cdot DOC_f \cdot MCF \cdot \sum_{x=1}^{y} \sum_{j} W_{j,x} \cdot DOC_j \cdot e^{-k_j \cdot (y-x)} \cdot (1-e^{-k_j}) \quad \textbf{(1)}$$

Waste type *j*		**Boreal and Temperate (MAT≤20°C)**		**Tropical (MAT>20°C)**	
		Dry (MAP/PET <1)	Wet (MAP/PET >1)	Dry (MAP< 1000mm)	Wet (MAP> 1000mm)
Slowly degrading	Pulp, paper, cardboard (other than sludge), textiles	0.04	0.06	0.045	0.07
	Wood, wood products and straw	0.02	0.03	0.025	0.035
Moderately degrading	Other (non-food) organic putrescible garden and park waste	0.05	0.10	0.065	0.17
Rapidly degrading	Food, food waste, sewage sludge, beverages and tobacco	0.06	0.185	0.085	0.40

$BE_{CH4,SWDS,y}$	=	Methane emissions avoided during the year *y* from preventing waste disposal at the solid waste disposal site (SWDS) during the period from the start of the project activity to the end of the year y (tCO_2e)
φ	=	Model correction factor to account for model uncertainties (0.9)
f	=	Fraction of methane captured at the SWDS and flared, combusted or used in another manner
GWP_{CH4}	=	Global Warming Potential (GWP) of methane, valid for the relevant commitment period
OX	=	Oxidation factor (reflecting the amount of methane from SWDS that is oxidised in the soil or other material covering the waste)
F	=	Fraction of methane in the SWDS gas (volume fraction) (0.5)
DOC_f	=	Fraction of degradable organic carbon (DOC) that can decompose
MCF	=	Methane correction factor
$W_{j,x}$	=	Amount of organic waste type *j* prevented from disposal in the SWDS in the year *x* (tons)
DOC_j	=	Fraction of degradable organic carbon (by weight) in the waste type *j*
k_j	=	Decay rate for the waste type *j*
j	=	Waste type category (index)
x	=	Year during the crediting period: x runs from the first year of the first crediting period (x = 1) to the year y for which avoided emissions are calculated (x = y)
y	=	Year for which methane emissions are calculated

Where different waste types *j* are prevented from disposal, determine the amount of different waste types ($W_{j,x}$) through sampling and calculate the mean from the samples, as follows:

$$W_{j,x} = W_x \cdot \frac{\sum_{n=1}^{z} p_{n,j,x}}{z} \qquad \textbf{(2)}$$

Where:

$W_{j,x}$	=	Amount of organic waste type *j* prevented from disposal in the SWDS in the year *x* (tons)
W_x	=	Total amount of organic waste prevented from disposal in year *x* (tons)
$p_{n,j,x}$	=	Weight fraction of the waste type *j* in the sample *n* collected during the year *x*
z	=	Number of samples collected during the year *x*

So it is very important to estimate the correction factors with high accuracy or if this is not possible to make tests at the site

Either

- Static tests (analyzing the gradients in the landfill)

Or

- Pumping tests (at several gas flows over two to three months)

- Fires can occur inside a landfill body and at the surface. Where as the influence at the surface is quite low, because the hot and toxic gases moves upwards the underground fires destroy a lot of degradable organic materials.
- Due to experiences where the hot spots were digged out, the spots itself had been locally. But the high temperatures with values of more then 90 °C could be measured in a larger extend. The calculation of the influence on the loss of the amount of carbon seems to be not possible. But when there are fires in a landfill it should be assumed that more then 10 % of the carbon will be lost. If there had been constantly fires it has to be expected that nearly 100 % of the degradable carbon will be destroyed..

Fires at the surface

Underground fires

Underground fires

Burning of the incoming waste

- From aerobic landfills it is known that the degradation of the waste needs around nine to twelve months. The degradation follows a first order process with a decay to 90 % in the mentioned time. The half time value is in the range of four to five months.

- This means that if a landfill surface is not covered within a year by the next shift most of the degradable carbon will be destroyed. And when the final shift is not covered during one year most of the degradable carbon will be lost in the landfill body to a depth of four to six meters .

- Therefore it is very important to know the area of the not covered landfill surface and the velocity of the growth of the landfill. From these values can be concluded the amount of waste which will not contribute to the gas production.

Landfill without cover

Landfill without cover

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Landfill with low compaction

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Landfill with low compaction

Landfill without final cover

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Bad conditions for gas recovery

- Bad conditions for gas production because of air intrusion to the landfill body, dry waste, water tables and others.
- Landfills with bales show fissures, so that air can flow into the landfill even in to deeper areas. So a bale landfill is hardly eligible for gas collection.
- If there occurs lot of annual rainfall occur high water tables can be the result if there is no cover. Gas recovery is not possible
- Steep slopes and no cover favour the intrusion of air into the landfill body. Therefore the vacuum pressure is limited for the gas collection.
- Shallow landfills have sometimes only depths of several meters. The waste remains more or less aerobic. Landfill gas can not expected. Landfill gas recovery is not possible.
- No or less compaction will influence the air intrusion

Bale landfill

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Steep and not covered slopes

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Shallow landfill

Air intrusion because of open passive venting wells

Conclusions

To start a successful gas recovery project the following steps should follow three steps:

- General gas prognosis should be done only to see if the landfill is suitable for a landfill gas project. The default values should be chosen on the secure side
- Site inspection with some static tests. With this step site specific conditions which may influence the gas production (bad compaction, slow growth) or the gas collection (steep slopes, high water table, and shallow areas) can be taken into consideration. Using the results of the field walk the gas prognosis from step one can be updated
- Pumping tests make only sense if they are carried out over a certain time (at least two to three months) using a full scale collection system. Therefore they need a sufficient budget. This pumping test can lead to another update of the gas prognosis.

Pumping test

Pumping test

Pumping test

Thank you for your attention!

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