Treatment of low caloric landfill gas – technical, economical and ecological comparison of different technologies

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Abstract

Methane, as a main compound of landfill gas, is one of the most important greenhouse gases. Therefore, landfill gas has to be treated, although the quantity and quality declines during the deposition of waste. In the course of decreasing quantity and quality the treatment via high- temperature combustion with flare stacks is connected with many problems.
To deal with these problems the treatment can be handled by thermal and biological processes, specifically for low caloric landfill gases.
The comparison of these processes with regard to technical, economical and ecological aspects will be presented.

Keywords: low caloric landfill gas; landfill gas forecast; treatment of low caloric landfill gas

1. INTRODUCTION

The extraction and treatment of landfill gas is an important part of the post closure care of landfills, even though the quality and quantity is decreasing when the biological degradation is declining and air is entering to the landfill site (e.g. caused by excessive extraction). An economic energy recovery of these resulting low caloric landfill gases is impossible for most of the smaller landfill sites. In the course of declining quality and quantity of gas there also appear several technical problems with the disposal of landfill gas via high-temperature combustion with flare sticks, so that landfill gas extraction systems and the flare sticks have to be run discontinuous. Discontinuous operation mode leads to an increasing risk of concentrated emissions via the landfill surface liner system in the phase of backing up the landfill gas and increasing wear of the components of the flare sticks because of starting up and shutting down more often.
But there are several technologies for a continuous treatment of the low caloric landfill gas available. The difficulty is to create an individual treatment concept for every landfill site. To provide a basis for such a concept a landfill gas forecast should be adapted to the local conditions and afterwards used for a technical, economical and ecological comparison of different technologies. The result of such a comparison is basis for the concluding recommended action.

2. LANDFILL GAS PROGNOSIS MODELS

The gas prognosis models of the gas flow of landfills is on one hand basis for the dimensioning of the gas extraction and treatment system and on the other hand it can be used for controlling the efficiency of the extraction system or implemented stabilisation measures. In German speaking countries two models are used: model of Weber and of Tabasaran / Rettenberger. The model equation of Weber is [Weber, 1990]:

$$Q_{a,t}\left[\frac{Nm^3}{a}\right] = 1{,}868 \cdot M \cdot TC \cdot f_{a0} \cdot f_a \cdot f_0 \cdot f_s \cdot k \cdot e^{-k \cdot t} \qquad [1]$$

The model equation of Tabasaran / Rettenberger [RETTENBERGER, 1992] is:

$$G_t\left[\frac{m^3}{Mg}\right] = 1{,}868 \cdot C_{org} \cdot (0{,}014 \cdot T + 0{,}28) \cdot (1 - 10^{-kt})$$ [2]

(The description of the correction factors goes beyond the scope of this short paper.)

The model of Tabasaran / Rettenberger only fits for landfills with optimal basic conditions, e.g. and optimal water content of 50 % in the waste body. But the water content in waste bodies often falls well below this value, so that gas production is reduced very much. [Rettenberger, 2004] Therefore the model equation of Tabasaran / Rettenberger is enhanced by equation [3].

$$\frac{G_{WG}}{G_e} = a \cdot 10^{-b(WG_{opt} - WG_{prob.})^2}\ [\%]$$ [3]

G_{WG} : gas production with real water content
G_e : gas production with optimal water content
WG_{opt} : water content for optimal gas production
WG_{prob} : real water content in waste body
a,b : constants (a=88; b=1/900)

The graphical interrelation between the water content and the relation between gas production with optimal water content (G_e) and gas production with real water content (G_{WG}) is shown in figure 1.

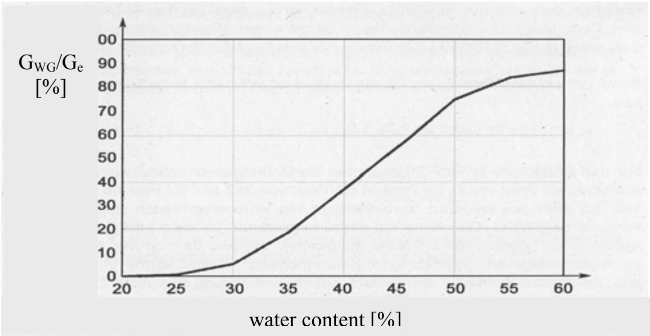
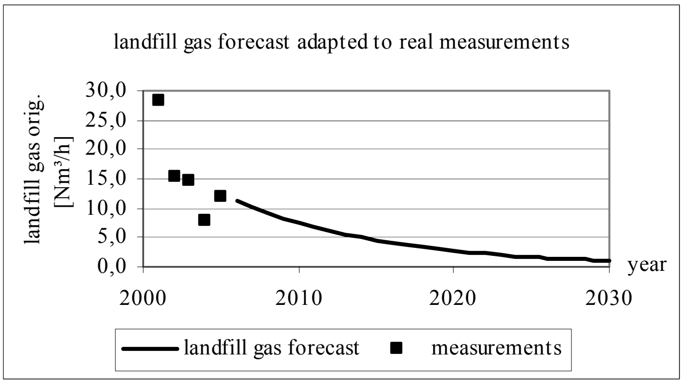


Figure 1 – interrelation between water content and gas production [RETTENBERGER, 2004]

Maybe this adaptation to the water content is a great advantage of the model of Tabasaran / Rettenberger for landfill gas forecasts for long closed landfills. This thesis has to be proved with long-term investigations. Exemplary a gas forecast for a German municipal solid waste landfill is shown in figure 2. In this case the data basis was very imprecise so that the forecast is a combination of both models with the parameter combinations that fit best.



\- **Figure 2 – landfill gas forecast adapted to real measurements**

The resulting landfill gas forecast is basis fort he following comparison.

3. TECHNOLOGIES FOR TREATMENT OF LOW CALORIC LANDFILL GAS

Technologies for treatment of low caloric gases can be divided in thermal and biological processes. To compare different technologies regarding to technical, economical and ecological aspects it is necessary to have detailed information about all the three aspects by the producers of such plants. Figure 3 shows the different technologies that are available at the moment and which are going to be compared.

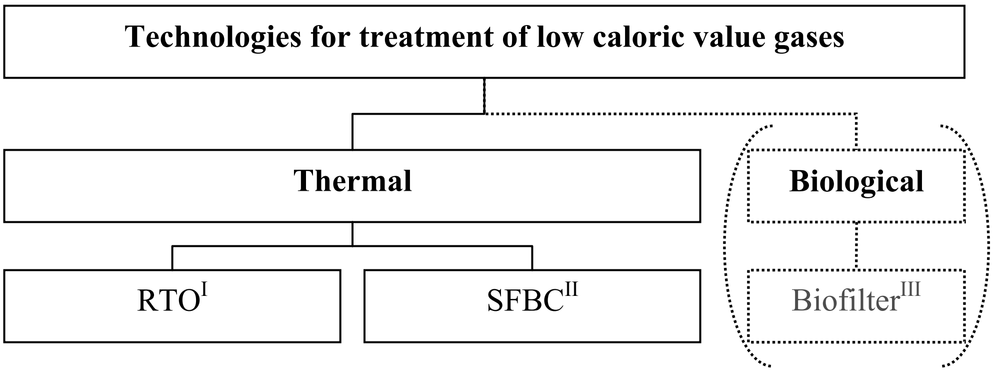


Figure 3 – Technologies for treatment of low caloric value gases

Remarks:

I) RTO = regenerative thermal oxidation;
offer (09/2006) by UMAT Deponietechnik GmbH (Germany) for a non catalytic RTO plant;
offer (09/2006) by Pro2 Anlagentechnik GmbH (Germany) for a catalytic RTO plant

II) Stationary Fluidised Bubbling Bed Combustion Plant; offer (09/2006) by ES+S GmbH (Germany)

III) own cost estimation regarding to [STREESE, 2005]
The enquiry showed that at the moment there seems to be no biological technology available for treatment of low caloric gases, which can ensure the oxidation of methane. Most companies wrote that bio filtration processes are mostly used for smell elimination. Bio filters for methane oxidation processes set a high standard for temperature regulation, moisture content etc. To have an idea what expenses are related to such a technical bio filter, cost estimation has been carried out according to [STREESE, 2005]. The estimated investment expenses for a bio filter for small landfill site (250.000 Mg input, ten years after closure) are approx. 125.000 € and operating expenses of approx. 23.000 €/a. These facts are not used for the following comparison.

Instead of treating the low caloric landfill gas it is also possible to operate an accelerated stabilisation affected by aeration. (e.g. with DEPO^{+}; offer by CDM Consult AG (Germany) in 09/2006)

4. ECONOMIC ASPECTS

An economic comparison can be carried out by a comparison of the annuities for each treatment system regarding to the company offers. This method bases on the determination of following data's:

- Incomings[1]:

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[1] For the aeration incomings cannot be taken into consideration, because the avoided emissions have to be entered measurement technology!)

$$E[€] = V_{CH_4}\left[\frac{Nm^3CH_4}{a}\right]\cdot 7{,}14\cdot 10^{-4}\left[\frac{MgCH_4}{Nm^3CH_4}\right]\cdot 23(GWP)\cdot \eta_{Oxid.}\cdot 5\left[\frac{€}{MgCO_2 - \ddot{A}quiv.}\right] \qquad [4]$$

- Expenses

  - running costs and - and investment costs

- Duration of use

  - Calculation regarding to methane volume flows (gas forecast), throughput and minimal needed methane concentration of plants

For the exemplary small/mid-sized German landfill site with a gas forecast like shown in figure 2 the resulting annuities relating to a standardised duration of use (10a) can be shown as follows.

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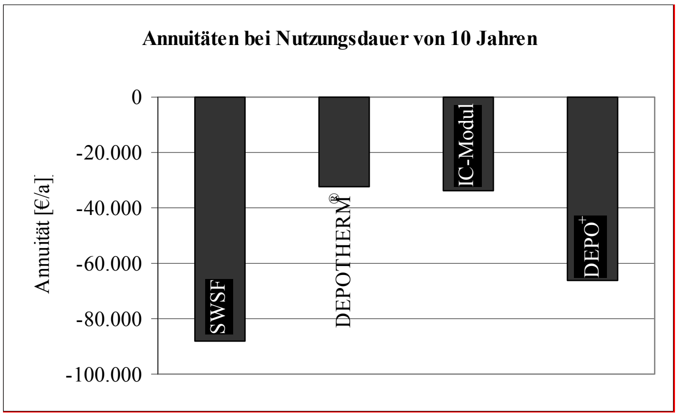

Figure 4 - annuities (duration of use = 10a)

Most profitable are the RTO-technologies, whereas the non catalytic RTO (DEPOTHERM®) must be favoured.

It becomes apparent that for landfill sites with such small gas volume flows no technology is economic. Besides the determination of the most profitable technology it seems to be interesting which gas volume flow is necessary to have an annuity and capital value respectively of 0, so that the incomings cover the expenses and the investment is neither economic nor no economic.

For the three thermal technologies the needed incomings per year were determined, whereas the payment flows were simplistically accepted to be constant. The duration of use was accepted for 10 years. The aeration cannot be taken into consideration because incomings cannot be generated.

The resulting values represent the needed incomings through emission trading (5 €/Mg CO_2-equivalent[2]) and the provided volume of methane and landfill gas respectively.

Tab. 1 - Calculation of needed incomings and landfill gas flows

	needed incomings [€/a]	Mg CO_2-equiv. [Mg/a]	Vol. CH_4 [Nm³/a]	Vol. orig. landfill gas [Nm³/a]
SFBC	98.407,15	19.681,43	1.198.000	2.178.181
DEPO-THERM®	40.940,11	8188,02	498.402	906.185
IC-Modul	44.851,58	8.970,32	546.020	992.763

These data represent theoretically averages, because landfill gas volume flows will not be constant under real conditions, but declining. Compared to the exemplary German landfill site there is factor 10 to 20 between the real and the needed volume flows.

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4. ECOLOGICAL ASPECTS

The ecological comparison can be done in the form of a balance of the avoided and produced emissions. Produced emissions are due to requirement of energy (RE), to gas consumption (GC) during the start up of the treatment plant over the duration of use (DU). Emissions caused by fabrication of the plant or transportation to the landfill site are not taken into consideration.

$$E_{prod.}[MgCO_2] = \left(RE[kW_{el}] \cdot operat.hours.\left[\frac{h}{a}\right] \cdot 0{,}9\left[\frac{kgCO_2}{kWh}\right] + GC\left[\frac{kg}{a}\right] \cdot 3\left[\frac{kgCO_2}{kgC_3H_8}\right]\right) \cdot \frac{1}{1000} \qquad [5]$$

Avoided emissions can be calculated with equation 6:

$$E_{verm.}[MgCO_2] = V_{CH_4}\left[\frac{Nm^3CH_4}{DU}\right] \cdot 7{,}14 \cdot 10^{-4}\left[\frac{MgCH_4}{Nm^3CH_4}\right] \cdot 23(GWP) \cdot \eta_{Oxid.} \qquad [6]$$

The volume of methane during the duration of use is calculated in the landfill gas forecast. Figure 5 shows the effective avoided mass of CO_2-equivalents for the duration of use.

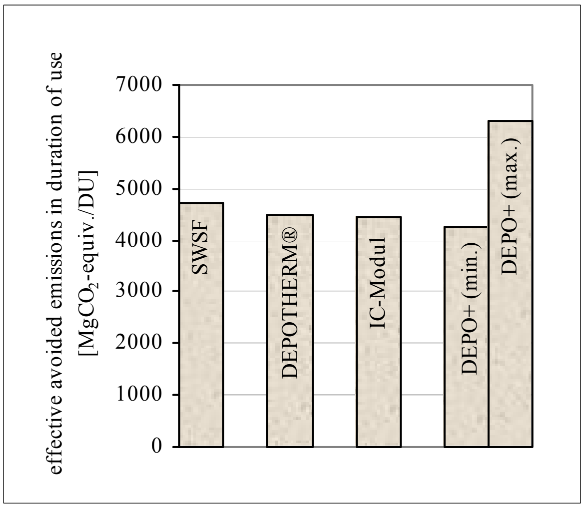

Figure 5 – balance of emissions

Among thermal technologies the SFBC has to be preferred under ecological aspects. But among all technologies the maximum value for the aeration with $DEPO^+$ represents the most ecological process. The maximum value relates to the fact, that all prospective methane emissions (regarding to the landfill gas forecast) can be avoided and this assumption takes into account, that after a stabilisation via aeration the waste body is stabilized and thus no emission will occur ever.
The minimum value is due to the assumption, which the avoided mass of CO_2-equivalents is as much as in a thermal process with an oxidation effectiveness of ≈ 1.

5. CONCLUDING RECOMMENDED ACTION

Finally the recommended action should follow from weighing the different aspects with a points rationing scheme. For the German exemplary landfill site the following result can be pointed out:

Tab. 2 – points rationing scheme

criterion (weighing)	SFBC	DEPOTHERM®	IC-Modul	$DEPO^+$
duration of use (25%)	3	4	2	1[3]
profitability (70%)	1	4	3	2
ecological aspects (5%)	3	2	1	4

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total	1,6	**3,9**	2,65	1,85

In the case of enforcement for taking measures for treatment of low caloric landfill gases the non-catalytic RTO-technology DEPOTHERM® can be recommended to the operator. If there is no obligation of an implementation of a continuous treatment of the landfill gas, the responsible administration cannot force the operator to invest in a treatment system and in this case the present discontinuous gas extraction and treatment has to be recommended, even if under ecological aspects a continuous treatment would be preferable.

In the future technologies should be created that make it cost-effective to treat small volume flows of low caloric landfill gases, as they occur at small and mid sized or very old landfill sites. The aim is to avoid even small quantities of green house gas emissions.

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