Umweltbundesamt
Referat Z 6
Dessau-Roßlau

"Methane emissions from the disposal of mechanically-biologically treated waste"

Project Z 6 – 30533/3

FKZ 360 16 036

Abbreviated version of the final report

IFAS - Ingenieurbüro für Abfallwirtschaft
Prof. R. Stegmann und Partner
Schellerdamm 19 - 21
21079 Hamburg
Germany

27 April 2012

Abbreviated version of the final report

1 Task

The task and aim of the expert opinion is to develop the technical basics for the calculation of the methane emissions from the disposal of MBT waste for the emission report.

For the implementation, research results and practical experiences of recent years were primarily evaluated, and in particular also the monitoring measures regarding the gas balance at the MBT disposal sites.

2 Situation of the mechanical-biological waste treatment in Germany

At the outset, the legal framework of mechanical-biological waste treatment and the demands on the disposal of mechanically-biologically treated waste were prepared.

For 2009, the Statistische Bundesamt (Federal Statistical Office) provides the following information:

Number of mechanical-biological waste treatment plants:		51
Total treatment capacity:		4.676 million Mg
Amount of waste treated:		3.958 million Mg
Output:		3.253 million Mg
Thereof deposited:	approx.	1 million Mg

Treatment residues from MBT plants are deposited at approximately 40 disposal sites.

3 Methane formation potential of mechanically-biologically treated waste

The evaluations of former and current investigations and the monitoring results from MBT disposal sites lead to the following findings:

- In the medium and long term, gas compositions occur at most of the MBT disposal sites, which correspond to those of the stable methane phase and the long-term phase.
- The evaluation indicates, with sufficiently pretreated waste ($AT_4 \leq 5$ mgO_2/gTS, $GB_{21} \leq 20$ Nl/kgTS), that a total gas formation potential in the range between 30 and 40 Nm^3/MgTS is to be expected. At an average methane content of 60 vol.-%, this corresponds to a methane formation potential between 18 and 24 Nm^3 CH_4/MgTS.

4 Half-life or reaction constants for the methane formation from deposited MBT waste

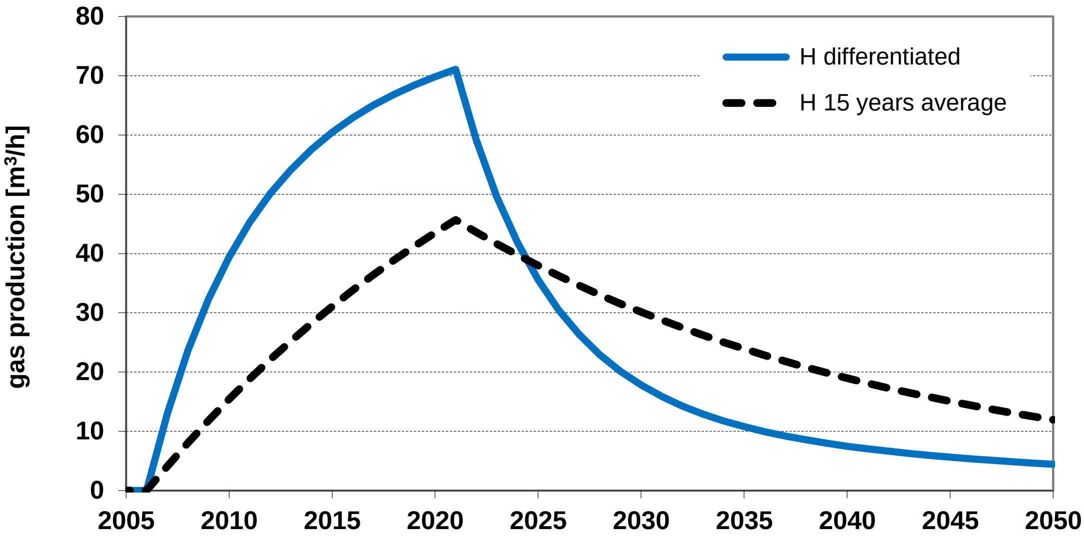
The rate and chronological sequence of the gas formation are influenced, amongst others, by the emplacement water content and the temperature in the landfill body, the share of aerobic degradation processes, and the methane oxidation processes at the deposition surface or in the soil cover.

The findings point out that, at the time of landfilling, a certain remaining share of readily and medium-degradable organic compounds is still present in the MBT waste and is even well available. When landfilled, the MBT waste boasts rather favourable boundary conditions for the start or continuation of biodegradation processes. Therefore, the following ranges of values are suggested for the emission assessment regarding the shares of biological availability and half-lives (H) of the MBT waste partial flow to be deposited:

- readily available/degradable organic subst.: approx. 60% with H = 3 ± 2 years
- medium available/degrad. organic subst.: approx. 20% with H = 10 ± 5 years
- poorly available/degradable organic subst.: approx. 20% with H = 25 ± 10 years

These half-lives lie in comparable ranges as the IPCC default values.

The approach with differentiated half-lives ("three-phase model") and the deduced residual gas formation potentials thus reflect the first monitoring results from MBT disposal sites that show that, during the first years of disposal, the anaerobic degradation processes proceed relatively intensively (Figure 1).



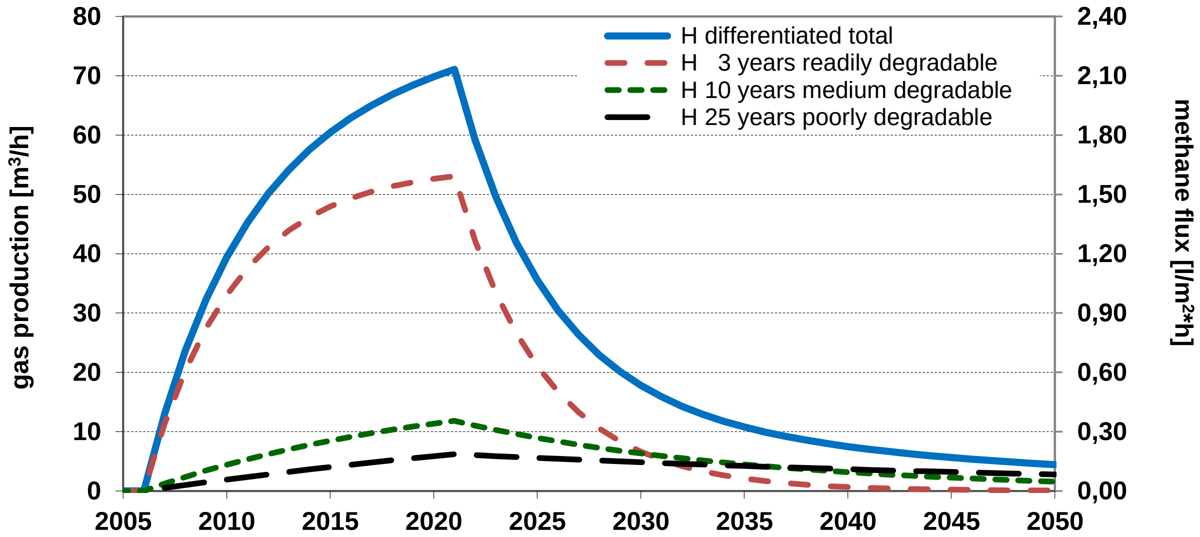


Fig. 1: At the top: gas forecast calculation for the one-phase model (half-life = 15 years) and the three-phase model (half-life H differentiated); at the bottom: share of readily, medium and poorly degradable organic substances in the gas production in the three-phase model

5 Biological methane oxidation during the disposal of MBT waste

The microbial oxidation of methane as a passive gas treatment measure was specified by the IPCC as a key technology for the treatment of landfill-induced methane emissions. For quantification, the methane oxidation factor OX was established.

On the one hand, high methane oxidation capacities of many soils and substrates were proven in laboratory tests and partially in field studies. On the other hand, however, measurements at MBT disposal sites and old disposal sites show that the major part of the landfill gas also leaves the landfill body via preferred gas emanation zones in MBT landfills that are not covered. From FID inspections at several MBT disposal sites, it can be inferred that approximately 63% to 95% of the total methane emission volume is released via only 10% of the sampled measuring points. This corresponds to a share that is higher than average. For most of these sampled gas emanation points (hot spots), it can be assumed that no noteworthy methane oxidation takes place.

Further limiting factors for methane oxidation are spatial and temporal load peaks, strongly varying moisture contents, soil temperatures that tend to be too low for optimum metabolic processes of the methanotrophic bacteria, and unfavourable methane/oxygen ratios in the methane oxidation horizon.

Against this background, methane oxidation factors that will remain low are deduced for the open and, where applicable, for the temporarily covered MBT landfill. Higher methane oxidation achievements require the dimensioning of the soil/recultivation layer for methane oxidation, corresponding soil selection, as well as a high-quality constructive realisation during the application, and a monitoring programme, so that the deduced methane oxidation factor reflects the "system methane oxidation capacity" (Table 1).

Table 1: Suggestions for default values of the methane oxidation factor OX as a function of the emitted methane volume flow and the covering situation of MBT disposal sites, ranges of variation

Landfill phase / covering situation	**OX at an average surface load < 4 l CH_4/m^2*h [-]**	**OX at an average surface load < 2 l CH_4/m^2*h [-]**	**OX at an average surface load < 0.5 l CH_4/m^2*h [-]**
Deposition phase: Open disposal area	0.1 ± 0.1	0.1 ± 0.1	0.2 ± 0.1
Deposition/closure phase: Temporary covering with humic soil	0.15 ± 0.1	0.3 ± 0.2	0.45 ± 0.2
Closure/post-closure phase: Technically optimised methane oxidation layer with monitoring and maintenance/repair works	0.6 ± 0.2	0.7 ± 0.2	0.75 ± 0.2

6 Examination of the First Order Decay model

Based on the evaluation and deduction of default values for the estimation of methane emissions from MBT disposal sites, the First Order Decay (FOD) model of the IPCC guidelines for National Greenhouse Gas Inventories, 2006[1], is examined and adjusted. The IPCC methods are based upon a 1st order approach. Three grades exist ("Tier 1 to Tier 3"), with which the quality of the estimation is classified depending on the raw data. The expert opinion was planned in such a manner that, in the future, the highest grade can be reached ("Tier 3"), when more monitoring results from MBT disposal sites are available.

The examination of the FOD model, in connection with the evaluations regarding the gas balance of MBT disposal sites, shows that there is no reason justifying the principle divergence from this model. Therefore, the model was validated and thus adjusted to the emission behaviour of MBT disposal sites for the following data and emission factors:

- Deposited MBT waste amounts
- Methane formation potential (L_0)
- "Methane Correction Factor" (MCF)
- Methane share in the produced landfill gas (F)
- Oxidation factors (OX)
- Half-lives ($t_{1/2}$ or H)
- Share of methane (R) collected via a technical gas collection system
- Delay time (time interval from the deposition to the start of intensive anaerobic degradation processes)

The results regarding the gas balance of MBT disposal sites that have been available until now do not yet allow for statistical evaluations, but the acquired data and the deduced emission factors can be classified as quite comprehensive and complete in the sense of the IPCC guidelines, to estimate the methane emissions from MBT disposal sites. With continuous updating of the estimation, the indicated uncertainties regarding several emission factors, such as the half-life or the methane oxidation rate, are increasingly reduced.

[1] 2006 IPCC Guidelines for National Greenhouse Gas Inventories; Chapter 3, Solid Waste Disposal; Intergovernmental Panel on Climate Change

7 Estimation regarding methane emissions from MBT disposal sites

On the basis of the evaluation of the methane formation potential of MBT material, half-lives, methane oxidation, and landfill-related boundary conditions, the methane emissions and the correspondingly resulting contamination of the atmosphere with carbon dioxide equivalents are estimated.

The gas forecast calculation is still carried out via a 1st order approach using the deduced assumed and default values. The estimation shows that the primal gas production already takes place during the filling phase and the first years of the closure/post-closure phase. As, particularly in this phase, only minor methane oxidation at the landfill surface is assumed for an open disposal area, the most intensive emissions into the atmosphere occur during this time. They decrease significantly with the application of a surface sealing designed for methane oxidation. Figure 2 presents an example for an MBA landfill section regarding the landfill gas production, the resulting methane emissions (including reduction through methane oxidation), and the added-up emissions relevant to the climate as CO_2 equivalents.

For the chosen assumptions, and as an estimation on the safe side, up to 266 kg CO_2-eq./MgTS of deposited MBT waste are emitted, and thereof up to approximately 80% of this total emission load already during the filling phase. The long-term landfill gas emissions would be negligible approximately 10 to 15 years subsequent to the completion of the filling process and application of the surface sealing with a methane oxidation function.

If more favourable assumptions are chosen regarding the landfill gas potential, the aerobic degradation of the deposited organic material and the methane oxidation at the open landfill surface to cover the variation ranges and uncertainties, the emissions will decrease correspondingly.

The estimation of the current total methane emissions of all MBT disposal sites in Germany finally results in a large range between 60,000 and 135,000 Mg CO_2-eq./a. During the years to come, at an average annual deposition in the previous magnitude of approximately 1 million Mg MBT waste moist mass, they may increase to approximately 90,000 to 210,000 Mg CO_2 eq./a.

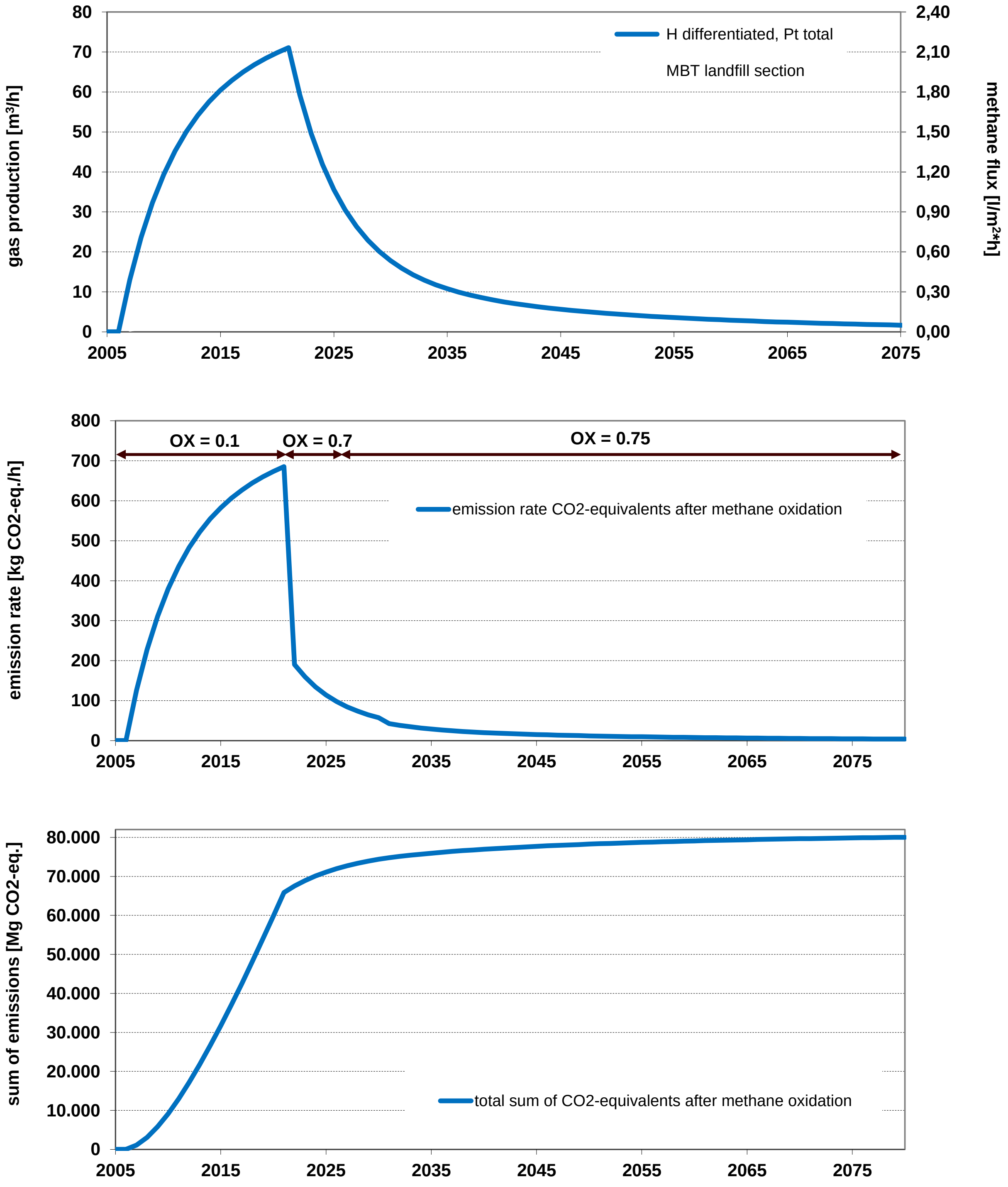


Fig. 2: Example MBT disposal site: landfill gas production and remaining methane emissions into the atmosphere in carbon dioxide equivalents subsequent to methane oxidation

8 Conclusions

Conclusions regarding the methane emissions of deposited MBT waste:

- MBT plants are operated in accordance with the specifications of the Landfill Ordinance, and in such a manner that the waste partial stream to be deposited does not exceed a biological residual activity and the corresponding landfill gas formation. On the one hand, the reduction of the gaseous emissions of approximately 80 to 90% is ensured with this. On the other hand, with 30 to 40 Nm^3/MgTS, the MBT waste still shows a landfill gas formation potential that can also be ascertained on former municipal solid waste landfills, approximately 10 to 20 years subsequent to the completion of the filling process.
- In the practice of waste emplacement and landfill operation, the MBT waste boasts rather favourable initial conditions for the start or continuation of biodegradation processes (homogeneity, moisture).
- For the gas production, this means that a larger share of the total gas potential with a short half-life is formed already in the deposition phase.

Conclusions regarding monitoring measures:

- Evaluations of FID measurements at MBT disposal sites, compared with the forecasted residual gas production, point out that FID inspections are suitable only to a very limited extent to reliably estimate methane emissions from MBT disposal sites. FID measurements are very strongly influenced by boundary conditions, such as air pressure variations, the water saturation degree of the surface and preferred emanation zones (hot spots).
- The data available for gaseous emissions from MBT disposal sites only improves gradually as a result of regular monitoring measures, as larger amounts of MBT waste are deposited in accordance with the applying requirements only during recent years.
- The requirements regarding the monitoring of landfill gas emissions are stipulated in Annex 5 of the Landfill Ordinance. The evaluations show that significant methane emissions can already develop shortly after deposition. Therefore, measurements regarding the methane formation and methane oxidation should particularly be carried out during this phase.

- Besides the monitoring measures and verifications in accordance with the requirements of the DepV, a scientific investigation program with regard to the emission behaviour of MBT disposal sites would be useful to cover the statements and the deduced values and forecasts with respect to the methane formation (methane formation potential and half-lives) and the release into the atmosphere (reducing influence of methane oxidation).

In the evaluation, the uncertainties of the deduced emission factors, on which the emission forecast is based, are identified. These uncertainties concern, in particular, the monitoring results regarding the gas balance of MBT disposal sites that are available only to a small extent. With the future monitoring results and probable supplementary investigations, those uncertainties can be reduced in order to further substantiate and assure the forecast of methane emissions from MBT disposal sites.

Issued by:

Dr.-Ing. Kai-Uwe Heyer Tel.: +00 49 40 77 11 07 42
Dr.-Ing. Karsten Hupe Tel.: +00 49 40 77 11 07 41
Prof. Dr.-Ing. Rainer Stegmann Tel.: +00 49 40 77 11 07 41

IFAS - Ingenieurbüro für Abfallwirtschaft Fax: +00 49 40 77 11 07 43
Prof. R. Stegmann und Partner
Schellerdamm 19 - 21
21079 Hamburg
Germany

E-mail: heyer@ifas-hamburg.de http://www.ifas-hamburg.de