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Methane emission from passively degased landfills and landfills with mechanically-biologically pre-treated municipal solid waste

- Prognosis of emissions and efficiency of biological methane oxidation -

Short summary

By

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1 Background

Within the framework of emission reports for the national greenhouse gas inventories the trend of the biological degradation process is described by the first order decay (FOD) model of the IPCC. Therein the reaction constant represents mathematically the velocity of the degradation / methane production.

On its way to the atmosphere the landfill gas is partially oxidised bio-chemically to CO_2 in the aerobic top layers of the landfill and landfill cover. This reduces the greenhouse potential significantly. This oxidation depends on a multiplicity of basic parameters that influence the performance of the oxidation positively or negatively in short or long term alterations.

The biochemical methane oxidation is considered by the factor OX in the FOD model but IPCC default values are not distinguished (undifferentiated) and set quite conservatively.

As in Germany landfilling of biologically degradable waste ended (to a large extend) in 2005, in the future emission balances for the new type of landfills with mechanically-biologically treated (MBT) waste have to be established. This landfill category is not considered in the IPCC defaults for the FOD model yet.

2 Task

Project target was to formulate scientific basics for the calculation of methane emissions from MBT-landfills and passively degased (vented) landfills. For the advancement of the FOD calculations the following tasks had to be completed:

- Description of the methane production potential of MBT landfills
- Qualified appraisal of half life period respectively reaction constants
- Qualified appraisal of the efficiency of biological methane oxidation at open emplacement areas of MBT landfills
- Qualified appraisal of the efficiency of biological methane oxidation at (old) landfills low gas production in case of passive degasing in combination with engineered gas oxidation layers in the landfill cover

3 Approach

A huge amount of scientific publications / investigations was reviewed. To minimise the range of values and uncertainties, to following strategy was applied:

- Inclusion of world wide, especially latest investigations
- Consulting experts (but no by the meaning of methodical „expert judgement“ according to IPCC)
- Description and discussion of the influences on the factors mentioned above in practice
- Description and discussion of the methodical uncertainties that exit in practice for the determination of the factors mentioned above

- Presentation and discussion of full scale and notably sound standing investigations that have the potential to deliver reliable results for landfill practice over a longer period of time

Special attention has to be paid to the fact that under landfill conditions space and time play a crucial role. For emission reporting total emissions over a long period of time are relevant. These emissions can not be determined e.g. by laboratory measurements or short term random survey field measurements. This aspect was of special importance for the evaluation of research results.

Further uncertainties result from very different conditions at each individual landfill. For the reaction constant k age and type of landfill have to be considered distinguishably, for the oxidation factor OX mainly the type of landfill cover.

Hence, suggestions for different applications (cases) were elaborated to cover the real existing cases (including MBT landfills) and establish a ranking order by the meaning of plausibility.

4 Suggested values for the reaction constant k

The reaction constant k [1/a] is mathematically bound to half life period $T_{1/2}$ [a]. For best clearness, values for both will be given.

Table 1 summarises reaction constants for 4 landfill categories /applications:

Category 1 and 2: Older landfills (usually before about 1995) tend to have a comparatively short half life period of about 5 years. This is confirmed by a leading manufacturer and operator of German landfill gas installations. Due to different history and landfill content, this category is subdivided in old landfills from former East (cat. 2) and from West Germany (cat. 1).

Category 3: For newer landfills or landfill sectors containing residual waste from times after nationwide implementation of source separated collection of recyclables [including garden and kitchen waste] (about 1995). Based on several eminently reliable sources, the suggested k value is k = 0.10 (equals $T_{1/2}$ = 6.9) This value is valid for the whole waste fraction in the one phase model as well as the moderately degrading waste fraction in the three phase model.

Category 4: MBT landfills. MBT output has undergone a similar biological degradation like untreated waste stored in a landfill for 2 decades or more (in opposite to a landfill situation, MBT affects all degradable components [shredded and no dry zones]). Based on this fact and existing model calculations, k value was set as k = 0.08 (equals $T_{1/2}$ = 8.7) for the one phase model. This value needs further investigation because there are significant inconsistencies between traditional model calculations, unsystematic single measurements and observations at landfill simulation reactors. Possibly it makes no sense to apply the three phase model to this kind of landfill. Hence, it could be omitted for MBT landfills.

Tabelle 1: Suggestions of default values for reaction constant k respectively hlf life period T1/2 depending on type of landfill (rounded values)

	Type of waste	Rapidly degrading		Moderately degrading		Slowly degrading	
	Landfill category	**k [1/a]**	**$T_{1/2}$ [a]**	**k [1/a]**	**$T_{1/2}$ [a]**	**k [1/a]**	**$T_{1/2}$ [a]**
1	Old landfills or landfill sectors closed on former West German territory before nationwide implementation of source separated collection of recyclables (about 1995). Often mixed with significant amounts of demolition waste and soil.	0,28	2,5	**0,14**	**5,0**	0,04	17,5
2	Old landfills (former East Germany) with low organic but high ash content (until 1990)	0,23	3,0	**0,12**	**5,8**	0,035	20
3	Newer landfills or landfill sectors containing residual waste after nationwide implementation of source separated collection of recyclables (about 1995)	0,19	3,6	**0,10**	**6,9**	0,03	23
4	Landfills or landfill sectors with mechanically-biologically treated waste (mainly since 2005)	0,17	4,1	**0,08**	**8,7**	0,03	23

Remark: For application of the one phase model the reaction constant for moderately degrading waste shoud be used.

5 Suggested values for methan oxidation factor OX

The methane oxidation factor OX represents non-dimensional the share of oxidised methane in the landfill cover.

IPCC default values for OX are:

OX = 0 Managed, unmanaged and uncategorised landfills

OX = 0,1 Managed landfill with methane oxidising cover material

In emission reporting OX is an annual mean value. Since it can’t be adopted each year to a changed situation, in fact it can be understood even as a long term mean.

A long term mean has to consider unfavourable climatic influences, methane load peaks (local and in variation of time), pedogenetic soil modifications, aging, compaction and bioturbation as well as insufficient or completely missing maintenance of the methane oxidation layer.

The oxidation performance is also dependent on the load per surface. Hence, default values for 2 categories of area loading were elaborated:

- Low load < 2 l CH_4/m^2 h

– Higher load > 2 l CH_4/m² h

An average load of > 2 l CH4/m² h (equals about > 100 ppm by FID measurements) should be found rarely on passively degased German landfills and if so, only on huge landfills.

On MBT landfills, emissions > 2 l CH_4/m² h should not exist in the length of time. The methane production of MBT landfills can be appraised at 5 – 10 m³ CH_4/Mg waste; average 7,5 m³ CH_4 / Mg waste.

Oxidation factor for 5 cases are summarised in table 2. On one hand, it can be assumed that even a simple soil cover on a passively degased landfill will have an average long term methane oxidation between 10 and 15% (0,1 – 0,15). On the other hand, a technically optimised methane oxidation layer will not achieve 100% methane oxidation permanently over a longer period of time.

An open MBT landfill offers better conditions for methane oxidation than a regular landfill with soil cover because the top layers of MBT material deliver good conditions for methane oxidation. Investigation of this fact is still required / missing.

Tabelle 2: Suggested values for methane oxidation factors

Cover		**Load per surface > 2 l CH_4 / m² * h**	**Load per surface < 2 l CH_4 / m² * h**
1	Cohesive soil (silty sand, sandy silt)	0,1	0,15
2	Humous soil and structure material	0,15	0,3
3	MBT landfill without cover*	not relevant	0,35 *
4	technically optimised methane oxidising cover, without monitoring **	0,4	0,5
5	technically optimised methane oxidising cover, with monitoring and repair **	0,6	0,7

* interim value based on (older) model calculation; no investigation values abailable
** optimisation e.g. according to the Austrian guideline for methane oxidising landfill covers, 2008

6 Plausibility control and uncertainties of the method

The classification in cases closely related to practice establishes at the same time a ranking of best to worst conditions for biochemical conversion (k) or biochemical methane oxidation (OX).

In the frame of this ranking every case classifies itself in the given scheme which results in a plausibility control.

Analogue to IPCC Guidelines „Waste“, Table 3.3 default values are suggested as well as minimum – maximum values. These values do not cover the whole range of evaluated literature data. They are evaluated ranges under consideration of the above mentioned work strategy. They describe the uncertainties and usually expedient range for application of default values.

These ranges of uncertainty are presented here but shown in tables in chapter 5.4 and 8 of the long version of the report.

7 Proposals for further minimisation of uncertainty ranges

The following topics should be subject of further research.

- Impact of dry zones and preferential flow on the biochemical processes
- Emissions of MBT output under true landfill and long term conditions;
- Total emissions of landfills for validation of relatively fuzzy input parameters for landfill gas prognosis based on the FOD-Modell;
- Long term determination of oxidation factors under real landfill conditions under consideration of frost, dryness and other negative influences.
- Long term influences on soil properties of methane oxidising covers
- Consideration of heterogeneity of landfill properties in investigations of average oxidation rates and remaining emissions
- Material supply and compatibility with other revegetation targets and demands on the landfill surface sealing system
- Oberflächenabdichtung.