Basics and concepts for landfilling of MBT output

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Abstract

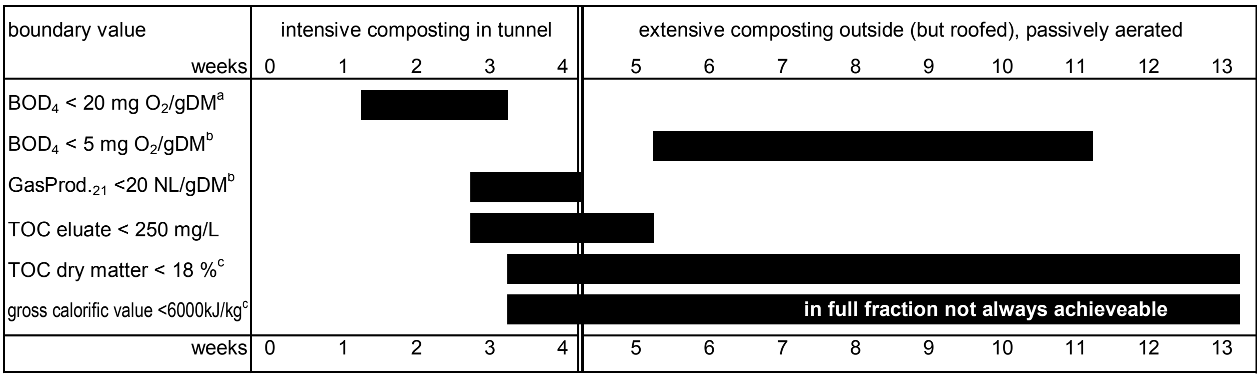
MBT-output differs significantly from untreated municipal waste. It is much more homogeneous, has a smaller average grain size and low biological activity. This affects the construction and operation of landfills. Based on tests and examinations, model calculations, literature review and practical experiences at MBT-landfills, the properties of MBT-output are described. As a result advises for landfill construction and operation are given.

Keywords

Mechanical biological waste treatment, MBP, MBT, landfill, slope stability, geomechanical properties.

1 Introduction

After May 2005 landfilling of untreated municipal waste will be prohibited in Germany. If mechanical-biological treatment (MBP / MBT) is used, drastic reductions of biological activity and energy content / total organic carbon have to be achieved (Figure 1). The bio-degradation can be compared with the situation in a conventional landfill after 50 years or more. But in opposite to a conventional landfill, the degradation is homogeneous and there are no areas, which were not or only insufficiently affected by the degradation process.



a) limit for not encapsulated treatment; b,c) can be alternatively used

Figure 1 Boundary values for landfilling of MBT-waste and range of the necessary biological treatment duration in a well operated composting tunnel

Figure 1 shows the future German standards for MBT-waste to be landfilled, and as an example the range of the necessary biological treatment time (results of 5 tests, each 25 Mg) in a very well operated aerobic tunnel treatment located in a rural area (SHG-county). In urban regions with more commercial waste, longer treatment times can be expected. The already existing MBT-plants do not completely fulfill the future standards. The requirements for the biological stabilisation are not always reached and especially the calorific value of the MBT-output is too high by far. A sufficient biological stabilisation can be achieved by a prolongation of the biological treatment. To reduce the calorific value, a sieving (< 60 mm or smaller) after the biological treatment is a possible way.

Fraction 0 – 20 mm   Fraction 0 – 40 mm   Fraction 0 – 60 mm

Figure 2 Sieve fractions of aerobic treatment in SHG (photogr. Ulrich Langer)

Table 1 Example for the properties of different sieve fractions from aerobic treatment (SHG) compared to German boundary values

fraction [mm]	whole (<150 mm)	> 60 mm	0-60 mm	0-40 mm	0-20 mm	boundary value
contingent [1)] [mass% WM]	100	9	91	80	59	
water content [% WM]	35,5	35,8	37,5	37,5	40,9	2)
ignition loss [% DM]	29,6	53,7	28,0	25,7	27,0	
AT_4 [mgO_2/gDM]	3,8	6,8	1,9	1,5	1,2	5,0
COD eluate [mg/L]	245	345	234	230	245	
TOC eluate [mg/L]	102	138	102	99	108	250
gas production GB_{21} [L/kgDM]	10,7	5,3	1,1	0,7	0,5	20,0
gross calorific value,wf [kJ/kg]	6.800	13.700	5.960	5.348	5400	6.000
TOC DM [mass% DM]	15,3	30,2	15,7	14,2	14,3	18,0

1) Contingent of the whole sample . 2) for implacement optimal Proctorwatercontnet

2 Mechanically and hydraulically properties of MBT-output

2.1 Particle size distribution

By the mechanical treatment the large / coarse waste components are removed or reduced to small pieces. To a minor degree, mechanical stress during the biological treatment and the biological degradation process also cause a further size reduction or a change of the waste structure. The biological treatment has only little influence on the particle size distribution of the MBT-output. Only within the fraction < 20 mm happens a clear refinement by the biological treatment. So the granulometry is mainly determinated by the mechanical treatment. The mass content is dominated by the fraction 0 - 20 mm, followed by the fraction 20 – 40 mm. the coarser fractions have only a small share of the MBT-output. As a result, the MBT-output has a much finer and homogeneous particle structure than raw waste. Under a mechanical point of view, a certain approximation to the properties of natural soils happens. Because of this, the geomechanical and hydraulical properties of MBT-output can be examined and described much better with conventional methods of the soil mechanics than it is possible for untreated waste.

2.2 Filter stability to the bottom drainage layer

If the MBT-waste is brought to a new landfill or new landfill sector, it is important to check, if the filter stability is given between the drainage layer and the waste. Otherwise waste particles may infiltrate in the drainage layer and block the pore space. Table 2 shows the grain size distribution of various MBT-wastes.

Table 2 Classification figures for checking the filter stability

material	H Lahe 0-30 mm	SHG 0-20 mm	SHG 0-40 mm	SHG 0-60 mm	SHG 0-150 mm	LG 0-100 mm
d_{10} (mm)	0,4	0,03	0,043	0,052	0,061	0,45
d_{15} (mm)	0,7	0,053	0,082	0,10	0,12	0,8
d_{50} (mm)	2,7	0,73	2,1	4,1	7,0	11
d_{60} (mm)	4,0	1,5	5,3	10	20	12
d_{85} (mm)	10	7,3	24	35	44	31
U ($=d_{60}/d_{10}$)	10	50	123	192	328	27

The frequently used formula from Terzaghi to check the filter stability can't be used in this case, because it is only valid, if the inequality factor U is < 2 which is exceeded by far by the presented materials. The same applies for other filter formulas based on Terzaghi and the formula of Cistin/Ziems (in Wittmann, 1982). Additionally these formulas act on the assumption, that the shape of the particles is spheroidal, but the MBT-output contains a lot of flat, plate like components. By its properties, the MBT-output is rather similar to a stable, cohesive soil. It contains sufficient fine and graded particles between the coarse components that it can be assumed, that no nameable washing out of fine material will happen (Bluemel, 2003). This is confirmed by percolation tests (Doedens et al., 2000), where a drainage layer (gravel 16-32 mm) underneath a 100 cm layer of MBT-output was not siltated (sludged). Hence no filter layer should be necessary, as long as the MBT-output isn't finer than the materials listed in Table 2. For extra security, the drainage layer can be made of gravel 8-32 mm instead of 16-32 mm.

2.3 Shear strength and oedometric modulus

As MBT changes particle size and structure significantly, a change of other geo-mechanical properties is likely. Ziehmann (1999), Table 3, distinguished the influence of mechanical and biological treatment (capital 2*1 m shear test jig).

Table 3 Influence of waste treatment on shear parameters (Ziehmann, 1999)

parameter	untreated	biologically treated	mechanically-biologically treated	mech.-biol. treated; < 60 mm
tensile force taking components [mass-%]	>25	>25	<25	<5
angle of tensile [°]	30-35	30-35	15	~0
shear angle [°]	30	35	35-38	35-38
cohesion [kN/m²]	15	15	15	15

Cohesion is not affected by the waste treatment (Table 3). The biological treatment has only influence on the angle of shear, which rises a little (about 17%). The mechanical treatment leads only to a marginal increase of the angle of shear, which isn't changed by the sieving < 60 mm. The angle of tensile was reduced from 30 – 35 to 15 degrees already by the mechanical treatment before the biological treatment. After the final sieving < 60 mm, the angle of tensile tends to zero. That means, that waste treated this way, has nearly no armouring components and the stability can be described completely by a shear test. Table 4 contains the results of geomechanical test at three sieve fractions of the MBT-output from the aerobically treatment tests in Schaumburg (SHG) county.

Table 4 Geomechanical properties of fractions from 2 different tests in SHG

grain size		mm	0-20			0-40			0-60		
origin			V4	V5		V4	V5		V4	V5	
placement moisture		%mo	36	41		37	46		36	41	
		%DM	56	70		58	84		57	70	
placement density	moist	g/cm³	1,40	1,50		1,40	1,50		1,40	1,40	
	dry	g/cm³	0,90	0,90		0,90	0,90		0,90	0,80	
angle of shear	fail / slide	°	33 / 33		34	34 / 34	36	36	35 / 35	35	27
cohesion c´	fail / slide	kN/m²	38 / 21		16	43 / 21	23	11	35 / 20	49	62
oedometric modulus E_S at a surcharge of	25-50	MN/m²		0,80			0,50			0,60	
	50-100	MN/m²		1,00			1,10			1,30	
	100-200	MN/m²		1,80			1,60			2,00	
	200-400	MN/m²					2,80			2,80	
permeability		Lab	a	a	b	a	a	b	a	a	b
		m/s	7,8*E-8	3,7*E-9	2,3*E-10	6,5*E-6	3,6*E-6	7,0*E-10	6,2*E-6	5,2*E-5	1,8*E-8
placement moisture		%DM	56	70	72	58	64	67	57	70	54
placement density	moist	g/cm³	1,2	1,4	1,4	1,1	1,2	1,4	1,2	1,0	1,3
	dry	g/cm³	0,8	0,8	0,8	0,7	0,7	0,9	0,8	0,6	0,9

The MBT leads to a rise of the friction angle, which remains on a level, which has been reached by some untreated wastes. The cohesion seems to be uninfluenced by MBT. The friction (shear) angles of MBT waste which fulfils the future German and Austrian legal standards, were found between 32 and 38 degrees, the cohesion was between 10 and 62 kN/m². It seems that the investigation of the cohesion of waste is in general difficult and only boundedly reliable.

Figure 3 and Table 4 present the oedometric modulus of the 3 fractions from SHG. Ziehmann (1999) investigated the oedometric modulus for 2 points in time (Table 5): Z1 was the end of the load step (not exactly defined). Z2 was defined as the point in time, when the settlement was < 0,1% of the initial height within 24 h. According to these results, MBT raises the oedometric modulus significantly, especially if the MBT-output is sieved < 60 mm.

Table 5 Oedometric modulus E_s of MBT-output (σ = 280-420 kN/m²), Ziehmann, (1999)

treatment	mechanical biological	mechanical biological <60mm
Z 1	3,8 MN/m²	4,3 MN/m²
Z 2	5,1 MN/m²	7,9 MN/m²

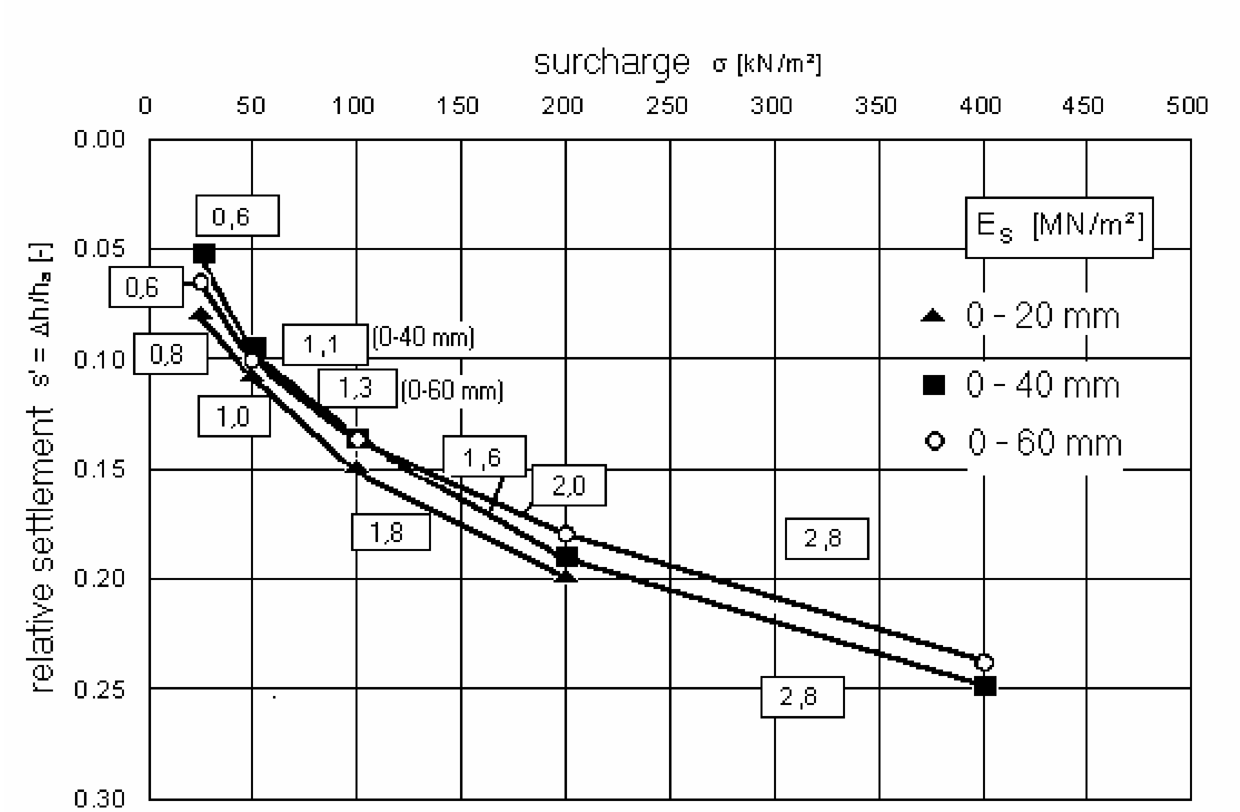


Figure 3 Settlement versus surcharge of 3 fractions from SHG

2.4 Water permeability

At proctor density or less, coefficients of permeability between 10^{-5} and 10^{-10}m/s were determined for various MBT materials. The water permeability is extremely dependent on implacement moisture and surcharge (see Figure 4 and Figure 5). Therefore coefficients of permeability are only meaningful if moisture content, proctor moisture content, placement density and surcharge are documented.

By-pass effects at the seam of the test vessel are often a serious problem (Ramke, 2001), which might be existent in most of the existing enquiries about the permeability of MBT-output. Especially measured permeabilities between 10^{-5} and 10^{-7} m/s may indicate problems in the test system, but not every value in this range has to be wrong. Compared to soil the maximum particle size of MBT-output is still quite large. Test vessels of an adequate size are not available in most laboratories.

The samples from SHG were tested in standard cells (diameter 18 cm) and also at the Geotechnical Bureau Prof. Duellmann, which uses 60 cm test vessels (Lab b). The results show an increasing permeability with increasing maximum particle size (Table 4). The absolute values of both laboratories are quite different. This can be caused by the following factors:

- different test vessels

- different implacement moisture
- different compaction / surcharge

As laboratory b (Prof. Duellmann) uses bigger (more adequate) test vessels, these values are more credible.

Tendentially the permeability of MBT-output decreases with decreasing maximum particle size compared in one specific MBT-output. If this is completely material specific or if it has technical measurement reasons can't be judged at the moment. Under surcharge in a landfill at least permeabilities of 10^{-9} m/s have to be expected, which might cause the rise of porous water pressure. At the landfill surface low permeabilities are not very likely.

At the Lahe landfill (Hanover), two proven grounds (test fields) 6x9 m where made of digested French waste, which had been composted for a time of 16 weeks after the digestion and finally has been sieved to a maximum particle size of 30 mm (attempt to keep the boundary value for the calorific value). Field 1 consisted of 8 layers with an uncompacted thickness of 30 cm each, and field 2 was made of five 50 cm layers. Material (H 0-30 mm) from these tests was also given to the Geotechnical Bureau Prof. Duellmann, where KD-tests were made, which measure the permeability in dependence of the surcharge. Figure 4 shows the strong dependence of the permeability from the surcharge and the connected density.

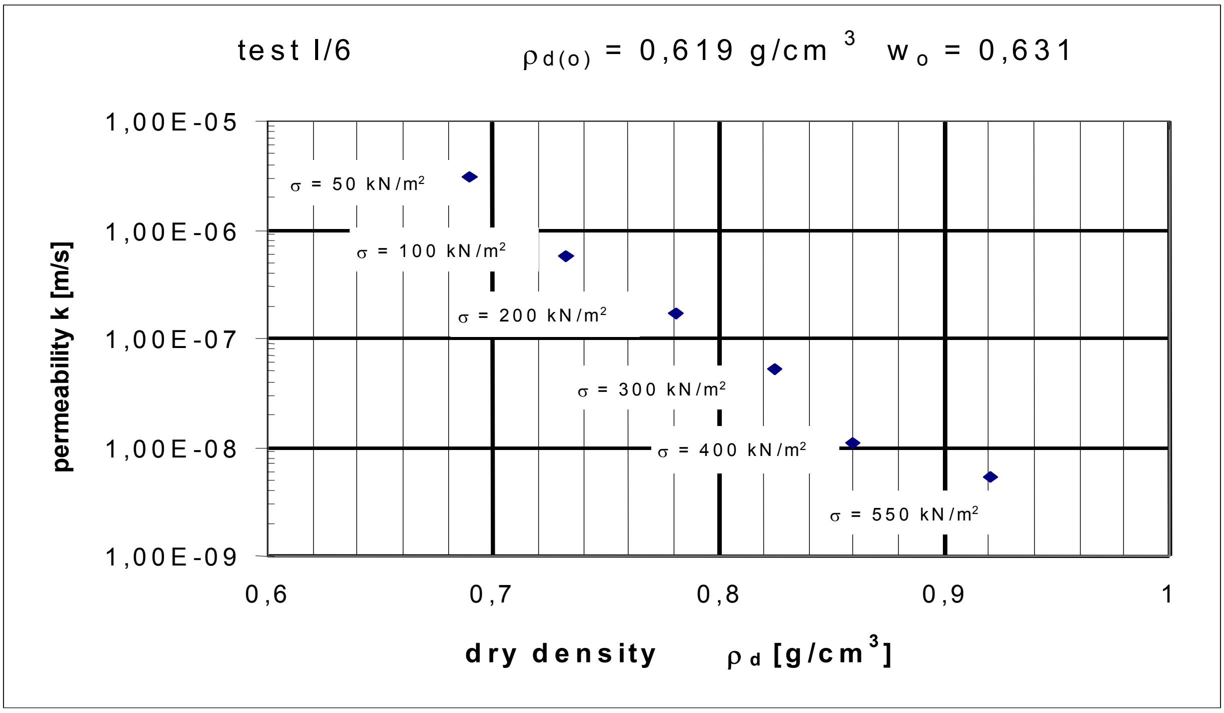


Figure 4 E.g.: Influence of surcharge and dry density on permeability and dry density on the material H 0-30mm (modified after Duellmann, 2002)

Figure 5 doesn't only show the proctor curve of the material H 0 – 30 mm, it also clarifies the dependence of the water permeability from the implacement moisture content (which has influence on the implacement density). A wettening after the implacement has no influence has no influence on the water permeability (Duellmann, 2002). In situ measurements in the proving grounds confirmed the laboratory measured permeability as well as the (related) dry density of the samples taken out of the test fields. The low density of the material might be caused by the digestion process, as another digested material from a completely different source had similar densities, while aerobically treated material from the same region and mechanical treatment reached significantly higher densities.

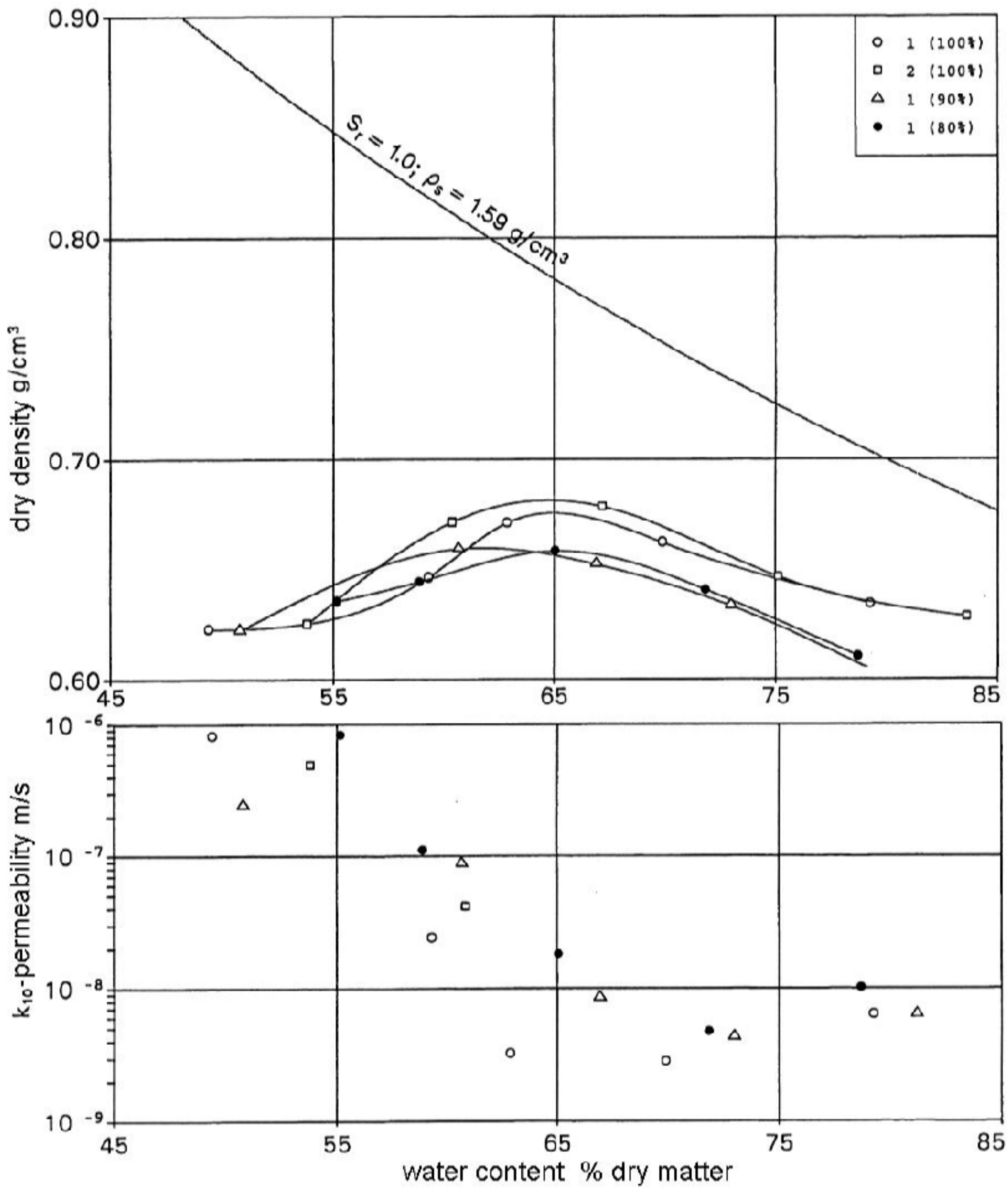


Figure 5 Proctor density and permeability of an aerobically-anaerobically treated material 0 – 30 mm (modified after Duellmann 2002)

2.5 Slope stability

Based on the values for the materials H 0 – 30 mm, SHG 0 – 20, 0 – 40 and 0 – 60 mm I calculated the slope stability of a 20 and a 40 m high landfill with the software GGU-Stability. A 36 t compactor 2 m away from the slope edge was set as traffic load. For landfill construction, safety factors of ≥ 2,0 are common (Schuhmann, 1989). This is caused by the unknown long term behaviour of waste components, which are important for the (mechanical) landfill stability. As the organic degradation has already gone quite far by MBT and a major part of organic fibres has already been removed, a calculation with a safety factor of 1,3 (which is used for mineral soil) has been added to compare. The shear angle has been attenuated by the factor of 1,2. Because of the limited reliability of cohesion values of waste, the cohesion was reduced to the values of Ziehmann (1999). The calculations do **not** consider any porous water pressure (set as zero), so they represent **the best possible case**! These calculations lead to a maximum slope inclination of a 20 m high landfill of about 1:1 at safety factor 1,3 and about 1:2 for a safety factor of 2,0. This situation will be changed by porous water pressure, which reduces the slope stability! These calculations are just an example for the best possible case and can't be simply transferred to MBT-output from other sources and plants. No warranty for the correctness of the calculations is given.

Bluemel & Mueller-Kirchenbauer (2004) made stability calculations considering the existence of water in the MBT-landfill (which will normally always be the case). They used a safety factor of 1.4. They found out, that with the chosen shear parameters $\varphi = 35°$ and $c = 15$ kN/m² slopes with an inclination between 1:3,5 and 1:3 should be stable. The water level was set at the half hight of the slope. This was done to consider the presence of porous water pressure, which easily can arise from the compression of the porous space by surcharge combined with the low permeability of MBT-output (Kuehle-Weidemeier, 2003). These calculations have to be seen as a parameter study. They don´t replace the necessary local calculation. Special attention has paid to the question, weather the laboratory results represent the situation in-situ.

To relax porous water pressure, drainage layers (e.g. made of waste with a higher permeability) should be scheduled in a MBT-landfill. It has to be considered, that these layers might have worse geomechanical parameters than the MBT-output.

2.6 Summary of the influence of MBT on the physical waste properties

Table 6 Effects of MBT on the physical waste properties

property / influence	mechanical treatment (grain size < 60 mm)	biological treatment	mechanical and biological treatment
water permeability			decrease (10^{-5}- 10^{-10}m/s)
angle of shear φ	apparently no change	increase	increase
cohesion c´*	apparently no change	app. no change	app. no change
angle of tensile ξ	extreme reduction	app. no change	extreme reduction
oedometric modulus	increase		increase
calorific value	~20% decrease	~15-40% decrease	~35-60% decrease
subsidence	decrease	decrease	huge decrease
mass reduction	25-50%	~15-30%*	40-70%

*Dependent on the amount of biodegradable waste; in areas with separate biowaste collection max. 20%.

3 Implacement of MBT-output

Field trials and practical landfill experience revealed (Kuehle-Weidemeier, 2003/5):

- Placement densities are usually between 1,0 and 1,6 g/cm³ (moist matter) within the upper 2 m of the landfill (densities up to 2,1 g/cm³ are mentioned by Hupe et al. (1998) and Reiff & Marx (1999).
- Compactor weight, method of compaction (dynamic / static) and layer thickness of 30 or 50 cm had only limited influence on the compaction success; a maximum of 3 compaction turns is enough, the remain is done by the surcharge of following layers.
- At wet conditions the material gets quickly swampy and impassable.

4 Emissions from MBT-landfills

4.1 Surface runoff

The test fields with a decline of 6% at Lahe landfill needed 230 mm (about 30% of annual rainfall!) of precipitation within 11½ hours until the runoff started. The runoff needed to be treated according to German Law (Table 7). Von Felde (1999) had similar results at the landfill of the Bassum MBT. Calculations with the hydraulic model WAT-FLOW had similar results for the H 0-30 mm but predicted surface runoff for the materials from SHG already at natural conditions.

Table 7 Surface runoff from heavy sprinkling (20 mm/h) on anaerobically-aerobically treated material, bold values exceed boundary values for direct discharge(Table 8)

parameter, unit	1st test 4 days after construction 30 cm layers		2nd test 5 weeks after construction 30 cm layers		2nd test 5 weeks after construction 50 cm layers	
start runoff [h:min]	11:25		2:30		4:15	
precipitation until runoff starts [mm]	230		50		85	
	homo-genised	filtered	homo-genised	filtered	homo-genised	filtered
COD [mg O_2/L]	**840**	**790**	**479**	**383**	156	111
BOD_5 [mg O_2/l]	**24**	**24**	4,8	7,5	3,8	4,8
NO_2-N [mg/L]		**7,5**		0,28		0,2
N-total [mg/L]		19,6		6,98		5,1

4.2 Leachate

MBT-plants with high technical standards are just operating since a few years. Hence the existing MBT-landfills are quite small and there is just a few experience about their operation. Figure 7 shows the leachate composition of a MBT-landfill (MBT does not completely comply with the future standards). The COD peaks emerged, when the MBT-landfill sector was flooded by surface runoff of a neighboured sealed landfill sector.

Doedens et al. (2000) published some leachate data of MBT-landfills about 2 years after the beginning of operation (Table 8).

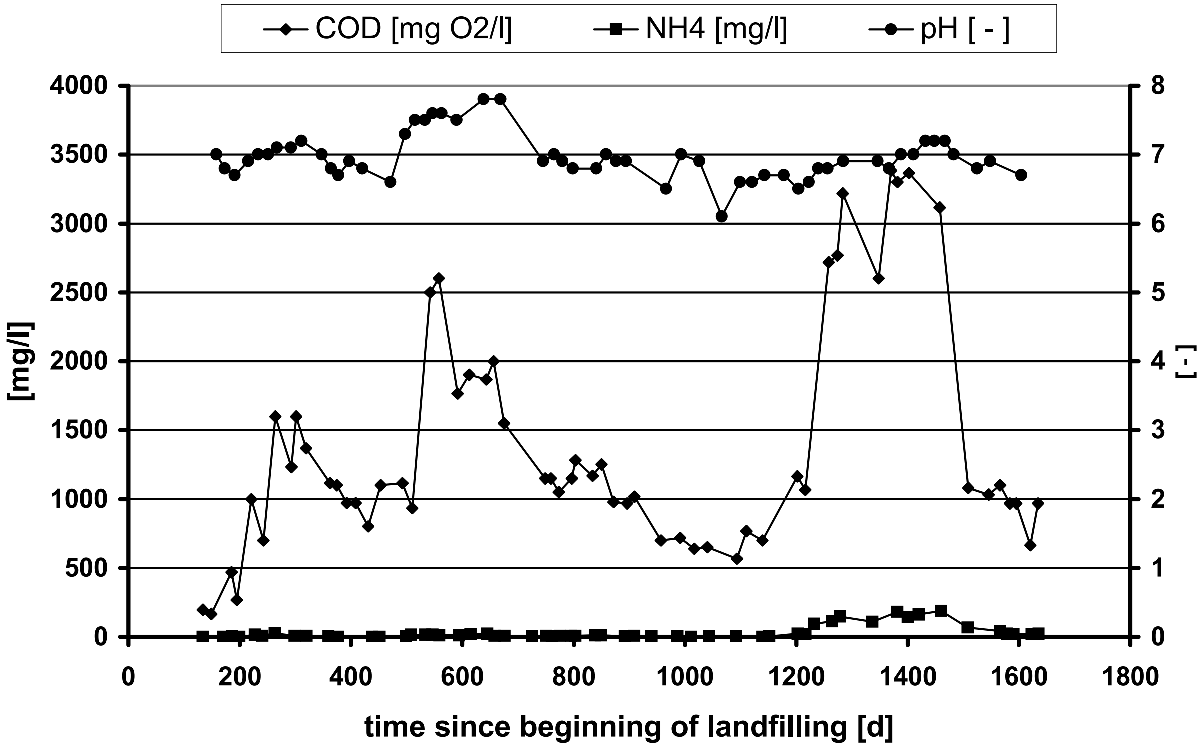


Figure 6 Leachate quality of a MBT-landfill (Friedrich, 2002) COD-peaks are caused by external influence and will not appear in usual operation

Table 8 MBT-leachate in the first 2 years after beginning of landfilling compared to untreated waste and boundary values for direct discharge (Doedens et al., 2000)

parameter	MBT Lueneburg, start phase	untreated municipal waste acid start phase	untreated waste stable methanic phase	German boudary value for direct discharge
pH [-]	7,5	4,5 - 7,5	7,5 - 9,0	-
COD [mg/L]	700 - 2.500	6.000 - 60.000	500 - 4.500	200
TOC [mg/L]	300 - 950	2.000 - 30.000	200 - 2.000	67
BOD_5 [mg/L]	1 - 55	4.000 - 40.000	20 - 550	20
COD / BOD_5 [-]	20 - 150	2	15 - 20	-
TKN [mg/L]	10 - 37	1.350	← identical	-
NH_4-N [mg/L]	0 - 27	750	← identical	-
NO_3-N [mg/L]	15 - 66		0	-
NO_2-N [mg/L]	0,1 - 1,7		0	2
$N_{inorganic}$ [mg/L]	16 - 75	750	← identical	70
total N [mg/L]	35- 140	1.350	← identical	-
COD / total N [-]	4,6 - 8,7	8 - 12	2 - 3	-
AOX [mg/L]	0,1 - 0,9	0,3 - 3,4	← identical	0,5

4.3 Gas

Fermentation tests (GB_{21}) allow inferences on the gas production potential of a material, but the real potential can be only determinated by long term tests with a duration of min. 200 – 500 days (Raninger et al., 2001). In the ideal case, these are measurements in a real MBT-landfill or a mono MBT landfill sector.

Von Felde (1999) made a gas prognosis based on the model of Weber (1990), which was calibrated on a landfill sector with 300 Mg MBT-output 1,5 years after the beginning of landfilling. The implaced material was nearly compliant (except calorific value and TOCDM) to the future German standards contains the main input parameters for the model. The anaerobically degradable part of the TOC of the treated waste is about one dimension lower than the one of the untreated waste. Because of the longer half-life period of the treated waste, the relative decrease of the MBT-waste gas production is slower. Von Felde compared 10 years of landfilling of 100.000 Mg/a untreated waste to 50.000 Mg/a MBT-waste (smaller amount of the MBT-waste because of the extractions of waste streams in the mechanical treatment and weight loss by the degradation in the biological treatment). Von Felde concluded, that the amount of produced gas was reduced by 95% and that a landfill with untreated municipal waste will reach this level after about 100 years. Figure 7 shows the prognosis for a period of one century.

Table 9 Input parameters in the gas prognosis model of Weber (1990) for MBT- and untreated waste chosen by von Felde (Doedens et al., 2000)

residual waste	untreated	after MBT
TOC [mg/gDM]	240 - 320	80 - 200
degradation factor f_a [-]	0,6 - 0,8	0,1 - 0,2
gasproduction relevant TOC [mg/gDM]	140 - 260	10 - 40
half-live period T_h [a]	5 - 15	20 - 40

Because existing MBT-landfills have no gas collecting system, full scale data about the quantity of landfill gas production is not available. 1998 in Austria 4 large, completely closed lysimeters (test cells) were built (5x5x5 m) and embedded in waste on the area of the landfill Allerheiligen ("Modelldeponie Allerheiligen"). The AT_4 of the input was between 3 and 11 mg O_2 / gDM (Raninger et al., 2001). 2 test cells were „irrigated" (fresh water added and leachate recirculation). To the other cells no water was added or recirculated, so they slowly dried because of water extraction on the leachate and gas path. The test should simulate the situation in an open and a closed (top sealing) landfill.

In the first 250 days, the total gas production of all 4 cells is quite similar, but the cells with leachate recirculation start with a higher production rate, which is afterwards quickly decreasing under the level of the unirrigated cells. After 266 days, the irrigation with additional water in cell 2 and 4 started and the gas production increased significantly (can bee seen in the literature source). Repeated addings of water caused no jump-like increase of the gas production, but it took about 533 days (material 800 days in test cells), until the gas production rate dropped to the level which was reached at the beginning of the water supply. Cell 4 has the highest gas production because the material in this cell was treated shorter and had the highest AT_4.

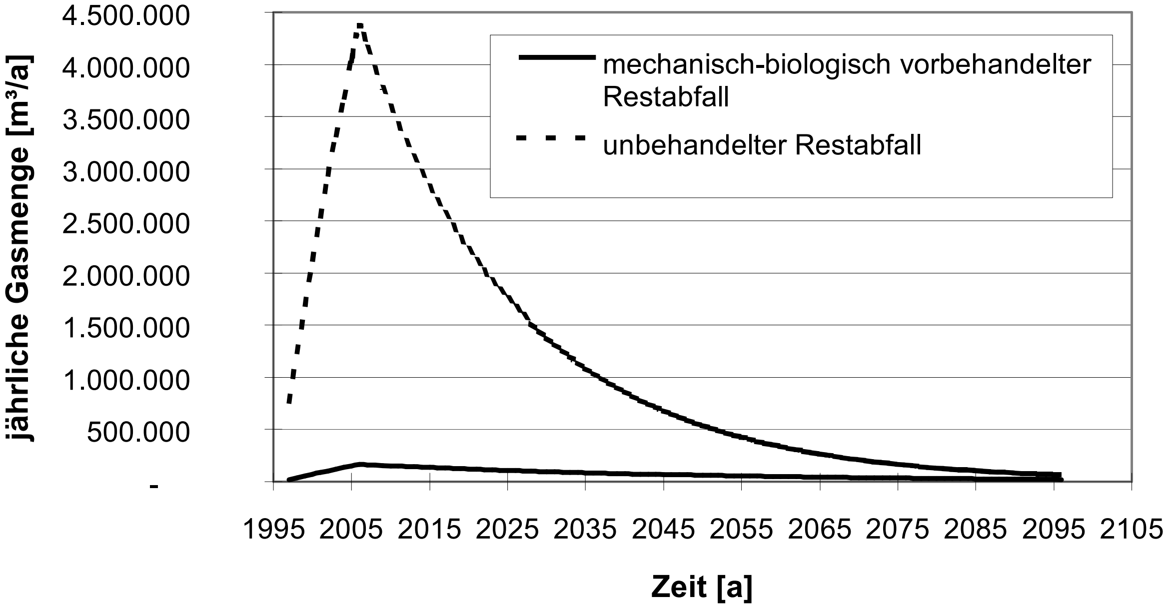


Figure 7 Annual gas production. [m³/a] 10 years operated landfill of 100.000 Mg/a untreated waste (upper curve) and 50.000 Mg/a MBT-output (von Felde, 1999)

After closing the cells, the stable methanogenic phase appeared instantly. The methane content of the gas decreased during the 800 days from initially 55% to about 45% in the irrigated cells and about 35 % in the unirrigated cells.

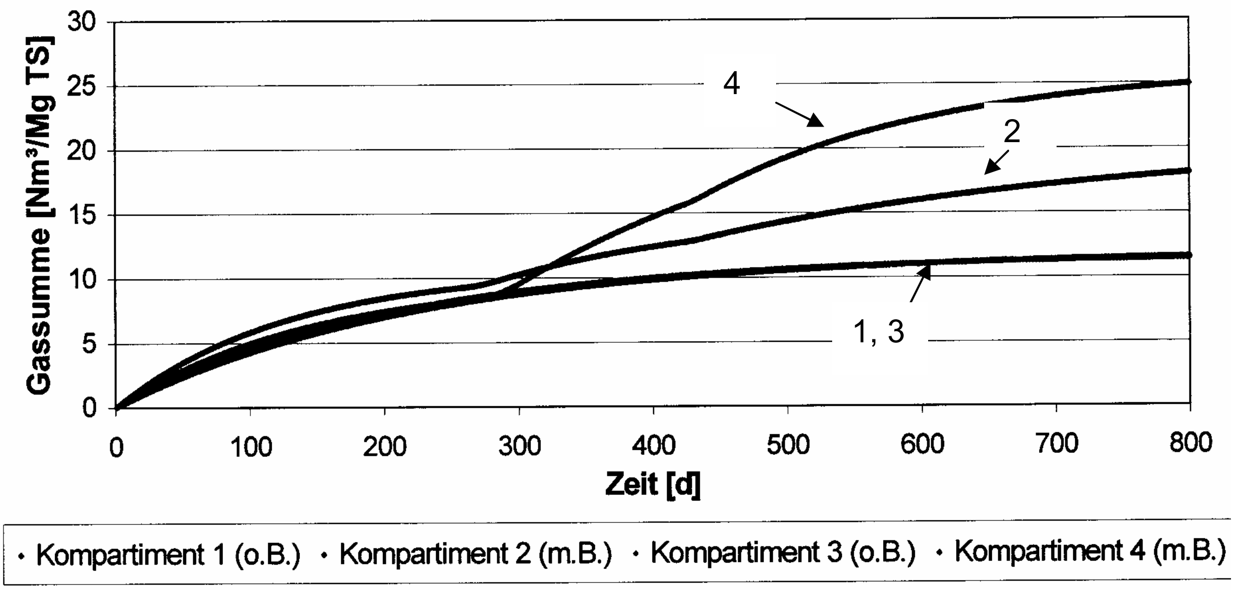


Figure 8 Total specific gas production [m³/Mg DM] of the test cells; cells 2 and 4 with irrigation (Raninger et al., 2001)

Table 10 Water management of the irrigated cells 2 and 4 Allerheiligen

	leachate recirculation	added fresh water	total	specific
	L / 800 d	L / 800 d	L / 800 d	L / Mg • 800 d
cell 2	2.666	34.240	36.906	858,3
cell 4	529	34.240	34.769	903,1

Table 11 Specific gas production in the reactors Allerheiligen

spec. gas production 800d	cell 1 / 2	cell 3 / 4	average	unit
without irrigation	11,55	11,47	11,51	(N)m³ / Mg DM
with irrigation	18,22	25,09	*(21,66)*[a)]	(N)m³ / Mg DM

[a)]The average value of the irrigated cells is not very suitable for comparing, because the material in cell 4 had a higher AT_4 than the material in the other cells. Hence the value of cell 2 should be used instead.

MBT-landfill gas composition was measured by Friedrich (2002) with a 2 meter probe at young MBT-landfills. The gas composition equals to a conventional landfill, which is in the stable methanic or the long time phase (Table 12). It has to be taken in account, that the probe reached just the younger layers. Similar gas compositions were measured by the author during a 3 year reactor test with MBT-output from the MBT Lueneburg. Bockreis (2004) observed a significant drop of the methane content within 7 years in the gas of several reactors filled with different kinds of MBT output.

Table 12 Gas composition of MBT-landfills in Lower Saxony (Friedrich, 2002)

landfill	CH_4 Vol.%	O_2 Vol.%	CO_2 Vol.%	equals to Rettenberger landfill phase
Bassum	70	0	22	end phase V, long time
Lueneburg	60	0	37	ende phase IV, stable methanic

5 Summary, further results and recommendations

- To keep German standards for calorific value or TOCDM, sieving to < 60 mm or less will be necessary. 24-40% of the MBT-input will be landfilled.
- A filter layer between MBT-output and bottom drainage layer seems to be not necessary. Drainage material 8-16 instead of 16-32 mm gives extra security.
- Besides implacement density and implacement moisture the surcharge of the overlaying waste layers has enormous importance for the final storage density.
- Close to the surface implacement densities between 1,0 and 1,6 g/cm³ WM or 0,7 - 1,1 g/cm³ DM can be expected, increasing with increasing surcharge.

- An increase of the uncompacted layer-thickness from 30 to 50 cm does not lower the implacement density.
- After 3 compaction turns 80-90% of the compaction of 5 turns is reached. A maximum of 3 turns is sufficient. Each turn decreases the traffic ability.
- Static compaction is equal or better than dynamic.
- Permeability decreases with increasing depth/surcharge/density several orders of magnitude (~10^{-7}-10^{-11}m/s at landfill bottom). This rises the risk of (excessive) porous water pressure.
- For a good mechanical stability and traffic ability waste should be implaced with a low moisture contend and be protected from wettening if possible.
- Under moderate moisture and permeability conditions maximum slope incli-nations of 1:3 – 1:3,5 are expected to be possible. In each case an individual stability calculation is necessary.
- For prevention or compensation of instabilities caused by porous water pressure, drain layers or supporting banks made of mineral waste could be useful.
- In dependence of surface near saturation deficit, permeability and inclination, surface runoff will appear or not. It usually has to be treated.
- Swampy conditions make the surface impassable for trucks / dumpers and in some cases even for heavy landfill compactors. For delivery of the waste stabilised roads to the discharging point are needed. Waste can be spread by a caterpillar or compactor with shield.
- Mixed landfilling with incineration ashes is unfavourable because of the mobilisation of pollutants (Doerrie, 2002).

6 Literature

Bluemel, W.; Mueller-Kirchenbauer, A.	2004	Unpublished calculations.
Bockreis, A., Steinberg, I.	2004	Emissionen mechanisch-biologisch behandelter Abfaelle bei der Deponierung – eine Bilanz aus Langzeitversuchen. In: Kuehle-Weidemeier (2004): Abfallforschungstage 2004. Conference proceedings. Cuvillier Verlag, Goettingen, Germany, ISBN 3-86537-121-3.
Doerrie, T.	2002	Kombinierte Ablagerung von MVA-Schlacken und MBA-Abfaellen. Master thesis at the University of Rostock.
Duellmann, H.	2002	Untersuchungen zum Einbau von MBA-Abfaellen auf der Zentraldeponie Hannover. Laboruntersuchungen zum

		Verdichtungs-,Durchlaessigkeits-, Last-Setzungs- und Scherverhalten. Unpublished. By order of aha Hannover.
Fehrer, K.	2002	Geotechnisches Verhalten von mechanisch-biologisch behandelten Abfaellen. Diplomarbeit, Universitaet fuer Bodenkultur, Vienna.
Friedrich, K.	2002	Ablagerung von mechanisch-biologisch behandelten Restabfaellen. Unpublished master thesis at the Institute for water quality and waste management (ISAH), University of Hanover. Supervisor: Matthias Kuehle-Weidemeier.
Hupe, K.	1998	Auswirkungen der mechanisch-biologischen Vorbehandlung von Restabfaellen auf die Deponietechnik. Muell & Abfall, Heft 3 / 1998; Erich Schmidt Verlag.
Kuehle-Weidemeier, M.	2003 / 2005	Bedarf, Konstruktionsgrundlagen und Betrieb von Deponien fuer mechanisch – biologisch behandelte Siedlungsabfaelle. Veroeffentlichungen des Institutes fuer Siedlungswasserwirtschaft und Abfalltechnik der Universitaet Hannover, Band 127. ISBN 3-921421-57-8.
Reiff, C.; Marx, B.	1999	Feldversuche zur Ermittlung der Einbaudichte von mechanisch-biologisch vorbehandelten Abfaellen mit unterschiedlichen Einbaugeraeten. Deponierung von vorbehandellten Siedlungsabfaellen. Veroeffentlichungen des Zentrums fuer Abfallforschung der TU Braunschweig, Heft 14.
Schuhmann	1989	Standfestigkeitsberechnung fuer Hausmuelldeponien – Praktische Erfahrungen - . In: Fehlau / Stief (Hrsg.) Fortschritte in der Deponietechnik 1989. S. 153. Band 30 der Reihe Abfallwirtschaft in Forschung und Praxis. Erich Schmidt Verlag.
von Felde, D.	1999	Ablagerung mechanisch-biologisch vorbehandelter Abfaelle. Ergebnisse der niedersaechsischen Demonstrationsanlagen. In: Muensteraner Schriften zur Abfallwirtschaft, Band 2, 6. Muensteraner Abfallwirtschaftstage.
Ziehmann, G.	1999	Veraenderung des mechanischen Verhaltens durch die mechanische und biologische Vorbehandlung. Deponierung von vorbehandelten Siedlungsabfaellen. Veroeffentlichungen des Zentrums fuer Abfallforschung, TU Braunschweig.

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