The Current Situation of MBT in Germany

Matthias Kuehle-Weidemeier[1], Ulrich Langer[2]

Abstract
More than 7 million Mg (tons) of mixed municipal solid waste are annually treated in Germany by mechanical (MA), mechanical-biological treatment (MBT), mechanical-biological drying (MBS) or mechanical-physical drying (MPS) treatment. Especially the launch of those plants that comprise biological treatment steps was often accompanied by severe technical problems. This led to controversial statements in the press and other public media. The German EPA (Umweltbundesamt, UBA) wanted to get an overview about the real situation to allow an objective, factual evaluation of the current situation. In the framework of the environment research plan (UFOPlan) Wasteconsult international received the order for data collection and evaluation. The present paper summarises the most important results concerning mass balance, the compliance of landfill criteria and compliance of boundary values for exhaust gas.

Keywords
German landfill directive (AbfAblV), mechanical-biological treatment (MBT), operational experience, boundary values, exhaust gas, alternative waste technologies, AWT

1 INTRODUCTION

1.1 Motive and initial situation

More than 7 million Mg (tons) of residual solid waste are annually treated in Germany in mechanical-biological waste treatment plants (MBT), mechanical-biological waste treatment plants with biological drying (MBS), mechanical-physical drying (MPS) or purely mechanic waste treatment plants (MA). The “cold” pre-treatment procedures have thus become a bearing pillar of the municipal solid waste management. The commissioning of many plants with biological process steps was related to essential technical problems, leading to controversial comments in the media and under experts. Therefore, the German EPA (Umweltbundesamt) wanted to get a comprehensive overview about the current situation in order to allow an objective, factual evaluation based on assured data. Wasteconsult international was assigned to carry out data collection and evaluation.

[1] Dr., CEO Wasteconsult international, Robert-Koch-Str. 48b, 30853 Langenhagen, Germany, www.wasteconsult.de, info@wasteconsult.de
[2] Dr., Project engineer, Wasteconsult international

1.2 Kinds and components of MBT

1.2.1 MBT for waste drying and sorting (MBS and MPS)

MBS are designed for a short and hot biological treatment just to dry the waste for later incineration and for sorting and sieving out usable fractions (minerals, metals). These plants produce only a small amount of material which might be landfilled. Most components are comparable to MBTs prior to landfilling. The main product is refuse derived fuel (RDF).

Similar are mechanical-physical plants (MPS), where the waste is dried with external energy. MPS usually have extensive sensor based sorting systems to produce various recyclable fractions like paper, wood, different kinds of plastics, ferrous and non ferrous metals, minerals etc, but about 80% of the output is RDF.

1.2.2 MBT prior to landfill (MBA)

1.2.2.1 Mechanical treatment before biological treatment

The initial mechanical treatment has the following functions:

- Separation or conditioning (e.g. shredding) of contraries. Method: Visual control and separation with polyp bucket.
- Separation of high calorific fractions for the use as refuse derived fuel (RDF). Method: Sieve (e.g. 80-150mm), sometimes air separation.
- Separation of waste components which can be recycled (e.g. metals). Method: Magnetic separator (Fe-metals) and often additionally eddy current separator (non-Fe-metals).
- Disintegration and homogenization of the waste for the biological treatment Method: Shredder / mill and mixing drum.

Depending on the local needs and legal demands, not all of these elements are used everywhere. Simple (in Germany: previous) MBTs just separate contraries to protect the machines and then shredder the waste. Commercial waste needs usually more mechanical processing than waste from private households.

With increasing prices for recovered materials, sensor based sorting systems are integrated in many MBTs for the production of secondary resources. The future development of MBT will be a move from a pre-treatment facility for landfills to a secondary resource separation plant that combines techniques of trational MBT and material recycling facilities (MRFs).

1.2.2.2 Mechanical treatment after biological treatment

Since May 2005 upper calorific value and TOC in the dry matter of landfilled waste are very strictly limited in Germany (similar in Austria). Often the boundary values can be only achieved, if the waste gets a second mechanical treatment after the biological treatment. This is usually a sieving < 60 mm or smaller.

1.2.2.3 Biological treatment

a) Aerobic treatment

Low technical level

The most simple way of biological treatment are mainly passively aerated windrows under a roof, which are shifted from time to time, or static open air windrows, which use the dome aeration method, which is explained in Paar et al., 1999. The dome aeration windrows can be operated in open air directly on the landfill surface. The low technical processes needs a long treatment time (e.g. 16-20 weeks) and therefore much space. Process control (e.g. moisture management) is difficult or at least not very precise, but it is possible to achieve a huge improvement of the landfilled waste at low investment costs. To run the windrows properly, experienced personal is needed.

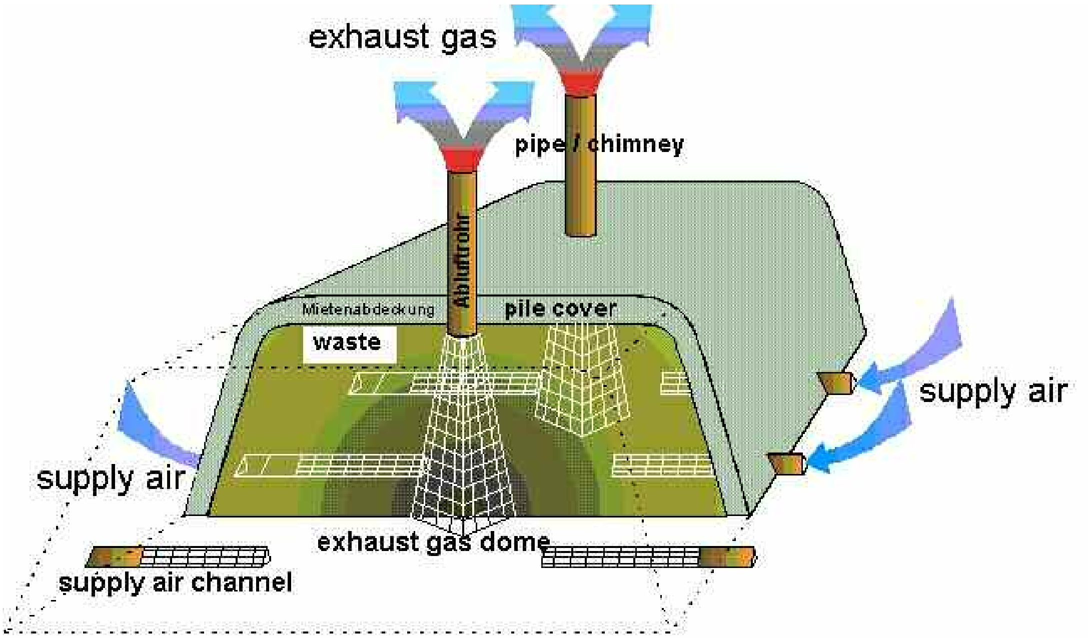


Figure 1 **Dome aeration windrow (modified from Brummack et al., 2004)**

High technical level

German legal regulations have high demands on gas emission control of MBT-plants and homogeneous "product" quality of the landfilled MBT-output. Hence, all MBTs are encapsulated and have high technical standards. The biological processing is done in actively aerated, frequently shifted, large and plane windrows located in sometimes in halls but mainly in composting tunnels, which allow a better process and emission control and minimize the amount of exhaust gas that has to be treated.

The biological treatment can be subdivided in "intensive processing" and "post processing". The intensive processing is actively aerated and has a duration between 2 and 6 weeks, dependent on the MBT conception. The most of the biological degradation happens during the intensive processing, which releases also the most exhaust gas. Composting tunnels are especially suitable for the intensive processing. At the end of the intensive processing, an AT_4 of < 20 mg O_2 / g DM should be reached.

In the post processing the metabolic rate is much lower, which allows to reduce the shifting intervals and the aeration. Triangular windrows might be only passively aerated, if they are shifted frequently (weekly, at least every second week). A hall is a good environment for the post processing.

b) Anaerobic treatment (digestion / fermentation)

In some MBTs the aerobic treatment is combined with an anaerobic digestion, which produces methane gas for energy production. The digestion can be designed as

- full stream digestion or
- part stream digestion.

The full stream digestion processes the whole waste stream that is biologically treated. This results in high demands on the mechanical properties / stability of the digestion step and the dewatering at the end of the digestion. The advantage is the use of the whole methane production potential.

Part stream digestion includes just the fine fraction (e.g. < 40mm), while the (coarse) rest of the waste, which contains many anaerobically poorly degradable substances, goes directly to the aerobic treatment. After digestion, the digested material is added to the aerobic treatment. A nameable dewatering is usually not necessary, as additional water is needed for the aerobic treatment of the undigested fraction.
To reach the German boundary values for landfilling and to prevent methane emissions, the digestion has always to be followed by an aerobic treatment step.

1.3 Advantages of MBT

Advantages vs. bioreactor landfill:

- Full control and avoidance of gaseous emissions in encapsulated systems
- Industrial process. All of the waste is affected (no dry zones like in a landfill)
- Valuable resources (metals, wood, plastic…) are extracted and not wasted / lost in the landfill
- Leaves better stabilised material in the landfill (aerobic degradation is more efficient than anaerobic on hardly degradable substances)
- Higher usable gas yield (intensive treatment and no loss via open surfaces

and leakages like in a landfill)

Advantages vs. MSW incinerator

- Usually cheaper in investment and operation
- Allows economic operation of smaller (decentralized) units
- Not burning water and stones, only feasible materials will be incinerated
- Lower potential of toxic emissions because the production of highly toxic organic compounds at incineration temperatures is avoided (except at the RDF incineration)

1.4 History of MBT and important frame conditions in Germany

First simple MBTs in Germany started operation in the 1970s, but remained a niche solution. At the end of the 70s producing RDF (called BRAM) became popular, but neither the production nor the marketing of RDF was very successful. In the 80s and early 90s bioreactor landfills became an object of research but were identified as a not sustainable solution. A milestone in German waste management were new legal regulations set in the 1990s which included strict boundary values for landfill input:

Boundary values for deposit on landfills have already been determined in the technical directive for municipal waste (TASi) of May 14. 1993, which could be met for "traditional household landfills" (category 2) only subsequent to pre-treatment of MSW. The objective was to assure harmless deposit and with respect to the German Waste Recycling Law of 1993 redirection of lots of waste into recycling, which had been deposited before.

A period of 12 years until June 1, 2005 had been granted for complete adherence to the boundary values defined in annex B of TASi so that the waste management companies were able to adapt their long-term concepts correspondingly and would get sufficient time for planning, authorisation and construction of the required waste treatment capacities.

The boundary values determined in annex B of TASi for landfill category 2, e.g. the ignition loss of 5 weight-% can be completely met e.g. for household waste only by thermal treatment (waste incineration [MVA]). Both on the level of politics and under experts, this indirect commitment to exclusively thermal procedures was criticised in parts. As a result of this, projects have been carried out to investigate the qualification of MBT as alternative and supplement, respectively, to incineration on a national level (joint project MBT of the Federal Ministry of Education and Research) (Soyez et al., 2000) and also in individual German states, predominantly in Lower Saxony (Doedens et al., 2000).

The MBTs used until this date mostly had a low degree of technology and predominately worked according to the chimney aeration method. On the locations in Bassum, Lüneburg and Wiefels in Lower Saxony, new full-scale pilot plants were constructed with a high degree of technology which received intense scientific assistance

(Doedens et al., 2000) and started operation from 1997. A similar project was accomplished in Bavaria with the MBT Erbenschwang (Hertel et al., 2001).

It was concluded from the results of the research projects that also by mechanical-biological treatment a deposit can be produced for depositing that is ecologically compatible to category 2 landfills, even if it does not comply with the requirements of annex B of TASi. Annex 2 of the Waste Deposit Regulation (AbfAblV) of March 1, 2001 thus contained as an innovation towards TASi allocation criteria and further requirements with regard to waste landfills for deposit of mechanically-biologically treated solid waste. In addition there were prescriptions under emission law in the 30th Federal Decree on the Prevention of Immissions (BImschV) and annex 23 of the Waste Water Ordinance (AbwV) for waste water from the MBT.

The total requirements have not been met by any of the plants existing until then. Therefore 45 MBTs had to be essentially reconstructed or built completely new in the remaining 4 years up until June 1, 2005. The feasibility of a plant to fulfil the requirements could however not be completely proven with regard to industrial scale, but it could be derived from the results of research which were available until this date. Eventually, this was confirmed also in practice.

Very different treatment concepts had been used in the plants, which partly had not been proven at industry scale and had to be adjusted to the most different requirements and objectives of the operators at each location.

Planning and execution of the plants had been carried out by few engineering consultants and some medium-sized plant constructors. As indicated by the arising problems/bottlenecks which resulted in late completion and commencement of regular operation, the large number of plants to be realised simultaneously within a short period of time clearly exceeded the capability of the few participating companies to some extent. This got worse because some operators delayed the period of tendering and assignment for a long time.

A hard price war came along to significant technical and logistic requirements which, in combination with carelessly (?) assumed warranties for procedures which had not been sufficiently tested before, endangered or destroyed the existence of the participating plant constructors. The insolvency of the companies Babcock-Borsig, Farmatic, Heese, Herhof and Horstmann additionally casts/casted a damp over realisation of numerous MBT-projects (some of these companies are now back on the market with new owners). Construction or completion of some plants or plant components thus occasionally had to be tendered anew. In the worst case this happened multiple times at the same location. Therefore, even with early planning and tendering, problems could arise for commissioning of plants in due time.

2 DATA COLLECTION

2.1 Development, content and dispatch of the questionnaire

In co-ordination with the Federal Environmental Agency, Wasteconsult international has developed a questionnaire which is universally suited for all types of plants inspected in the project. Particularly technical equipment, capacity, problems in operation, compliance with the legal boundary values and efficiency of the plants should be evaluated by it. At the same time, the intermediate storages allocated to the plants were listed.

Further information was gathered from a report of LAGA (LAGA, 2004) and an online-database of the German Association for the Waste Disposal Industry (BDE).

From a total of 78 plants, 1 BA (biological treatment plant), 10 MA, 2 MBT and 2 MBS did not provide data. Data of such plants which had not provided any data was investigated in the internet, at the Federal State Environment Agencies as well as at the Regional Commissions.

2.2 Considered plants

The plants considered in the project are shown in Figure 2-1. For both biological plants a mechanical treatment plant also exists at the same location, from where the biological plant receives the material to be treated. Therefore, it principally is a matter of two mechanical-biological plants acting as separated plants predominantly for legal reasons. For presentation of the general information (also within the characteristics) and technical equipment, these linked plants will still be contemplated separately. For the further analyses on the quantity flow and adherence to boundary values, both BAs will be combined with the appropriate MA and treated according to their technology as aerobic MBT.

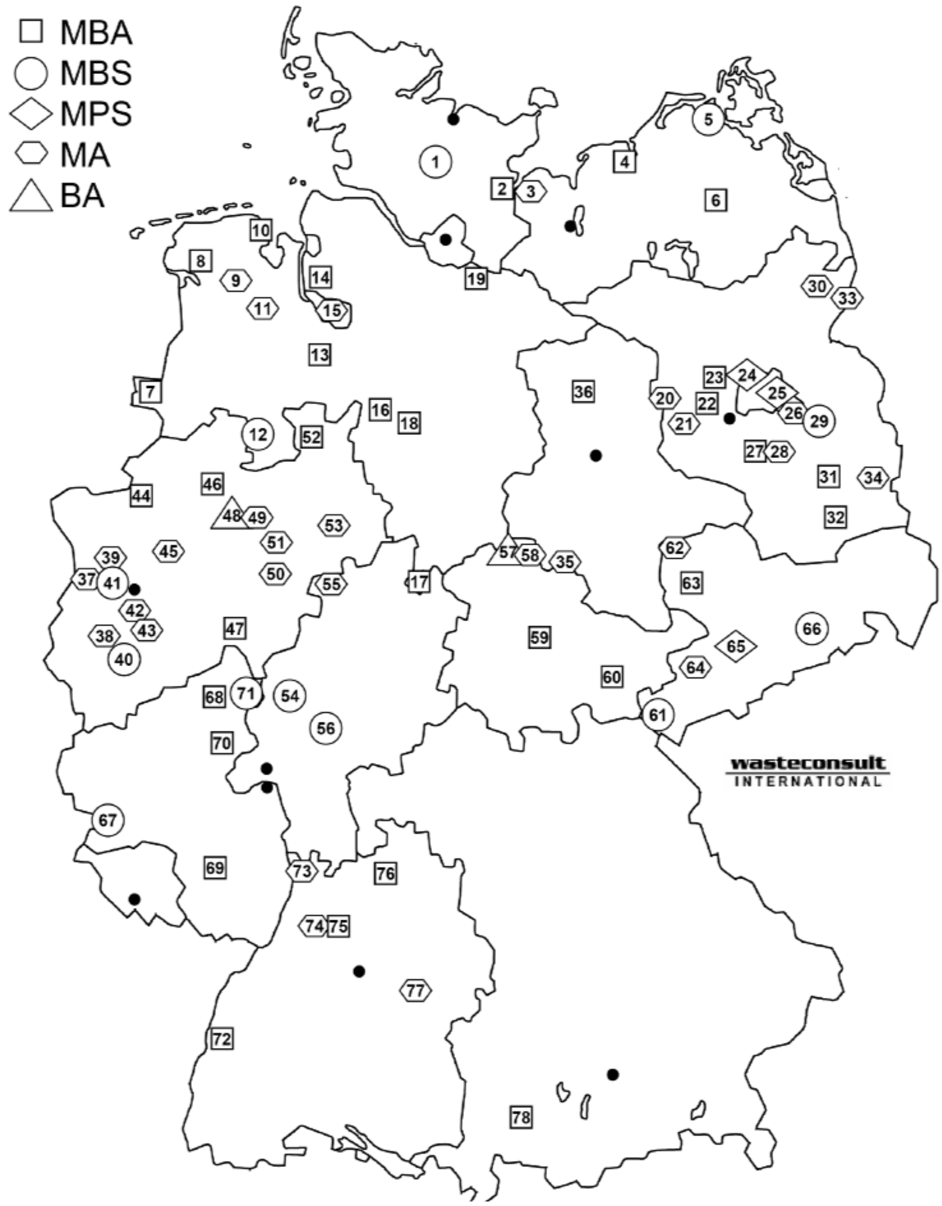


Figure 2-1 **Site plan of mechanical, mechanical-biological and mechanical-physical solid waste treatment plants in Germany**

3 RESULTS

3.1 Preliminary note

The investigation in the present paper is focused on such plants that are subject to the German Waste Storage Ordinance (AbfAblV) and/or 30th Federal Decree on the Prevention of Immissions (BImschV) as well as annex 23 of the Waste Water Ordinance (AbwV), thus mechanical-biological plants (MBT) prior to deposit and mechanical-biological drying plants (MBS).

3.2 Material flow and treated amounts of waste

Figure 3-1 represents the material flow arising from the total of the considered plants (extrapolation) including the pure mechanical treatment plants (MA). It should be observed for contemplation of the treatment capacity that 3.6 million Mg (tons) of plant output require further treatment or energetic utilisation.

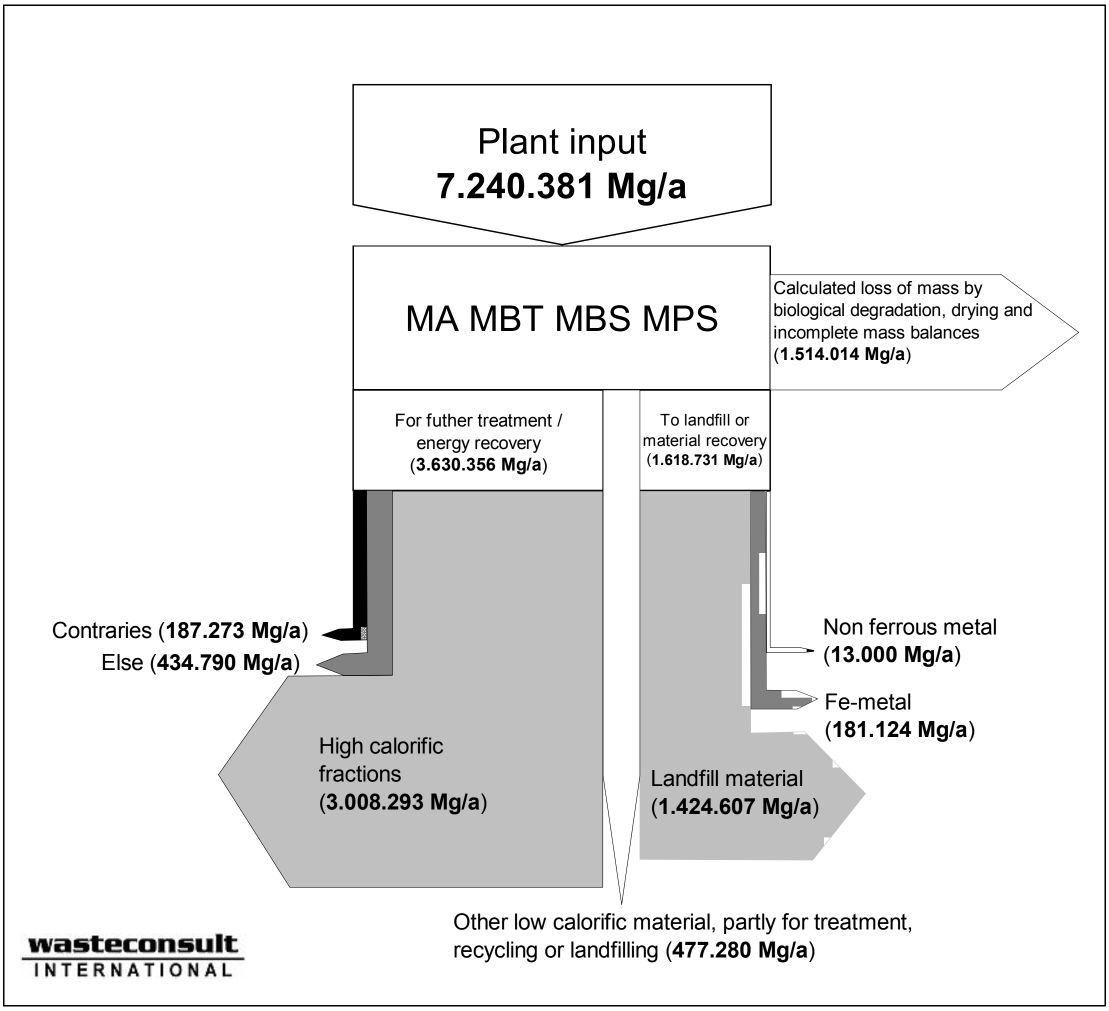


Figure 3-1 Material flow extrapolated to the overall stock of plants (76*) in 2006

Table 3-1 shows the number of plants of the different procedure types and the extrapolated actual operational capacity in the year 2006. The completely plausible input/output relation for the MAs might be attributed to inaccurateness for mass accounting of the plants.

Table 3-1 Total number of plants and extrapolated actually treated waste amount 2006

Plant type	Number	Input [Mg/a]	Output [Mg/a]
MA	30	2,333,040	2,006,666
MBA*	33*	3,082,898	2,339,407
MBS	12	1,361,443	1,071,135
MPS	3	463,000	309,160
Sum	**76* (78)**	**7,240,381**	**5,726,367**

*incl. 2 separately authorised BA / MA combinations at one location each

The fractions of output materials are partitioned quite differently depending on type of plant, thus as to the purpose of the plant. In Figure 3-2 this is shown with the exception of the MA.

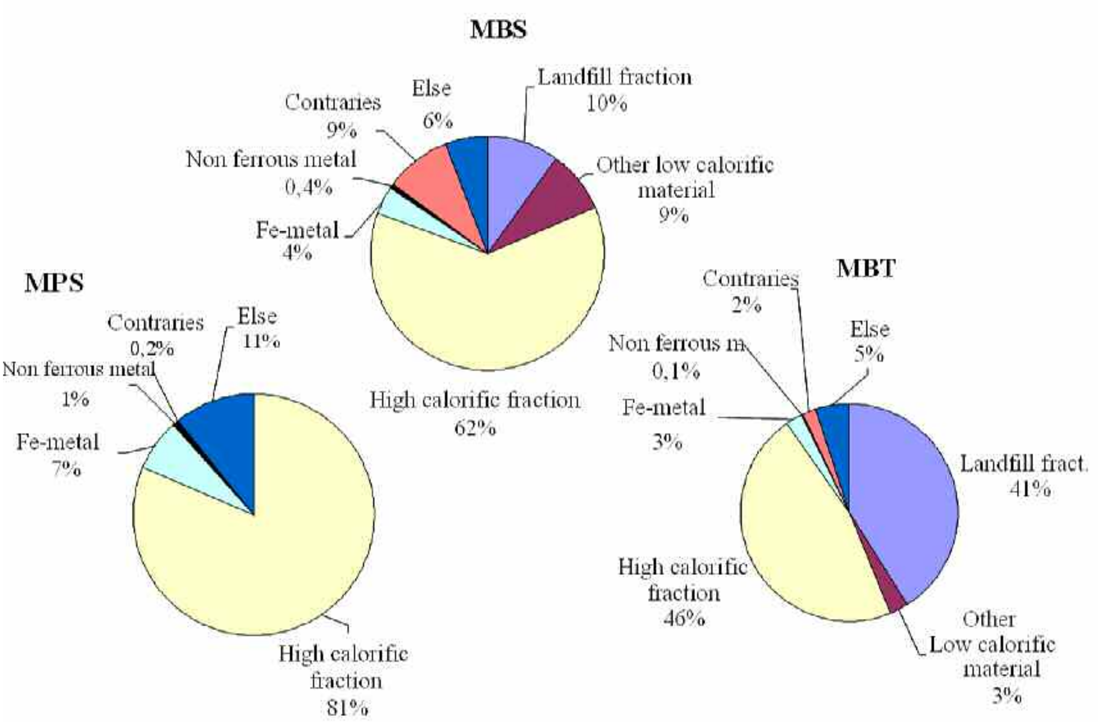


Figure 3-2 Fractioning of output flow with regard to total output (without loss due to degradation and drying) of the different plant concepts

3.3 Problems in operation and adjustment of waste treatment technology

Several plants had to be changed with respect to the operating method or technical equipment in order to reliably produce a deposit which meets the Waste Deposit Regulation.

The shredding technology (e.g. higher degree of crushing) was improved in many plants or amended by additional units. Also the screening lines have been adjusted to finer screening.

For biological treatment changes have been accomplished with regard to duration and cultivation of the post-composting. Also improvements have been made to ventilation and irrigation. For some plants with anaerobic process steps additional cleaning or external disposal of process water was attached. Measures for early fire detection were required locally.

The following further occurring problems have been mentioned:
Mechanical Treatment:

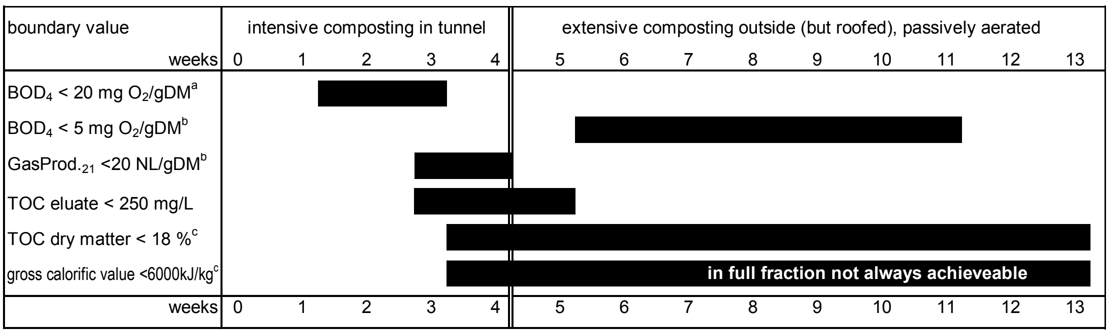
- Congestions due to ribbons, deadlocks / standstill / damages by contraries
- High wear, change of the degree of crushing and screen cut due to wear

Biological Treatment

- High cleaning effort, particularly for ventilation
- Wear, e.g. for walking floors
- Limited potentiality for hall ventilation
- Release of ammonia gas, anaerobic zones in the composting
- Instable process during fermentation
- High employment of labour and machine breakdown in wet processing
- Formation of floating cover, foam formation, decanter problems
- Fluctuation in drying, too wet compost output

3.4 Compliance with landfill parameters

In the following the number of plants is evaluated whose landfill output meets the requirements of the German Waste Deposit Regulation (AbfAblV). Foreign readers should consider that significantly stricter values apply in Germany compared to other nations. Compliance with the boundary values that apply in other states should therefore rarely state a problem for the plants inspected in the scope of the project.



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

Figure 3-3 **Boundary values for landfilling of MBT-waste and range of the necessary biological treatment duration (0-150mm fraction) in a very well operated composting tunnel in a rural area (DOC eluate is 300mg/L since 2007)**

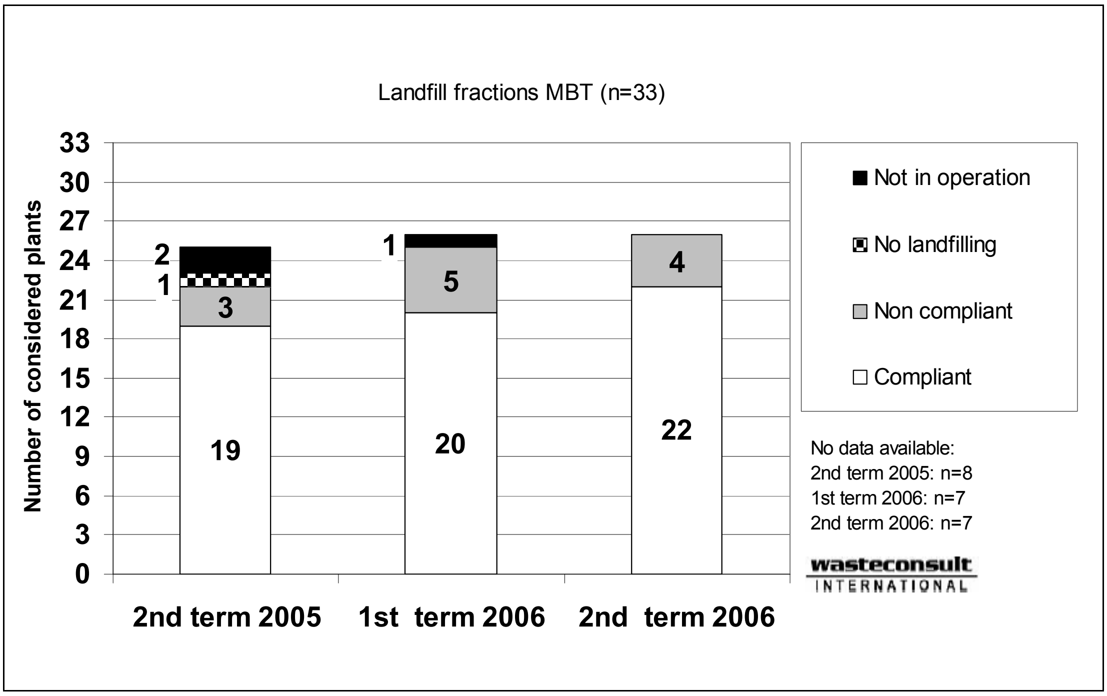


Figure 3-4 MBA total: Simultaneous compliance with the boundary values AT4/GB21, TOC in eluate and gross (upper) calorific value (Ho)/TOC DM of the landfill fraction

Figure 3-4 shows which part of the plants have consistently met the most important parameters influenced by the treatment method according to annex 2 of the Waste Deposit Regulation (AbfAblV). The situation will further improve in 2007, since 2 of the plants which were not able to meet the boundary values for landfilling shall be shut down in 2007. Also by optimisation of the rest of the plants the situation will further improve.

Aerobic plants and plants with anaerobic process steps are able to a different degree to meet the requirements of the Waste Deposit Regulation (AbfAblV). There are noticeably greater problems with the anaerobic plants (see Figure 3-5). Mainly percolation systems and plants with full-flow wet fermentation are affected by this.

A particularly critical parameter for many plants turned out to be the TOC in the eluate. The boundary value for the TOC (respectively DOC from 2007) in the eluate determined in the version of the Waste Deposit Regulation was raised in the Waste Deposit Regulation valid from February 2007 from 250 to 300mg/L and the permissible range was considerably extended[1]. This will further increase the share of those

[1] This is particularly due to considerable range of fluctuation for the results of the analyses of the same samples.

plants producing disposable material, as can be derived from Figure 3-6.

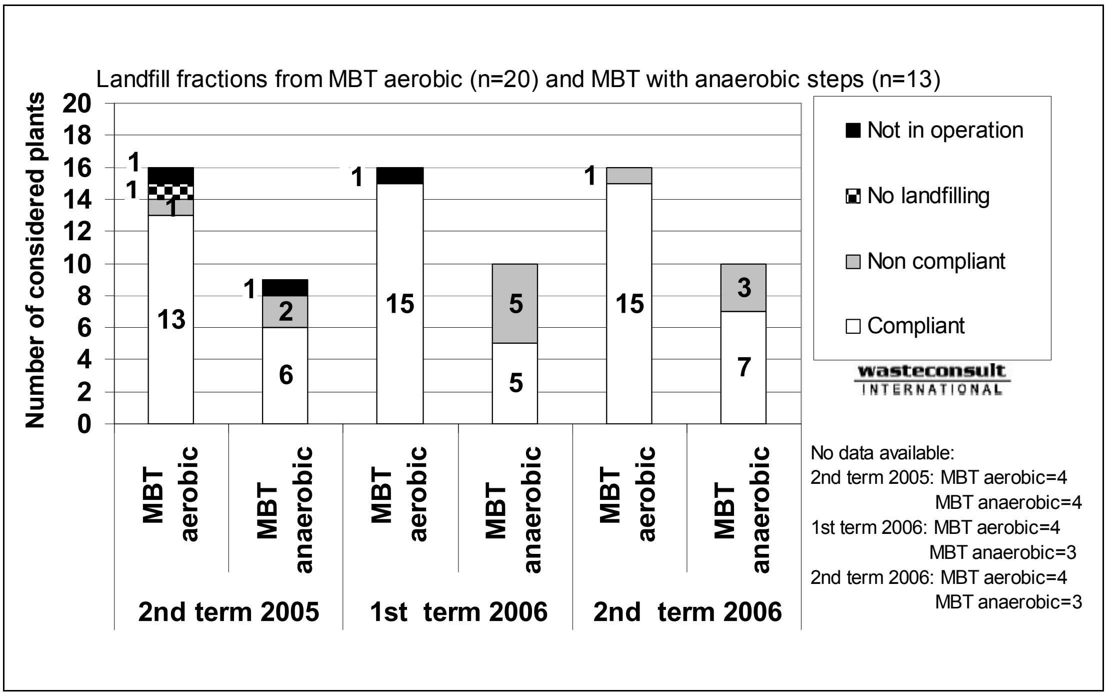


Figure 3-5 **Compliance AT4/GB21, TOC in eluate and Ho/TOC DM for aerobic and plants with anaerobic process steps**

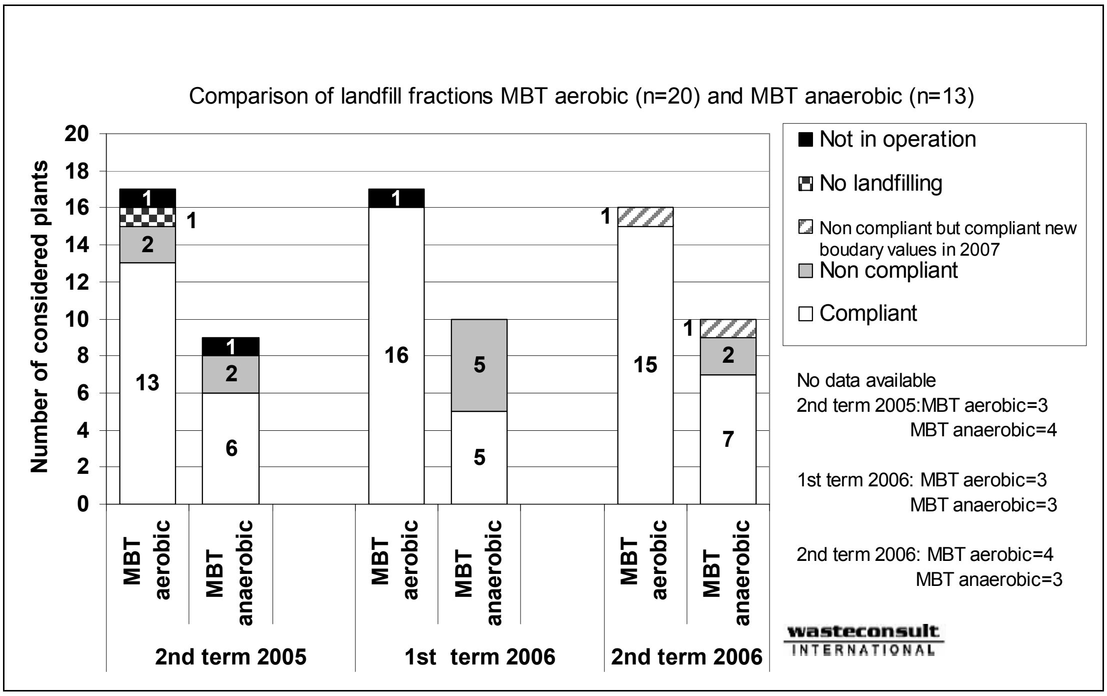


Figure 3-6 **MBA aerobic / anaerobic: Compliance with boundary value TOC-eluate**

3.5 Treatment of exhaust gas

3.5.1 Operation problems and adjustment of exhaust gas treatment

Particularly the regenerative-thermal treatment of exhaust gas (RTO) resulted in considerable problems. Next to corrosion problems (e.g. by condensation), primarily silica deposits in the heat exchangers led to substantial maintenance effort and thus to limitation in functionality of the plants. In a lot of cases the RTO-systems had been dimensioned too small so that an additional line had to be installed. Problems also arose in many cases from the measuring technology, most notably for the parameter of dust.

Next to increase of RTO-capacity, particularly shortened maintenance intervals, insulation of pipelines and containers as well as improvements to the measuring technology have been accomplished.

Nevertheless the following problems are still often occurring:

- **Siloxane blocking of RTO**
- **Corrosion**
- High energy consumption
- Failure of measuring and control technology, particularly dust measuring (e.g. caused by condensate)
- Too low availability

3.5.2 Compliance with boundary values of the 30th Federal Decree on the Prevention of Immissions (BImSchV)

The retrofitted RTO-lines and shortened maintenance intervals have led to a considerably improved situation also on the side of discharged air. This is represented on the basis of the parameter 'organic substances' in Figure 3-7.

However, problems occurred not only with the exhaust gas treatment systems itself, but also with the emission measuring technology, where it came to breakdowns/disruption of operations. It must be acted on the assumption that exceeding the parameter 'total dust', which can easily be met by means of the conventional technology, must be attributed to failure of the measuring technology to a considerable part and not to actually raised emissions.

Figure 3-7 shows the situation with respect to compliance with the boundary values for emission of organic substances (VOC) representative for the parameters listed in the 30^{th} Federal Decree on the Prevention of Immissions (BImSchV) in Germany.

Table 3-2 Boudary values for VOC (volatile organic carbon) emissions from MBT in Germany and Austria

VOC	Germany	Austria	Unit
Concentration, 1/2 hour mean	40	40	mg/m³
Concentration, daily mean	20	20	mg/m³
Load, monthly mean	55	100	g/Mg MBT input

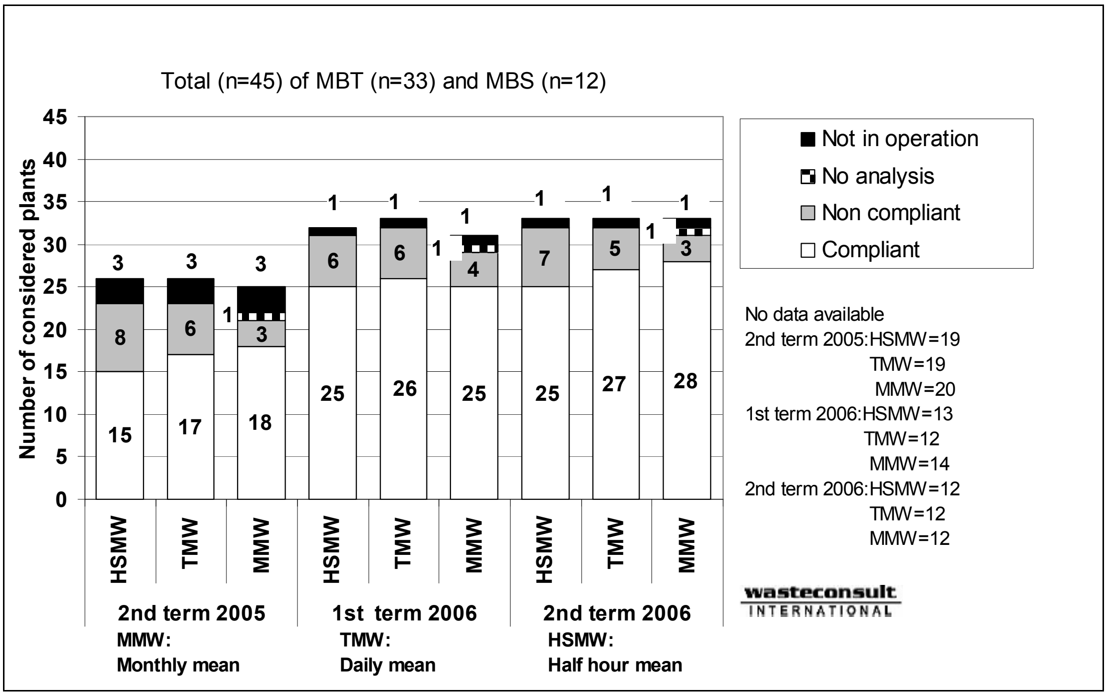


Figure 3-7 Compliance with emission of organic substances (VOC) MBT + MBS (45 plants)

3.5.3 Odour problems

17% of all plants considered in the study confirm the occurrence of odour problems (Table 3-3). These particularly resulted from waste handling as well as dealing with compost material. Also adjacent landfills and intermediate storage sites have been specified as odour source in the broader sense. This should be regarded specifically in dealing with complaints of residents. It is hard to differentiate from outside if MBT, composting, intermediate storage or landfills are the source of possible odour emission.

Table 3-3 Occurrence of odour problems

Plant type	Number	Yes	No	n/a	Yes	No	n/a
BA	2			2			100%
MA	30	1	10	19	3%	33%	63%
MBT aerobic	18	4	10	4	22%	56%	22%
MBT partial flow fermentation	4		2	2		50%	50%
MBT full flow fermentation	6	2	3	1	33%	50%	17%
MBT percolate	3	2	1		67%	33%	
MBS	12	3	4	5	25%	33%	42%
MPS	3	1		2	33%		67%
Total	78	13	30	35	17%	38%	45%

4 CONCLUSION

A challenging pioneer work has been done by large-scale introduction of MBT under difficult general conditions. Not all constructed plants proved of value, which is reflected in the shut-down of 2 plants.

It should be pointed out here that the development of thermal waste treatment plants over decades, which also left expensive investment ruins as the failure of pyrolysis plants according to the Thermoselect® method or smouldering-combustion procedure, however will in no way question the efficiency and qualification of thermal waste treatment. Mostly complex optimisation processes, but also throwbacks must be taken into account when introducing new technologies.

The problems existing for MBT could be resolved to a great extent, or clearly be reduced. MBT has proven to be an appropriate technology for the treatment of municipal solid waste according to legal requirements. The still existing difficulties are focused mainly to plants with anaerobic process steps, particularly percolation and full-flow wet fermentation.

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Author's address

Dr.-Ing. Matthias Kuehle-Weidemeier
Wasteconsult international
Robert-Koch-Str. 48 b
D-30853 Langenhagen
Telephone +49 511 23 59 383
Email: info@wasteconsult.de
Website: www.wasteconsult.de