Overview of Best Available Techniques for Mechanical Biological Treatment of Residual Municipal Solid Waste

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Driven by the EU Landfill Directive (Council Directive 1999/31/EC of 26 April 1999 on the landfill of waste), mechanical biological treatment (MBT) technology was developed in the 1990s as a pre-treatment step of waste before landfill. The main goals of this technology are the reduction of organic matter content in the waste and subsequently the reduction of waste volume sent to landfill. Since the landfill ban of untreated municipal solid wastes in 2005 in Germany, residual municipal solid wastes are treated either via MBT or through incineration. MBT technology has undergone since then constant development and becomes an established technology not only for the pre-treatment of waste, but also for the recycling of valuable materials such as metals and for the production of refuse derived fuel (RDF).

Best available techniques (BAT) for MBT in Europe were first documented in the Reference Document of Best Available Techniques (BREF) for Waste Treatments Industries in 2006. Under the Directive 2010/75/EU of the European Parliament and the Council on industrial emissions (IED), this BREF was reviewed and updated between 2013 and 2018 by a European technical working group (TWG).

This paper gives an insight into the current status of MBT treatment of residual municipal solid waste in Germany and the major BAT conclusions relevant to the MBT technology. At the end, an ongoing study on the further development of MBT in Germany is briefly described.

1. Current status of mechanical biological treatment of residual municipal solid waste in Germany

The mechanical biological treatment (MBT) process combines mechanical sorting/separation technologies and biological treatment processes, such as composting and anaerobic digestion. The exact process combination varies case by case and is determined by a number of factors, for instance, the characteristics of input materials and the requirements on the final output materials/products. In general, MBT plants can be categorized into three different groups:

- MBT with composting (MBT C),
- MBT with anaerobic digestion (MBT AD), and
- mechanical biological stabilization with biological drying (MBS).

In addition, mechanical processes without biological steps, i.e. mechanical physical stabilization with thermal drying (MPS), are considered as MBT in a broad sense in Germany. It is, however, noteworthy that MPS plants are subject to legal requirements different from those of the three aforementioned groups.

1.1. Legal requirements

Quality standards and environmental regulations for the installation, the configuration and the operation of MBT plants (excluding MPS) were established in the Ordinance on Facilities for the Biological Treatment of Waste (30. BImSchV) in 2001. Accordingly, in areas with high emissions, such as areas of waste delivery, mechanical and biological treatment steps, contaminated waste air or gas shall be collected and purified before it is emitted into the air through a chimney. The combination of acid scrubber and thermal afterburning via regenerative thermal oxidizer (RTO) has proven to be state-of-the-art waste gas purification system for MBT. Additionally, biofilter can be used for the treatment of waste air with low pollutant concentrations.

Emission limit values for different air pollution parameters are specified in the 30. BImSchV and listed in the following Table 1.

Table 1: Emission limit values of air pollution parameters for MBT plants (excluding MPS)

Continuous measurement			
Parameter	Daily Average	Half-hourly Average	Monthly Average (emission load per tonne of treated waste)
	mg/m³		g/t
total dust	10	30	–
organic substances, given as total carbon	20	40	55
nitrous oxide	–	–	100
Discontinuous measurement			
Parameter	**Measured value**	**Average over the sampling period**	
odour	500 ou_E/m^3	–	
dioxins and furans, given as cumulative value according to appendix to the 17. BImSchV [4]	–	0.1 ng/m^3	

MPS plants are regulated by the German Technical Instructions on Air Quality Control (TA Luft). Requirements on construction and operation of MPS plants are similar to those defined in the 30. BImSchV. Emission limit values for different air pollution parameters are listed in the following Table 2.

Table 2: Emission limit values of air pollution parameters for MPS plants

Discontinuous measurement	
Parameter	Measured value
total dust	10 mg/m^3
ammonia	0.1 kg/h or 20 mg/m^3
hydrogen chloride	0.1 kg/h or 20 mg/m^3
organic substances, given as total carbon	90 % reduction rate and 20 mg/m^3
odour	500 ou_E/m^3

To reduce emissions to water, the waste delivery and storage areas as well as the mechanical and biological treatment facilities shall be covered, enclosed or encapsulated such that rainfall shall not come into contact with waste or the treatment facilities. Process water originated from the biological treatment and the waste air/gas purification facilities shall be reused within the process to a large extent. Requirements on the wastewater before discharge are set out in the Annex 23 to the German Waste Water Ordinance (AbwV). Emissions limit values of water pollution parameters for direct discharge from MBT plants (excluding MPS) into water bodies are listed in the following Table 3. For indirect discharge, i.e. discharge to the sewer, only the emission limit values of AOX, heavy metals, easily released cyanide and sulphide shall be complied.

Table 3: Emission limit values of water pollution parameters for direct discharge from MBT plants (excluding MPS)

Parameter	Qualified grab sample or 2-hour composite sample	Parameter	Qualified grab sample or 2-hour composite sample
	mg/l		mg/l
chemical oxygen demand (COD)	200	total chromium	0.5
biochemical oxygen demand in 5 days (BSB5)	20	hexavalent chromium (Cr(VI))	0.1
total nitrogen, as a sum of ammoniacal-, nitrite- and nitrate nitrogen (N_{total})	70	nickel	1
total phosphorus	3	lead	0.5
total hydrocarbon	10	copper	0.5
toxicity to fish eggs (G_{egg})	2	zinc	2
adsorbable organic halides (AOX)	0.5	arsenic	0.1
mercury	0.05	cyanide, easily released	0.2
cadmium	0.1	sulfide, easily released	1

MBT plants (excluding MPS) produce, inter alia, a stabilized output for disposal to landfill. The requirements on the output materials are specified in the Landfill Ordinance (DepV). Accordingly, the total carbon content of the stabilized output materials shall not exceed 18 %.

1.2. Development and current status of mechanical biological treatment plants in Germany

1.2.1. Number and treatment capacities of MBT plants

MBT plants in Germany undergo constant adjustment, which is mainly driven by market needs. There were 44 MBT plants with a total yearly treatment capacity of around 5.2 million tons in 2005. From 2005 to 2018, some of the MBT plants have been taken out of service or converted to solely mechanical treatment (MT) or biological treatment (BT) plants. Only organic waste are treated in the BT plants. In 2018, the total number of MBT plants has been reduced to 36, among which 11 MBT C, 10 MBT AD, 12 MBS and 3 MPS. Nevertheless, the total yearly treatment capacity adds up to around 4.8 million tons.

Figure 1 and 2 show the historical development of the number and the treatment capacities of MBT plants, respectively.

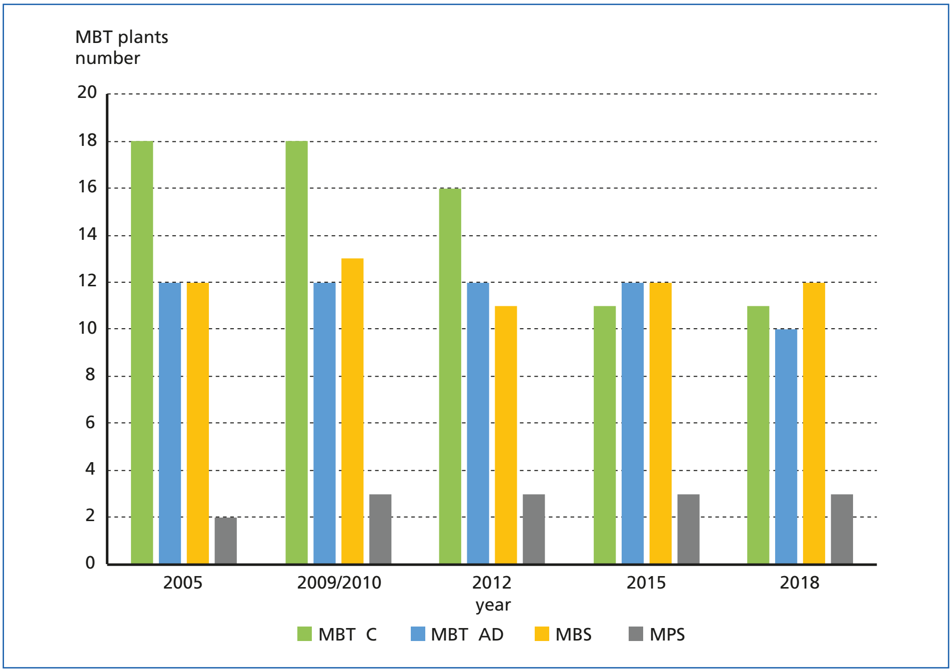

Figure 1: Number of MBT plants in Germany

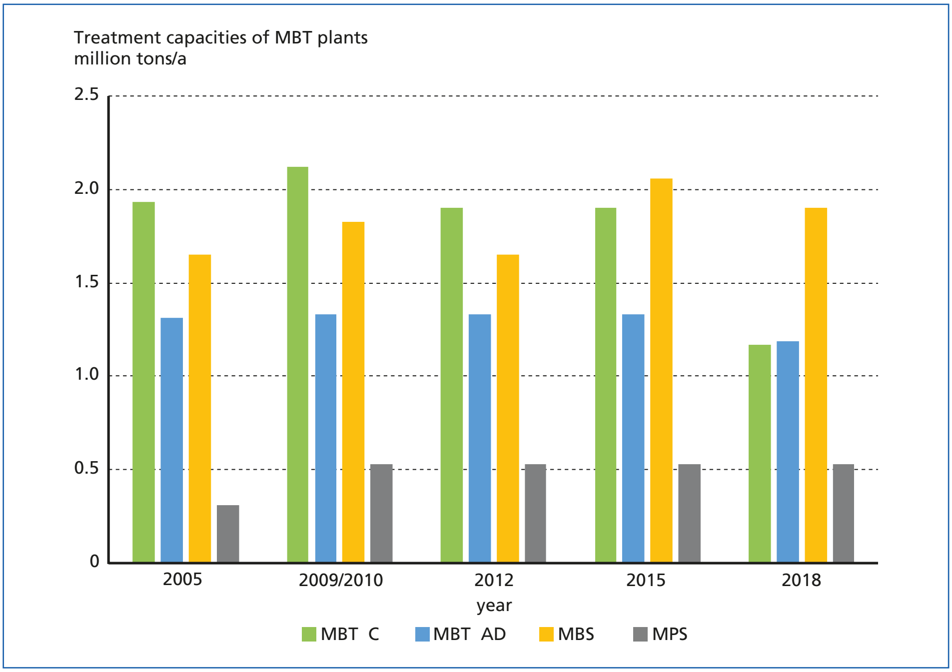

Figure 2: Treatment capacities of MBT plants in Germany

1.2.2. Material flow and energy consumption

The first MBT plants were developed with the aim of pretreating residual MSW before landfill. Over the years, MBT plants have become more resource efficient and contribute to the national recycling targets by sorting out recyclable materials such as metals, glass, plastics and paper from incoming waste. Additionally, biogas and RDF produced by MBT plants are used to substitute fossil fuels for the generation of electricity and heat.

An ongoing study [3] shows that, in 2015, MBT plants in Germany treated around 3.8 million tons of waste, from which

- 106,000 tons of ferrous and non-ferrous metals were recycled,
- approximately 50 million Nm^3 biogas were generated, of which about 84.2 % was used for cogeneration and 9.2 % for energy supply to RTO, and
- around 2.1 million tons RDF were produced for waste-to-energy plants, cement plants, coal power plants and others.

In the same year, roughly 660,000 tons of treated waste were sent to landfill, marking a reduction of 35 % when compared to 2010.

The varied process combination of MBT plants leads to different consumption of electricity and gas (natural gas, landfill gas or biogas). For instance, the average specific consumption of electricity in 2015 was estimated to be 63.9 kWh per ton of waste (kWh/t) for MPS plants, while 45.8 kWh/t for MBT C plants. And it is worth mentioning that the electricity consumption between facilities within one MBT group (MBT C, MBT AD, MBS or MPS) differs remarkably from each other. As an example, the electricity consumption of different MBS plants ranges from 20 kWh/t to 110 kWh/t. Some MBT plants have put continuous effort into the optimization of energy management systems, operation modes and energy efficiency of equipment, through which significant reduction on the electricity consumption has been achieved.

Gas (natural gas, landfill gas or biogas) is required for energy supply to the drying of waste, RTO and anaerobic digestion. Among the four MBT groups (MBT C, MBT AD, MBS and MPS), MPS plants have the highest demand on gas. The average specific gas consumption in 2015 was 137 kWh/t for MPS plants, 34.6 kWh/t for MBT C plants, 26.0 kWh/t for MBT AD plants, and 25 kWh/t for MBS plants. Nonetheless, gas consumption in MPS plants decreases continuous in the last five years, mainly due to the reduced drying of waste. Regarding gas consumption of RTO, three configurations of the waste air/gas purification system have to be differentiated:

- only RTO (mainly applied in MBT AD plants),
- RTO and biofilter (mainly applied in MBT C plants), and
- RTO and bag filter (mainly applied in MBS and MPS plants).

The gas consumption of RTO depends on the amount of waste gas and its pollutant load. When only RTO is used for the waste air/gas purification, the specific gas consumption of RTO (about 49 to 56 kWh/t) is subsequently the highest among the three aforementioned configurations. When the waste air/gas stream with lower pollutant load is diverted to a biofilter or a bag filter and RTO is only used to treat waste air/gas stream with high pollutant load, the specific gas consumption can be significantly reduced. This is mainly due to the lower amount of waste gas sent to RTO and the higher heating value of the heavily polluted waste gas.

1.2.3. Emissions to air

Emissions limit values of air pollution parameters given in Section 1.1. can be complied with proper waste air/gas purification systems. Concentrations of total dust, dioxins and total carbon are reported to be well below the limit values. For MBT C and MBT AD plants, the removal of ammonia using acid washers before RTO results in a yearly average load of N_2O emission at 20 g per ton of waste. Purified gas existing RTO might have a higher odour concentration. It is currently under investigation if this is correlated to the NO_x concentration in the waste gas.

2. Best Available Techniques Reference Document for Waste Treatment and its conclusions for mechanical biological treatment of waste

The Council Directive 96/61/EC of September 24, 1996 concerning integrated pollution prevention and control (the IPPC Directive) applied an integrated approach to the regulation of large industrial installations, which took into account the whole environmental performance including emissions to air, water and land. Accordingly, regulators must set permit conditions so as to achieve a high level of protection of the environment as a whole. The permit conditions including emission limit values must be based on Best Available Techniques (BAT). Under this directive, 33 Reference Documents on Best Available Techniques (BREF) were drawn up as a result of information exchange between EU Member States and industries concerned under the direction of the European IPPC Bureau (EIPPCB) in Seville. The BREF for the Waste Treatments Industries was completed in 2006.

The IPPC Directive was codified in 2008 (Directive 2008/1/EC of the European Parliament and of the Council of January 15, 2008 concerning integrated pollution prevention and control) and subsequently was repealed with effect from January 7, 2014 by Directive 2010/75/EU on industrial emissions (IED), which is a new directive recasting seven past directives, including the IPPC Directive. According to the IED, the aforementioned information exchange shall take place between Member States, the industries concerned, non-governmental organizations promoting environmental protection and the Commission. A significant change compared to BREFs under the IPPC Directive is that the BREF documents under IED contain a chapter named *BAT Conclusions*, which lays down the *conclusions on best available techniques, their description, information to assess their applicability, the emission levels associated with the best available techniques, associated monitoring, associated consumption levels and, where appropriate, relevant site remediation measures* [2]. BAT conclusions will be published in the Official Journal of the European Union and thus become legally binding for industrial installations listed in Annex I of the IED. Within four years after publication, competent authorities in the EU Member States shall ensure that a) all the permit conditions for the installation concerned are reconsidered and, if necessary, updated to ensure compliance with the corresponding BAT Conclusions, and b) the installation concerned complies with those permit conditions [2].

2.1. Review of the Best Available Techniques Reference Document for waste treatment

The review of BREF for the Waste Treatments Industries, renamed as BREF for Waste Treatment, started officially in June 2013 with the re-activation of the technical working group (TWG). The major steps of this review process are listed in the Table 4. It can be seen that, until the publication of the BAT Conclusions for Waste Treatment in the Official Journal of the European Union on August 10, 2018, this process lasted more than five years.

Table 4: Review process of the BREF for waste treatment

Main steps	Date
reactivation of TWG	June 2013
call for wish list (revision requests of TWG members)	July 2013
kick-off meeting of TWG	November 2013
elaboration of questionnaires	December 2013 – June 2014
activation of three subgroups (biological treatment, mechanical treatment, physical-chemical treatment)	March 2014
collection of information	March – June 2014
data collection via questionnaires	June – November 2014
site visits in Germany (4 plants)	April 2015
draft 1 of revised WT BREF	December 2015
commenting period (> 3 400 comments)	December 2015 – March 2016
site visits in France (5 plants)	March 2016
interactive webinars on data assessment	19, 20 und 22 September 2016
background paper and revised draft BAT conclusions for the final TWG meeting	January 2017
final TWG meeting	19 – 23 March 2017
pre-final draft of the WT BREF	14 June 2017
final draft of the WT BREF	19 October 2017
meeting of article 13 forum	19 – 20 December 2017
meeting of article 75 committee	12 April 2018
translation of BAT conclusions in all EU languages	November 2017 – July 2018
publication of BAT conclusions in the official journal of the European Union	17 August 2018
publication of BREF for waste treatment	October 2018

BAT reference documents and their BAT Conclusions are drawn up on the basis of the collected information including, among others, environmental performance and operational data. The main types of data required are outlined in the BREF guidance [1] and listed in the following:

- consumption (general information on consumption, consumption of raw and auxiliary materials/feedstocks, water use and energy use),
- emissions to water,
- air emissions,
- residues/waste,
- other information (e.g. the year the installation was built and commissioned, the main operating conditions of the process or the different types of products manufactured)
- reference information that must accompany emission data (general information such as emission source; monitoring; averages, ranges and distributions of emission values), and
- specific issues under the remit of each TWG.

For the review of BREF for Waste Treatment, a questionnaire was elaborated by the TWG according to the aforementioned BREF guidance. This questionnaire was sent out to the operators of selected waste treatment facilities in Europe. At the end of the data collection period, 501 filled-in questionnaires from 338 waste treatment plants located in 18 EU Member States were submitted. For MBT plants (excluding MPS), a total of 21 filled-in questionnaires were collected, seven of which were from Germany. The origins of other filled-in questionnaires for MBT plants are shown in the following Figure 3.

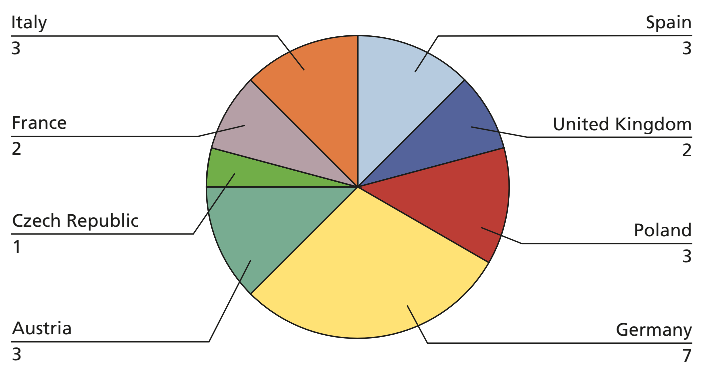

Figure 3: Distribution of submitted filled-in questionnaires for MBT plants

The collected information and data were evaluated by the EIPPCB, particularly with regard to emissions to air and to water in correlation to the applied abatement techniques. Results of this evaluation served as a basis for the derivation of BAT and *emission levels associated with the best available techniques* (BAT AEL). BAT AEL means *the range of emission levels obtained under normal operating conditions using a best available technique or a combination of best available techniques, as described in BAT conclusions, expressed as an average over a given period of time, under specified reference conditions* [2].

2.2. Conclusions on Best Available Techniques for mechanical biological treatment of waste

A total of 53 BAT conclusions are laid down in the Commission Implementing Decision (EU) 2018/1147 of August 10, 2018 establishing best available techniques (BAT) conclusions for waste treatment. Nearly half of the BAT conclusions are general BAT conclusion, which are applicable in all waste treatment facilities regardless of the treatment process. Nonetheless, applicability is given in some BAT conclusions, where restrictions apply. The distribution of the 53 BAT conclusions is shown in the following Figure 4.

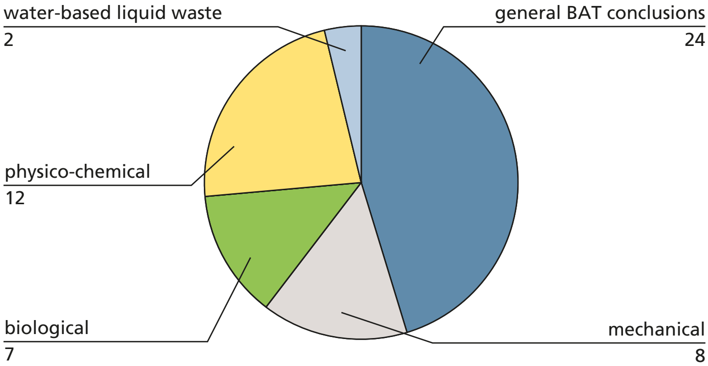

Figure 4: Distribution of BAT conclusions

An overview of the 24 general BAT conclusions are provided in keywords in the Table 5.

Table 5: Overview of general BAT conclusions

BAT No.	Content
	General BAT conclusions
1	implement and adhere to an environmental management system (EMS)
2	techniques to improve the overall environmental performance of the plant
3	establish and maintain an inventory of waste water and waste gas stream
4	techniques to reduce the environmental risk associated with the storage of waste
5	set up and implement handling and transfer procedures

Table 5: Overview of general BAT conclusions – continuation

	Monitoring
6	monitor key process parameters at key locations
7	monitor emissions to water
8	monitor channelled emissions to air
9	monitor diffuse emissions of organic compounds
10	monitor odour emissions periodically
11	monitor the annual consumption of water, energy and raw materials as well as the annual generation of residues and waste water
	Emissions to air
12	set up, implement and regularly review an odour management plan
13	techniques to reduce odour emissions
14	techniques to reduce diffuse emissions to air
15	techniques to use flaring only for safety reasons or for non-routine operating conditions
16	techniques to reduce emissions to air from flares when flaring is unavoidable
	Noise and vibrations
17	set up, implement and regularly review a noise and vibration management plan
18	techniques to prevent or reduce noise and vibration emissions
	Emissions to water
19	techniques to optimize water consumption, to reduce the volume of waste water generated and to prevent or reduce emissions to soil and water
20	techniques to treat waste water
	Emissions from accidents and incidents
21	techniques to prevent or limit the environmental consequences of accidents and incidents
	Material efficiency
22	substitute materials with waste
	Energy efficiency
23	techniques to use energy efficiently
	Reuse of packaging
24	maximize the reuse of packaging

BAT conclusions particularly relevant to MBT plants are BAT 7, 8, 20, 34, 35 and 39.

2.2.1. BAT conclusions for emissions to water

According to BAT 35, three techniques should be used in order to reduce the generation of waste water and to reduce water usage:

a) segregation of water streams,

b) water recirculation, and

c) minimization of the generation of leachate.

While BAT 35 b) and c) have long become state of the art in Germany, effort will be required for the implementation of BAT 35 a).

The monitoring requirements for emissions to water are defined in the BAT 7 and listed in the following Table 6.

Table 6: Monitoring requirements for emissions to water

Substance/parameter	Standard(s)	Minimum monitoring frequency (1) (2)
arsenic (As), cadmium (Cd), chromium (Cr), copper (Cu), nickel (Ni), lead (Pb), zinc (Zn) (3) (4)	various EN standards available (e.g. EN ISO 11885, EN ISO 17294-2, EN ISO 15586)	once every month
mercury (Hg) (3) (4)	various EN standards available (i.e. EN ISO 17852, EN ISO 12846)	once every month
chemical oxygen demand (COD) (5) (6)	no EN standard available	once every month
perfluorooctanoic acid (PFOA) (3)	no EN standard available	once every six months
perfluorooctanesulfonic acid (PFOS) (3)	no EN standard available	once every six months
total nitrogen (total N) (6)	EN 12260, EN ISO 11905-1	once every month
total organic carbon (TOC) (5) (6)	EN 1484	once every month
total phosphorus (total P) (6)	various EN standards available (i.e. EN ISO 15681-1 and -2, EN ISO 6878, EN ISO 11885)	once every month
total suspended solids (TSS) (6)	EN 872	once every month

(1) Monitoring frequencies may be reduced if the emission levels are proven to be sufficiently stable.
(2) In the case of batch discharge less frequent than the minimum monitoring frequency, monitoring is carried out once per batch.
(3) The monitoring only applies when the substance concerned is identified as relevant in the waste water inventory mentioned in BAT 3.
(4) In the case of an indirect discharge to a receiving water body, the monitoring frequency may be reduced if the downstream waste water treatment plant abates the pollutants concerned.
(5) Either TOC or COD is monitored. TOC is the preferred option, because its monitoring does not rely on the use of very toxic compounds.
(6) The monitoring applies only in the case of a direct discharge to a receiving water body.

Most of the listed substances have been regulated in the Annex 23 to the German Wastewater Ordinance. Monitoring of four parameters, i.e. PFOA, PFOS, TOC and TSS shall be added to the Annex 23.

Techniques for the treatment of waste water are provided in the BAT 20, which are sorted in the following groups:

- preliminary and primary treatment, such as equalization, neutralization and physical separation,
- physico-chemical treatment, such as adsorption, distillation, precipitation, chemical oxidation, chemical reduction, evaporation, ion exchange and striping,
- biological treatment, such as activated sludge process and membrane bioreactor
- nitrogen removal, such as nitrification/denitrification, and
- solids removal, such as coagulation and flocculation, sedimentation, filtration and flotation.

The BAT AELs for direct and indirect discharges to a receiving water body are also provided in the BAT 20 and listed in the following Table 7 and 8, respectively.

Table 7: BAT-associated emission levels (BAT-AELs) for direct discharges to a receiving water body

Substance/Parameter		BAT-AEL (1) mg/l
total organic carbon (TOC) (2)		10 – 60
chemical oxygen demand (COD) (2)		30 – 180
total suspended solids (TSS)		5 – 60
total nitrogen (total N)		1 – 25 (3) (4)
total phosphorus (total P)		0.3 – 2
metals and metalloids (5)	arsenic (expressed as As)	0.01 – 0.05
	cadmium (expressed as Cd)	0.01 – 0.05
	chromium (expressed as Cr)	0.01 – 0.15
	copper (expressed as Cu)	0.05 – 0.5
	lead (expressed as Pb)	0.05 – 0.1
	nickel (expressed as Ni)	0.05 – 0.5
	mercury (expressed as Hg)	0.0005 – 0.005
	zinc (expressed as Zn)	0.1 – 1.0

(1) The averaging periods are defined in the General considerations.
(2) Either the BAT-AEL for COD or the BAT-AEL for TOC applies. TOC monitoring is the preferred option because it does not rely on the use of very toxic compounds.
(3) The BAT-AEL may not apply when the temperature of the waste water is low (e.g. below 12° C).
(4) The BAT-AEL may not apply in the case of high chloride concentrations (e.g. above 10 g/l in the waste input).
(5) The BAT-AELs only apply when the substance concerned is identified as relevant in the waste water inventory mentioned in BAT 3.

Table 8: BAT-associated emission levels (BAT-AELs) for indirect discharges to a receiving water body

Substance/Parameter		BAT-AEL (1)(2) mg/l
metals and metalloids (3)	arsenic (expressed as As)	0.01 – 0.05
	cadmium (expressed as Cd)	0.01 – 0.05
	chromium (expressed as Cr)	0.01 – 0.15
	copper (expressed as Cu)	0.05 – 0.5
	lead (expressed as Pb)	0.05 – 0.1
	nickel (expressed as Ni)	0.05 – 0.5
	mercury (expressed as Hg)	0.0005 – 0.005
	zinc (expressed as Zn)	0.1 – 1.0

(1) The averaging periods are defined in the General considerations.
(2) The BAT-AELs may not apply if the downstream waste water treatment plant abates the pollutants concerned, provided this does not lead to a higher level of pollution in the environment.
(3) The BAT-AELs only apply when the substance concerned is identified as relevant in the waste water inventory mentioned in BAT 3.

BAT AELs for metals and metalloids are more stringent when compared to the emission limit values given in the Annex 23 to the German Wastewater Ordinance. The implementation of these BAT AELs in the Annex 23 is currently being discussed in a working group consisting representatives from federal states, German Environment Agency and federal government.

2.2.2. BAT conclusions for emissions to air

BAT 39 specifies the following techniques for the reduction of emissions to air from MBT plants:

a) segregation of the waste gas streams, and

b) recirculation of waste gas.

Both techniques have long been applied in practice in Germany. For instance, gas stream with low pollutant content is treated in a biofilter, while gas stream with high pollutant content is treated in a RTO.

The monitoring requirements for channelled emissions to air are defined in the BAT 8 and listed in the following Table 9.

Table 9: Monitoring requirements for channelled emissions to air

Substance/Parameter	Standard(s)	Minimum monitoring frequency (1)	Monitoring associated with
dust	EN 13284-1	once every six months	BAT 34
H_2S (2)	no EN standard available	once every six months	BAT 34
NH_3 (2)	no EN standard available	once every six months	BAT 34
odour concentration (3)	EN 13725	once every six months	BAT 34
TVOC	EN 12619	once every six months	BAT 34

(1) Monitoring frequencies may be reduced if the emission levels are proven to be sufficiently stable.
(2) The odour concentration may be monitored instead.
(3) The monitoring of NH_3 and H_2S can be used as an alternative to the monitoring of the odour concentration.

According to BAT 34, one or a combination of the following techniques should be used to reduce channelled emissions to air of dust, organic compounds and odorous compounds, including H_2S and NH_3:

a) adsorption,

b) biofilter,

c) fabric filter,

d) thermal oxidation, and

e) wet scrubbing.

The BAT AELs for channelled NH_3, odour, dust and TVOC emissions to air are also provided in the BAT 34 and listed in the following Table 10.

The BAT AEL for dust is more stringent when compared to the emission limit value given in the 30. BImSchV (Table 1) or the TA Luft (Table 2). However, the upper range of this BAT AEL can be complied with a proper operation of fabric filter.

Table 10: BAT-associated emission levels (BAT-AELs) from MBT plants

Parameter	Unit	BAT-AEL (Average over the sampling period)
NH_3 (1)	mg/Nm³	0.3 – 20
odour concentration (1)	ou_E/Nm³	200 – 1,000
dust	mg/Nm³	2 – 5
TVOC	mg/Nm³	5 – 40 (2)

(1) Either the BAT-AEL for NH3 or the BAT-AEL for the odour concentration applies.
(2) The lower end of the range can be achieved by using thermal oxidation.

3. Further development of MBT in Germany

The mechanical biological treatment of residual municipal solid waste has contributed to a significant reduction of methane emission from landfill. In addition, MBT outputs such as recycled metals or RDF have been used to substitute primary raw materials and fossil fuels, thus preserving limited natural resources and playing a part in the circular economy. Nonetheless, there are still optimization potentials for the MBT technology in terms of resource and energy efficiency. For instance, the plant configuration can be optimized in respect of waste input, technical processes or other operation conditions. In addition, the treatment process can be optimized to increase the quantity and quality of MBT outputs and to reduce the greenhouse gas emissions. The aforementioned aspects are currently under investigation in an ongoing study supervised by the German Environment Agency [3]. Results of this study are expected in 2020.

4. Sources

[1] Commission Implementing Decision 2012/119/EU of 10 February 2012 laying down rules concerning guidance on the collection of data and on the drawing up of BAT reference documents and on their quality assurance referred to in Directive 2010/75/EU of the European Parliament and of the Council on industrial emissions, OJ L 63/1, 2.3.2012.

[2] European Union: Directive 2010/75/EU of the European Parliament and of the Council of 24 November 2010 on industrial emissions (integrated pollution prevention and control).

[3] Ketelsen, K.; Becker, G.: Weiterentwicklung der mechanisch-biologischen Abfallbehandlung (MBA) mit den Zielen der Optimierung der Ressourceneffizienz und Minimierung von Treibhausemissionen. Interim report of a research project (FKZ 3717 34 331 0) funded by the Federal Ministry of the Environment, Nature Conservation and Nuclear Safety of Germany, 2019.

[4] 17th Ordinance on the incineration and co-incineration of waste (17. BImSchV)

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