

## II

(Non-legislative acts)

## DECISIONS

## COMMISSION IMPLEMENTING DECISION (EU) 2017/2117

of 21 November 2017

**establishing best available techniques (BAT) conclusions, under Directive 2010/75/EU of the European Parliament and of the Council, for the production of large volume organic chemicals**

(notified under document C(2017) 7469)

(Text with EEA relevance)

THE EUROPEAN COMMISSION,

Having regard to the Treaty on the Functioning of the European Union,

Having regard to Directive 2010/75/EU of the European Parliament and of the Council of 24 November 2010 on industrial emissions (integrated pollution prevention and control) <sup>(1)</sup>, and in particular Article 13(5) thereof,

Whereas:

- (1) Best available techniques (BAT) conclusions are the reference for setting permit conditions for installations covered by Chapter II of Directive 2010/75/EU and competent authorities should set emission limit values which ensure that, under normal operating conditions, emissions do not exceed the emission levels associated with the best available techniques as laid down in the BAT conclusions.
- (2) The forum composed of representatives of Member States, the industries concerned and non-governmental organisations promoting environmental protection, established by Commission Decision of 16 May 2011 <sup>(2)</sup>, provided the Commission on 5 April 2017 with its opinion on the proposed content of the BAT reference document for the production of large volume organic chemicals. That opinion is publicly available.
- (3) The BAT conclusions set out in the Annex to this Decision are the key element of that BAT reference document.
- (4) The measures provided for in this Decision are in accordance with the opinion of the Committee established by Article 75(1) of Directive 2010/75/EU,

HAS ADOPTED THIS DECISION:

*Article 1*

The best available techniques (BAT) conclusions for the production of large volume organic chemicals, as set out in the Annex, are adopted.

<sup>(1)</sup> OJ L 334, 17.12.2010, p. 17.

<sup>(2)</sup> Commission Decision of 16 May 2011 establishing a forum for the exchange of information pursuant to Article 13 of the Directive 2010/75/EU on industrial emissions (OJ C 146, 17.5.2011, p. 3).

*Article 2*

This Decision is addressed to the Member States.

Done at Brussels, 21 November 2017.

*For the Commission*  
Karmenu VELLA  
*Member of the Commission*

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## ANNEX

**BEST AVAILABLE TECHNIQUES (BAT) CONCLUSIONS FOR THE PRODUCTION OF LARGE VOLUME ORGANIC CHEMICALS**

## SCOPE

These BAT conclusions concern the production of the following organic chemicals, as specified in Section 4.1 of Annex I to Directive 2010/75/EU:

- (a) simple hydrocarbons (linear or cyclic, saturated or unsaturated, aliphatic or aromatic);
- (b) oxygen-containing hydrocarbons such as alcohols, aldehydes, ketones, carboxylic acids, esters and mixtures of esters, acetates, ethers, peroxides and epoxy resins;
- (c) sulphurous hydrocarbons;
- (d) nitrogenous hydrocarbons such as amines, amides, nitrous compounds, nitro compounds or nitrate compounds, nitriles, cyanates, isocyanates;
- (e) phosphorus-containing hydrocarbons;
- (f) halogenic hydrocarbons;
- (g) organometallic compounds;
- (k) surface-active agents and surfactants.

These BAT conclusions also cover the production of hydrogen peroxide as specified in Section 4.2(e) of Annex I to Directive 2010/75/EU.

These BAT conclusions cover combustion of fuels in process furnaces/heaters, where this is part of the abovementioned activities.

These BAT conclusions cover production of the aforementioned chemicals in continuous processes where the total production capacity of those chemicals exceeds 20 kt/year.

These BAT conclusions do not address the following:

- combustion of fuels other than in a process furnace/heater or a thermal/catalytic oxidiser; this may be covered by the BAT conclusions for Large Combustion Plants (LCP);
- incineration of waste; this may be covered by the BAT conclusions for Waste Incineration (WI);
- ethanol production taking place on an installation covered by the activity description in Section 6.4(b)(ii) of Annex I to Directive 2010/75/EU or covered as a directly associated activity to such an installation; this may be covered by the BAT conclusions for Food, Drink and Milk Industries (FDM).

Other BAT conclusions which are complementary for the activities covered by these BAT conclusions include:

- Common Waste Water/Waste Gas Treatment/Management Systems in the Chemical Sector (CWW);
- Common Waste Gas Treatment in the Chemical Sector (WGC).

Other BAT conclusions and reference documents which may be of relevance for the activities covered by these BAT conclusions are the following:

- Economics and Cross-media Effects (ECM);
- Emissions from Storage (EFS);
- Energy Efficiency (ENE);
- Industrial Cooling Systems (ICS);

- Large Combustion Plants (LCP);
- Refining of Mineral Oil and Gas (REF);
- Monitoring of Emissions to Air and Water from IED installations (ROM);
- Waste Incineration (WI);
- Waste Treatment (WT).

#### GENERAL CONSIDERATIONS

#### Best Available Techniques

The techniques listed and described in these BAT conclusions are neither prescriptive nor exhaustive. Other techniques may be used that ensure at least an equivalent level of environmental protection.

Unless otherwise stated, the BAT conclusions are generally applicable.

#### Averaging periods and reference conditions for emissions to air

Unless stated otherwise, the emission levels associated with the best available techniques (BAT-AELs) for emissions to air given in these BAT conclusions refer to values of concentration, expressed as mass of emitted substance per volume of waste gas under standard conditions (dry gas at a temperature of 273,15 K, and a pressure of 101,3 kPa), and expressed in the unit mg/Nm<sup>3</sup>.

Unless stated otherwise, the averaging periods associated with the BAT-AELs for emissions to air are defined as follows.

Type of measurement	Averaging period	Definition
Continuous	Daily average	Average over a period of 1 day based on valid hourly or half-hourly averages
Periodic	Average over the sampling period	Average of three consecutive measurements of at least 30 minutes each <sup>(1)</sup> <sup>(2)</sup>

<sup>(1)</sup> For any parameter where, due to sampling or analytical limitations, 30-minute sampling is inappropriate, a suitable sampling period is employed.

<sup>(2)</sup> For PCDD/F, a sampling period of 6 to 8 hours is used.

Where BAT-AELs refer to specific emission loads, expressed as load of emitted substance per unit of production output, the average specific emission loads  $l_s$  are calculated using Equation 1:

Equation 1: 
$$l_s = \frac{1}{n} \sum_{i=1}^n \frac{c_i q_i}{p_i}$$

where:

$n$  = number of measurement periods;

$c_i$  = average concentration of the substance during  $i^{\text{th}}$  measurement period;

$q_i$  = average flow rate during  $i^{\text{th}}$  measurement period;

$p_i$  = production output during  $i^{\text{th}}$  measurement period.

#### Reference oxygen level

For process furnaces/heaters, the reference oxygen level of the waste gases ( $O_R$ ) is 3 vol-%.

### Conversion to reference oxygen level

The emission concentration at the reference oxygen level is calculated using Equation 2:

$$\text{Equation 2: } E_R = \frac{21 - O_R}{21 - O_M} \times E_M$$

where:

$E_R$  = emission concentration at the reference oxygen level  $O_R$ ;

$O_R$  = reference oxygen level in vol-%;

$E_M$  = measured emission concentration;

$O_M$  = measured oxygen level in vol-%.

### Averaging periods for emissions to water

Unless stated otherwise, the averaging periods associated with the environmental performance levels associated with the best available techniques (BAT-AEPLs) for emissions to water expressed in concentrations are defined as follows.

Averaging period	Definition
Average of values obtained during one month	Flow-weighted average value from 24-hour flow-proportional composite samples obtained during 1 month under normal operating conditions <sup>(1)</sup>
Average of values obtained during one year	Flow-weighted average value from 24-hour flow-proportional composite samples obtained during 1 year under normal operating conditions <sup>(1)</sup>

<sup>(1)</sup> Time-proportional composite samples can be used provided that sufficient flow stability can be demonstrated.

Flow-weighted average concentrations of the parameter ( $c_w$ ) are calculated using Equation 3:

$$\text{Equation 3: } c_w = \frac{\sum_{i=1}^n c_i q_i}{\sum_{i=1}^n q_i}$$

where:

$n$  = number of measurement periods;

$c_i$  = average concentration of the parameter during  $i^{\text{th}}$  measurement period;

$q_i$  = average flow rate during  $i^{\text{th}}$  measurement period.

Where BAT-AEPLs refer to specific emission loads, expressed as load of emitted substance per unit of production output, the average specific emission loads are calculated using Equation 1.

### Acronyms and definitions

For the purposes of these BAT conclusions, the following acronyms and definitions apply.

Term used	Definition
BAT-AEPL	Environmental performance level associated with BAT, as described in Commission Implementing Decision 2012/119/EU <sup>(1)</sup> . BAT-AEPLs include emission levels associated with the best available techniques (BAT-AELs) as defined in Article 3(13) of Directive 2010/75/EU
BTX	Collective term for benzene, toluene and ortho-/meta-/para-xylene or mixtures thereof
CO	Carbon monoxide

Term used	Definition
Combustion unit	Any technical apparatus in which fuels are oxidised in order to use the heat thus generated. Combustion units include boilers, engines, turbines and process furnaces/heaters, but do not include waste gas treatment units (e.g. a thermal/catalytic oxidiser used for the abatement of organic compounds)
Continuous measurement	Measurement using an 'automated measuring system' permanently installed on site
Continuous process	A process in which the raw materials are fed continuously into the reactor with the reaction products then fed into connected downstream separation and/or recovery units
Copper	The sum of copper and its compounds, in dissolved or particulate form, expressed as Cu
DNT	Dinitrotoluene
EB	Ethylbenzene
EDC	Ethylene dichloride
EG	Ethylene glycols
EO	Ethylene oxide
Ethanolamines	Collective term for monoethanolamine, diethanolamine and triethanolamine, or mixtures thereof
Ethylene glycols	Collective term for monoethylene glycol, diethylene glycol and triethylene glycol, or mixtures thereof
Existing plant	A plant that is not a new plant
Existing unit	A unit that is not a new unit
Flue-gas	The exhaust gas exiting a combustion unit
I-TEQ	International toxic equivalent – derived by using the international toxic equivalence factors, as defined in Annex VI, part 2 to Directive 2010/75/EU
Lower olefins	Collective term for ethylene, propylene, butylene and butadiene, or mixtures thereof
Major plant upgrade	A major change in the design or technology of a plant with major adjustments or replacements of the process and/or abatement units and associated equipment
MDA	Methylene diphenyl diamine
MDI	Methylene diphenyl diisocyanate
MDI plant	Plant for the production of MDI from MDA via phosgenation
New plant	A plant first permitted on the site of the installation following the publication of these BAT conclusions or a complete replacement of a plant following the publication of these BAT conclusions
New unit	A unit first permitted following the publication of these BAT conclusions or a complete replacement of a unit following the publication of these BAT conclusions

Term used	Definition
NO <sub>x</sub> precursors	Nitrogen-containing compounds (e.g. ammonia, nitrous gases and nitrogen-containing organic compounds) in the input to a thermal treatment that lead to NO <sub>x</sub> emissions. Elementary nitrogen is not included
PCDD/F	Polychlorinated dibenzo-dioxins and -furans
Periodic measurement	Measurement at specified time intervals using manual or automated methods
Process furnace/heater	<p>Process furnaces or heaters are:</p> <ul style="list-style-type: none"> <li>— combustion units whose flue-gases are used for the thermal treatment of objects or feed material through direct contact, e.g. in drying processes or chemical reactors; or</li> <li>— combustion units whose radiant and/or conductive heat is transferred to objects or feed material through a solid wall without using an intermediary heat transfer fluid, e.g. furnaces or reactors heating a process stream used in the (petro-)chemical industry such as steam cracker furnaces.</li> </ul> <p>It should be noted that, as a consequence of the application of good energy recovery practices, some of the process furnaces/heaters may have an associated steam/electricity generation system. This is considered to be an integral design feature of the process furnace/heater that cannot be considered in isolation.</p>
Process off-gas	The gas leaving a process which is further treated for recovery and/or abatement
NO <sub>x</sub>	The sum of nitrogen monoxide (NO) and nitrogen dioxide (NO <sub>2</sub> ), expressed as NO <sub>2</sub>
Residues	Substances or objects generated by the activities covered by the scope of this document, as waste or by-products
RTO	Regenerative thermal oxidiser
SCR	Selective catalytic reduction
SMPO	Styrene monomer and propylene oxide
SNCR	Selective non-catalytic reduction
SRU	Sulphur recovery unit
TDA	Toluene diamine
TDI	Toluene diisocyanate
TDI plant	Plant for the production of TDI from TDA via phosgenation
TOC	Total organic carbon, expressed as C; includes all organic compounds (in water)
Total suspended solids (TSS)	Mass concentration of all suspended solids, measured via filtration through glass fibre filters and gravimetry
TVOC	Total volatile organic carbon; total volatile organic compounds which are measured by a flame ionisation detector (FID) and expressed as total carbon
Unit	A segment/subpart of a plant in which a specific process or operation is carried out (e.g. reactor, scrubber, distillation column). Units can be new units or existing units

Term used	Definition
Valid hourly or half-hourly average	An hourly (or half-hourly) average is considered valid when there is no maintenance or malfunction of the automated measuring system
VCM	Vinyl chloride monomer
VOCs	Volatile organic compounds as defined in Article 3(45) of Directive 2010/75/EU

(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, 2.3.2012, p. 1).

## 1. GENERAL BAT CONCLUSIONS

The sector-specific BAT conclusions included in Sections 2 to 11 apply in addition to the general BAT conclusions given in this section.

### 1.1. Monitoring of emissions to air

BAT 1: BAT is to monitor channelled emissions to air from process furnaces/heaters in accordance with EN standards and with at least the minimum frequency given in the table below. If EN standards are not available, BAT is to use ISO, national or other international standards that ensure the provision of data of an equivalent scientific quality.

Substance/Parameter	Standard(s) (1)	Total rated thermal input (MW <sub>th</sub> ) (2)	Minimum monitoring frequency (3)	Monitoring associated with
CO	Generic EN standards	≥ 50	Continuous	Table 2.1, Table 10.1
	EN 15058	10 to < 50	Once every 3 months (4)	
Dust (5)	Generic EN standards and EN 13284-2	≥ 50	Continuous	BAT 5
	EN 13284-1	10 to < 50	Once every 3 months (4)	
NH <sub>3</sub> (6)	Generic EN standards	≥ 50	Continuous	BAT 7, Table 2.1
	No EN standard available	10 to < 50	Once every 3 months (4)	
NO <sub>x</sub>	Generic EN standards	≥ 50	Continuous	BAT 4, Table 2.1, Table 10.1
	EN 14792	10 to < 50	Once every 3 months (4)	
SO <sub>2</sub> (7)	Generic EN standards	≥ 50	Continuous	BAT 6
	EN 14791	10 to < 50	Once every 3 months (4)	

(1) Generic EN standards for continuous measurements are EN 15267-1, -2, and -3, and EN 14181. EN standards for periodic measurements are given in the table.

(2) Refers to the total rated thermal input of all process furnaces/heaters connected to the stack where emissions occur.

(3) In the case of process furnaces/heaters with a total rated thermal input of less than 100 MW<sub>th</sub> operated less than 500 hours per year, the monitoring frequency may be reduced to at least once every year.

(4) The minimum monitoring frequency for periodic measurements may be reduced to once every 6 months, if the emission levels are proven to be sufficiently stable.

(5) Monitoring of dust does not apply when combusting exclusively gaseous fuels.

(6) Monitoring of NH<sub>3</sub> only applies when SCR or SNCR is used.

(7) In the case of process furnaces/heaters combusting gaseous fuels and/or oil with a known sulphur content and where no flue-gas desulphurisation is carried out, continuous monitoring can be replaced either by periodic monitoring with a minimum frequency of once every 3 months or by calculation ensuring the provision of data of an equivalent scientific quality.



BAT 2: BAT is to monitor channelled emissions to air other than from process furnaces/heaters in accordance with EN standards and with at least the minimum frequency given in the table below. If EN standards are not available, BAT is to use ISO, national or other international standards that ensure the provision of data of an equivalent scientific quality.

Substance/Parameter	Processes/Sources	Standard(s)	Minimum monitoring frequency	Monitoring associated with
Benzene	Waste gas from the cumene oxidation unit in phenol production <sup>(1)</sup>	No EN standard available	Once every month <sup>(2)</sup>	BAT 57
	All other processes/sources <sup>(3)</sup>			BAT 10
Cl <sub>2</sub>	TDI/MDI <sup>(1)</sup>	No EN standard available	Once every month <sup>(2)</sup>	BAT 66
	EDC/VCM			BAT 76
CO	Thermal oxidiser	EN 15058	Once every month <sup>(2)</sup>	BAT 13
	Lower olefins (decoking)	No EN standard available <sup>(4)</sup>	Once every year or once during decoking, if decoking is less frequent	BAT 20
	EDC/VCM (decoking)			BAT 78
Dust	Lower olefins (decoking)	No EN standard available <sup>(5)</sup>	Once every year or once during decoking, if decoking is less frequent	BAT 20
	EDC/VCM (decoking)			BAT 78
	All other processes/sources <sup>(3)</sup>	EN 13284-1	Once every month <sup>(2)</sup>	BAT 11
EDC	EDC/VCM	No EN standard available	Once every month <sup>(2)</sup>	BAT 76
Ethylene oxide	Ethylene oxide and ethylene glycols	No EN standard available	Once every month <sup>(2)</sup>	BAT 52
Formaldehyde	Formaldehyde	No EN standard available	Once every month <sup>(2)</sup>	BAT 45
Gaseous chlorides, expressed as HCl	TDI/MDI <sup>(1)</sup>	EN 1911	Once every month <sup>(2)</sup>	BAT 66
	EDC/VCM			BAT 76
	All other processes/sources <sup>(3)</sup>			BAT 12
NH <sub>3</sub>	Use of SCR or SNCR	No EN standard available	Once every month <sup>(2)</sup>	BAT 7
NO <sub>x</sub>	Thermal oxidiser	EN 14792	Once every month <sup>(2)</sup>	BAT 13
PCDD/F	TDI/MDI <sup>(6)</sup>	EN 1948-1, -2, and -3	Once every 6 months <sup>(2)</sup>	BAT 67
PCDD/F	EDC/VCM			BAT 77

Substance/Parameter	Processes/Sources	Standard(s)	Minimum monitoring frequency	Monitoring associated with
SO <sub>2</sub>	All processes/sources <sup>(3)</sup>	EN 14791	Once every month <sup>(2)</sup>	BAT 12
Tetrachloromethane	TDI/MDI <sup>(1)</sup>	No EN standard available	Once every month <sup>(2)</sup>	BAT 66
TVOC	TDI/MDI	EN 12619	Once every month <sup>(2)</sup>	BAT 66
	EO (desorption of CO <sub>2</sub> from scrubbing medium)		Once every 6 months <sup>(2)</sup>	BAT 51
	Formaldehyde		Once every month <sup>(2)</sup>	BAT 45
	Waste gas from the cumene oxidation unit in phenol production	EN 12619	Once every month <sup>(2)</sup>	BAT 57
	Waste gas from other sources in phenol production when not combined with other waste gas streams		Once every year	
	Waste gas from the oxidation unit in hydrogen peroxide production		Once every month <sup>(2)</sup>	BAT 86
	EDC/VCM		Once every month <sup>(2)</sup>	BAT 76
	All other processes/sources <sup>(3)</sup>	Once every month <sup>(2)</sup>	BAT 10	
VCM	EDC/VCM	No EN standard available	Once every month <sup>(2)</sup>	BAT 76

<sup>(1)</sup> The monitoring applies where the pollutant is present in the waste gas based on the inventory of waste gas streams specified by the CWW BAT conclusions.

<sup>(2)</sup> The minimum monitoring frequency for periodic measurements may be reduced to once every year, if the emission levels are proven to be sufficiently stable.

<sup>(3)</sup> All (other) processes/sources where the pollutant is present in the waste gas based on the inventory of waste gas streams specified by the CWW BAT conclusions.

<sup>(4)</sup> EN 15058 and the sampling period need adaptation so that the measured values are representative of the whole decoking cycle.

<sup>(5)</sup> EN 13284-1 and the sampling period need adaptation so that the measured values are representative of the whole decoking cycle.

<sup>(6)</sup> The monitoring applies where the chlorine and/or chlorinated compounds are present in the waste gas and thermal treatment is applied

## 1.2. Emissions to air

### 1.2.1. Emissions to air from process furnaces/heaters

BAT 3: In order to reduce emissions to air of CO and unburnt substances from process furnaces/heaters, BAT is to ensure an optimised combustion.

Optimised combustion is achieved by good design and operation of the equipment which includes optimisation of the temperature and residence time in the combustion zone, efficient mixing of the fuel and combustion air, and combustion control. Combustion control is based on the continuous monitoring and automated control of appropriate combustion parameters (e.g. O<sub>2</sub>, CO, fuel to air ratio, and unburnt substances).

BAT 4: In order to reduce NO<sub>x</sub> emissions to air from process furnaces/heaters, BAT is to use one or a combination of the techniques given below.

	Technique	Description	Applicability
a.	Choice of fuel	See Section 12.3. This includes switching from liquid to gaseous fuels, taking into account the overall hydrocarbon balance	The switch from liquid to gaseous fuels may be restricted by the design of the burners in the case of existing plants
b.	Staged combustion	Staged combustion burners achieve lower NO <sub>x</sub> emissions by staging the injection of either air or fuel in the near burner region. The division of fuel or air reduces the oxygen concentration in the primary burner combustion zone, thereby lowering the peak flame temperature and reducing thermal NO <sub>x</sub> formation	Applicability may be restricted by space availability when upgrading small process furnaces, thus limiting the retrofit of fuel/air staging without reducing capacity For existing EDC crackers, the applicability may be restricted by the design of the process furnace
c.	Flue-gas recirculation (external)	Recirculation of part of the flue-gas to the combustion chamber to replace part of the fresh combustion air, with the effect of reducing the oxygen content and therefore cooling the temperature of the flame	For existing process furnaces/heaters, the applicability may be restricted by their design. Not applicable to existing EDC crackers
d.	Flue-gas recirculation (internal)	Recirculation of part of the flue-gas within the combustion chamber to replace part of the fresh combustion air, with the effect of reducing the oxygen content and therefore reducing the temperature of the flame	For existing process furnaces/heaters, the applicability may be restricted by their design
e.	Low-NO <sub>x</sub> burner (LNB) or ultra-low-NO <sub>x</sub> burner (ULNB)	See Section 12.3	For existing process furnaces/heaters, the applicability may be restricted by their design
f.	Use of inert diluents	'Inert' diluents, e.g. steam, water, nitrogen, are used (either by being premixed with the fuel prior to its combustion or directly injected into the combustion chamber) to reduce the temperature of the flame. Steam injection may increase CO emissions	Generally applicable
g.	Selective catalytic reduction (SCR)	See Section 12.1	Applicability to existing process furnaces/heaters may be restricted by space availability
h.	Selective non-catalytic reduction (SNCR)	See Section 12.1	Applicability to existing process furnaces/heaters may be restricted by the temperature window (900–1 050 °C) and the residence time needed for the reaction. Not applicable to EDC crackers

BAT-associated emission levels (BAT-AELs): See Table 2.1 and Table 10.1.

BAT 5: In order to prevent or reduce dust emissions to air from process furnaces/heaters, BAT is to use one or a combination of the techniques given below.

Technique		Description	Applicability
a.	Choice of fuel	See Section 12.3. This includes switching from liquid to gaseous fuels, taking into account the overall hydrocarbon balance	The switch from liquid to gaseous fuels may be restricted by the design of the burners in the case of existing plants
b.	Atomisation of liquid fuels	Use of high pressure to reduce the droplet size of liquid fuel. Current optimal burner design generally includes steam atomisation	Generally applicable
c.	Fabric, ceramic or metal filter	See Section 12.1	Not applicable when only combusting gaseous fuels

BAT 6: In order to prevent or reduce SO<sub>2</sub> emissions to air from process furnaces/heaters, BAT is to use one or both of the techniques given below.

Technique		Description	Applicability
a.	Choice of fuel	See Section 12.3. This includes switching from liquid to gaseous fuels, taking into account the overall hydrocarbon balance	The switch from liquid to gaseous fuels may be restricted by the design of the burners in the case of existing plants
b.	Caustic scrubbing	See Section 12.1	Applicability may be restricted by space availability

#### 1.2.2. Emissions to air from the use of SCR or SNCR

BAT 7: In order to reduce emissions to air of ammonia which is used in selective catalytic reduction (SCR) or selective non-catalytic reduction (SNCR) for the abatement of NO<sub>x</sub> emissions, BAT is to optimise the design and/or operation of SCR or SNCR (e.g. optimised reagent to NO<sub>x</sub> ratio, homogeneous reagent distribution and optimum size of the reagent drops).

BAT-associated emission levels (BAT-AELs) for emissions from a lower olefins cracker furnace when SCR or SNCR is used: Table 2.1.

#### 1.2.3. Emissions to air from other processes/sources

##### 1.2.3.1. Techniques to reduce emissions from other processes/sources

BAT 8: In order to reduce the load of pollutants sent to the final waste gas treatment, and to increase resource efficiency, BAT is to use an appropriate combination of the techniques given below for process off-gas streams.

Technique		Description	Applicability
a.	Recovery and use of excess or generated hydrogen	Recovery and use of excess hydrogen or hydrogen generated from chemical reactions (e.g. for hydrogenation reactions). Recovery techniques such as pressure swing adsorption or membrane separation may be used to increase the hydrogen content	Applicability may be restricted where the energy demand for recovery is excessive due to the low hydrogen content or when there is no demand for hydrogen

Technique		Description	Applicability
b.	Recovery and use of organic solvents and unreacted organic raw materials	Recovery techniques such as compression, condensation, cryogenic condensation, membrane separation and adsorption may be used. The choice of technique may be influenced by safety considerations, e.g. presence of other substances or contaminants	Applicability may be restricted where the energy demand for recovery is excessive due to the low organic content
c.	Use of spent air	The large volume of spent air from oxidation reactions is treated and used as low-purity nitrogen	Only applicable where there are available uses for low-purity nitrogen which do not compromise process safety
d.	Recovery of HCl by wet scrubbing for subsequent use	Gaseous HCl is absorbed in water using a wet scrubber, which may be followed by purification (e.g. using adsorption) and/or concentration (e.g. using distillation) (see Section 12.1 for the technique descriptions). The recovered HCl is then used (e.g. as acid or to produce chlorine)	Applicability may be restricted in the case of low HCl loads
e.	Recovery of H <sub>2</sub> S by regenerative amine scrubbing for subsequent use	Regenerative amine scrubbing is used for recovering H <sub>2</sub> S from process off-gas streams and from the acidic off-gases of sour water stripping units. H <sub>2</sub> S is then typically converted to elemental sulphur in a sulphur recovery unit in a refinery (Claus process).	Only applicable if a refinery is located nearby
f.	Techniques to reduce solids and/or liquids entrainment	See Section 12.1	Generally applicable

BAT 9: In order to reduce the load of pollutants sent to the final waste gas treatment, and to increase energy efficiency, BAT is to send process off-gas streams with a sufficient calorific value to a combustion unit. BAT 8a and 8b have priority over sending process off-gas streams to a combustion unit.

*Applicability:*

Sending process off-gas streams to a combustion unit may be restricted due to the presence of contaminants or due to safety considerations.

BAT 10: In order to reduce channelled emissions of organic compounds to air, BAT is to use one or a combination of the techniques given below.

Technique		Description	Applicability
a.	Condensation	See Section 12.1. The technique is generally used in combination with further abatement techniques	Generally applicable

Technique		Description	Applicability
b.	Adsorption	See Section 12.1	Generally applicable
c.	Wet scrubbing	See Section 12.1	Only applicable to VOCs that can be absorbed in aqueous solutions
d.	Catalytic oxidiser	See Section 12.1	Applicability may be restricted by the presence of catalyst poisons
e.	Thermal oxidiser	See Section 12.1. Instead of a thermal oxidiser, an incinerator for the combined treatment of liquid waste and waste gas may be used	Generally applicable

BAT 11: In order to reduce channelled dust emissions to air, BAT is to use one or a combination of the techniques given below.

Technique		Description	Applicability
a.	Cyclone	See Section 12.1. The technique is used in combination with further abatement techniques	Generally applicable
b.	Electrostatic precipitator	See Section 12.1	For existing units, the applicability may be restricted by space availability or safety considerations
c.	Fabric filter	See Section 12.1	Generally applicable
d.	Two-stage dust filter	See Section 12.1	
e.	Ceramic/metal filter	See Section 12.1	
f.	Wet dust scrubbing	See Section 12.1	

BAT 12: In order to reduce emissions to air of sulphur dioxide and other acid gases (e.g. HCl), BAT is to use wet scrubbing.

*Description:*

For the description of wet scrubbing, see Section 12.1

#### 1.2.3.2. Techniques to reduce emissions from a thermal oxidiser

BAT 13: In order to reduce emissions to air of NO<sub>x</sub>, CO, and SO<sub>2</sub> from a thermal oxidiser, BAT is to use an appropriate combination of the techniques given below.

Technique		Description	Main pollutant targeted	Applicability
a.	Removal of high levels of NO <sub>x</sub> precursors from the process off-gas streams	Remove (if possible, for reuse) high levels of NO <sub>x</sub> precursors prior to thermal treatment, e.g. by scrubbing, condensation or adsorption	NO <sub>x</sub>	Generally applicable

Technique		Description	Main pollutant targeted	Applicability
b.	Choice of support fuel	See Section 12.3	NO <sub>x</sub> , SO <sub>2</sub>	Generally applicable
c.	Low-NO <sub>x</sub> burner (LNB)	See Section 12.1	NO <sub>x</sub>	Applicability to existing units may be restricted by design and/or operational constraints
d.	Regenerative thermal oxidiser (RTO)	See Section 12.1	NO <sub>x</sub>	Applicability to existing units may be restricted by design and/or operational constraints
e.	Combustion optimisation	Design and operational techniques used to maximise the removal of organic compounds, while minimising emissions to air of CO and NO <sub>x</sub> (e.g. by controlling combustion parameters such as temperature and residence time)	CO, NO <sub>x</sub>	Generally applicable
f.	Selective catalytic reduction (SCR)	See Section 12.1	NO <sub>x</sub>	Applicability to existing units may be restricted by space availability
g.	Selective non-catalytic reduction (SNCR)	See Section 12.1	NO <sub>x</sub>	Applicability to existing units may be restricted by the residence time needed for the reaction

### 1.3. Emissions to water

BAT 14: In order to reduce the waste water volume, the pollutant loads discharged to a suitable final treatment (typically biological treatment), and emissions to water, BAT is to use an integrated waste water management and treatment strategy that includes an appropriate combination of process-integrated techniques, techniques to recover pollutants at source, and pretreatment techniques, based on the information provided by the inventory of waste water streams specified in the CWW BAT conclusions.

### 1.4. Resource efficiency

BAT 15: In order to increase resource efficiency when using catalysts, BAT is to use a combination of the techniques given below.

Technique		Description
a.	Catalyst selection	Select the catalyst to achieve the optimal balance between the following factors: — catalyst activity;

Technique		Description
		<ul style="list-style-type: none"> <li>— catalyst selectivity;</li> <li>— catalyst lifetime (e.g. vulnerability to catalyst poisons);</li> <li>— use of less toxic metals.</li> </ul>
b.	Catalyst protection	Techniques used upstream of the catalyst to protect it from poisons (e.g. raw material pretreatment)
c.	Process optimisation	Control of reactor conditions (e.g. temperature, pressure) to achieve the optimal balance between conversion efficiency and catalyst lifetime
d.	Monitoring of catalyst performance	Monitoring of the conversion efficiency to detect the onset of catalyst decay using suitable parameters (e.g. the heat of reaction and the CO <sub>2</sub> formation in the case of partial oxidation reactions)

BAT 16: In order to increase resource efficiency, BAT is to recover and reuse organic solvents.

*Description:*

Organic solvents used in processes (e.g. chemical reactions) or operations (e.g. extraction) are recovered using appropriate techniques (e.g. distillation or liquid phase separation), purified if necessary (e.g. using distillation, adsorption, stripping or filtration) and returned to the process or operation. The amount recovered and reused is process-specific.

#### 1.5. Residues

BAT 17: In order to prevent or, where that is not practicable, to reduce the amount of waste being sent for disposal, BAT is to use an appropriate combination of the techniques given below.

Technique	Description	Applicability	
<b><i>Techniques to prevent or reduce the generation of waste</i></b>			
a.	Addition of inhibitors to distillation systems	Selection (and optimisation of dosage) of polymerisation inhibitors that prevent or reduce the generation of residues (e.g. gums or tars). The optimisation of dosage may need to take into account that it can lead to higher nitrogen and/or sulphur content in the residues which could interfere with their use as a fuel	Generally applicable
b.	Minimisation of high-boiling residue formation in distillation systems	Techniques that reduce temperatures and residence times (e.g. packing instead of trays to reduce the pressure drop and thus the temperature; vacuum instead of atmospheric pressure to reduce the temperature)	Only applicable to new distillation units or major plant upgrades



Technique	Description	Applicability	
<b>Techniques to recover materials for reuse or recycling</b>			
c.	Material recovery (e.g. by distillation, cracking)	Materials (i.e. raw materials, products, and by-products) are recovered from residues by isolation (e.g. distillation) or conversion (e.g. thermal/catalytic cracking, gasification, hydrogenation)	Only applicable where there are available uses for these recovered materials
d.	Catalyst and adsorbent regeneration	Regeneration of catalysts and adsorbents, e.g. using thermal or chemical treatment	Applicability may be restricted where regeneration results in significant cross-media effects.
<b>Techniques to recover energy</b>			
e.	Use of residues as a fuel	Some organic residues, e.g. tar, can be used as fuels in a combustion unit	Applicability may be restricted by the presence of certain substances in the residues, making them unsuitable to use in a combustion unit and requiring disposal

#### 1.6. Other than normal operating conditions

BAT 18: In order to prevent or reduce emissions from equipment malfunctions, BAT is to use all of the techniques given below.

Technique	Description	Applicability	
a.	Identification of critical equipment	Equipment critical to the protection of the environment ('critical equipment') is identified on the basis of a risk assessment (e.g. using a Failure Mode and Effects Analysis)	Generally applicable
b.	Asset reliability programme for critical equipment	A structured programme to maximise equipment availability and performance which includes standard operating procedures, preventive maintenance (e.g. against corrosion), monitoring, recording of incidents, and continuous improvements	Generally applicable
c.	Back-up systems for critical equipment	Build and maintain back-up systems, e.g. vent gas systems, abatement units	Not applicable if appropriate equipment availability can be demonstrated using technique b.

BAT 19: In order to prevent or reduce emissions to air and water occurring during other than normal operating conditions, BAT is to implement measures commensurate with the relevance of potential pollutant releases for:

- (i) start-up and shutdown operations;
- (ii) other circumstances (e.g. regular and extraordinary maintenance work and cleaning operations of the units and/or of the waste gas treatment system) including those that could affect the proper functioning of the installation.

## 2. BAT CONCLUSIONS FOR LOWER OLEFINS PRODUCTION

The BAT conclusions in this section apply to the production of lower olefins using the steam cracking process, and apply in addition to the general BAT conclusions given in Section 1.

## 2.1. Emissions to air

## 2.1.1. BAT-AELs for emissions to air from a lower olefins cracker furnace

Table 2.1

**BAT-AELs for emissions to air of NO<sub>x</sub> and NH<sub>3</sub> from a lower olefins cracker furnace**

Parameter	BAT-AELs <sup>(1)</sup> <sup>(2)</sup> <sup>(3)</sup> (daily average or average over the sampling period) (mg/Nm <sup>3</sup> , at 3 vol-% O <sub>2</sub> )	
	New furnace	Existing furnace
NO <sub>x</sub>	60–100	70–200
NH <sub>3</sub>	< 5–15 <sup>(4)</sup>	

<sup>(1)</sup> Where the flue gases of two or more furnaces are discharged through a common stack, the BAT-AEL applies to the combined discharge from the stack.

<sup>(2)</sup> The BAT-AELs do not apply during decoking operations.

<sup>(3)</sup> No BAT-AEL applies for CO. As an indication, the CO emission level will generally be 10–50 mg/Nm<sup>3</sup> expressed as a daily average or an average over the sampling period.

<sup>(4)</sup> The BAT-AEL only applies when SCR or SNCR are used.

The associated monitoring is in BAT 1.

## 2.1.2. Techniques to reduce emissions from decoking

BAT 20: In order to reduce emissions to air of dust and CO from the decoking of the cracker tubes, BAT is to use an appropriate combination of the techniques to reduce the frequency of decoking given below and one or a combination of the abatement techniques given below.

Technique	Description	Applicability	
<b>Techniques to reduce the frequency of decoking</b>			
a.	Tube materials that retard coke formation	Nickel present at the surface of the tubes catalyses coke formation. Employing materials that have lower nickel levels, or coating the interior tube surface with an inert material, can therefore retard the rate of coke build-up	Only applicable to new units or major plant upgrades
b.	Doping of the raw material feed with sulphur compounds	As nickel sulphides do not catalyse coke formation, doping the feed with sulphur compounds when they are not already present at the desired level can also help retard the build-up of coke, as this will promote the passivation of the tube surface	Generally applicable

	Technique	Description	Applicability
c.	Optimisation of thermal decoking	Optimisation of operating conditions, i.e. airflow, temperature and steam content across the decoking cycle, to maximise coke removal	Generally applicable

#### **Abatement techniques**

d.	Wet dust scrubbing	See Section 12.1	Generally applicable
e.	Dry cyclone	See Section 12.1	Generally applicable
f.	Combustion of decoking waste gas in process furnace/heater	The decoking waste gas stream is passed through the process furnace/heater during decoking where the coke particles (and CO) are further combusted	Applicability for existing plants may be restricted by the design of the pipework systems or fire-duty restrictions

## 2.2. Emissions to water

BAT 21: In order to prevent or reduce the amount of organic compounds and waste water discharged to waste water treatment, BAT is to maximise the recovery of hydrocarbons from the quench water of the primary fractionation stage and reuse the quench water in the dilution steam generation system.

#### *Description:*

The technique consists of ensuring an effective separation of organic and aqueous phases. The recovered hydrocarbons are recycled to the cracker or used as raw materials in other chemical processes. Organic recovery can be enhanced, e.g. through the use of steam or gas stripping, or the use of a reboiler. Treated quench water is reused within the dilution steam generation system. A quench water purge stream is discharged to downstream final waste water treatment to prevent the build-up of salts in the system.

BAT 22: In order to reduce the organic load discharged to waste water treatment from the spent caustic scrubber liquor originating from the removal of H<sub>2</sub>S from the cracked gases, BAT is to use stripping.

#### *Description:*

For the description of stripping see Section 12.2. The stripping of scrubber liquors is carried out using a gaseous stream, which is then combusted (e.g. in the cracker furnace).

BAT 23: In order to prevent or reduce the amount of sulphides discharged to waste water treatment from the spent caustic scrubber liquor originating from the removal of acid gases from the cracked gases, BAT is to use one or a combination of the techniques given below.

	Technique	Description	Applicability
a.	Use of low-sulphur raw materials in the cracker feed	Use of raw materials that have a low sulphur content or have been desulphurised	Applicability may be restricted by a need for sulphur doping to reduce coke build-up
b.	Maximisation of the use of amine scrubbing for the removal of acid gases	The scrubbing of the cracked gases with a regenerative (amine) solvent to remove acid gases, mainly H <sub>2</sub> S, to reduce the load on the downstream caustic scrubber	Not applicable if the lower olefin cracker is located far away from an SRU. Applicability for existing plants may be restricted by the capacity of the SRU

	Technique	Description	Applicability
c.	Oxidation	Oxidation of sulphides present in the spent scrubbing liquor to sulphates, e.g. using air at elevated pressure and temperature (i.e. wet air oxidation) or an oxidising agent such as hydrogen peroxide	Generally applicable

### 3. BAT CONCLUSIONS FOR AROMATICS PRODUCTION

The BAT conclusions in this section apply to the production of benzene, toluene, ortho-, meta- and para-xylene (commonly known as BTX aromatics) and cyclohexane from the pygas by-product of steam crackers and from reformat/naphtha produced in catalytic reformers; and apply in addition to the general BAT conclusions given in Section 1.

#### 3.1. Emissions to air

BAT 24: In order to reduce the organic load from process off-gases sent to the final waste gas treatment and to increase resource efficiency, BAT is to recover organic materials by using BAT 8b. or, where that is not practicable, to recover energy from these process off-gases (see also BAT 9).

BAT 25: In order to reduce emissions to air of dust and organic compounds from the regeneration of hydrogenation catalyst, BAT is to send the process off-gas from catalyst regeneration to a suitable treatment system.

##### *Description:*

The process off-gas is sent to wet or dry dust abatement devices to remove dust and then to a combustion unit or a thermal oxidiser to remove organic compounds in order to avoid direct emissions to air or flaring. The use of decoking drums alone is not sufficient.

#### 3.2. Emissions to water

BAT 26: In order to reduce the amount of organic compounds and waste water discharged from aromatic extraction units to waste water treatment, BAT is either to use dry solvents or to use a closed system for the recovery and reuse of water when wet solvents are used.

BAT 27: In order to reduce the waste water volume and the organic load discharged to waste water treatment, BAT is to use an appropriate combination of the techniques given below.

	Technique	Description	Applicability
a.	Water-free vacuum generation	Use mechanical pumping systems in a closed circuit procedure, discharging only a small amount of water as blowdown, or use dry-running pumps. In some cases, wastewater-free vacuum generation can be achieved by use of the product as a barrier liquid in a mechanical vacuum pump, or by use of a gas stream from the production process	Generally applicable

Technique		Description	Applicability
b.	Source segregation of aqueous effluents	Aqueous effluents from aromatics plants are segregated from waste water from other sources in order to facilitate the recovery of raw materials or products	For existing plants, the applicability may be restricted by site-specific drainage systems
c.	Liquid phase separation with recovery of hydrocarbons	Separation of organic and aqueous phases with appropriate design and operation (e.g. sufficient residence time, phase boundary detection and control) to prevent any entrainment of undissolved organic material	Generally applicable
d.	Stripping with recovery of hydrocarbons	See Section 12.2. Stripping can be used on individual or combined streams	Applicability may be restricted when the concentration of hydrocarbons is low
e.	Reuse of water	With further treatment of some waste water streams, water from stripping can be used as process water or as boiler feed water, replacing other sources of water	Generally applicable

### 3.3. Resource efficiency

BAT 28: In order to use resources efficiently, BAT is to maximise the use of co-produced hydrogen, e.g. from dealkylation reactions, as a chemical reagent or fuel by using BAT 8a. or, where that is not practicable, to recover energy from these process vents (see BAT 9).

### 3.4. Energy efficiency

BAT 29: In order to use energy efficiently when using distillation, BAT is to use one or a combination of the techniques given below.

Technique		Description	Applicability
a.	Distillation optimisation	For each distillation column, the number of trays, reflux ratio, feed location and, for extractive distillations, the solvents to feed ratio are optimised	Applicability to existing units may be restricted by design, space availability and/or operational constraints
b.	Recovery of heat from column overhead gaseous stream	Reuse condensation heat from the toluene and the xylene distillation column to supply heat elsewhere in the installation	

Technique		Description	Applicability
c.	Single extractive distillation column	In a conventional extractive distillation system, the separation would require a sequence of two separation steps (i.e. main distillation column with side column or stripper). In a single extractive distillation column, the separation of the solvent is carried out in a smaller distillation column that is incorporated into the column shell of the first column	Only applicable to new plants or major plant upgrades. Applicability may be restricted for smaller capacity units as operability may be constrained by combining a number of operations into one piece of equipment
d.	Distillation column with a dividing wall	In a conventional distillation system, the separation of a three-component mixture into its pure fractions requires a direct sequence of at least two distillation columns (or main columns with side columns). With a dividing wall column, separation can be carried out in just one piece of apparatus	
e.	Thermally coupled distillation	If distillation is carried out in two columns, energy flows in both columns can be coupled. The steam from the top of the first column is fed to a heat exchanger at the base of the second column	Only applicable to new plants or major plant upgrades. Applicability depends on the set-up of the distillation columns and process conditions, e.g. working pressure

### 3.5. Residues

BAT 30: In order to prevent or reduce the amount of spent clay being sent for disposal, BAT is to use one or both of the techniques given below.

Technique		Description	Applicability
a.	Selective hydrogenation of reformat or pygas	Reduce the olefin content of reformat or pygas by hydrogenation. With fully hydrogenated raw materials, clay treaters have longer operating cycles	Only applicable to plants using raw materials with a high olefin content
b.	Clay material selection	Use a clay that lasts as long as possible for its given conditions (i.e. having surface/structural properties that increase the operating cycle length), or use a synthetic material that has the same function as the clay but that can be regenerated	Generally applicable

## 4. BAT CONCLUSIONS FOR ETHYLBENZENE AND STYRENE MONOMER PRODUCTION

The BAT conclusions in this section apply to the production of ethylbenzene using either the zeolite or  $AlCl_3$  catalysed alkylation process; and the production of styrene monomer either by ethylbenzene dehydrogenation or co-production with propylene oxide; and apply in addition to the general BAT conclusions given in Section 1.

#### 4.1. Process selection

BAT 31: In order to prevent or reduce emissions to air of organic compounds and acid gases, the generation of waste water and the amount of waste being sent for disposal from the alkylation of benzene with ethylene, BAT for new plants and major plant upgrades is to use the zeolite catalyst process.

#### 4.2. Emissions to air

BAT 32: In order to reduce the load of HCl sent to the final waste gas treatment from the alkylation unit in the  $\text{AlCl}_3$ -catalysed ethylbenzene production process, BAT is to use caustic scrubbing.

*Description:*

For the description of caustic scrubbing, see Section 12.1.

*Applicability:*

Only applicable to existing plants using the  $\text{AlCl}_3$  catalysed ethylbenzene production process.

BAT 33: In order to reduce the load of dust and HCl sent to the final waste gas treatment from catalyst replacement operations in the  $\text{AlCl}_3$ -catalysed ethylbenzene production process, BAT is to use wet scrubbing and then use the spent scrubbing liquor as wash water in the post-alkylation reactor wash section.

*Description:*

For the description of wet scrubbing, see Section 12.1.

BAT 34: In order to reduce the organic load sent to the final waste gas treatment from the oxidation unit in the SMPO production process, BAT is to use one or a combination of the techniques given below.

	Technique	Description	Applicability
a.	Techniques to reduce liquids entrainment	See Section 12.1	Generally applicable
b.	Condensation	See Section 12.1	Generally applicable
c.	Adsorption	See Section 12.1	Generally applicable
d.	Scrubbing	See Section 12.1. Scrubbing is carried out with a suitable solvent (e.g. the cool, recirculated ethylbenzene) to absorb ethylbenzene, which is recycled to the reactor	For existing plants, the use of the recirculated ethylbenzene stream may be restricted by the plant design

BAT 35: In order to reduce emissions of organic compounds to air from the acetophenone hydrogenation unit in the SMPO production process, during other than normal operating conditions (such as start-up events), BAT is to send the process off-gas to a suitable treatment system.

#### 4.3. Emissions to water

BAT 36: In order to reduce waste water generation from ethylbenzene dehydrogenation and to maximise the recovery of organic compounds, BAT is to use an appropriate combination of the techniques given below.

Technique		Description	Applicability
a.	Optimised liquid phase separation	Separation of organic and aqueous phases with appropriate design and operation (e.g. sufficient residence time, phase boundary detection and control) to prevent any entrainment of undissolved organic material	Generally applicable
b.	Steam stripping	See Section 12.2	Generally applicable
c.	Adsorption	See Section 12.2	Generally applicable
d.	Reuse of water	Condensates from the reaction can be used as process water or as boiler feed after steam stripping (see technique b.) and adsorption (see technique c.)	Generally applicable

BAT 37: In order to reduce emissions to water of organic peroxides from the oxidation unit in the SMPO production process and to protect the downstream biological waste water treatment plant, BAT is to pretreat waste water containing organic peroxides using hydrolysis before it is combined with other waste water streams and discharged to the final biological treatment.

*Description:*

For the description of hydrolysis see Section 12.2.

#### 4.4. Resource efficiency

BAT 38: In order to recover organic compounds from ethylbenzene dehydrogenation prior to the recovery of hydrogen (see BAT 39), BAT is to use one or both of the techniques given below.

Technique		Description	Applicability
a.	Condensation	See Section 12.1	Generally applicable
b.	Scrubbing	See Section 12.1. The absorbent consists of commercial organic solvents (or tar from ethylbenzene plants) (see BAT 42b). VOCs are recovered by stripping of the scrubber liquor	

BAT 39: In order to increase resource efficiency, BAT is to recover the co-produced hydrogen from ethylbenzene dehydrogenation, and to use it either as a chemical reagent or to combust the dehydrogenation off-gas as a fuel (e.g. in the steam superheater).

BAT 40: In order to increase the resource efficiency of the acetophenone hydrogenation unit in the SMPO production process, BAT is to minimise excess hydrogen or to recycle hydrogen by using BAT 8a. If BAT 8a is not applicable, BAT is to recover energy (see BAT 9).

#### 4.5. Residues

BAT 41: In order to reduce the amount of waste being sent for disposal from spent catalyst neutralisation in the  $AlCl_3$ -catalysed ethylbenzene production process, BAT is to recover residual organic compounds by stripping and then concentrate the aqueous phase to give a usable  $AlCl_3$  by-product.



*Description:*

Steam stripping is first used to remove VOCs, then the spent catalyst solution is concentrated by evaporation to give a usable  $\text{AlCl}_3$  by-product. The vapour phase is condensed to give a HCl solution that is recycled into the process.

BAT 42: In order to prevent or reduce the amount of waste tar being sent for disposal from the distillation unit of ethylbenzene production, BAT is to use one or a combination of the techniques given below.

Technique		Description	Applicability
a.	Material recovery (e.g. by distillation, cracking)	See BAT 17c	Only applicable where there are available uses for these recovered materials
b.	Use of tar as an absorbent for scrubbing	See section 12.1. Use the tar as an absorbent in the scrubbers used in styrene monomer production by ethylbenzene dehydrogenation, instead of commercial organic solvents (see BAT 38b). The extent to which tar can be used depends on the scrubber capacity	Generally applicable
c.	Use of tar as a fuel	See BAT 17e	Generally applicable

BAT 43: In order to reduce the generation of coke (which is both a catalyst poison and a waste) from units producing styrene by ethylbenzene dehydrogenation, BAT is to operate at the lowest possible pressure that is safe and practicable.

BAT 44: In order to reduce the amount of organic residues being sent for disposal from styrene monomer production including its co-production with propylene oxide, BAT is to use one or a combination of the techniques given below.

Technique		Description	Applicability
a.	Addition of inhibitors to distillation systems	See BAT 17a	Generally applicable
b.	Minimisation of high-boiling residue formation in distillation systems	See BAT 17b	Only applicable to new distillation units or major plant upgrades
c.	Use of residues as a fuel	See BAT 17e	Generally applicable

## 5. BAT CONCLUSIONS FOR FORMALDEHYDE PRODUCTION

The BAT conclusions in this section apply in addition to the general BAT conclusions given in Section 1.

5.1. **Emissions to air**

BAT 45: In order to reduce emissions of organic compounds to air from formaldehyde production and to use energy efficiently, BAT is to use one of the techniques given below.

Technique		Description	Applicability
a.	Send the waste gas stream to a combustion unit	See BAT 9	Only applicable to the silver process
b.	Catalytic oxidiser with energy recovery	See Section 12.1. Energy is recovered as steam	Only applicable to the metal oxide process. The ability to recover energy may be restricted in small stand-alone plants
c.	Thermal oxidiser with energy recovery	See Section 12.1. Energy is recovered as steam	Only applicable to the silver process

Table 5.1

**BAT-AELs for emissions of TVOC and formaldehyde to air from formaldehyde production**

Parameter	BAT-AEL (daily average or average over the sampling period) (mg/Nm <sup>3</sup> , no correction for oxygen content)
TVOC	< 5–30 <sup>(1)</sup>
Formaldehyde	2–5

<sup>(1)</sup> The lower end of the range is achieved when using a thermal oxidiser in the silver process.

The associated monitoring is in BAT 2.

5.2. **Emissions to water**

BAT 46: In order to prevent or reduce waste water generation (e.g. from cleaning, spills and condensates) and the organic load discharged to further waste water treatment, BAT is to use one or both of the techniques given below.

Technique		Description	Applicability
a.	Reuse of water	Aqueous streams (e.g. from cleaning, spills and condensates) are re-circulated into the process mainly to adjust the formaldehyde product concentration. The extent to which water can be reused depends on the desired formaldehyde concentration	Generally applicable
b.	Chemical pretreatment	Conversion of formaldehyde into other substances which are less toxic, e.g. by addition of sodium sulphite or by oxidation	Only applicable to effluents which, due to their formaldehyde content, could have a negative effect on the downstream biological waste water treatment

5.3. **Residues**

BAT 47: In order to reduce the amount of paraformaldehyde-containing waste being sent for disposal, BAT is to use one or a combination of the techniques given below.

Technique		Description	Applicability
a.	Minimisation of paraformaldehyde generation	The formation of paraformaldehyde is minimised by improved heating, insulation and flow circulation	Generally applicable
b.	Material recovery	Paraformaldehyde is recovered by dissolution in hot water where it undergoes hydrolysis and depolymerisation to give a formaldehyde solution, or is reused directly in other processes	Not applicable when the recovered paraformaldehyde cannot be used due to its contamination
c.	Use of residues as a fuel	Paraformaldehyde is recovered and used as a fuel	Only applicable when technique b. cannot be applied

## 6. BAT CONCLUSIONS FOR ETHYLENE OXIDE AND ETHYLENE GLYCOLS PRODUCTION

The BAT conclusions in this section apply in addition to the general BAT conclusions given in Section 1.

6.1. **Process selection**

BAT 48: In order to reduce the consumption of ethylene and emissions to air of organic compounds and CO<sub>2</sub>, BAT for new plants and major plant upgrades is to use oxygen instead of air for the direct oxidation of ethylene to ethylene oxide.

6.2. **Emissions to air**

BAT 49: In order to recover ethylene and energy and to reduce emissions of organic compounds to air from the EO plant, BAT is to use both of the techniques given below.

Technique		Description	Applicability
<b><i>Techniques to recover organic material for reuse or recycling</i></b>			
a.	Use of pressure swing adsorption or membrane separation to recover ethylene from the inerts purge	With the pressure swing adsorption technique, the target gas (in this case ethylene) molecules are adsorbed on a solid (e.g. molecular sieve) at high pressure, and subsequently desorbed in more concentrated form at lower pressure for reuse or recycling.  For membrane separation, see Section 12.1	Applicability may be restricted when the energy demand is excessive due to a low ethylene mass flow
<b><i>Energy recovery techniques</i></b>			
b.	Send the inerts purge stream to a combustion unit	See BAT 9	Generally applicable

BAT 50: In order to reduce the consumption of ethylene and oxygen and to reduce CO<sub>2</sub> emissions to air from the EO unit, BAT is to use a combination of the techniques in BAT 15 and to use inhibitors.

*Description:*

The addition of small amounts of an organochlorine inhibitor (such as ethylchloride or dichloroethane) to the reactor feed in order to reduce the proportion of ethylene that is fully oxidised to carbon dioxide. Suitable parameters for the monitoring of catalyst performance include the heat of reaction and the CO<sub>2</sub> formation per tonne of ethylene feed.

BAT 51: In order to reduce emissions of organic compounds to air from the desorption of CO<sub>2</sub> from the scrubbing medium used in the EO plant, BAT is to use a combination of the techniques given below.

Technique	Description	Applicability	
<b>Process-integrated techniques</b>			
a.	Staged CO <sub>2</sub> desorption	The technique consists of conducting the depressurisation necessary to liberate the carbon dioxide from the absorption medium in two steps rather than one. This allows an initial hydrocarbon-rich stream to be isolated for potential recirculation, leaving a relatively clean carbon dioxide stream for further treatment.	Only applicable to new plants or major plant upgrades
<b>Abatement techniques</b>			
b.	Catalytic oxidiser	See Section 12.1	Generally applicable
c.	Thermal oxidiser	See Section 12.1	Generally applicable

Table 6.1

**BAT-AEL for emissions of organic compounds to air from the desorption of CO<sub>2</sub> from the scrubbing medium used in the EO plant**

Parameter	BAT-AEL
TVOC	1–10 g/t of EO produced <sup>(1)</sup> <sup>(2)</sup> <sup>(3)</sup>

<sup>(1)</sup> The BAT-AEL is expressed as an average of values obtained during 1 year.

<sup>(2)</sup> In the case of significant methane content in the emission, methane monitored according to EN ISO 25140 or EN ISO 25139 is subtracted from the result.

<sup>(3)</sup> EO produced is defined as the sum of EO produced for sale and as an intermediate.

The associated monitoring is in BAT 2.

BAT 52: In order to reduce EO emissions to air, BAT is to use wet scrubbing for waste gas streams containing EO.

*Description:*

For the description of wet scrubbing, see Section 12.1. Scrubbing with water to remove EO from waste gas streams before direct release or before further abatement of organic compounds.

BAT 53: In order to prevent or reduce emissions of organic compounds to air from cooling of the EO absorbent in the EO recovery unit, BAT is to use one of the techniques given below.

Technique		Description	Applicability
a.	Indirect cooling	Use indirect cooling systems (with heat exchangers) instead of open cooling systems	Only applicable to new plants or major plant upgrades
b.	Complete EO removal by stripping	Maintain appropriate operating conditions and use online monitoring of the EO stripper operation to ensure that all EO is stripped out; and provide adequate protection systems to avoid EO emissions during other than normal operating conditions	Only applicable when technique a. cannot be applied

### 6.3. Emissions to water

BAT 54: In order to reduce the waste water volume and to reduce the organic load discharged from the product purification to final waste water treatment, BAT is to use one or both of the techniques given below.

Technique		Description	Applicability
a.	Use of the purge from the EO plant in the EG plant	The purge streams from the EO plant are sent to the EG process and not discharged as waste water. The extent to which the purge can be reused in the EG process depends on EG product quality considerations.	Generally applicable
b.	Distillation	Distillation is a technique used to separate compounds with different boiling points by partial evaporation and recondensation.  The technique is used in EO and EG plants to concentrate aqueous streams to recover glycols or enable their disposal (e.g. by incineration, instead of their discharge as waste water) and to enable the partial reuse/recycling of water.	Only applicable to new plants or major plant upgrades

### 6.4. Residues

BAT 55: In order to reduce the amount of organic waste being sent for disposal from the EO and EG plant, BAT is to use a combination of the techniques given below.

Technique		Description	Applicability
a.	Hydrolysis reaction optimisation	Optimisation of the water to EO ratio to both achieve lower co-production of heavier glycols and avoid excessive energy demand for the dewatering of glycols. The optimum ratio depends on the target output of di- and triethylene glycols	Generally applicable
b.	Isolation of by-products at EO plants for use	For EO plants, the concentrated organic fraction obtained after the dewatering of the liquid effluent from EO recovery is distilled to give valuable short-chain glycols and a heavier residue	Only applicable to new plants or major plant upgrades
c.	Isolation of by-products at EG plants for use	For EG plants, the longer chain glycols fraction can either be used as such or further fractionated to yield valuable glycols	Generally applicable

## 7. BAT CONCLUSIONS FOR PHENOL PRODUCTION

The BAT conclusions in this section apply to the production of phenol from cumene, and apply in addition to the general BAT conclusions given in Section 1.

### 7.1. Emissions to air

BAT 56: In order to recover raw materials and to reduce the organic load sent from the cumene oxidation unit to the final waste gas treatment, BAT is to use a combination of the techniques given below.

Technique		Description	Applicability
<b><i>Process-integrated techniques</i></b>			
a.	Techniques to reduce liquids entrainment	See Section 12.1	Generally applicable
<b><i>Techniques to recover organic material for reuse</i></b>			
b.	Condensation	See Section 12.1	Generally applicable
c.	Adsorption (regenerative)	See Section 12.1	Generally applicable

BAT 57: In order to reduce emissions of organic compounds to air, BAT is to use technique d given below for waste gas from the cumene oxidation unit. For any other individual or combined waste gas streams, BAT is to use one or a combination of the techniques given below.

Technique		Description	Applicability
a.	Send the waste gas stream to a combustion unit	See BAT 9	Only applicable where there are available uses for the waste gas as gaseous fuel
b.	Adsorption	See Section 12.1	Generally applicable
c.	Thermal oxidiser	See Section 12.1	Generally applicable
d.	Regenerative thermal oxidiser (RTO)	See Section 12.1	Generally applicable

Table 7.1

**BAT-AELs for emissions of TVOC and benzene to air from the production of phenol**

Parameter	Source	BAT-AEL (daily average or average over the sampling period) (mg/Nm <sup>3</sup> , no correction for oxygen content)	Conditions
Benzene	Cumene oxidation unit	< 1	The BAT-AEL applies if the emission exceeds 1 g/h
TVOC		5–30	—

The associated monitoring is in BAT 2.

**7.2. Emissions to water**

BAT 58: In order to reduce emissions to water of organic peroxides from the oxidation unit and, if necessary, to protect the downstream biological waste water treatment plant, BAT is to pretreat waste water containing organic peroxides using hydrolysis before it is combined with other waste water streams and discharged to the final biological treatment.

*Description:*

For the description of hydrolysis, see Section 12.2. Waste water (mainly from the condensers and the adsorber regeneration, after phase separation) is treated thermally (at temperatures above 100 °C and a high pH) or catalytically to decompose organic peroxides to non-ecotoxic and more readily biodegradable compounds.

Table 7.2

**BAT-AEPL for organic peroxides at the outlet of the peroxides decomposition unit**

Parameter	BAT-AEPL (average value from at least three spot samples taken at intervals of at least half an hour)	Associated monitoring
Total organic peroxides, expressed as cumene hydroperoxide	< 100 mg/l	No EN standard available. The minimum monitoring frequency is once every day and may be reduced to four times per year if adequate performance of the hydrolysis is demonstrated by controlling the process parameters (e.g. pH, temperature and residence time)

BAT 59: In order to reduce the organic load discharged from the cleavage unit and the distillation unit to further waste water treatment, BAT is to recover phenol and other organic compounds (e.g. acetone) using extraction followed by stripping.

*Description:*

Recovery of phenol from phenol-containing waste water streams by adjustment of the pH to < 7, followed by extraction with a suitable solvent and stripping of the waste water to remove residual solvent and other low-boiling compounds (e.g. acetone). For the description of the treatment techniques, see Section 12.2.

### 7.3. Residues

BAT 60: In order to prevent or reduce the amount of tar being sent for disposal from phenol purification, BAT is to use one or both of the techniques given below.

	Technique	Description	Applicability
a.	Material recovery (e.g. by distillation, cracking)	See BAT 17c. Use distillation to recover cumene, $\alpha$ -methylstyrene phenol, etc.	Generally applicable
b.	Use of tar as a fuel	See BAT 17e.	Generally applicable

## 8. BAT CONCLUSIONS FOR ETHANOLAMINES PRODUCTION

The BAT conclusions in this section apply in addition to the general BAT conclusions given in Section 1.

### 8.1. Emissions to air

BAT 61: In order to reduce ammonia emissions to air and to reduce the consumption of ammonia from the aqueous ethanolamines production process, BAT is to use a multistage wet scrubbing system.

*Description:*

For the description of wet scrubbing, see Section 12.1. Unreacted ammonia is recovered from the off-gas of the ammonia stripper and also from the evaporation unit by wet scrubbing in at least two stages followed by ammonia recycling into the process.

### 8.2. Emissions to water

BAT 62: In order to prevent or reduce emissions of organic compounds to air and emissions to water of organic substances from the vacuum systems, BAT is to use one or a combination of the techniques given below.

	Technique	Description	Applicability
a.	Water-free vacuum generation	Use of dry-running pumps, e.g. positive displacement pumps	Applicability to existing plants may be restricted by design and/or operational constraints
b.	Use of water ring vacuum pumps with recirculation of the ring water	The water used as the sealant liquid of the pump is recirculated to the pump casing via a closed loop with only small purges, so that waste water generation is minimised	Only applicable when technique a. cannot be applied. Not applicable for triethanolamine distillation



Technique		Description	Applicability
c.	Reuse of aqueous streams from vacuum systems in the process	Return aqueous streams from water ring pumps or steam ejectors to the process for recovery of organic material and reuse of the water. The extent to which water can be reused in the process is restricted by the water demand of the process	Only applicable when technique a. cannot be applied
d.	Condensation of organic compounds (amines) upstream of vacuum systems	See Section 12.1	Generally applicable

### 8.3. Raw material consumption

BAT 63: In order to use ethylene oxide efficiently, BAT is to use a combination of the techniques given below.

Technique		Description	Applicability
a.	Use of excess ammonia	Maintaining a high level of ammonia in the reaction mixture is an effective way of ensuring that all the ethylene oxide is converted into products	Generally applicable
b.	Optimisation of the water content in the reaction	Water is used to accelerate the main reactions without changing the product distribution and without significant side reactions with ethylene oxide to glycols	Only applicable for the aqueous process
c.	Optimise the process operating conditions	Determine and maintain the optimum operating conditions (e.g. temperature, pressure, residence time) to maximise the conversion of ethylene oxide to the desired mix of mono-, di-, triethanolamines	Generally applicable

### 9. BAT CONCLUSIONS FOR TOLUENE DIISOCYANATE (TDI) AND METHYLENE DIPHENYL DIISOCYANATE (MDI) PRODUCTION

The BAT conclusions in this section cover the production of:

- dinitrotoluene (DNT) from toluene;
- toluene diamine (TDA) from DNT;
- TDI from TDA;
- methylene diphenyl diamine (MDA) from aniline;
- MDI from MDA;

and apply in addition to the general BAT conclusions given in Section 1.

#### 9.1. Emissions to air

BAT 64: In order to reduce the load of organic compounds, NO<sub>x</sub>, NO<sub>x</sub> precursors and SO<sub>x</sub> sent to the final waste gas treatment (see BAT 66) from DNT, TDA and MDA plants, BAT is to use a combination of the techniques given below.

Technique		Description	Applicability
a.	Condensation	See Section 12.1	Generally applicable
b.	Wet scrubbing	See Section 12.1. In many cases, scrubbing efficiency is enhanced by the chemical reaction of the absorbed pollutant (partial oxidation of NO <sub>x</sub> with recovery of nitric acid, removal of acids with caustic solution, removal of amines with acidic solutions, reaction of aniline with formaldehyde in caustic solution)	
c.	Thermal reduction	See Section 12.1	Applicability to existing units may be restricted by space availability
d.	Catalytic reduction	See Section 12.1	

BAT 65: In order to reduce the load of HCl and phosgene sent to the final waste gas treatment and to increase resource efficiency, BAT is to recover HCl and phosgene from the process off-gas streams of TDI and/or MDI plants by using an appropriate combination of the techniques given below.

Technique		Description	Applicability
a.	Absorption of HCl by wet scrubbing	See BAT 8d.	Generally applicable
b.	Absorption of phosgene by scrubbing	See Section 12.1. The excess phosgene is absorbed using an organic solvent and returned to the process	Generally applicable
c.	HCl/phosgene condensation	See Section 12.1	Generally applicable

BAT 66: In order to reduce emissions to air of organic compounds (including chlorinated hydrocarbons), HCl and chlorine, BAT is to treat combined waste gas streams using a thermal oxidiser followed by caustic scrubbing.

*Description:*

The individual waste gas streams from DNT, TDA, TDI, MDA and MDI plants are combined to one or several waste gas streams for treatment. (See Section 12.1 for the descriptions of thermal oxidiser and scrubbing.) Instead of a thermal oxidiser, an incinerator may be used for the combined treatment of liquid waste and the waste gas. Caustic scrubbing is wet scrubbing with caustic added to improve the HCl and chlorine removal efficiency.

Table 9.1

**BAT-AELs for emissions of TVOC, tetrachloromethane, Cl<sub>2</sub>, HCl and PCDD/F to air from the TDI/MDI process**

Parameter	BAT-AEL (mg/Nm <sup>3</sup> , no correction for oxygen content)
TVOC	1–5 <sup>(1)</sup> <sup>(2)</sup>
Tetrachloromethane	≤ 0,5 g/t MDI produced <sup>(3)</sup> ≤ 0,7 g/t TDI produced <sup>(3)</sup>

Parameter	BAT-AEL (mg/Nm <sup>3</sup> , no correction for oxygen content)
Cl <sub>2</sub>	< 1 <sup>(2)</sup> <sup>(4)</sup>
HCl	2–10 <sup>(2)</sup>
PCDD/F	0,025–0,08 ng I-TEQ/Nm <sup>3</sup> <sup>(2)</sup>

<sup>(1)</sup> The BAT-AEL only applies to combined waste gas streams with flow rates of > 1 000 Nm<sup>3</sup>/h.

<sup>(2)</sup> The BAT-AEL is expressed as a daily average or an average over the sampling period.

<sup>(3)</sup> The BAT-AEL is expressed as an average of values obtained during 1 year. TDI and/or MDI produced refers to the product without residues, in the sense used to define the capacity of the plant.

<sup>(4)</sup> In the case of NO<sub>x</sub> values above 100 mg/Nm<sup>3</sup> in the sample, the BAT-AEL may be higher and up to 3 mg/Nm<sup>3</sup> due to analytical interferences.

The associated monitoring is in BAT 2.

BAT 67: In order to reduce emissions to air of PCDD/F from a thermal oxidiser (see Section 12.1) treating process off-gas streams containing chlorine and/or chlorinated compounds, BAT is to use technique a, if necessary followed by technique b, given below.

Technique	Description	Applicability
a. Rapid quenching	Rapid cooling of exhaust gases to prevent the <i>de novo</i> synthesis of PCDD/F	Generally applicable
b. Activated carbon injection	Removal of PCDD/F by adsorption onto activated carbon that is injected into the exhaust gas, followed by dust abatement	

BAT-associated emission levels (BAT-AELs): See Table 9.1.

## 9.2. Emissions to water

BAT 68: BAT is to monitor emissions to water with at least the frequency given below and in accordance with EN standards. If EN standards are not available, BAT is to use ISO, national or other international standards that ensure the provision of data of an equivalent scientific quality.

Substance/Parameter	Plant	Sampling point	Standard(s)	Minimum monitoring frequency	Monitoring associated with
TOC	DNT plant	Outlet of the pretreatment unit	EN 1484	Once every week <sup>(1)</sup>	BAT 70
	MDI and/or TDI plant	Outlet of the plant		Once every month	BAT 72
Aniline	MDA plant	Outlet of the final waste water treatment	No EN standard available	Once every month	BAT 14
Chlorinated solvents	MDI and/or TDI plant		Various EN standards available (e.g. EN ISO 15680)		BAT 14

<sup>(1)</sup> In the case of discontinuous waste water discharges, the minimum monitoring frequency is once per discharge.

BAT 69: In order to reduce the load of nitrite, nitrate and organic compounds discharged from the DNT plant to waste water treatment, BAT is to recover raw materials, to reduce the waste water volume and to reuse water by using an appropriate combination of the techniques given below.

Technique		Description	Applicability
a.	Use of highly concentrated nitric acid	Use highly concentrated HNO <sub>3</sub> (e.g. about 99 %) to increase the process efficiency and to reduce the waste water volume and the load of pollutants	Applicability to existing units may be restricted by design and/or operational constraints
b.	Optimised regeneration and recovery of spent acid	Perform the regeneration of the spent acid from the nitration reaction in such a way that water and the organic content are also recovered for reuse, by using an appropriate combination of evaporation/distillation, stripping and condensation	Applicability to existing units may be restricted by design and/or operational constraints
c.	Reuse of process water to wash DNT	Reuse process water from the spent acid recovery unit and the nitration unit to wash DNT	Applicability to existing units may be restricted by design and/or operational constraints
d.	Reuse of water from the first washing step in the process	Nitric and sulphuric acid are extracted from the organic phase using water. The acidified water is returned to the process, for direct reuse or further processing to recover materials	Generally applicable
e.	Multiple use and recirculation of water	Reuse water from washing, rinsing and equipment cleaning e.g. in the counter-current multistep washing of the organic phase	Generally applicable

BAT-associated waste water volume: See Table 9.2.

BAT 70: In order to reduce the load of poorly biodegradable organic compounds discharged from the DNT plant to further waste water treatment, BAT is to pretreat the waste water using one or both of the techniques given below.

Technique		Description	Applicability
a.	Extraction	See Section 12.2	Generally applicable
b.	Chemical oxidation	See Section 12.2	

Table 9.2

**BAT-AEPLs for discharge from the DNT plant at the outlet of the pretreatment unit to further waste water treatment**

Parameter	BAT-AEPL (average of values obtained during 1 month)
TOC	< 1 kg/t DNT produced
Specific waste water volume	< 1 m <sup>3</sup> /t DNT produced

The associated monitoring for TOC is in BAT 68.

BAT 71: In order to reduce waste water generation and the organic load discharged from the TDA plant to waste water treatment, BAT is to use a combination of techniques a., b. and c. and then to use technique d. as given below.

Technique		Description	Applicability
a.	Evaporation	See Section 12.2	Generally applicable
b.	Stripping	See Section 12.2	
c.	Extraction	See Section 12.2	
d.	Reuse of water	Reuse of water (e.g. from condensates or from scrubbing) in the process or in other processes (e.g. in a DNT plant). The extent to which water can be reused at existing plants may be restricted by technical constraints	Generally applicable

Table 9.3

**BAT-AEPL for discharge from the TDA plant to waste water treatment**

Parameter	BAT-AEPL (average of values obtained during 1 month)
Specific waste water volume	< 1 m <sup>3</sup> /t TDA produced

BAT 72: In order to prevent or reduce the organic load discharged from MDI and/or TDI plants to final waste water treatment, BAT is to recover solvents and reuse water by optimising the design and operation of the plant.

Table 9.4

**BAT-AEPL for discharge to waste water treatment from a TDI or MDI plant**

Parameter	BAT-AEPL (average of values obtained during 1 year)
TOC	< 0,5 kg/t product (TDI or MDI) <sup>(1)</sup>

<sup>(1)</sup> The BAT-AEPL refers to the product without residues, in the sense used to define the capacity of the plant.

The associated monitoring is in BAT 68.

BAT 73: In order to reduce the organic load discharged from a MDA plant to further waste water treatment, BAT is to recover organic material using one or a combination of the techniques given below.

Technique		Description	Applicability
a.	Evaporation	See Section 12.2. Used to facilitate extraction (see technique b)	Generally applicable
b.	Extraction	See Section 12.2. Used to recover/remove MDA	Generally applicable
c.	Steam stripping	See Section 12.2. Used to recover/remove aniline and methanol	For methanol, the applicability depends on the assessment of alternative options as part of the waste water management and treatment strategy
d.	Distillation	See Section 12.2. Used to recover/remove aniline and methanol	

### 9.3. Residues

BAT 74: In order to reduce the amount of organic residues being sent for disposal from the TDI plant, BAT is to use a combination of the techniques given below.

Technique		Description	Applicability
<b><i>Techniques to prevent or reduce the generation of waste</i></b>			
a.	Minimisation of high-boiling residue formation in distillation systems	See BAT 17b.	Only applicable to new distillation units or major plant upgrades
<b><i>Techniques to recover organic material for reuse or recycling</i></b>			
b.	Increased recovery of TDI by evaporation or further distillation	Residues from distillation are additionally processed to recover the maximum amount of TDI contained therein, e.g. using a thin film evaporator or other short-path distillation units followed by a dryer.	Only applicable to new distillation units or major plant upgrades
c.	Recovery of TDA by chemical reaction	Tars are processed to recover TDA by chemical reaction (e.g. hydrolysis).	Only applicable to new plants or major plant upgrades

### 10. BAT CONCLUSIONS FOR ETHYLENE DICHLORIDE AND VINYL CHLORIDE MONOMER PRODUCTION

The BAT conclusions in this section apply in addition to the general BAT conclusions given in Section 1.

## 10.1. Emissions to air

## 10.1.1. BAT-AEL for emissions to air from an EDC cracker furnace

Table 10.1

**BAT-AELs for emissions to air of NO<sub>x</sub> from an EDC cracker furnace**

Parameter	BAT-AELs <sup>(1)</sup> <sup>(2)</sup> <sup>(3)</sup> (daily average or average over the sampling period) (mg/Nm <sup>3</sup> , at 3 vol-% O <sub>2</sub> )
NO <sub>x</sub>	50–100

<sup>(1)</sup> Where the flue-gases of two or more furnaces are discharged through a common stack, the BAT-AEL applies to the combined discharge from the stack.

<sup>(2)</sup> The BAT-AELs do not apply during decoking operations.

<sup>(3)</sup> No BAT-AEL applies for CO. As an indication, the CO emission level will generally be 5–35 mg/Nm<sup>3</sup> expressed as a daily average or an average over the sampling period.

The associated monitoring is in BAT 1.

## 10.1.2. Techniques and BAT-AEL for emissions to air from other sources

BAT 75: In order to reduce the organic load sent to the final waste gas treatment and to reduce raw material consumption, BAT is to use all of the techniques given below.

Technique	Description	Applicability	
<b>Process-integrated techniques</b>			
a.	Control of feed quality	Control the quality of the feed to minimise the formation of residues (e.g. propane and acetylene content of ethylene; bromine content of chlorine; acetylene content of hydrogen chloride)	Generally applicable
b.	Use of oxygen instead of air for oxychlorination		Only applicable to new oxychlorination plants or major oxychlorination plant upgrades
<b>Techniques to recover organic material</b>			
c.	Condensation using chilled water or refrigerants	Use condensation (see Section 12.1) with chilled water or refrigerants such as ammonia or propylene to recover organic compounds from individual vent gas streams before sending them to final treatment	Generally applicable

BAT 76: In order to reduce emissions to air of organic compounds (including halogenated compounds), HCl and Cl<sub>2</sub>, BAT is to treat the combined waste gas streams from EDC and/or VCM production by using a thermal oxidiser followed by two-stage wet scrubbing.

*Description:*

For the description of thermal oxidiser, wet and caustic scrubbing, see Section 12.1. Thermal oxidation can be carried out in a liquid waste incineration plant. In this case, the oxidation temperature exceeds 1 100 °C with a minimum residence time of 2 seconds, with subsequent rapid cooling of exhaust gases to prevent the *de novo* synthesis of PCDD/F.

Scrubbing is carried out in two stages: Wet scrubbing with water and, typically, recovery of hydrochloric acid, followed by wet scrubbing with caustic.

Table 10.2

**BAT-AELs for emissions of TVOC, the sum of EDC and VCM, Cl<sub>2</sub>, HCl and PCDD/F to air from the production of EDC/VCM**

Parameter	BAT-AEL (daily average or average over the sampling period) (mg/Nm <sup>3</sup> , at 11 vol-% O <sub>2</sub> )
TVOC	0,5–5
Sum of EDC and VCM	< 1
Cl <sub>2</sub>	< 1–4
HCl	2–10
PCDD/F	0,025–0,08 ng I-TEQ/Nm <sup>3</sup>

The associated monitoring is in BAT 2.

BAT 77: In order to reduce emissions to air of PCDD/F from a thermal oxidiser (see Section 12.1) treating process off-gas streams containing chlorine and/or chlorinated compounds, BAT is to use technique a, if necessary followed by technique b, given below.

Technique	Description	Applicability
a. Rapid quenching	Rapid cooling of exhaust gases to prevent the <i>de novo</i> synthesis of PCDD/F	Generally applicable
b. Activated carbon injection	Removal of PCDD/F by adsorption onto activated carbon that is injected into the exhaust gas, followed by dust abatement	

BAT-associated emission levels (BAT-AELs): See Table 10.2.

BAT 78: In order to reduce emissions to air of dust and CO from the decoking of the cracker tubes, BAT is to use one of the techniques to reduce the frequency of decoking given below and one or a combination of the abatement techniques given below.

Technique	Description	Applicability
<b>Techniques to reduce the frequency of decoking</b>		
a. Optimisation of thermal decoking	Optimisation of operating conditions, i.e. airflow, temperature and steam content across the decoking cycle, to maximise coke removal	Generally applicable



	Technique	Description	Applicability
b.	Optimisation of mechanical decoking	Optimise mechanical decoking (e.g. sand jetting) to maximise coke removal as dust	Generally applicable

**Abatement techniques**

c.	Wet dust scrubbing	See Section 12.1	Only applicable to thermal decoking
d.	Cyclone	See Section 12.1	Generally applicable
e.	Fabric filter	See Section 12.1	Generally applicable

**10.2. Emissions to water**

BAT 79: BAT is to monitor emissions to water with at least the frequency given below and in accordance with EN standards. If EN standards are not available, BAT is to use ISO, national or other international standards that ensure the provision of data of an equivalent scientific quality.

Substance/Parameter	Plant	Sampling point	Standard(s)	Minimum monitoring frequency	Monitoring associated with				
EDC	All plants	Outlet of the waste water stripper	EN ISO 10301	Once every day	BAT 80				
VCM									
Copper	Oxy-chlorination plant using the fluidised-bed design	Outlet of the pretreatment for solids removal	Various EN standards available, e.g. EN ISO 11885, EN ISO 15586, EN ISO 17294-2	Once every day <sup>(1)</sup>	BAT 81				
PCDD/F						No EN standard available	Once every 3 months		
Total suspended solids (TSS)						EN 872	Once every day <sup>(1)</sup>		
Copper	Oxy-chlorination plant using the fluidised-bed design	Outlet of the final waste water treatment	Various EN standards available, e.g. EN ISO 11885, EN ISO 15586, EN ISO 17294-2	Once every month	BAT 14 and BAT 81				
EDC						All plants	EN ISO 10301	Once every month	BAT 14 and BAT 80
PCDD/F							No EN standard available	Once every 3 months	BAT 14 and BAT 81

<sup>(1)</sup> The minimum monitoring frequency may be reduced to once every month if adequate performance of the solids and copper removal is controlled by frequent monitoring of other parameters (e.g. by continuous measurement of turbidity).

BAT 80: In order to reduce the load of chlorinated compounds discharged to further waste water treatment and to reduce emissions to air from the waste water collection and treatment system, BAT is to use hydrolysis and stripping as close as possible to the source.

*Description:*

For the description of hydrolysis and stripping, see Section 12.2. Hydrolysis is carried out at alkaline pH to decompose chloral hydrate from the oxychlorination process. This results in the formation of chloroform which is then removed by stripping, together with EDC and VCM.

BAT-associated environmental performance levels (BAT-AEPLs): See Table 10.3.

BAT-associated emission levels (BAT-AELs) for direct emissions to a receiving water body at the outlet of the final treatment: See Table 10.5.

Table 10.3

**BAT-AEPLs for chlorinated hydrocarbons in waste water at the outlet of a waste water stripper**

Parameter	BAT-AEPL (average of values obtained during 1 month) <sup>(1)</sup>
EDC	0,1–0,4 mg/l
VCM	< 0,05 mg/l

<sup>(1)</sup> The average of values obtained during 1 month is calculated from the averages of values obtained during each day (at least three spot samples taken at intervals of at least half an hour).

The associated monitoring is in BAT 79.

BAT 81: In order to reduce emissions to water of PCDD/F and copper from the oxychlorination process, BAT is to use technique a. or, alternatively, technique b together with an appropriate combination of techniques c., d. and e. given below.

Technique	Description	Applicability	
<b>Process-integrated techniques</b>			
a.	Fixed-bed design for oxychlorination	Oxychlorination reaction design: in the fixed-bed reactor, catalyst particulates entrained in the overhead gaseous stream are reduced	Not applicable to existing plants using the fluidised-bed design
b.	Cyclone or dry catalyst filtration system	A cyclone or a dry catalyst filtration system reduces catalyst losses from the reactor and therefore also their transfer to waste water	Only applicable to plants using the fluidised-bed design
<b>Waste water pretreatment</b>			
c.	Chemical precipitation	See Section 12.2. Chemical precipitation is used to remove dissolved copper	Only applicable to plants using the fluidised-bed design
d.	Coagulation and flocculation	See Section 12.2	Only applicable to plants using the fluidised-bed design
e.	Membrane filtration (micro- or ultrafiltration)	See Section 12.2	Only applicable to plants using the fluidised-bed design

Table 10.4

**BAT-AEPLs for emissions to water from EDC production via oxychlorination at the outlet of the pretreatment for solids removal at plants using the fluidised-bed design**

Parameter	BAT-AEPL (average of values obtained during 1 year)
Copper	0,4–0,6 mg/l
PCDD/F	< 0,8 ng I-TEQ/l
Total suspended solids (TSS)	10–30 mg/l

The associated monitoring is in BAT 79.

Table 10.5

**BAT-AELs for direct emissions of copper, EDC and PCDD/F to a receiving water body from EDC production**

Parameter	BAT-AEL (average of values obtained during 1 year)
Copper	0,04–0,2 g/t EDC produced by oxychlorination <sup>(1)</sup>
EDC	0,01–0,05 g/t EDC purified <sup>(2)</sup> <sup>(3)</sup>
PCDD/F	0,1– 0,3 µg I-TEQ/t EDC produced by oxychlorination

<sup>(1)</sup> The lower end of the range is typically achieved when the fixed-bed design is used.

<sup>(2)</sup> The average of values obtained during one year is calculated from the averages of values obtained during each day (at least three spot samples taken at intervals of at least half an hour).

<sup>(3)</sup> Purified EDC is the sum of EDC produced by oxychlorination and/or direct chlorination and of EDC returned from VCM production to purification.

The associated monitoring is in BAT 79.

### 10.3. Energy efficiency

BAT 82: In order to use energy efficiently, BAT is to use a boiling reactor for the direct chlorination of ethylene.

*Description:*

The reaction in the boiling reactor system for the direct chlorination of ethylene is typically carried out at a temperature between below 85 °C and 200 °C. In contrast to the low-temperature process, it allows for the effective recovery and reuse of the heat of reaction (e.g. for the distillation of EDC).

*Applicability:*

Only applicable to new direct chlorination plants.

BAT 83: In order to reduce the energy consumption of EDC cracker furnaces, BAT is to use promoters for the chemical conversion.

*Description:*

Promoters, such as chlorine or other radical-generating species, are used to enhance the cracking reaction and reduce the reaction temperature and therefore the required heat input. Promoters may be generated by the process itself or added.

## 10.4. Residues

BAT 84: In order to reduce the amount of coke being sent for disposal from VCM plants, BAT is to use a combination of the techniques given below.

Technique		Description	Applicability
a.	Use of promoters in cracking	See BAT 83	Generally applicable
b.	Rapid quenching of the gaseous stream from EDC cracking	The gaseous stream from EDC cracking is quenched by direct contact with cold EDC in a tower to reduce coke formation. In some cases, the stream is cooled by heat exchange with cold liquid EDC feed prior to quenching	Generally applicable
c.	Pre-evaporation of EDC feed	Coke formation is reduced by evaporating EDC upstream of the reactor to remove high-boiling coke precursors	Only applicable to new plants or major plant upgrades
d.	Flat flame burners	A type of burner in the furnace that reduces hot spots on the walls of the cracker tubes	Only applicable to new furnaces or major plant upgrades

BAT 85: In order to reduce the amount of hazardous waste being sent for disposal and to increase resource efficiency, BAT is to use all of the techniques given below.

Technique		Description	Applicability
a.	Hydrogenation of acetylene	HCl is generated in the EDC cracking reaction and recovered by distillation.  Hydrogenation of the acetylene present in this HCl stream is carried out to reduce the generation of unwanted compounds during oxychlorination. Acetylene values below 50 ppmv at the outlet of the hydrogenation unit are advisable	Only applicable to new plants or major plant upgrades
b.	Recovery and reuse of HCl from incineration of liquid waste	HCl is recovered from incinerator off-gas by wet scrubbing with water or diluted HCl (see Section 12.1) and reused (e.g. in the oxychlorination plant)	Generally applicable
c.	Isolation of chlorinated compounds for use	Isolation and, if needed, purification of by-products for use (e.g. monochloroethane and/or 1,1,2-trichloroethane, the latter for the production of 1,1-dichloroethylene)	Only applicable to new distillation units or major plant upgrades.  Applicability may be restricted by a lack of available uses for these compounds

## 11. BAT CONCLUSIONS FOR HYDROGEN PEROXIDE PRODUCTION

The BAT conclusions in this section apply in addition to the general BAT conclusions given in Section 1.

## 11.1. Emissions to air

BAT 86: In order to recover solvents and to reduce emissions of organic compounds to air from all units other than the hydrogenation unit, BAT is to use an appropriate combination of the techniques given below. In the case of using air in the oxidation unit, this includes at least technique d. In the case of using pure oxygen in the oxidation unit, this includes at least technique b. using chilled water.

Technique	Description	Applicability	
<b>Process-integrated techniques</b>			
a.	Optimisation of the oxidation process	Process optimisation includes elevated oxidation pressure and reduced oxidation temperature in order to reduce the solvent vapour concentration in the process off-gas	Only applicable to new oxidation units or major plant upgrades
b.	Techniques to reduce solids and/or liquids entrainment	See Section 12.1	Generally applicable
<b>Techniques to recover solvent for reuse</b>			
c.	Condensation	See Section 12.1	Generally applicable
d.	Adsorption (regenerative)	See Section 12.1	Not applicable to process off-gas from oxidation with pure oxygen

Table 11.1

**BAT-AELs for emissions of TVOC to air from the oxidation unit**

Parameter	BAT-AEL <sup>(1)</sup> (daily average or average over the sampling period) <sup>(2)</sup> (no correction for oxygen content)
TVOC	5–25 mg/Nm <sup>3</sup> <sup>(3)</sup>

<sup>(1)</sup> The BAT-AEL does not apply when the emission is below 150 g/h.

<sup>(2)</sup> When adsorption is used, the sampling period is representative of a complete adsorption cycle.

<sup>(3)</sup> In the case of significant methane content in the emission, methane monitored according to EN ISO 25140 or EN ISO 25139 is subtracted from the result.

The associated monitoring is in BAT 2.

BAT 87: In order to reduce emissions of organic compounds to air from the hydrogenation unit during start-up operations, BAT is to use condensation and/or adsorption.

*Description:*

For the description of condensation and adsorption, see Section 12.1.

BAT 88: In order to prevent benzene emissions to air and water, BAT is not to use benzene in the working solution.

11.2. **Emissions to water**

BAT 89: In order to reduce the waste water volume and the organic load discharged to waste water treatment, BAT is to use both of the techniques given below.

Technique		Description	Applicability
a.	Optimised liquid phase separation	Separation of organic and aqueous phases with appropriate design and operation (e.g. sufficient residence time, phase boundary detection and control) to prevent any entrainment of undissolved organic material	Generally applicable
b.	Reuse of water	Reuse of water, e.g. from cleaning or liquid phase separation. The extent to which water can be reused in the process depends on product quality considerations	Generally applicable

BAT 90: In order to prevent or reduce emissions to water of poorly bioeliminable organic compounds, BAT is to use one of the techniques given below.

Technique		Description
a.	Adsorption	See Section 12.2. Adsorption is carried out prior to sending waste water streams to the final biological treatment
b.	Waste water incineration	See Section 12.2

*Applicability:*

Only applicable to waste water streams carrying the main organic load from the hydrogen peroxide plant and when the reduction of the TOC load from the hydrogen peroxide plant by means of biological treatment is lower than 90 %.

## 12. DESCRIPTIONS OF TECHNIQUES

12.1. **Process off-gas and waste gas treatment techniques**

Technique	Description
Adsorption	A technique for removing compounds from a process off-gas or waste gas stream by retention on a solid surface (typically activated carbon). Adsorption may be regenerative or non-regenerative (see below).
Adsorption (non-regenerative)	In non-regenerative adsorption, the spent adsorbent is not regenerated but disposed of.
Adsorption (regenerative)	Adsorption where the adsorbate is subsequently desorbed, e.g. with steam (often on site) for reuse or disposal and the adsorbent is reused. For continuous operation, typically more than two adsorbers are operated in parallel, one of them in desorption mode.

Technique	Description
Catalytic oxidiser	Abatement equipment which oxidises combustible compounds in a process off-gas or waste gas stream with air or oxygen in a catalyst bed. The catalyst enables oxidation at lower temperatures and in smaller equipment compared to a thermal oxidiser.
Catalytic reduction	NO <sub>x</sub> is reduced in the presence of a catalyst and a reducing gas. In contrast to SCR, no ammonia and/or urea are added.
Caustic scrubbing	The removal of acidic pollutants from a gas stream by scrubbing using an alkaline solution.
Ceramic/metal filter	Ceramic filter material. In circumstances where acidic compounds such as HCl, NO <sub>x</sub> , SO <sub>x</sub> and dioxins are to be removed, the filter material is fitted with catalysts and the injection of reagents may be necessary. In metal filters, surface filtration is carried out by sintered porous metal filter elements.
Condensation	A technique for removing the vapours of organic and inorganic compounds from a process off-gas or waste gas stream by reducing its temperature below its dew point so that the vapours liquefy. Depending on the operating temperature range required, there are different methods of condensation, e.g. cooling water, chilled water (temperature typically around 5 °C) or refrigerants such as ammonia or propene.
Cyclone (dry or wet)	Equipment for removal of dust from a process off-gas or waste gas stream based on imparting centrifugal forces, usually within a conical chamber.
Electrostatic precipitator (dry or wet)	A particulate control device that uses electrical forces to move particles entrained within a process off-gas or waste gas stream onto collector plates. The entrained particles are given an electrical charge when they pass through a corona where gaseous ions flow. Electrodes in the centre of the flow lane are maintained at a high voltage and generate the electrical field that forces the particles to the collector walls.
Fabric filter	Porous woven or felted fabric through which gases flow to remove particles by use of a sieve or other mechanisms. Fabric filters can be in the form of sheets, cartridges or bags with a number of the individual fabric filter units housed together in a group.
Membrane separation	Waste gas is compressed and passed through a membrane which relies on the selective permeability of organic vapours. The enriched permeate can be recovered by methods such as condensation or adsorption, or can be abated, e.g. by catalytic oxidation. The process is most appropriate for higher vapour concentrations. Additional treatment is, in most cases, needed to achieve concentration levels low enough to discharge.
Mist filter	Commonly mesh pad filters (e.g. mist eliminators, demisters) which usually consist of woven or knitted metallic or synthetic monofilament material in either a random or specific configuration. A mist filter is operated as deep-bed filtration, which takes place over the entire depth of the filter. Solid dust particles remain in the filter until it is saturated and requires cleaning by flushing. When the mist filter is used to collect droplets and/or aerosols, they clean the filter as they drain out as a liquid. It works by mechanical impingement and is velocity-dependent. Baffle angle separators are also commonly used as mist filters.

Technique	Description
Regenerative thermal oxidiser (RTO)	Specific type of thermal oxidiser (see below) where the incoming waste gas stream is heated by a ceramic-packed bed by passing through it before entering the combustion chamber. The purified hot gases exit this chamber by passing through one (or more) ceramic-packed bed(s) (cooled by an incoming waste gas stream in an earlier combustion cycle). This reheated packed bed then begins a new combustion cycle by preheating a new incoming waste gas stream. The typical combustion temperature is 800–1 000 °C.
Scrubbing	Scrubbing or absorption is the removal of pollutants from a gas stream by contact with a liquid solvent, often water (see 'Wet scrubbing'). It may involve a chemical reaction (see 'Caustic scrubbing'). In some cases, the compounds may be recovered from the solvent.
Selective catalytic reduction (SCR)	The reduction of NO <sub>x</sub> to nitrogen in a catalytic bed by reaction with ammonia (usually supplied as an aqueous solution) at an optimum operating temperature of around 300–450 °C. One or more layers of catalyst may be applied.
Selective non-catalytic reduction (SNCR)	The reduction of NO <sub>x</sub> to nitrogen by reaction with ammonia or urea at a high temperature. The operating temperature window must be maintained between 900 °C and 1 050 °C.
Techniques to reduce solids and/or liquids entrainment	Techniques that reduce the carry-over of droplets or particles in gaseous streams (e.g. from chemical processes, condensers, distillation columns) by mechanical devices such as settling chambers, mist filters, cyclones and knock-out drums.
Thermal oxidiser	Abatement equipment which oxidises the combustible compounds in a process off-gas or waste gas stream by heating it with air or oxygen to above its auto-ignition point in a combustion chamber and maintaining it at a high temperature long enough to complete its combustion to carbon dioxide and water.
Thermal reduction	NO <sub>x</sub> is reduced at elevated temperatures in the presence of a reducing gas in an additional combustion chamber, where an oxidation process takes place but under low oxygen conditions/deficit of oxygen. In contrast to SNCR, no ammonia and/or urea are added.
Two-stage dust filter	A device for filtering on a metal gauze. A filter cake builds up in the first filtration stage and the actual filtration takes place in the second stage. Depending on the pressure drop across the filter, the system switches between the two stages. A mechanism to remove the filtered dust is integrated into the system.
Wet scrubbing	See 'Scrubbing' above. Scrubbing where the solvent used is water or an aqueous solution, e.g. caustic scrubbing for abating HCl. See also 'Wet dust scrubbing'.
Wet dust scrubbing	See 'Wet scrubbing' above. Wet dust scrubbing entails separating the dust by intensively mixing the incoming gas with water, mostly combined with the removal of the coarse particles by the use of centrifugal force. In order to achieve this, the gas is released inside tangentially. The removed solid dust is collected at the bottom of the dust scrubber.



12.2. **Waste water treatment techniques**

All of the techniques listed below can also be used to purify water streams in order to enable reuse/recycling of water. Most of them are also used to recover organic compounds from process water streams.

Technique	Description
Adsorption	Separation method in which compounds (i.e. pollutants) in a fluid (i.e. waste water) are retained on a solid surface (typically activated carbon).
Chemical oxidation	Organic compounds are oxidised with ozone or hydrogen peroxide, optionally supported by catalysts or UV radiation, to convert them into less harmful and more easily biodegradable compounds
Coagulation and flocculation	Coagulation and flocculation are used to separate suspended solids from waste water and are often carried out in successive steps. Coagulation is carried out by adding coagulants with charges opposite to those of the suspended solids. Flocculation is carried out by adding polymers, so that collisions of microfloc particles cause them to bond to produce larger flocs.
Distillation	Distillation is a technique to separate compounds with different boiling points by partial evaporation and recondensation. Waste water distillation is the removal of low-boiling contaminants from waste water by transferring them into the vapour phase. Distillation is carried out in columns, equipped with plates or packing material, and a downstream condenser.
Extraction	Dissolved pollutants are transferred from the waste water phase to an organic solvent, e.g. in counter-current columns or mixer-settler systems. After phase separation, the solvent is purified, e.g. by distillation, and returned to the extraction. The extract containing the pollutants is disposed of or returned to the process. Losses of solvent to the waste water are controlled downstream by appropriate further treatment (e.g. stripping).
Evaporation	The use of distillation (see above) to concentrate aqueous solutions of high-boiling substances for further use, processing or disposal (e.g. waste water incineration) by transferring water to the vapour phase. Typically carried out in multistage units with increasing vacuum, to reduce the energy demand. The water vapours are condensed, to be reused or discharged as waste water.
Filtration	The separation of solids from a waste water carrier by passing it through a porous medium. It includes different types of techniques, e.g. sand filtration, microfiltration and ultrafiltration.
Flotation	A process in which solid or liquid particles are separated from the waste water phase by attaching to fine gas bubbles, usually air. The buoyant particles accumulate at the water surface and are collected with skimmers.
Hydrolysis	A chemical reaction in which organic or inorganic compounds react with water, typically in order to convert non-biodegradable to biodegradable or toxic to non-toxic compounds. To enable or enhance the reaction, hydrolysis is carried out at an elevated temperature and possibly pressure (thermolysis) or with the addition of strong alkalis or acids or using a catalyst.

Technique	Description
Precipitation	The conversion of dissolved pollutants (e.g. metal ions) into insoluble compounds by reaction with added precipitants. The solid precipitates formed are subsequently separated by sedimentation, flotation or filtration.
Sedimentation	Separation of suspended particles and suspended material by gravitational settling.
Stripping	Volatile compounds are removed from the aqueous phase by a gaseous phase (e.g. steam, nitrogen or air) that is passed through the liquid, and are subsequently recovered (e.g. by condensation) for further use or disposal. The removal efficiency may be enhanced by increasing the temperature or reducing the pressure.
Waste water incineration	The oxidation of organic and inorganic pollutants with air and simultaneous evaporation of water at normal pressure and temperatures between 730 °C and 1 200 °C. Waste water incineration is typically self-sustaining at COD levels of more than 50 g/l. In the case of low organic loads, a support/auxiliary fuel is needed.

### 12.3. Techniques to reduce emissions to air from combustion

Technique	Description
Choice of (support) fuel	The use of fuel (including support/auxiliary fuel) with a low content of potential pollution-generating compounds (e.g. lower sulphur, ash, nitrogen, mercury, fluorine or chlorine content in the fuel).
Low-NO <sub>x</sub> burner (LNB) and ultra-low-NO <sub>x</sub> burner (ULNB)	The technique is based on the principles of reducing peak flame temperatures, delaying but completing the combustion and increasing the heat transfer (increased emissivity of the flame). It may be associated with a modified design of the furnace combustion chamber. The design of ultra-low-NO <sub>x</sub> burners (ULNB) includes (air)/fuel staging and exhaust/flue-gas recirculation.