3.5 BAT reference documents (BREFs)

The BAT reference documents (BREFS) provide information on the Best Available Techniques (BAT) for controlling the emissions released by processes and installations. These documents were drawn up on the basis of Art. 16.2 of the European IPPC Directive (EU Directive 96/61).

If a BREF has been adopted for a specific sector of industry or activity by the European Commission, the summary of the BREF is included in the NeR, along with a brief guidance note specifying how the information of the BREF must be applied in the Netherlands. If a special regulation already existed in the NeR for the sector of industry described, this special regulation is cancelled. Only if a special regulation regulates specific aspects not dealt with in the NeR, for example, noise nuisance, part of that special regulation can be maintained in the NeR.

The text in the NeR consists of the text of the Dutch summary of the BREF and the guidance note. The summary of the BREF is the text drawn up by the European Commission. The guidance notes are drawn up in the Netherlands in consultation with the sectors of industry involved and the public authorities and endorsed by the NeR advisory group.

For background information on the summary, you can consult the original English BREF. You can find these documents on the InfoMil internet site.

You can find an explanation of how the BREFS are applied in the Netherlands in Chapter 2.12 of the NeR.

BREF	Dutch version admitted to the NeR
BREF Non-Ferrous Metal processes	2004
BREF Iron and Steel production	2004
BREF Pulp and Paper manufacture	2004
BREF Cement and Lime production	2004
BREF Chlor-Alkali manufacture	2004
BREF Ferrous Metal processing	2004
BREF Cooling Systems	p.m.
BREF Glass manufacture	2004
BREF Tanning of hides and skins	p.m.
BREF Monitoring systems	p.m.
BREF Textile processing	p.m.
BREF Refineries	p.m.
BREF Smitheries and Foundries	p.m.
BREF Large Volume Organic Chemicals	p.m.
BREF Intensive Livestock Farming	p.m.
BREF Emissions from storage of bulk or dangerous materials	p.m.
BREF Common waste water and waste gas treatment and management systems in the chemical sector	p.m.
BREF Economic and cross media issues under IPPC	p.m.
BREF Large Volume Inorganic Chemicals – Ammonia, Acids & Fertilisers	p.m.
BREF Large Volume Inorganic Chemicals - Solid & Others	p.m.
BREF Food, Drink and Milk processes	p.m.
BREF Slaughterhouses and Animal By-products	p.m.
BREF Large Combustion Plants	p.m.
BREF Waste Treatments	p.m.
BREF Waste Incineration	p.m.
BREF Polymers	p.m.
BREF Surface treatment of metals	p.m.
BREF Surface treatments using solvents	p.m.
BREF Ceramics	p.m.
BREF Organic fine chemicals	p.m.
BREF Speciality inorganic chemicals	p.m.
BREF Management of Tailings and Waste-Rock in Mining Activities	p.m.

3.5.1 Chlorine-alkaline producing industry

This guidance note was adopted on 28 September 2004

3.5.1.1 Guidance note

Introduction

Status of guidance note

This guidance note is intended to support the competent authority in applying the BAT Reference (BREF) document for the chlor-alkali producing industry. It describes the field of application of the BREF, the changes in the Dutch legislation as a result of this BREF and the relationship between this BREF and other relevant legislation.

The guidance note must be read in combination with the BREF document.

Status of BREF

The BREF has a comparable status as the NeR and the Commission on Integral Water Management (CIW) recommendations; it may only be departed from on duly stated grounds (for more information refer to the NeR (Chapter 2.12) and the Handbook on the use of permits under the Pollution of Surface Waters Act [WVO]).

Field of application

The BREF relates to chemical installations for the manufacture of the basic inorganic-chemical products chlorine, sodium hydroxide and potassium hydroxide.

In the manufacture of chlorine and caustic solutions by means of the electrosis of brine, the following processes play a role:

- the unloading and storage of salt;
- the purification and re-saturation of brine;
- the different electrolytic production processes (membrane, diaphragm and mercury);
- the concentration, storage and transhipment of caustic solutions;
- the cooling, drying and making soluble of chlorine prior to storage and transhipment;
- the cooling, purification and compression of hydrogen prior to storage and transhipment.

As far as the Best Available Techniques are concerned, the BREF deals in particular with the choice between the different electrolytic production processes and the possibilities to improve these processes.

The strong toxic nature of chlorine is an important factor within the chlorine-alkaline industry. The BREF therefore deals with:

- safety-management procedures;
- monitoring of storage and transhipment;
- prevention of chlorine loss.

The BREF disregards environmental and safety aspects that do not relate directly to the chlor-alkali sector. This concerns, for example, the environmental aspects of the cooling system and the emission from the storage and transhipment of feedstock; for these aspects, reference is made to the horizontal BREF documents for industrial cooling system and for storage and transhipment of bulk goods.

At the moment of publication of this BREF. membrane-cell, mercury-cell and diaphragm-cell installations are being used in the Netherlands. The BREF is therefore in its entirety relevant for the issue of permits on the basis of the Environmental Protection Act and the Pollution of Surface Waters Act.

Conclusions and recommendations

The implementation of the BREF 'Chlor-Alkali Manufacturing Industry' in the Dutch legislation mean that:

1. special regulation E2 of the NeR 'Production of chlorine' has been cancelled and replaced by the BREF and this guidance note;
2. upon issue of WVO permits, the CIW recommends taking into account the Best Available Techniques as described in the BREF and this guidance note.

Supplementary to this, the following applies:

- Existing installations must have switched to a mercury-free process before the year 2010. This will satisfy PARCOM Decision 90/3, which specifies that mercury-cell installations must be replaced by a mercury-free process (as soon as possible) before 2010; the time limit specified in the BREF, 'during the remaining life cycle', must therefore be interpreted in this context.
- If emissions in the BREF are not expressly differentiated, the general stipulations of the NeR (latest version) apply, and the emission policy for water (NW4 1998, CIW 1999).

References

NeR	Netherlands Emission Guidelines for Air
NW4	*Fourth Policy Document on Water Management,* 1998
CIW May 1999	*Handbook on the use of permits under the Pollution of Surface Waters Act (WVO)* Commission on Integrated Water Management, May 1999
PARCOM Decision 90/3	*PARCOM Decision 90/3 of 14 June 1990 on reducing atmospheric emissions from existing chlor-alkali plants,* Paris Commission, June 1990
BREF	Reference Document on Best Available Techniques in the Chlor-Alkali Manufacturing industry, December 2001

3.5.1.2 Summary of BREF

This reference document on best available techniques in the chlor-alkali industry reflects an information exchange carried out according to Article 16(2) of Council Directive 96/61/EC. The document has to be seen in the light of the preface which describes the objectives of the document and its use.

The chlor-alkali industry

The chlor-alkali industry is the industry that produces chlorine (Cl2) and alkali, sodium hydroxide (NaOH) or potassium hydroxide (KOH), by electrolysis of a salt solution. The main technologies applied for chlor-alkali production are mercury, diaphragm and membrane cell electrolysis, mainly using sodium chloride (NaCl) as feed or to a lesser extent using potassium chloride (KCl) for the production of potassium hydroxide.

The diaphragm cell process (Griesheim cell, 1885) and the mercury cell process (Castner-Kellner cell, 1892) were both introduced in the late 1800s. The membrane cell process was developed much more recently (1970). Each of these processes represents a different method of keeping the chlorine produced at the anode separate from the caustic soda and hydrogen produced, directly or indirectly, at the cathode. Currently, 95% of world chlorine production is obtained by the chlor-alkali process.

The geographic distribution of chlor-alkali processes world-wide differs appreciably (production capacity of chlorine):

- western Europe, predominance of mercury cell process (June 2000): 55%
- United States, predominance of diaphragm cell process: 75%
- Japan, predominance of membrane cell process: >90%.

The remaining chlorine production capacity in western Europe consists of (June 2000) diaphragm cell process 22%, membrane cell process 20% and other processes 3%.

Chlorine production since the 1940s has risen enormously, on the back of the burgeoning demand for plastics, notably PVC and polyurethanes. The production of chloroaromatics (e.g. chlorobenzene for phenol synthesis), propylene oxide (chlorohydrin process), solvents containing chlorinated hydrocarbons, and inorganic chlorine compounds are also important factors behind the increased use of chlorine after 1940. The chlorine production of a country is an indicator of the state of development of its chemical industry.

Global production capacity of chlorine in 1995 was about 44 million tonnes, the EU accounting for about 24% of that capacity. In June 2000 the chlorine production capacity in western Europe was 11.3 million tonnes. Of world chlor-alkali capacity, 65% is concentrated in three regions; North America, western Europe and Japan. After a fall at the beginning of the 1990s, production in western Europe now seems to be stabilised at around 9 millions tonnes per year (9.2 million tonnes in 1999).

The chlor-alkali sector in Europe has developed over time and is scattered geographically. The inevitable co-production of chlorine and sodium hydroxide in almost equal amounts has always been a problem for the chlor-alkali industry. Both products are used for very different end uses with differing market dynamics and it is only by rare chance that demand for the two coincides. Europe is approximately in balance in chlorine, and has traditionally been the world's second largest exporter of caustic; currently it is a net importer.

Chlorine is largely used in the synthesis of chlorinated organic compounds. VCM for the synthesis of PVC still remains the driver of chlor-alkali production in most European countries.
Chlorine is difficult to store and transport economically and it is therefore generally produced near consumers. More than 85% of the chlorine produced in EU is used on the same or adjacent sites for other chemical processes.

Sodium hydroxide is usually supplied as a 50% aqueous solution and can be stored for long periods and readily transported (rail, road and ship). The main areas of application of sodium hydroxide today are:

- chemicals: synthesis of organic or inorganic compounds
- metallurgy, alumina/aluminium industry
- pulp and paper industry
- textile industry
- soaps, surfactants
- water treatment
- consumer products.

Inputs and pollutant outputs

Some inputs and pollutant outputs from the chlor-alkali industry are common to all processes. Others are specific to the cell technology used, the purity of the incoming salt and the specifications of the products.

The inputs are primarily salt and water as feedstock; acids and chemical precipitants used to remove impurities in the input brine or output chlorine/caustic soda; cooling agents (CFCs, HCFCs, HFCs, ammonia, etc.) for liquefying and purifying the chlorine gas produced. The chlor-alkali process needs huge amounts of electricity and electrical energy is a major input.

The main pollutant outputs which are common to all three electrolytic processes are chlorine gas emissions to air, free oxidants to water, spent acids, cooling agents, and impurities removed from the input salt or brine.

The pollutant of most concern from the chlor-alkali industry is mercury, which is specific to the mercury cell technology. Due to the process characteristics, mercury can be emitted from the process through air, water, wastes and in the products. The total mercury emission to air, water and products from chlor-alkali plants in western Europe was 9.5 tonnes in 1998, ranging from 0.2–3.0 g Hg/tonne of chlorine capacity at the individual plants.

The majority of mercury losses occur, however, in the various process wastes. For 1997, OSPARCOM reported 31 tonnes of mercury in solid wastes not recycled. Mercury in solids disposal plant-by-plant were in the range of 0–84 g Hg/tonne chlorine capacity in 1998, as reported by Euro Chlor (see Annex C to this document).

At present some 12000 tonnes of mercury are contained in mercury cells used for chlorine production in the EU. When the plants are converted or shut down, this mercury has the potential to be released into the global environment. Currently, there is no European Union policy or legislation on how to deal with this huge amount of pure mercury.

The main issue with the diaphragm technology is asbestos. Both the potential exposure of employees to asbestos and releases of asbestos to the environment are of concern.

Historical mercury and PCDD/FS contamination of land and waterways from mercury and diaphragm chlor-alkali plants is a big environmental problem at some sites. The contamination is due to fallout of mercury and historical disposal of graphite sludges, from the use of graphite anodes, and other wastes on and around the plant sites.

The membrane cell process has inherent ecological advantages over the two older processes, as it does not use mercury or asbestos, and it is the most energy efficient process. Despite these advantages, the change of technology to membrane cells has been slow in western Europe because most existing chlorine plants were installed in the 1970s with a plant life of 40–60 years and there has been no need for new production capacity. Nor has there been a legislative drive to change technology.

With the inputs/outputs of the chlor-alkali sector, it is also relevant to point out the special importance of safety aspects related to production, handling and storage of chlorine.

Conclusions about best available techniques (BAT)

BAT for the production of chlor-alkali is considered to be membrane technology. Non-asbestos diaphragm technology can also be considered as BAT. The total energy use associated with BAT for producing chlorine gas and 50% caustic soda is less than 3000 kWh (AC) per tonne of chlorine when chlorine liquefaction is excluded and less than 3200 kWh (AC) per tonne of chlorine when chlorine liquefaction and evaporation are included.

All cell plants

Best available techniques for the manufacture of chlor-alkali include the following measures:

- Use of management systems to reduce the environmental, health and safety risks of operating a chlor-alkali plant. The risk level should tend to zero. The management systems will include:
  - training of personnel
  - identification and evaluation of major hazards
  - instructions for safe operation
  - planning for emergencies and recording of accidents and near-misses
  - continuous improvement including feedback and learning from experience.

- A chlorine destruction unit designed to be able to absorb the full cell-room production in the event of a process upset until the plant can be shut down. The chlorine absorption unit prevents emissions of chlorine gas in the event of emergencies and/or irregular plant operation.

The absorption unit should be designed to lower the chlorine content in the emitted gas to less than 5 mg/m^3 in the worst case scenario.
All chlorine-containing waste gas streams should be directed to the chlorine absorption unit. The chlorine emission level to air associated with BAT during normal operation is less than 1 mg/m^3 in the case of partial liquefaction and less than 3 mg/m^3 in the case of total liquefaction.

No systematic discharge of hypochlorite to water should take place from the chlorine destruction unit.

- Minimising consumption/avoiding discharge of sulphuric acid by means of one or more of the following options or equivalent systems:
  - on-site reconcentration in closed loop evaporators
  - using the spent acid to control pH in process and waste water streams
  - selling the spent acid to a user that accepts this quality of acid
  - returning the spent acid to a sulphuric acid manufacturer for reconcentration.

If the sulphuric acid is reconcentrated on-site in closed loop evaporators, the consumption can be reduced to 0.1 kg of acid per tonne of chlorine produced.

- Minimising the discharge of free oxidants to water by applying:
  - fixed bed catalytic reduction
  - chemical reduction
  - any other method with equally efficient performance.

The emission level of free oxidants to water associated with BAT is less than 10 mg/l. The overall environmental impact should be considered when the destruction method is chosen.

- Use of carbon tetrachloride-free chlorine liquefaction and purification processes
- Hydrogen should be used as a chemical or as fuel in order to conserve resources.

Membrane cell plants

Best available techniques specific to membrane cell plants include the following measures:

- Minimising the discharge of chlorate and bromate to water by applying:
  - acid conditions in the anolyte (pH 1-2) to minimise the formation of chlorate (ClO_3-) and bromate (BrO_3-)
  - chlorate destruction in the brine circuit to remove chlorate before purging.

The acidity of the anolyte is a design parameter of membrane cell plants and cannot be adjusted without affecting the operation of the membrane cell. If this is not the chosen option, a chlorate decomposer may be necessary to remove chlorate before purging. The chlorate level associated with BAT in the brine circuit is 1–5 g/l and the associated bromate level is 2–10 mg/l (note that the bromate level depends on the bromide level in the salt).

- Appropriate handling of spent membranes and gaskets.

Mercury cell plants

Best available techniques specific to mercury cell plants is considered to be conversion to membrane cell technology.

During the remaining life of mercury cell plants all possible measures should be taken to protect the environment as a whole. The best performing mercury cell plants are achieving total mercury losses to air, water and with products in the range of 0.2–-0.5 g Hg/tonne of chlorine capacity as a yearly average. The majority of mercury losses are in the various wastes from the process. Measures should be taken to minimise current and future mercury emissions from handling, storage, treatment and disposal of mercury-contaminated wastes. Decommissioning of mercury cell plants should be carried out in a way that prevents environmental impact during and after the shutdown process as well as safeguarding human health.

Chapter 4.2 gives more details about available techniques for prevention and/or reduction of emissions, handling and treatments of wastes, energy use, decommissioning of mercury cell plants and conversion to membrane cell technology.

Asbestos diaphragm cell plants

Best available techniques specific to asbestos diaphragm cell plants is considered to be conversion to membrane cell technology or, when the energy use criterion is fulfilled, the use of non-asbestos diaphragms.

During the remaining life of asbestos diaphragm cell plants all possible measures should be taken to protect the environment as a whole. Chapter 4.3 gives more details about available techniques for prevention and/or reduction of emissions, wastes and energy use in asbestos diaphragm cell plants.

3.5.2 Manufacture of iron and steel

This guidance note was adopted on 28 September 2004

3.5.2.1 Guidance note

Introduction

Status of guidance note

This guidance not is intended to support the competent authorities in applying the BAT Reference (BREF) document for the manufacture of iron and steel (version December 2001). It describes the field of application of the BREF, the changes in the Dutch legislation and the relationship between this BREF and other relevant legislation.

The guidance note must be read in combination with the BREF.

Status of BREF

The BREF has a comparable status as the NeR and the recommendations of the Commission on Integrated Water Management (CIW); it may only be departed from on duly stated grounds (for more information refer to the NeR (Chapter 2.12) and the Handbook on the use of permits under the Pollution of Surface Waters Act [WVO]).

Field of application

The BREF relates to the manufacture of iron and steel in integrated steel plants and to the manufacture of steel in arc furnaces.

In the manufacture of iron and steel, the following processes play a role:

- the sintering of iron ore in the sintering plant;
- the pelletising of iron ore in the pelletising plant;
- the carbonisation of coal in the coking plant;
- the manufacture of pig iron in the blast furnaces;
- the manufacture of steel in the oxygen steelmaking plant;
- ingot casting or continuous casting.

The manufacture of steel in arc furnaces consists of smelting the steel from steel scrap in an arc furnace and casting (ingot casting or continuous casting).

The most important environmental aspects of iron and steel manufacture are emissions to the air, manufacture of solids waste products and by-products, energy consumption and emissions to water. The BREF considers this in detail per process.

The BREF disregards environmental and safety aspects that do not relate directly to the manufacture of iron and steel. It concerns, for example, the environmental aspects of cooling systems. For these aspects, reference is made to the horizontal BREF document for industrial cooling systems.

Nor are aspects that are predominantly of a local nature, such as noise, vibration, odour, soil pollution and safety, considered in detail in the BREF.

One chapter of the BREF is devoted to alternative processes for the manufacture of iron and steel (direct reduction and smelt reduction).

At the moment of publication of this BREF, iron and steel are being manufactured in the Netherlands both via the integrated route and via the arc furnace. The BREF is therefore in its entirety relevant for the issue of permits on the basis of the Environmental Protection Act and the Pollution of Surface Waters Act.

Conclusions and recommendations

The implementation of the BREF 'Production of Iron and Steel' in Dutch legislation mean that:

1. The following special NeR regulations are cancelled:
   - 'D1a Production of pig iron; Sintering of iron ore'
   - 'D1b Production of pig iron; Pelletising of iron ore'
   - 'D1c Production of pig iron; Blast Furnaces'
   - 'D1d Production of oxygen steel'
   - 'C1 Coking plants'
2. In taking decisions on the basis of the Environmental Protection Act and the Pollution of Surface Waters Act, account must be taken of the Best Available Techniques as described in the BREF.

Supplementary to this, the following applies:

If emissions are not expressly differentiated in the BREF, the stipulations of the NeR apply (latest version) and the emission policy for water (NW4 1998, CIW 1999). The negative environmental effects of, for example, the storage and transhipment of coal, ore, scrap and (hazardous) waste products are not considered in detail in the BREF. For the issue of permits, use can be made in this part of the special regulation of the NeR 'particulate emission in the processing, preparation, transport, loading and unloading of drift-sensitive goods'.

- In several places in the BREF (page IV, point 8 and 9; page V, point 4; page VII, point 4) mention is made of circumstances in which it is unlikely that the environmental standards are complied with. In the Dutch situation, this is, in any event, true in those situations where the air quality standards are exceeded and/or the national objectives for a substance are not realised.
- Process and burner installations used in the iron and steel industry fall, upon commissioning, under the general administrative order on NO_x emission trading.

References

NeR	Netherlands Emission Guidelines for Air
NW4	*Fourth Policy Document on Water Management,* 1998
CIW May 1999	*Handbook on the use of permits under the Pollution of Surface Waters Act (WVO)* Commission on Integrated Water Management, May 1999
BREF	*Best Available Techniques Reference Document on the Production of Iron and Steel,* December 2001

3.5.2.2 Summary of BREF

This Reference Document on best available techniques in the Iron and Steel Industry reflects an information exchange carried out according to Article 16(2) of Council Directive 96/61/EC. The document has to be seen in the light of the preface, which describes the objectives of the document and its use.

Scope
It covers the environmental aspects of iron and steel making in integrated steelworks (sinter plants, pelletisation plants, coke oven plants, blast furnaces and basic oxygen furnaces including continuous or ingot casting) and electric arc furnace steelmaking. Ferrous metal processing downstream to casting is not covered in this document.

Submitted information
The most important environmental issues of iron and steelmaking relate to emissions to air and to solid wastes/by-products. Wastewater emissions from coke oven plants, blast furnaces and basic oxygen furnaces are the most relevant emissions to water in this sector. It is no surprise, therefore, that there is good information available on these aspects but only limited information is available about noise/vibration emissions and related measures to minimise them. The same is for soil pollution, health & safety and also for natural aspects.
In addition, little information is available on the sampling methods, analysis methods, time intervals, computation methods and reference conditions used as a basis for the data submitted.

Structure of the document
The overall structure of this BREF is characterised by three main parts:
- General information on the sector
- Information on integrated iron and steelworks
- Information on electric arc furnace steelmaking.

The general information includes statistical data about iron and steel production in the EU, the geographical distribution, economic and employment aspects together with rough assessment of the environmental significance of the sector. Because of the complexity of integrated steelworks an overview is given (chapter 3) before providing a full information set for the main production steps which are:
- sinter plants (chapter 4)
- pelletisation plants (chapter 5)
- coke oven plants (chapter 6)
- blast furnaces (chapter 7)
- basic oxygen steelmaking incl. casting (chapter 8).

A full information set means all the information for these production steps according to the General Outline for IPPC BAT Reference Documents. Such a 'plant wise' compilation of information is made to assist the use of the document in practice. Electric arc furnace steelmaking differs totally from integrated steelworks and is therefore presented in a separate chapter (chapter 9).
Finally, to complete the picture, information is submitted on new/alternative ironmaking techniques (chapter 10).
Chapter 11 contains the conclusions and recommendations.

General information
Iron and steel are important products that are widely used. The production of crude steel in the European Union stood at 155.3 million tonnes in 1999, equivalent to about 20% of world production.
In the EU about two thirds of crude steel are produced via the blast furnace route at 40 sites and one third is produced in 246 electric arc furnaces. In 1995, around 330,000 people were employed in the iron and steel industry, with large numbers working in dependent industries such as construction, car manufacturing, mechanical engineering etc.

Production of iron and steel
The iron and steel industry is a highly material and energy intensive industry. More than half of the mass input becomes outputs in the form of off-gases and solid wastes/by-products. The most relevant emissions are those to air. Those from sinter plants dominate the overall emissions for most of the pollutants. Although big efforts have been made to reduce emissions, the contribution of the sector to the total emissions to air in the EU is considerable for a number of pollutants, especially for some heavy metals and PCDD/F. The rate of reuse and recycling of solid wastes/by-products has been increased dramatically in the past but considerable amounts are still disposed to landfills.

The information on the main production plants in integrated steelworks (see above) and for electric arc furnace steelmaking, begins with a concise description of applied processes and techniques in order to achieve a proper understanding of both the environmental problems and the further information.
The emission and consumption data characterise in detail the input and output mass streams structured according to the media of air, water and soil and also to energy and noise aspects (for sinter plants: table 4.1; for pelletisations plants: table 5.1; for coke oven plants: tables 6.2 and 6.3; for blast furnaces: table 7.1; for basic oxygen steelmaking and casting: table 8.2). All these data derive from existing installations and are very necessary for the evaluation of the described techniques to consider in the determination of BAT. The description of these techniques follows a certain structure (description of the technique, main achieved levels, applicability, cross-media effects, reference plants, operational data, driving force, economics, reference literature) and ends up in conclusions as to what is considered as BAT. These conclusions are based upon expert judgement in the TWG.

BAT for sinter plants (chapter 4)
Sinter, as a product of an agglomeration process of iron-containing materials, represents a major part of the burden of blast furnaces. The most relevant environmental issues are the off-gas emissions from the sinter strand, which contains a wide range of pollutants such as dust, heavy metals, SO_2, HCl, HF, PAHs and organochlorine compounds (such as PCB and PCDD/F). Thus most of the described techniques to consider in the determination of BAT refer to the reduction of emissions to air. The same applies to the conclusions; therefore the most important parameters are dust and PCDD/F. For sinter plants, the following techniques or combination of techniques are considered as BAT.

1 Waste gas de-dusting by application of:
  – Advanced electrostatic precipitation (ESP) (moving electrode ESP, ESP pulse system, high voltage operation of ESP …) *or*
  – electrostatic precipitation plus fabric filter or
  – pre-dedusting (e.g. ESP or cyclones) plus high pressure wet scrubbing system.

Using these techniques dust emission concentrations <50 mg/Nm³ are achieved in normal operation.
In case of application of a fabric filter, emissions of 10–20 mg/Nm³ are achieved.

2 Waste gas recirculation, if sinter quality and productivity are not significantly affected, by applying:
  – recirculation of part of the waste gas from the entire surface of the sinter strand, *or*
  – sectional waste gas recirculation
3 Minimising of PCDD/F emissions, by means of:
  – Application of waste gas recirculation;
  – Treatment of waste gas from sinter strand;
  – use of fine wet scrubbing systems, values <0.4 ng I-TEQ/Nm³ have been achieved.
  – Fabric filtration with addition of lignite coke powder also achieves low PCDD/F emissions (>98 % reduction, 0.1 – 0.5 ng I-TEQ/Nm³. – this range is based on a 6 hours random sample and steady state conditions).
4 Minimisation of heavy metal emissions
  – Use of fine wet scrubbing systems in order to remove water-soluble heavy metal chlorides, especially lead chloride(s) with an efficiency of >90% or a bag filter with lime addition;
  – Exclusion of dust from last ESP field from recycling to the sinter strand, dumping it on a secure landfill (watertight sealing, collection and treatment of leachate), possibly after water extraction with subsequent precipitation of heavy metals in order to minimise the quantity to dump.

5 Minimisation of solid waste
  – Recycling of by-products containing iron and carbon from the integrated works, taking into account the oil content of the single by-products (<0.1 %).

  For solid wastes generation, the following techniques are considered BAT in descending order of priority:
  – Minimising waste generation
  – Selective recycling back to the sinter process
  – Whenever internal reuse is hampered, external reuse should be aimed at
  – If all reuse is hampered, controlled disposal in combination with the minimisation principle is the only option.

6 Lowering the hydrocarbon content of the sinter feed and avoidance of anthracite as a fuel.
  – Oil contents of the recycled by-products/residues <0.1% are achievable.

7 Recovery of sensible heat:
  – Sensible heat can be recovered from the sinter cooler waste gas and is feasible in some cases to recover it from the sinter grate waste gas. The application of waste gas recirculation can also be considered a form of sensible heat recovery.

8 Minimisation of SO_2 emissions by, for example:
  – Lowering the sulphur input (use of coke breeze with low sulphur content and minimisation of coke breeze consumption, use of iron ore with low sulphur content); with these measures emission concentrations <500 mg SO_2/Nm^3 can be achieved.
  – With wet waste gas desulphurisation, reduction of SO_2 emissions >98% and SO_2 emission concentrations <100 mg SO_2/Nm^3 are achievable. Due to the high cost wet waste gas desulphurisation should only be required in circumstances where environmental quality standards are not likely to be met.

9 Minimisation of NO_x emissions by, for example:
  – waste gas recirculation
  – waste gas denitrification, applying
  – regenerative activated carbon process
  – selective catalytic reduction.

  Due to the high cost waste gas denitrification is not applied except in circumstances where environmental quality standards are not likely to be met.

10 Emissions to water (not cooling water)
  – These are only relevant when rinsing water is used or when wet waste gas treatment system is employed. In these cases, the effluent water to the receiving environment should be treated by heavy metal precipitation, neutralisation and sand filtration. TOC concentrations <20 mg C/l and heavy metal concentrations <0.1 mg/l (Cd, Cr, Cu, Hg, Ni, Pb, Zn) are achieved. When the receiving water is fresh, attention has to be paid to salt content. Cooling water can be recycled.

In principle the techniques mentioned in points 1–10 are applicable to both new and existing installations considering the preface.

BAT for pelletisation plants (chapter 5)

Pelletisation is another process to agglomerate iron-containing materials. While sinter is practically always produced at the steelworks site for various reasons, pellets are mainly produced at the site of the mine or its shipping port. Therefore in the EU there is only one pelletisation plant as part of an integrated steelworks and four stand-alone plants. Also for these plants, emissions to air dominate the environmental issues. As a consequence, most of the described techniques to consider in the determination of BAT refer to emissions to air and the conclusions as well.
For pelletisation plants, the following techniques or combination of techniques are considered as BAT.

1 Efficient removal of particulate matter, SO_2, HCl and HF from the induration strand waste gas, by means of:
  – Scrubbing *or*
  – Semi-dry desulphurisation and subsequent de-dusting (e.g. gas suspension absorber [GSA]) *or* any other device with the same efficiency.

  Achievable removal efficiency for these compounds are:
  – Particulate matter: >95%; corresponding to achievable concentration of <10 mg dust/Nm^3
  – SO_2: >80%; corresponding to achievable concentration of <20 mg SO_2/Nm^3
  – HF: >95%; corresponding to achievable concentration of <1 mg HF/Nm^3
  – HCl: >95%; corresponding to achievable concentration of <1 mg HCl/Nm^3

2 Emissions to water from scrubbers are minimised by means of water cycle closure, heavy metal precipitation, neutralisation and sand filtration.

3 Process-integrated NO_x abatement;
  Plant design should be optimised for recovery of sensible heat and low-NO_x emissions from all firing sections (induration strand, where applicable and drying at the grinding mills).
  In one plant, of the grate-kiln type and using manetite ore emissions <150 g NO_x/t pellets are achieved. In other plants (existing or new, of the same or other type, using the same or other raw materials), solutions have to be tailor-made and the possible No_x emission level might vary from site to site.

4 Minimisation of end-of-pipe NO_x emissions by means of end-of-pipe techniques:
  Selective Catalytic Reduction or any other technique with a NO_x reduction efficiency of at least 80%.
  Due to high cost waste gas denitrification should only be considered in circumstances where environmental quality standards are otherwise not likely to be met; to date there are no de-NO_x systems in operation at any commercial pelletisation plant.

5 Minimising solid waste/by-products
The following techniques are considered BAT in descending order of priority:
- Minimising waste generation
- Effective utilisation (recycling or reuse) of solid wastes/by-products
- Controlled disposal of unavoidable wastes/by-products.

6 Recovery of sensible heat;
Most pelletisation plants already have a high rate of energy recovery. For further improvements, tailor-made solutions are usually necessary. In principle the techniques listed in points 1–6 are applicable to both new and to existing installations considering the preface.

BAT for coke oven plants (chapter 6)

Coke is needed as the primary reducing agent in blast furnaces. Also for coke oven plants, emissions to air are most significant. However, many of these are fugitive emissions from various sources such as leakages from lids, oven doors and leveller doors, ascension pipes and emissions from certain operations like coal charging, coke pushing and coke quenching. In addition, fugitive emissions arise from the coke oven gas treatment plant. The main point source for emissions to air is the waste gas from the underfiring systems. Because of this special emission situation, detailed information is compiled in order to provide an adequate understanding. Consequently most of the techniques to consider in the determination of BAT refer to the minimisation of emissions to air. Emphasis has been placed on smooth and undisturbed operation as well as on maintenance of coke ovens, which appears to be essential. Desulphurisation of coke oven gas is a measure of high priority to minimise SO_2 emissions, not only at coke oven plants themselves but also at other plants where the coke oven gas is used as a fuel. Wastewater disposal is another major issue for coke oven plants. Detailed information provides a clear picture together with described techniques in order to minimise emissions to water. The conclusions reflect the above mentioned issues. Therefore it has to be noted that coke dry quenching is not considered generally as BAT but only under certain circumstances.

For coke oven plants, the following techniques or combination of techniques are considered as BAT.

1 General:
- Extensive maintenance of oven chambers, oven doors and frame seals, ascension pipes, charging holes and other equipment (systematic programme carried out by specially trained maintenance personnel)
- Cleaning of doors, frame seals, charging holes and lids and ascension pipes after handling
- Maintaining a free gas flow in the coke ovens.

2 Charging:
- Charging with charging cars.
From an integrated point of view, 'smokeless' charging or sequential charging with double ascension pipes or jumper pipes are the preferred types, because all gases and particulate matter are treated as part of coke oven gas treatment.
If however the gases are extracted and treated outside the coke oven, charging with land-based treatment of the extracted gases is the preferred method. Treatment should consist of efficient evacuation and subsequent combustion and fabric filtration Emissions of particulate matter <5 g/t coke are achievable.

3 Coking:
A combination of the following measures:
- Smooth, undisturbed coke oven operation, avoiding strong temperature fluctuations;
- Application of spring-loaded flexible-sealing doors or knife edged doors (in case of ovens ≤5m high and good maintenance) achieving: <5% visible emissions (frequency of any leaks compared to the total number of doors) from all doors in new plants and <10% visible emissions from all doors in existing plants.
- Water-sealed ascension pipes, achieving <1% visible emissions (frequency of any leaks compared to the total number of ascension pipes) from all pipes;
- Luting charging holes with clay-suspension (or other suitable sealing material), achieving <1% visible emissions (frequency of any leaks compared to the total number of holes) from all holes;
- Levelling doors equipped with sealing package achieving <5% visible emissions.

4 Firing:
- Use of desulphurized COG
- Prevention of leakage between oven chamber and heating chamber by means of regular coke oven operation *and*
- Repair of leakage between oven chamber and heating chamber *and*
- incorporation of low-NO_x techniques in the construction of new batteries, such as stage combustion (emissions in the order of 450–700 g/t coke and 500–770 mg/Nm^3 respectively are achievable in new/modern plants).
- Due to the high cost, flue gas denitrification (e.g. SCR) is not applied except in new plants under circumstances where environmental quality standards are not likely to be met.

5 Pushing:
- Extraction with an (integrated) hood on coke transfer machine and land-based extraction gas treatment with fabric filter and usage of one point quenching car to achieve less than 5 g particulate matter/t coke (stack emission).

6 Quenching:
  – Emission minimised wet quenching with less than 50 g particulate matter/t coke (determined according VDI method). The use of process-water with significant organic load (like raw coke oven wastewater, wastewater with high content of hydrocarbons etc.) as quenching water is avoided.
  – Coke dry quenching (CDQ) with recovery of sensible heat and removal of dust from charging, handling and sieving operations by means of fabric filtration. With respect to present energy prices in the EU, 'instrument/operational costenvironmental benefit'- consideration sets strong limitations on the applicability of CDQ. In addition a use of recovered energy must be available.
7 Coke oven gas desulphurisation:
  – Desulphurisation by absorption systems (H_2S content grid gas 500–1000 mg H_2S/Nm^3) *or*
  – Oxidative desulphurisation (<500 mg H_2S/Nm^3), provided that cross-media effects of toxic compounds are abated to a large extent.
8 Gas-tight operation of gas treatment plant:
  All measures to enable virtually gas-tight operation of the gas treatment plant should be considered like:
  – Minimising the number of flanges by welding piping connections wherever possible
  – Use of gas-tight pumps (e.g. magnetic pumps)
  – Avoiding emissions from pressure valves in storage tanks, by means of connection of the valve outlet to the coke oven gas collecting main (or by means of collecting the gases and subsequent combustion).
9 Wastewater pre-treatment:
  – Efficient ammonia stripping, using alkalis. Stripping efficiency should be related to subsequent wastewater treatment. Stripper effluent NH^3 concentrations of 20 mg/l are achievable;
  – Tar removal.
10 Wastewater treatment:
  Biological wastewater treatment with integrated nitrification/denitrification achieving:

– COD removal:	>90%
– Sulphide:	<0.1 mg/l
– PAH (6 Borneff):	<0.05 mg/l
– CN^-:	<0.1 mg/l
– Phenols:	<0.5 mg/l
– Sum of NH_4^+, NO_3^- and NO_2^-:	<30 mgN/l
– Suspended solids:	<40 mg/l

These concentrations are based on a specific wastewater flow of 0.4 m^3/t coke. In principle the techniques listed under points 1–10 are applicable to new as well as to existing installations considering the preface except low-NO_x techniques (only for new plants).

BAT for blast furnaces (chapter 7)

The blast furnace remains by far the most important process to produce pig iron from iron containing materials. Because of the high input of reducing agents (mainly coke and coal) this process consumes most of the overall energy input of an integrated steelworks. Relevant emissions to all media occur and these are described in detail. Therefore the techniques described to consider in the determination of BAT cover all these aspects including minimisation of energy input. The subsequent conclusions are mainly concerned with the reduction of dust from the cast house, treatment of wastewater from blast furnace gas scrubbing, reuse of slag and dusts/sludges and finally the energy input minimisation and the reuse of blast furnace gas.
For blast furnaces, the following techniques or combination of techniques are considered as BAT.

1 Blast furnace gas recovery.
2 Direct injection of reducing agents; e.g. a pulverised coal injection of 180 kg/t pig iron is already proven, but higher injection rates could be possible.
3 Energy recovery of top BF gas pressure where prerequisites are present.
4 Hot stoves:
  – emission concentration of dust <10 mg/Nm^3 and of NO_x<350 mg/Nm^3 (related to an oxygen content of 3%) can be achieved
  – energy savings where design permits.
5 Use of tar-free runner linings.
6 Blast furnace gas treatment with efficient de-dusting; Coarse particulate matter is preferably removed by means of dry separation techniques (e.g. deflector) and should be reused. Subsequently fine particulate matter is removed by means of:
  – a scrubber *or*
  – a wet electrostatic precipitator *or*
  – any other technique achieving the same removal efficiency
  A residual particulate matter concentration of <10 mg/Nm^3 is possible.
7 Cast house de-dusting (tap-holes, runners, skimmers, torpedo ladle charging points).
  Emissions should be minimised by covering the runners and evacuation of the mentioned emission sources and purification by means of fabric filtration or electrostatic precipitation. Dust emission concentrations of 1–15 mg/Nm^3 can be achieved. Regarding fugitive emissions 5–15 g dust/t pig iron can be achieved; thereby the capture efficiency of fumes is important. Fume suppression using nitrogen (in specific circumstances, e.g. where the design of the casthouse allows and nitrogen is available).

8 Treatment of blast furnace gas scrubbing wastewater:
   a Reuse of scrubbing water as much as possible;
   b Coagulation/sedimentation of suspended solids (residual suspended solids <20 mg/l can be achieved as an annual average, a single daily value up to 50 mg/l may occur);
   c Hydrocyclonage of sludge with subsequent reuse of the coarse fraction when grain size distribution allows reasonable separation.
9 Minimising slag treatment emissions and slag to landfill;
   Slag treatment preferably by means of granulation where market conditions allow. Condensation of fume if odour reduction is required. Whenever pit slag is produced, forced cooling with water should be minimised or avoided where possible and where space restrictions allow.
10 Minimising solid waste/by-products.
   For solid wastes, the following techniques are considered BAT in descending order of priority:
   a Minimising solid waste generation
   b Effective utilisation (recycling or reuse) of solid wastes/by-products; especially recycling of coarse dust from BF gas treatment and dust from cast house de-dusting, complete reuse of slag (e.g. in the cement industry or for road construction)
   c Controlled disposal of unavoidable wastes/by-products (fine fraction of sludge from BF gas treatment, part of the rubble)

In principle the techniques listed as points 1–10 are applicable to both new and existing installations considering the preface.

BAT for basic oxygen steelmaking and casting (chapter 8)

The objective of oxygen steelmaking is to oxidise the undesirable impurities still contained in the hot metal from blast furnaces. It includes the pre-treatment of hot metal, the oxidation process in the basic oxygen furnace, secondary metallurgical treatment and casting (continuous and/or ingot). The main environmental issues are emissions to air from various sources as described and various solid waste/by-products which are also described. In addition wastewater arises from wet de-dusting (when applied) and from continuous casting. Consequently the techniques to consider in the determination of BAT cover these aspects as well as the recovery of basic oxygen furnace gas. The conclusions are mainly concerned with minimisation of dust emissions from the different sources and measures to reuse/recycle solid waste/by-products, wastewater from wet de-dusting and the recovery of basic oxygen furnace gas.
For basic oxygen steelmaking and casting, the following techniques or combination of techniques are considered as BAT.

1 Particulate matter abatement from hot metal pre-treatment (including hot metal transfer processes, desulphurisation and deslagging), by means of:
   – Efficient evacuation;
   – Subsequent purification by means of fabric filtration or ESP. Emission concentrations of 5–15 mg/Nm^3 are achievable with bag filters and 20–30 mg/Nm^3 with ESP.
2 BOF gas recovery and primary de-dusting, applying:
   – Suppressed combustion *and*
   – Dry electrostatic precipitation (in new and existing situations) *or*
   – Scrubbing (in existing situations).
   Collected BOF gas is cleaned and stored for subsequent use as a fuel. In some cases, it may not be economical or, with regard to appropriate energy management, not feasible to recover the BOF gas. In these cases, the BOF gas may be combusted with generation of steam. The kind of combustion (full combustion or suppressed combustion) depends on the local energy management. Collected dusts and/or sludges should be recycled as much as possible. Note the usually high zinc content of the dust/sludge. Special attention should be paid to the emissions of particulate matter from the lance hole. This hole should be covered during oxygen blowing and, if necessary, inert gas injected into the lance hole to dissipate the particulate matter.
3 Secondary de-dusting, applying:
   – Efficient evacuation during charging and tapping with subsequent purification by means of fabric filtration or ESP or any other technique with the same removal efficiency. Capture efficiency of about 90% can be achieved. Residual dust content of 5–15 mg/Nm^3 in case of bag filters and of 20–30 mg/Nm^3 in case of ESP can be achieved. Note the usually high zinc content of the dust.
   – Efficient evacuation during hot metal handling (reladling operations), deslagging of hot metal and secondary metallurgy with subsequent purification by means of fabric filtration or any other technique with the same removal efficiency. For these operations emission factors below 5 g/t LS are achievable. Fume suppression with inert gas during reladling of hot metal from torpedo ladle (or hot metal mixer) to charging ladle in order to minimise fume/dust generation.
4 Minimisation/abatement of emissions to water from primary wet de-dusting of BOF gas applying the following measures:
   – Dry BOF gas cleaning can be applied when space permits;
   – Recycling of scrubbing water as much as possible (e.g. by means of CO_2 injection in case of suppressed combustion systems);
   – Coagulation and sedimentation of suspended solids; 20 mg/l suspended solids can be achieved.

5 Abatement of emissions to water from direct cooling at the continuous casting machines by:
  – Recycling of process and cooling water as much as possible;
  – Coagulation and sedimentation of suspended solids;
  – Removal of oil using skimming tanks or any other effective device;
6 Minimisation of solid waste. For solid waste generation, the following techniques are considered BAT in descending order of priority:
  – Minimising waste generation
  – Effective utilisation (recycling or reuse) of solid wastes/by-products; especially recycling of BOF slag and coarse and fine dust from BOF gas treatment
  – Controlled disposal of unavoidable wastes. In principle the techniques according to items 1–6 are applicable to new as well as to existing installations (if there are no other indications) considering the preface.

BAT for electric steelmaking and casting (chapter 9)

The direct smelting of iron-containing materials, mainly scrap is usually performed in electric arc furnaces which need considerable amounts of electric energy and causes substantial emissions to air an solid wastes/by-products mainly filter dust and slags. The emissions to air from the furnace consist of a wide range of inorganic compounds (iron oxide dust and heavy metals) and organic compounds such as the important organochlorine compounds chlorobenzenes, PCB and PCDD/F. The techniques to consider in the determination of BAT reflect this and focus on these issues. In the conclusions, regarding emissions to air, dust and PCDD/F are the most relevant parameters. Scrap preheating is also considered as BAT just as reuse/recycling of slags and dusts.

For electric steelmaking and casting, the following techniques or combination of techniques are considered as BAT.

1 Dust collection efficiency
  – With a combination of direct off gas extraction (4th or 2nd hole) and hood systems *or*
  – dog-house and hood systems *or*
  – total building evacuation 98% and more collection efficiency of primary and secondary emissions from EAF are achievable.
2 Waste gas de-dusting by application of:
  – Well-designed fabric filter achieving less than 5 mg dust/Nm^3 for new plants and less than 15 mg dust/Nm^3 for existing plants, both determined as daily mean values. The minimisation of the dust content correlates with the minimisation of heavy metal emissions except for heavy metals present in the gas phase like mercury.
3 Minimising of organochlorine compounds, especially PCDD/F and PCB emissions, by means of:
  – appropriate post-combustion within the off gas duct system or in a separate postcombustion chamber with subsequent rapid quenching in order to avoid de novo synthesis *and/or*
  – injection of lignite powder into the duct before fabric filters.
  Emission concentrations of PCDD/F 0.1 - 0.5 ng I-TEQ/Nm^3 are achievable.
4 Scrap preheating (in combination with 3.) in order to recover sensible heat from primary off gas
  – With scrap preheating of part of the scrap about 60 kWh/t can be saved, in case of preheating the total scrap amount up to 100 kWh/t liquid steel can be saved. The applicability of scrap preheating depends on the local circumstances and has to be proved on a plant by plant basis. When applying scrap preheating it has to be taken care of possibly increased emissions of organic pollutants.
5 Minimising solid waste/by-products
  For solid wastes, the following techniques are considered BAT in descending order of priority:
  – Minimisation of waste generation.
  – Waste minimisation by recycling of EAF slags and filter dusts; depending on local circumstances filter dust can be recycled to the electric arc furnace in order to achieve a zinc enrichment up to 30%. Filter dust with zinc contents of more than 20% can be used in the non-ferrous metal industry.
  – Filter dusts from the production of high alloyed steels can be treated to recover alloying metals.
  – For solid wastes, which can not be avoided or recycled, the generated quantity should be minimised. If all minimisation/reuse is hampered, controlled disposal is the only option.
6 Emissions to water
  – Closed loop water cooling system for the cooling of furnace devices
  – Wastewater from continuous casting
  – Recycling of cooling water as much as possible
  – Precipitation/sedimentation of suspended solids
  – Removal of oil in shimming tanks or any other effective device.

In principle the techniques according to items 1–6 are applicable to new as well as to existing installations considering the preface.

Level of consensus

This BREF enjoys a high level of consensus. No split views had to be noted during TWG and IEF discussions. There is a broad agreement on the document.

3.5.3 Pulp and paper industry

This guidance note was adopted on 28 September 2004

3.5.3.1 Guidance note

Introduction

Status of guidance note

This guidance note is intended to support the competent authorities in applying the BAT Reference (BREF) document for the pulp and paper industry. It describes the field of application of the BREF, the changes in the Dutch legislation as a result of this BREF and the relationship between this BREF and other relevant legislation.

The guidance note must be read in combination with the BREF document.

Status of BREF

The BREF has a comparable status as the NeR and the recommendations of the Commission on Integrated Water Management (CIW); it may only be departed from on duly stated grounds (for more information refer to the NeR (Chapter 2.12) and the Handbook on the use of permits under the Pollution of Surface Waters Act [WVO]).

Field of application

The Pulp and Paper Industry BREF describes the relevant production processes, the associated environmental aspects, the techniques regarded as BAT (Best Available Techniques) and the results that can be achieved with these techniques.

The following 5 pulp and paper industry processes are described:

- kraft fibre production(Chapter 2);
- sulphite fibre production(Chapter 3);
- mechanical and chemical pulp production (Chapter 4);
- processing of recycled fibres (Chapter 5);
- paper production and related processes (Chapter 6).

The BREF disregards environmental and safety aspects that do not relate directly to the pulp and paper industry. This concerns, for example, the environmental aspects of cooling systems and the emission from the storage and transhipment of feedstock; for these aspects, reference is made to the horizontal BREF documents for industrial cooling systems and for storage and transhipment of feedstock.

In the Netherlands, paper and cardboard is chiefly produced from recycled fibres (approx. 75%). New fibres are mainly imported from abroad. Pulp production from wood takes place marginally and amounts to merely a few per cents of the total production. In the Netherlands, pulp production only takes place by mechanical or heat-mechanical processes. The mechanical pulp production is integrated in the paper plant.

The sulphate or kraft fibre process and the sulphite fibre process are not used in the Netherlands.

The Pulp and Paper Industry BREF is therefore only partly relevant in the current situation (Chapter 1, 4, 5 and 6) for the issue of permits on the basis of the Environmental Protection Act (Wm) and the Pollution of Surface Waters Act (WVO).

Conclusions and recommendations

1. In the issue of WVO and Wm permits to the paper and cardboard industry in the Netherlands, the competent authorities must take into account the Best Available Techniques (BAT) as described in the Pulp and Paper Industry BREF.
2. The Best Available Techniques define the clean-up efforts that must be made pursuant to the emission policy for water to prevent contamination of surface water. For the relationship between the IPPC Directive and the elaboration of the emission policy for water in the issue of permits under the WVO, reference is made to the CIW Handbook on the use of permits under the WVO (CIW May 1999).
3. For the assessment of substances and preparations and the assessment of residual discharges, the General Assessment Method (ABM) and the immission test (CIW, May 2000; CIW June 2000) apply.
4. If emissions in the BREF are not expressly differentiated, the general stipulations of the NeR apply.

References:

CIW May 1999: *Handbook on the use of permits under the Pollution of Surface Waters Act*, Commission on Integrated Water Management, May 1999

CIW May 2000: *The assessment of substances and preparations for the implementation of the emission policy for water*, Commission on Integrated Water Management, May 2000

CIW June 2000: *Emission-immission, prioritising of sources and the immission test*, Commission on Integrated Water Management, June 2000

BREF: *Reference document on Best Available Techniques in the Pulp and Paper Industry,* December 2001

The following horizontal BREFs are also relevant for the paper manufacturing industry:

- Industrial cooling installations
- Treatment of waste water and emissions
- Monitoring
- Economic and cross-media issues
- Emissions from storage of hazardous materials

3.5.3.2 Summary of BREF

This Reference Document on best available techniques in the pulp and paper industry reflects the information exchange carried out according to Article 16(2) of Council Directive 96/61/EC.
The document has to be seen in the light of the preface, which describes the objectives of the document and its use.

Paper is essentially a sheet of fibres with a number of added chemicals that affect the properties and quality of the sheet. Besides fibres and chemicals, manufacturing of pulp and paper requires a large amount of process water and energy in the form of steam and electric power. Consequently, the main environmental issues associated with pulp and paper production are emissions to water, emissions to air, and energy consumption. Waste is expected to become a gradually increasing environmental issue of concern.

Pulp for papermaking may be produced from virgin fibre by chemical or mechanical means or may be produced by the re-pulping of recovered paper. A paper mill may simply reconstitute pulp made elsewhere or may be integrated with the pulping operations on the same site.

This document covers the relevant environmental aspects of pulp and papermaking from various fibrous materials in integrated and non-integrated pulp and paper mills. Non-integrated pulp mills (market pulp) are only manufacturing pulp that is then sold on the open market. Non-integrated paper mills are using purchased pulp for their paper production. In integrated pulp and paper mills the activities of pulp and papermaking are undertaken on the same site. Kraft pulp mills are operating in both non-integrated and integrated manner whereas sulphite pulp mills are normally integrated with paper production. Mechanical pulping and recycled fibre processing is usually an integrated part of papermaking but has become a stand-alone activity in a few single cases.

Neither environmentally relevant upstream processes like forestry management, production of process chemicals off-site and transport of raw materials to the mill nor downstream activities like paper converting or printing are included in this document. Environmental aspects which do not specifically relate to pulp and paper production such as storage and handling of chemicals, occupational safety and hazard risk, heat and power plants, cooling and vacuum systems and raw water treatment are not or only briefly treated.

This BREF consists of an introductory section (general information, Chapter 1) and five major parts:
- the kraft pulping process (Chapter 2),
- the sulphite pulping process (Chapter 3),
- mechanical pulping and chemi-mechanical pulping (Chapter 4),
- recycled fibre processing (Chapter 5), and
- papermaking and related processes (Chapter 6).

Each of these chapters has five main sections according to the general outline of IPPC BAT Reference Documents. For most readers it will not be necessary to read the whole document but only those chapters or sections that are of interest for the mill in question. For example, market kraft pulp mills are only concerned by Chapter 2; integrated kraft pulp and paper mills are concerned by Chapter 2 and 6, relevant information on integrated recycled paper processing mills can be found in Chapter 5 and 6. At the end of the document there is a list of references and a glossary of terms and abbreviations that facilitates understanding.

The general information (Chapter 1) include statistical data about paper consumption in Europe, the geographical distribution for pulp and paper production across Europe, some economic aspects, a rough overview about pulp and paper production and major environmental issues, and a classification of pulp and paper mills in Europe. The chapter on general information closes with some general remarks on the determination of BAT for the sector that is characterised by a high diversity of products and (combinations of) processes involved and a high degree of process-integrated technical solutions.

For each of the major 5 chapters information on the following aspects are presented: applied processes and techniques; major environmental concerns such as resource and energy demand, emissions and waste; description of relevant techniques for emission abatement, waste minimisation and energy savings; identification of best available techniques; and emerging techniques.

As for the reported emission and consumption figures, it should be borne in mind that, due to the use of some different measurement methods in the various Member States, data are not always strictly comparable from country to country. (See Annex III for more information on this issue but the different methods used do not alter the conclusions drawn in this document). The discussion of the techniques to consider in determination of BAT all follow the same structure and cover a short description of the technique, main achieved environmental performance, applicability, cross-media-effects, operational experiences, economics, driving forces for implementing this technique, example plants and reference literature.

The section on Best Available Techniques includes ranges of emission and consumption levels that are associated with the use of BAT. The conclusions on BAT are based on experiences from real world examples and the expert judgement of the TWG.

Pulp and papermaking is a complex area that consists of quite many process stages and different products. However, the wide range of raw materials used, processes involved in pulp and papermaking can be broken down into a number of unit operations for the sake of discussion. In this document, environmental concerns and relevant techniques for prevention and reduction of emissions/waste and reducing consumption of energy and raw materials are described separately for five major classes (Chapter 2 to 6). Where appropriate and considered as necessary, these main classes are further sub-divided in sub-classes.

The document reflects at sector level the variety in terms of raw materials, energy sources, products and processes in the European paper industry. However, in specific cases within each main product category there is a certain range of raw materials and product specification that differ from production of standard qualities and may have an impact on operational conditions and the potential for improvement. This is especially true for special paper mills producing a high number of different qualities in sequential manner on their machines or for paper mills producing 'special qualities' of paper.

The exchange of information has allowed conclusions on BAT. The sections in each of the Chapters that describe BAT should be referred to for a complete understanding of BAT and the associated emissions. The key findings are summarized below.

General BAT for all processes

During the information exchange it emerged that the most effective measure for the reduction of emissions/consumption and the improvement of economic performance is the implementation of the best available process and abatement technologies in combination with the following:

- Training, education and motivation of staff and operators;
- Process control optimisation;
- Sufficient maintenance of the technical units and the associated abatement techniques;
- Environmental management system which optimises management, increases awareness and includes goals and measures, process and job instructions etc.

BAT for Kraft pulp processing (Chapter 2)

The sulphate or kraft process is the dominating pulping process worldwide due to the superior pulp strength properties and its application to all wood species. In kraft pulping the wastewater effluents, the emissions to air including malodorous gases and the energy consumption are the centres of interest. In some countries also waste is expected to become an environmental issue of concern. The main raw materials are renewable resources (wood and water) and chemicals for cooking and bleaching. Emissions to water are dominated by organic substances. Effluent from bleach plant, where chlorine-containing bleaching chemicals are used, contains organically bound chlorine compounds, measured as AOX. Some compounds discharged from mills show toxic effects on aquatic organisms. Emissions of coloured substances may effect the living species in the recipient negatively. Emissions of nutrients (nitrogen and phosphorus) can contribute to eutrophication in the recipient. Metals extracted from the wood are discharged in low concentrations but due to high flows the load can be of significance. A significant reduction of both chlorinated and non-chlorinated organic substances in the effluent of pulp mills have been achieved to a large extent by in-process measures.

Best available techniques for kraft pulp mills are considered to be:

- Dry debarking of wood;
- Increased delignification before the bleach plant by extended or modified cooking and additional oxygen stages;
- Highly efficient brown stock washing and closed cycle brown stock screening;
- Elemental chlorine free (ECF) bleaching with low AOX or Totally chlorine free (TCF) bleaching;
- Recycling of some, mainly alkaline process water from the bleach plant;
- Effective spill monitoring, containment and recovery system;
- Stripping and reuse of the condensates from the evaporation plant;
- Sufficient capacity of the black liquor evaporation plant and the recovery boiler to cope with the additional liquor and dry solids load;
- Collection and reuse of clean cooling waters;
- Provision of sufficiently large buffer tanks for storage of spilled cooking and recovery liquors and dirty condensates to prevent sudden peaks of loading and occasional upsets in the external effluent treatment plant;
- In addition to process-integrated measures, primary treatment and biological treatment is considered BAT for kraft pulp mills.

For bleached and unbleached kraft pulp mills the BAT emission levels to water that are associated with the use of a suitable combination of these techniques are the following:

	Flow m3/Adt	COD kg/Adt	BOD kg/Adt	TSS kg/Adt	AOX kg/Adt	Total N kg/Adt	Total P kg/Adt
Bleached pulp	30-50	8-23	0.3-1.5	0.6-1.5	< 0.25	0.1-0.25	0.01-0.03
Unbleached pulp	15-25	5-10	0.2-0.7	0.3-1.0	–	0.1-0.2	0.01-0.02

These emission levels refer to yearly averages. The water flow is based on the assumption that cooling water and other clean water are discharged separately. The values refer to the contribution of pulping only. In integrated mills emissions from papermaking (see Chapter 6) have to be added according to product mix manufactured.

Off-gas emissions from different sources are considered as the other relevant environmental issue. Emissions to the atmosphere originate from recovery boiler, lime kiln, bark furnace, chip storage, cooking digester, pulp washing, bleaching plant, bleaching chemical preparation, evaporation, screening, washing, white liquor preparation, and various tanks. A part of this is the diffuse emissions that escape from various points of the process. The main point sources are the recovery boiler, the lime kiln and auxiliary boilers. Emissions consist mainly of nitrogen oxides, sulphur-containing compounds such as sulphur dioxide, and malodorous reduced sulphur compounds. In addition there are emissions of particulates.

Best available techniques for reducing emissions to air are:

- Collection and incineration of concentrated malodorous gases and control the resulting SO_2 emissions. The strong gases can be burnt in the recovery boiler, in the lime kiln or a separate, low NO_x furnace. The flue gases of the latter have a high concentration of SO_2 that is recovered in a scrubber.
- Diluted malodorous gases from various sources are also collected and incinerated and the resulting SO_2 controlled.
- TRS emissions of the recovery boiler are mitigated by efficient combustion control and CO measurement;
- TRS emissions of the lime kiln are mitigated by controlling the excess oxygen, by using low-S fuel, and by controlling the residual soluble sodium in the lime mud fed to the kiln.
- The SO_2 emissions from the recovery boilers are controlled by firing high dry solids concentration black liquor in the recovery boiler and/or by using a flue gas scrubber;
- BAT is further the control of NO_x emissions from the recovery boiler (i.e. ensuring proper mixing and division of air in the boiler), lime kiln and from auxiliary boilers by controlling the firing conditions, and for new or altered installations also by appropriate design;
- SO_2 emissions from auxiliary boilers are reduced by using bark, gas, low sulphur oil and coal or controlling S emissions with a scrubber.
- Flue gases from recovery boilers, auxiliary boilers (in which other biofuels and/or fossil fuels are incinerated) and lime kiln are cleaned with efficient electrostatic precipitators to mitigate dust emissions.

For bleached and unbleached kraft pulp mills the BAT emission levels to air from the process that are associated with a combination of these techniques are shown in the following table. The emission levels refer to yearly averages and standard conditions. Emissions from auxiliary boilers e.g. due to production of steam used for drying of pulp and/or paper are not included. For emission levels from auxiliary boilers it is referred to the section BAT for auxiliary boilers further below.

	Dust kg/Adt	SO_2 (as S) kg/Adt	NO_x ($NO+NO_2$ as NO_2) in kg/Adt	TRS (as S) kg/Adt
Bleached and unbleached kraft pulp	0.2-0.5	0.2-0.4	1.0-1.5	0.1-0.2

The values refer to the contribution of the pulp production only. That means that in integrated mills the figures for the process emissions are related to the kraft pulp production only and do not include air emissions from steam boilers or power plants that might be operated to provide the energy needed for paper production.

Best available techniques for reducing waste is to minimise the generation of solid waste and recover, recycle and reuse these materials, wherever practicable. Separate collection and intermediate storage of waste fractions at source can be beneficial to meet this aim. When the collected waste is not reusable in the process external utilisation of residuals/waste as substitutes or incineration of organic materials in suitably designed boilers with energy recovery is considered as BAT.

In order to reduce the consumption of fresh steam and electric power, and to increase the generation of steam and power internally, a number of measures are available. In energy efficient non-integrated pulp mills the heat generated from black liquor and incineration of bark exceeds the energy required for the entire production process. However, fuel oil will be needed at certain occasions like start-up and also at many mills in the lime kiln.

Energy efficient kraft pulp and paper mills consume heat and power as follows:

- Non-integrated bleached kraft pulp mills: 10–14 GJ/Adt process heat and 0.6–0.8 MWh/Adt of power;
- Integrated bleached kraft pulp and paper mills (e.g. uncoated fine paper): 14–20 GJ/Adt process heat and 1.2–1.5 MWh/Adt of power;

- Integrated unbleached kraft pulp and paper mills (e.g. kraftliner): 14–17.5 GJ/Adt process heat and 1–1.3 MWh/Adt power.

BAT for Sulphite pulp processing (Chapter 3)
The production of sulphite pulp is much smaller than the production of kraft pulp. The pulping process can be carried out with different cooking chemicals. The document focuses on magnesium sulphite pulping because of its importance in terms of capacity and numbers of mills running in Europe.

In many respects the kraft and sulphite processes have similarities not least regarding the possibilities of applying different internal and external measures to reduce emissions to environment. The major differences between the two chemical pulping processes from an environmental point-of-view are to be found in the chemistry of the cooking process, the chemical preparation and recovery system and the reduced bleaching required because of better initial brightness of sulphite pulp.

As in kraft pulping also in sulphite pulping the wastewater effluents and the emissions to air are the centres of interest. The main raw materials are renewable resources (wood and water) and chemicals for cooking and bleaching. Emissions to water are dominated by organic substances. Some compounds discharged from mills show toxic effects on aquatic organisms. Emissions of coloured substances may effect the living species in the recipient negatively. Emissions of nutrients (nitrogen and phosphorus) can contribute to eutrophication in the recipient. Metals extracted from the wood are discharged in low concentrations but due to high flows the load can be of significance. For bleaching of sulphite pulp the use of chlorine containing bleaching chemicals is normally avoided, i.e. TCF-bleaching is applied. Therefore, the effluents from the bleach plant do not contain relevant amounts of organically bound chlorine compounds.

Information on techniques to consider in the determination of BAT is generally much weaker for sulphite mills than for kraft pulp mills. Therefore, from the limited information supplied by the members of the TWG in the course of the information exchange on BAT only a few techniques could be described to the same extent as for kraft pulping. The available data set is relatively small. This could be partly compensated because of the inherent similarities between sulphite and kraft pulping. A number of techniques for pollution prevention and control for kraft pulping are also valid in most respects for sulphite pulping. Where there are particular differences between kraft and sulphite technologies attempts have been made to collect the necessary information. However, only information from Austria, Germany and Sweden could be used for the description of the techniques and the conclusion on BAT. A significant reduction of emissions to water has been achieved by in-process measures.

Best available techniques for sulphite pulp mills are considered to be:
- Dry debarking of wood;
- Increased delignification before the bleach plant by extended or modified cooking;
- Highly efficient brown stock washing and closed cycle brown stock screening;
- Effective spill monitoring containment and recovery system;
- Closure of the bleach plant when sodium based cooking processes is being used;
- TCF bleaching;
- Neutralising of weak liquor before evaporation followed by reuse of most condensate in the process or anaerobic treatment;
- For prevention of unnecessary loading and occasionally upsets in the external effluent treatment due to process cooking and recovery liquors and dirty condensates sufficiently large buffer tanks for storage are considered as necessary;
- In addition to process-integrated measures, primary and biological treatment is considered BAT for sulphite pulp mills.

For bleached sulphite pulp mills the BAT emission levels to water that are associated with the use of a suitable combination of these techniques are the following:

	Flow m3/Adt	COD kg/Adt	BOD kg/Adt	TSS kg/Adt	AOX kg/Adt	Total N kg/Adt	Total P kg/Adt
Bleached pulp	40-55	20-30	1-2	1.0-2.0	–	0.15-0.5	0.02-0.05

These emission levels refer to yearly averages. The waste water flow is based on the assumption that cooling water and other clean water are discharged separately. The values refer to the contribution of pulping only. In integrated mills emissions from papermaking (see Chapter 6) have to be added according to product mix manufactured.

Off-gas emissions from different sources are considered as the other relevant environmental issue. Emissions to the atmosphere originate from different sources the most relevant being the recovery boiler and the bark furnace. Less concentrated SO_2 containing releases originate from washing and screening operations and from vents of the evaporators and from various tanks. A part of these emissions escapes diffuse from various points of the process. Emissions consist mainly of sulphur dioxide, nitrogen oxides and dust.

Best available techniques for reducing emissions to air are:
- Collection of concentrated SO_2 releases and recovery in tanks with different pressure levels;
- Collection of diffuse SO_2 releases from various sources and introducing them in the recovery boiler as combustion air;
- Control of SO_2 emissions from the recovery boiler(s) by use of electrostatic precipitators and multi-stage flue gas scrubbers and collection and scrubbing of various vents;

- Reduction of SO_2 emissions from auxiliary boilers by using bark, gas, low sulphur oil and coal or controlling S emissions;
- Reduction of odorous gases by efficient collection systems;
- Reduction of NO_x emissions from the recovery boiler and from auxiliary boilers by controlling the firing conditions;
- Cleaning of the auxiliary boilers flue gases with efficient electrostatic precipitators to mitigate dust emissions;
- Emission optimised incineration of residues with energy recovery.

The BAT emission levels from the process associated with a combination of these techniques are depicted in the following table. Emissions from auxiliary boilers e.g. due to production of steam used for drying of pulp and/or paper are not included. For these installations emission levels that are associated with BAT are presented in the section BAT for auxiliary boilers further below.

	Dust kg/Adt	SO_2 (as S) kg/Adt	NO_x (as NO_2) kg/Adt
Bleached pulp	0.02-0.15	0.5-1.0	1.0-2.0

These emission levels refer to yearly averages and standard conditions. The values refer to the contribution of the pulp production only. That means that in integrated mills the figures for the process emissions are related to the pulp production only and do not include air emissions from auxiliary boilers or power plants that might be operated to provide the energy needed for paper production.

Best available techniques for reducing waste is to minimise the generation of solid waste and recover, recycle and reuse these materials, wherever practicable. Separate collection and intermediate storage of waste fractions at source can be beneficial to meet this aim. When the collected waste is not reusable in the process, external utilisation of residuals/waste as substitutes or incineration of organic materials in suitably designed boilers with energy recovery is considered as BAT.

In order to reduce the consumption of fresh steam and electric power, and to increase the generation of steam and power internally, a number of measures are available. Sulphite pulp mills are heat and power self-sufficient by using the heat value of the thick liquor, bark and wood waste. In integrated mills there is a need for additional steam and electricity that is generated in on- or off-site power plants. Integrated sulphite pulp and paper mills consume 18–24 GJ/Adt process heat and 1.2–1.5 MWh/Adt electricity.

BAT for mechanical pulping and chemi-mechanical pulping (Chapter 4)

In mechanical pulping the wood fibres are separated from each other by mechanical energy applied to the wood matrix. The objective is to maintain the main part of the lignin in order to achieve high yield with acceptable strength properties and brightness. There are two main processes to be distinguished:

- The groundwood process where logs are pressed against a rotating grinder stone with simultaneous action of water *and*
- Refiner mechanical pulp that is produced by defiberizing wood chips between disc refiners.

The characteristics of the pulp can be affected by increasing the process temperature and, in the case of refining, by the chemical pre-treatment of the wood chips. The pulping process in which the wood is pre-softened with chemicals and refined under pressure is called chemo-thermomechanical pulping and is also covered by this document. Most mechanical pulping is integrated with paper manufacture. Therefore, the emission levels associated with the use of BAT are given for integrated pulp and paper mills (except for CTMP).

In mechanical pulping and chemi-mechanical pulping the wastewater effluents and consumption of electricity for the drives of grinders or refiners are the centres of interest. The main raw materials are renewable resources (wood and water) and some chemicals for bleaching (for CTMP also for chemical pre-treatment of the chips). As processing aids and to improve the product properties (paper auxiliaries) various additives are applied during paper manufacturing. Emissions to water are dominated organic substances that are lost in the water phase in the form of dissolved or dispersed substances. If mechanical pulp is bleached in one or two alkaline peroxide steps the releases of organic pollutants increase significantly. Peroxide bleaching result in additional COD-loads before treatment of about 30 kg O_2/Adt. Some compounds discharged from mills show toxic effects on aquatic organisms. Emissions of nutrients (nitrogen and phosphorus) can contribute to eutrophication in the recipient. Metals extracted from the wood are discharged in low concentrations but due to high flows the load can be of significance.

A big part of techniques to consider in the determination of BAT refer to the reduction of emissions to water. In mechanical pulping processes the water systems are usually quite close. Surplus clarified waters from the paper machine are usually used to compensate for the water leaving the circuit with the pulp and the rejects.

Best available techniques for mechanical pulp mills are considered to be:

- Dry debarking of wood
- Minimisation of reject losses by using efficient reject handling stages
- Water recirculation in the mechanical pulping department
- Effective separation of the water systems of the pulp and paper mill by use of thickeners
- Counter-current white water system from paper mill to pulp mill depending on the degree of integration
- Use of sufficiently large buffer tanks for storage of concentrated wastewater streams from the process (mainly for CTMP)
- Primary and biological treatment of the effluents, and in some cases also flocculation or chemical precipitation.

For CTMP mills a combination of an anaerobic and aerobic treatment of the wastewater is also regarded as an efficient treatment system. Finally, evaporation of the most contaminated wastewater and burning of the concentrate plus activated sludge treatment of the rest might be especially an interesting solution for upgrading mills.

The emission levels that are associated with a suitable combination of these techniques are presented separately for non-integrated CTMP mills and integrated mechanical pulp and paper mills. These emission levels refer to yearly average values.

In case of integrated CTMP mills, emissions from papermaking (see Chapter 6) have to be added according to product mix manufactured.

For integrated mechanical pulp and paper mills the emission levels refer to both pulping and papermaking and are related to kg pollutant per tonne of paper produced.

In mechanical pulping, the ranges for COD depend especially on the share of the fibre furnish that is bleached with peroxide because peroxide bleaching results in higher initial loads of organic substances before treatment. Therefore, the upper end of the emission range associated with BAT is valid for paper mills with a high proportion of peroxide bleached TMP.

Emissions to the atmosphere are mainly emissions from heat and electricity generation in auxiliary boilers and volatile organic carbons (VOC). Sources of VOC emissions are chip heaps and evacuation of air from chests from wood-chip washing and from other chests and condensates from the steam recovery from refiners that are contaminated with volatile wood components. A part of these emissions escapes diffuse from various points of the process.

	Flow m3/Adt	COD kg/Adt	BOD kg/Adt	TSS kg/Adt	AOX kg/Adt	Total N kg/Adt	Total P kg/Adt
Non-integrated CTMP mills[1)]	15-20	10-20	0.5-1.0	0.5-1.0	–	0.1-0.2	0.005-0.01
Integrated mechanical pulp & paper mills[2)]	12-20	2.0-5.0	0.2-0.5	0.2-0.5	<0.01	0.04-0.1	0.004-0.01

[1)] Contribution of pulping only.
[2)] Such as newsprint, LWC and SC paper mills.

Best available techniques for reducing emissions to air is efficient heat recovery from refiners and abatement of VOC emissions from contaminated steam. Apart from VOC emissions, mechanical pulping generate releases to the atmosphere that are not process-related but caused by energy generation on-site. Heat and power is produced by combustion of different types of fossil fuels or renewable wood residuals like bark. BAT for auxiliary boilers is discussed further below.

Best available techniques for reducing waste is to minimise the generation of solid waste and recover, recycle and reuse these materials, wherever practicable. Separate collection and intermediate storage of waste fractions at source can be beneficial to meet this aim. When the collected waste is not reusable in the process external utilisation of residuals/waste as substitutes or incineration of organic materials in suitably designed boilers with energy recovery is considered as BAT, thus minimising the disposal of rejects to landfill.

In order to reduce the consumption of fresh steam and electric power a number of measures are available. Energy efficient mechanical pulp and paper mills consume heat and power as follows:

- Non-integrated CTMP: For pulp drying recovered process heat can be used i.e. no primary steam is needed. The power consumption is 2–3 MWh/Adt.
- Integrated newsprint mills consume 0–3 GJ/t process heat and 2–3 MWh/t of electricity. The steam demand depends on the fibre furnish and the degree of steam recovery from the refiners.
- Integrated LWC paper mills consume 3–12 GJ/t process heat and 1.7–2.6 MWh/t of electricity. It has to be noted that the fibre furnish of LWC consists usually only of about one third of PGW or TMP the rest being bleached kraft pulp and fillers and coating colours. If the production of bleached kraft pulp is carried out at the same site (integrated) the contribution of the energy demand of kraft pulping have to be added according to fibre furnish mix manufactured.
- Integrated SC paper mills consume 1–6 GJ/t process heat and 1.9–2.6 MWh/t of electricity.

BAT for Recycled fibre processing (Chapter 5)
Recovered fibre has become an indispensable raw material for the paper manufacturing industry because of the favourable price of recovered fibres in comparison with the corresponding grades of virgin pulp and because of the promotion of recovered paper recycling by many European countries. The recovered paper processing systems vary according to the paper grade to be produced e.g. packaging paper, newsprint, testliner, or tissue paper and the type of furnish used. Generally, recycled fibre (RCF) processes can be divided in two main categories:

- processes with exclusively mechanical cleaning i.e. without de-inking. They comprise products like testliner, corrugating medium, board and cartonboard.
- processes with mechanical and chemical unit processes i.e. with de-inking. They comprise products like newsprint, tissue, printing and copy paper, magazine papers (SC/LWC), some grades of cartonboard or market DIP.

	Flow m^3/t	COD kg/t	BOD kg/t	TSS kg/t	Total N kg/t	Total P kg/t	AOX kg/t
Integrated RCF paper mills without de-inking[1)]	<7	0.5-1.5	<0.05-0.15	0.05-0.15	0.02-0.05	0.002-0.005	<0.5
RCF paper-mills with de-inking[2)]	8–15	2-4	<0.05-0.5	0.1-0.3	0.05-0.1	0.005-0.01	<0.5
RCF based-tissue mills	8-25	2.0-4.0	<0.05-0.4	0.1-0.4	0.05-0.25	0.005-0.015	<0.5

[1)] e.g. wellenstoff, testliner, white topliner, cartonboard etc.
[2)] e.g. newsprint, printing & writing paper etc.

The raw materials for RCF based paper production consist mainly of recovered paper, water, chemical additives, and energy in the form of steam and power. Large quantities of water are used as process water and cooling water. As processing aids and to improve the product properties (paper auxiliaries) various additives are applied during paper manufacturing. The environmental impact of recovered paper processing comprises basically emissions to water, solid waste (especially if wash de-inking is applied as e.g. in tissue mills) and atmospheric emissions. Emissions to the atmosphere are mainly related to energy generation by combustion of fossil fuels in power plants.

Most recovered paper processing mills are integrated with paper manufacture. Therefore, the emission levels associated with the use of BAT are given for integrated mills.

A big part of techniques to consider in the determination of BAT refer to the reduction of emissions to water.

Best available techniques for recovered paper processing mills are considered to be:

- Separation of less contaminated water from contaminated one and recycling of process water;
- Optimal water management (water loop arangement), water clarification by sedimentation, flotation or filtration techniques and recycling of process water for different purposes;
- Strict separation of water loops and counter-currents flow of process water;
- Generation of clarified water for de-inking plants (flotation);
- Installation of an equalisation basin and primary treatment;
- Biological effluent treatment. An effective option for de-inked grades and depending on the conditions also for non-de-inked grades is aerobic biological treatment and in some cases also flocculation and chemical precipitation. Mechanical treatment with subsequent anaerobic-aerobic biological treatment is the preferable option for non-deinked grades. These mills usually have to treat more concentrated wastewater because of higher degree of water circuit closure;
- Partial recycling of treated water after biological treatment. The possible degree of water recycling is depending on the specific paper grades produced. For non-deinked paper grades this technique is BAT. However, the advantages and drawbacks need to be carefully investigated and will usually require additional polishing (tertiary treatment).
- Treating internal water circuits.

For integrated recovered paper mills, the emission levels associated with the use of a suitable combination of best available techniques are the following: (see table).

The BAT emission levels refer to yearly averages and are presented separately for processes with and without de-inking. The waste water flow is based on the assumption that cooling water and other clean water are discharged separately. The values refer to integrated mills i.e. recovered paper processing and papermaking is carried out at the same site.

Common treatment of wastewater from a RCF paper mill or a consortium of RCF paper mills in the municipal wastewater treatment plant is also considered as BAT when the common treatment system is appropriate for dealing with paper mill effluents. The removal efficiencies of the common waste water treatment system should be calculated and the comparable removal efficiencies or concentrations of releases established before considering this option as BAT.

Air emissions in RCF based paper mills are mainly related to plants installed for the production of heat and in some cases for co-generation of electricity. Saving of energy corresponds therefore with reduction of air emissions. The power plants are usually standard boilers and can be treated like any other power plants.

To decrease energy consumption and air emission the following measures are considered as BAT: Co-generation of heat and power, improving existing boilers and when equipment is replaced use of less energy consuming equipment. For emission levels associated with the use of BAT it is referred to the section BAT for auxiliary boilers further below.

Best available techniques for reducing waste are to minimise the generation of solid waste and recover, recycle and reuse these materials, wherever practicable. Separate collection and intermediate storage of waste fractions at source can be beneficial to meet this aim. When the collected waste is not reusable in the process external utilisation of residuals/waste as substitutes or incineration of organic materials in suitably designed boilers with energy recovery is considered as BAT. Reduction of solid waste can be achieved by optimising the fibre recovery by upgrading of stock preparation plants, optimisation of the amount of cleaning stages in the stock preparation, application of dissolved air flotation (DAF) as in-line treatment of water-loops to recover fibres and fillers and to clarify process water. A balance between cleanliness of stock, fibre losses and energy requirements and costs has to found and are usually depending on the paper grades. The reduction of the amount of solid waste to be landfilled is BAT. This can be achieved by efficient reject and sludge handling on-site (de-watering) to enhance dry solids content and subsequent incineration of sludge and/rejects with energy recovery. Produced ash can be used as raw material in the building materials industry. Different options for incineration of rejects and sludge are available. The applicability is limited by the size of the mill and to a certain extent by the fuel used for generation of steam and power respectively.

Energy efficient recovered paper mills consume process heat and power as follows:

- Integrated non-deinked RCF paper mills (e.g. testliner, fluting): 6–6.5 GT/t process heat and 0.7–0.8 MWh/t of power;
- Integrated tissue mills with DIP plant: 7–12 GT/t process heat and 1.2–1.4 MWh/t of power;
- Integrated newsprint or printing and writing paper mills with DIP plant: 4–6.5 GT/t process heat and 1–1.5 MWh/t of power.

BAT for Papermaking and related processes (Chapter 6)

The manufacturing of fibres used for papermaking has been described in the Chapters 2 to 5. In Chapter 6 paper and board manufacturing is described independently from pulp manufacturing. This approach has been chosen because the same unit processes around the paper and board machine are required in every paper mill whether it is integrated with pulp production or not. The description of papermaking as part of integrated pulp mills would increase the complexity of the technical description. Finally, in numbers, most paper mills in Europe are non-integrated mills. For integrated paper mills this chapter is relevant as far as the papermaking is concerned.

Paper is made from fibres, water and chemical additives. Furthermore, a lot of energy is needed to drive the whole process. Electric power is mainly consumed for the operation of various motor drives and for refining in stock preparation. Process heat is mainly used for heating of water, other liquors, and air, evaporating water in the dryer section of the paper machine, and conversion of steam into electric power (in case of co-generation). Large quantities of water are used as process water and cooling water. As processing aids and to improve the product properties (paper auxiliaries) various additives may be applied during paper manufacturing.

The environmental issues of paper mills are dominated by emissions to water and by the consumption of energy and chemicals. Solid waste is also generated. Atmospheric emissions are mainly related to energy generation by combustion of fossil fuels in power plants.

Best available techniques for reducing emissions to water are:

- Minimising water usage for different paper grades by increased recycling of process waters and water management;
- Control of potential disadvantages of closing up the water systems;
- Construction of a balanced white water, (clear) filtrate and broke storage system and use of constructions, design and machinery with reduced water consumption when practicable. This is normally when machinery or components are replaced or at rebuilds;
- Application of measures to reduce frequency and effects of accidental discharge;
- Collection and reuse of clean cooling and sealing waters or separate discharge;
- Separate pre-treatment of coating wastewaters;
- Substitution of potentially harmful substances by use of less harmful alternatives;
- Effluent treatment of wastewater by installation of an equalisation basin;
- Primary treatment, secondary biological, and/or in some cases, secondary chemical precipitation or flocculation of wastewater. When only chemical treatment is applied the discharges of COD will be somewhat higher but mainly made up of easily degradable matter.

For non-integrated paper mills the emissions levels that are associated with the use of BAT are presented for uncoated and coated fine paper and tissue separately in the table below. However, the differences between the paper grades are not very distinct.

Parameters	Units	Uncoated fine paper	Coated fine paper	Tissue
BOD_5	kg/t of paper	0.15-0.25	0.15-0.25	0.15-0.4
COD	kg/t of paper	0.5-2	0.5-1.5	0.4-1.5
TSS	kg/t of paper	0.2-0.4	0.2-0.4	0.2-0.4
AOX	kg/t of paper	<0.005	<0.005	<0.01
Total P	kg/t of paper	0.003-0.01	0.003-0.01	0.003-0.015
Total N	kg/t of paper	0.05-0.2	0.05-0.2	0.05-0.25
Flow	m^3/t of paper	10-15	10-15	10-25

The BAT emission levels refer to yearly averages and exclude the contribution of pulp manufacturing. Although these values refer to non-integrated mills they can also be used to approximate emissions caused by papermaking units in integrated mills. The waste water flow is based on the assumption that cooling water and other clean water are discharged separately.

Common treatment of wastewater from a paper mill or a consortium of paper mills in the municipal wastewater treatment plant is also considered as BAT when the common treatment system is appropriate for dealing with paper mill effluents. The removal efficiencies of the common wastewater treatment system should be calculated and the comparable removal efficiencies or concentrations of releases established before considering this option as BAT.

Air emissions from non-integrated paper mills are mainly related to steam boilers and power plants. These plants are generally standard boilers and do not differ from any other combustion plants. It is assumed that they are regulated like any other auxiliary boiler of the same capacity (see below).

BAT concerning solid waste is the minimisation the generation of solid waste and recovery, reuse and re-cycle of reusable materials as far as possible. Separate collection of waste fractions at source and intermediate storage of residuals/waste can be beneficial to allow for a greater proportion to be reused or recycled rather than landfilled. Reduction of fibre and filler losses, the application of ultra-filtration for coating wastewater recovery (only for coated grades), efficient de-watering of the residues and sludge to high dry solids are further available echniques. BAT is the reduction of the amount of waste to be landfilled by identification of possibilities for recovery operations and – if feasible – utilisation of waste for material recycling or incineration with energy recovery.

In general in this sector BAT is considered to be the use of energy efficient technologies. A lot of options for energy saving in many stages within the manufacturing process are available. Usually these measures are linked with investments to replace, rebuild or upgrade process equipment. It should be noticed that energy saving measures are mostly not applied only for energy saving. Production efficiency, improvement of product quality and reduction of overall costs is the most important basis for investments.

Energy savings can be achieved by implementation of a system for monitoring energy usage and performance, more effective dewatering of the paper web in the press section of the paper machine by using wide nip (shoe) pressing technologies and use of other energy efficient technologies as e.g. high consistency slushing, energy efficient refining, twin wire forming, optimised vacuum systems, speed adjustable drives for fans and pumps, high efficiency electric motors, well sized electric motors, steam condensate recovery, increasing size press solids or exhaust air heat recovery systems. A reduction of direct use of steam can be achieved by careful process integration by using pinch analysis.

Energy efficient non-integrated paper mills consume heat and power as follows:

- Non-integrated uncoated fine paper mills have a process heat demand of 7–7.5 GT/t and a power demand of 0.6–0.7 MWh/t;
- Non-integrated coated fine paper mills have a process heat demand of 7–8 GT/t and a power demand of 0.7–0.9 MWh/t;
- Non-integrated tissue mills based on virgin fibre have a process heat demand of 5.5–7.5 GT/t and a power demand of 0.6–1.1 MWh/t.

BAT for auxiliary boilers

Depending on the actual energy balance of the given pulp or paper mill, the type of external fuels used and the fate of possible biofuels as bark and wood-waste there are atmospheric emissions from auxiliary boilers to consider. Pulp and paper mills manufacturing pulp from virgin fibres are normally operating bark boilers. For non-integrated paper mills and RCF paper mills air emissions are mainly related to steam boilers and/or power plants. These plants are generally standard boilers and do not differ from any other combustion plant. It is assumed that they are regulated like any other installation of the same capacity. Therefore, generally acknowledged BAT for auxiliary boilers are only briefly mentioned in this document. Those techniques are:

- application of cogeneration of heat and power if the heat/power-ratio allows it;
- use of renewable sources as fuel such as wood or wood waste, if generated, to reduce the emissions of fossil CO_2;
- control of NO_x emissions from auxiliary boilers by controlling the firing conditions, and installation of low-NO_x burners;
- reducing SO_2 emissions by using bark, gas or low sulphur fuels or controlling S emissions;
- In auxiliary boilers burning solid fuels efficient ESPs (or bag filters) are used for the removal of dust.

Released substances	Coal	Heavy fuel oil	Gas oil	Gas (e.g. bark)	Biofuel
mg S/MJ fuel input	100-200[1] (50-100)[5]	100-200[1] (50-100)[5]	25-50	<5	<15
mg NO_x/MJ fuel input	80-110[2] (50-80 SNCR)[3]	80-110[2] (50-80 SNCR)[3]	45-60[2]	30-60[2]	60-100[2] (40-70 SNCR)[3]
mg dust/Nm^3	10-30[4] at 6% O_2	10-40[4] at 3% O_2	10-30 at 3% O_2	<5 at 3% O_2	10-30[4] at 6% O_2

[1] Sulphur emissions of oil or coal fired boilers depend on the availability of low-S oil and coal. Certain reduction of sulphur could be achieved with injection of calcium carbonate.
[2] Only combustion technology is applied.
[3] Secondary measures as SNCR are also applied; normally only larger installations.
[4] Associated values when efficient electrostatic precipitators are used.
[5] When a scrubber is used; only applied to larger installations.

BAT associated emission levels from auxiliary boilers in pulp and paper industry that incinerate different kind of fuels are summarized in the above table. The values refer to yearly average values and standard conditions. However, the total product specific releases to air are very site specific (e.g. type of fuel, size and type of installation, integrated or non-integrated mill, production of electricity).

It has to be noted that auxiliary boilers within the pulp and paper industry are of a very variable size (from 10 to above 200 MW). For the smaller only the use of low-S fuel and combustion techniques can be applied at reasonable costs while for the larger also control measures. This difference is reflected in the table above. The higher range is considered BAT for smaller installations and is achieved when only quality of fuel and internal measures are applied; the lower levels (in brackets) are associated with additional control measures like SNCR and scrubbers and are regarded as BAT for larger installations.

Use of chemicals and additives

In the pulp and paper industry a large number of chemicals are used depending on the paper grade produced, the process design and operation and the product qualities to be achieved. On the one hand process chemicals for the production of pulp are required, on the other hand chemical additives and auxiliaries are applied in paper production. Chemical additives are used to give paper various characteristics while chemical auxiliaries are used to increase efficiency and reduce disruption of the production process.
For chemical usage the availability of a database for all used chemicals and additives and the application of the principle of substitution is considered as BAT. That means that less hazardous products are used when available. Measures to avoid accidental discharges to soil and water from handling and storage of chemicals are applied.

Degree of consensus

This BREF has met support from most members of the TWG and participants at the 7th meeting of the Information Exchange Forum. However, CEPI – representing the pulp and paper industry – and a few Member States did not express their full support for this final draft and contested some of the conclusions presented in the document. Mention is made below of some of the key areas of contention and Chapter 7 provides further detail. CEPI and one Member State took the view that the economic difference between new/existing and large/small mills had not been sufficiently considered and that clear differences should have been established in the BREF. Furthermore, CEPI and three Member States believe that a typical mill will not be able to, at the same time, reach all the presented emission and consumption levels associated with the use of a suitable combination of the various techniques that are considered as BAT. In their view, no sufficiently integrated assessment of all parameters has been carried out. Contrary to this view, however, mills have been identified who do achieve all the presented levels at the same time and this minority view above was not shared by most members of the TWG.

Apart from these general issues, there are also a few specific issues where the final conclusions did not receive unanimous support in the TWG. CEPI and two Member States consider that for TSS for bleached kraft pulping, the upper end of the range associated with the use of BAT should be 2.0 kg/Adt instead of 1.5 kg/Adt. CEPI and one Member State also consider that some of the ranges associated with the use of BAT for the various paper grades are too stringent. Conversely, there are TWG members who consider that certain concluded BAT associated levels are excessively lenient bearing in mind the more recent achievements of some pulp and paper mills.

The European Environmental Bureau – representing environmental organisations – expressed some further dissenting views, including that ECF-bleaching in kraft pulp mills does not meet the BAT criteria regarding the precautionary and the prevention principles and that, in general, tertiary treatment of effluents should include treatment with ozone, peroxide or UV radiation followed by a biofiltration step.

3.5.4 Cement and lime manufacturing industry

This guidance note was adopted on 28 September 2004

3.5.4.1 Guidance note

Introduction

Status of guidance note

This guidance note is intended to support the competent authorities in applying the BAT Reference (BREF) document for the cement and lime manufacturing industry. It describes the field of application of the BREF, the changes in the Dutch legislation as a result of this BREF and the relationship between this BREF and other relevant legislation. The guidance not must be read in combination with the BREF document.

Status BREF

The BREF has a comparable status as the NeR and the recommendations of the Commission on Integrated Water Management (CIW); it may only be departed from on duly stated grounds (for more information refer to the NeR (Chapter 2.12) and the Handbook on the use of permits under the Pollution of Surface Waters Act [WVO]).

Field of application

The BREF relates to the processes for the manufacture of cement clinkers and unslaked lime.

The BREF describes the Best Available Techniques for the manufacture of cement clinkers in cement furnaces and for the manufacture of lime in lime furnaces and grinding installations.

No techniques are described for extraction, storage and processing of feedstock, fuels and additives and the further processing, storage, packing and transport of semi-finished products and end-products.

The most important environmental aspects of the manufacture of cement clinkers are emissions of nitrogen oxides, sulphur oxides and particulates. The most important environmental aspect of lime manufacture is the emission of particulates.

In the choice of Best Available Techniques, the BREF bases itself on general primary measures (process-integrated measures), whether or not in combination with end-of-pipe emission-abatement techniques.

The BREF disregards environmental and safety aspects that do not relate directly to the manufacture of cement and lime. This concerns, for example, the environmental aspects of cooling systems and the emission from the storage and transhipment of feedstock; for these aspects, reference is made to the horizontal BREF documents for industrial cooling systems and for storage and transhipment of bulk goods.

There is one cement plant in the Netherlands that falls under the IPPC Directive. There are no independently-operating lime plants in the Netherlands. There are lime production lines that operate as part of sugar plants. These also fall under the IPPC Directive.

The BREF is relevant in its entirety for the issue of permits on the basis of the Environmental Protection Act and the Pollution of Surface Waters Act.

Special points for attention

Upon commissioning, cement furnaces fall under the General Administrative Order on NO_x emission trading. This order gives a so-called PSR value for the manufacture of cement clinkers.

The cement furnaces must also comply with the emission requirements that fall within the limits designated in the BREF as Best Available Techniques.

In the second half of 2003, the Incineration of Waste Products Decree (Bva) entered into force. This decree implements European Directive 2000/76/EC relating to the incineration of waste. Cement furnaces are subject to the Bva. The Bva gives emission requirements for cement furnaces in which waste products are also burned in the manufacturing process. The emission requirements for existing cement furnaces are in force as per 28 December 2005 and apply directly.

Conclusions and recommendations

The implementation of the BREF 'Cement and Lime Manufacturing Industries' in the Dutch legislation means that:

- the general requirements of the NeR on emissions of fine particulates, sox and nox are cancelled and replaced by the bref and this guidance note if they relate to the manufacture of cement clinkers as described in Annex I of the IPPC Directive and if no waste products are burned in the manufacturing process.
- the general requirements of the NeR on emissions of fine particulates are cancelled and replaced by the BREF and this guidance note if they relate to the manufacture of unslaked lime as described in Annex I of the IPPC Directive; cement furnaces fall under the General Administrative Order on NO_x emission trading; existing cement furnaces in which waste products are also burned in the manufacturing process must comply as per 28 December 2005 with the emission requirements for cement furnaces as specified in the Waste Products Incineration Decree.
- in the issue of permits under the WVO, the CIW recommends taking into account the Best Available Techniques as described in the BREF and this guidance note.

Supplementary to this, the following applies:

- If emissions are not expressly differentiated in the BREF, the general stipulations of the NeR apply (latest version) and the emission policy for water (NW4 1998, CIW 1999).

References

NeR	Netherlands Emission Guidelines for Air
NW4	*Fourth Policy Document on Water Management,* 1998
CIW May 1999	*Handbook on the use of permits under the Pollution of Surface Waters Act (WVO)* Commission on Integrated Water Management, May 1999
BREF	*Reference document on Best Available Techniques in the Cement and Lime Manufacturing Industries,* December 2001

3.5.4.2 Summary of BREF

This Reference Document on best available techniques in the cement and lime industries reflects an information exchange carried out according to Article 16(2) of Council Directive 96/61/EC. The document has to be seen in the light of the preface which describes the objectives of the document and its use.

This BREF document has two parts, one for the cement industry and one for the lime industry, which each have 7 chapters according to the general outline.

Cement industry

Cement is a basic material for building and civil engineering construction. Output from the cement industry is directly related to the state of the construction business in general and therefore tracks the overall economic situation closely. The production of cement in the European Union stood at 172 million tonnes in 1995, equivalent to about 12% of world production.

After mining, grinding and homogenisation of raw materials; the first step in cement manufacture is calcination of calcium carbonate followed by burning the resulting calcium oxide together with silica, alumina, and ferrous oxide at high temperatures to form clinker. The clinker is then ground or milled together with gypsum and other constituents to produce cement.

Naturally occurring calcareous deposits such as limestone, marl or chalk provide the source for calcium carbonate. Silica, iron oxide and alumina are found in various ores and minerals, such as sand, shale, clay and iron ore. Power station ash, blast furnace slag, and other process residues can also be used as partial replacements for the natural raw materials.

To produce 1 tonne of clinker the typical average consumption of raw materials in the EU is 1.57 tonnes. Most of the balance is lost from the process as carbon dioxide emission to air in the calcination reaction ($CaCO_3 \rightarrow CaO + CO_2$).

The cement industry is an energy intensive industry with energy typically accounting for 30–40% of production costs (i.e. excluding capital costs). Various fuels can be used to provide the heat required for the process. In 1995 the most commonly used fuels were petcoke (39%) and coal (36%) followed by different types of waste (10%), fuel oil (7%), lignite (6%) and gas (2%).

In 1995 there were 252 installations producing cement clinker and finished cement in the European Union and a total of 437 kilns, but not all of them in operation. In addition there were a further 68 grinding plants (mills) without kilns. In recent years typical kiln size has come to be around 3000 tonnes clinker/day.

The clinker burning takes place in a rotary kiln which can be part of a wet or dry long kiln system, a semi-wet or semi-dry grate preheater (Lepol) kiln system, a dry suspension preheater kiln system or a preheater/precalciner kiln system. The best available technique[1] for the production of cement clinker is considered to be a dry process kiln with multi-stage suspension preheating and precalcination. The associated BAT heat balance value is 3000 MJ/tonne clinker.

At present, about 78% of Europe's cement production is from dry process kilns, a further 16% of production is accounted for by semi-dry and semi-wet process kilns, with the remainder of European production, about 6%, coming from wet process kilns. The wet process kilns operating in Europe are generally expected to be converted to dry process kiln systems when renewed, as are semi-dry and semi-wet processes kiln systems.

The clinker burning is the most important part of the process in terms of the key environmental issues for the manufacture of cement; energy use and emissions to air. The key environmental emissions are nitrogen oxides (NO_x), sulphur dioxide (SO_2) and dust. Whilst dust abatement has been widely applied for more than 50 years and SO_2 abatement is a plant specific issue, the abatement of NO_x is a relatively new issue for the cement industry.

Many cement plants have adopted general primary measures, such as process control optimisation, use of modern, gravimetric solid fuel feed systems, optimised cooler connections and use of power management systems. These measures are usually taken to improve clinker quality and lower production costs but they also reduce the energy use and air emissions.

The best available techniques[1] for reducing NO_x emissions are a combination of general primary measures, primary measures to control NO_x emissions, staged combustion and selective non-catalytic reduction (SNCR). The BAT emission level[2] associated with the use of these techniques is 200–500 mg NO_x/m^3 (as NO_2). This emission level could be seen in context of the current reported emission range of <200–3000 mg NO_x/m^3, and that the majority of kilns in the European Union is said to be able to achieve less than 1200 mg/m³ with primary measures.

Whilst there was support for the above concluded BAT to control NO_x emissions, there was an opposing view[3] within the TWG that the BAT emission level associated with the use of these techniques is 500–800 mg NO_x/m^3 (as NO_2). There was also a view[3] that selective catalytic reduction (SCR) is BAT with an associated emission level of 100–200 mg NO_x/m^3 (as NO_2).

The best available techniques[1] for reducing SO_2 emissions are a combination of general primary measures and absorbent addition for initial emission levels not higher than about 1200 mg SO_2/m^3 and a wet or dry scrubber for initial emission levels higher than about 1200 mg SO_2/m^3. The BAT emission level[2] associated with these techniques is 200–400 mg SO_2/m^3. SO_2 emissions from cement plants are primarily determined by the content of the volatile sulphur in the raw materials. Kilns that use raw materials with little or no volatile sulphur have SO_2 emission levels well below this level without using abatement techniques. The current reported emission range is <10–3500 mg SO_2/m^3.

The best available techniques for reducing dust emissions are a combination of general primary measures and efficient removal of particulate matter from point sources by application of electrostatic precipitators and/or fabric filters. The BAT emission level[2] associated with these techniques is 20–30 mg dust/m³. The current reported emission range is 5–200 mg dust/m³ from point sources. Best available techniques also include minimisation and prevention of dust emissions from fugitive sources as described in section 1.4.7.3.

The best available techniques for reducing waste are to recycle collected particulate matter to the process wherever practicable. When the collected dusts are not recyclable the utilisation of these dusts in other commercial products, when possible, is considered BAT.

It is recommended to consider an update of this BAT reference document around year 2005, in particular regarding NO_x abatement (development of SCR technology and high efficiency SNCR). Other issues, that have not been fully dealt with in this document, that could be considered/discussed in the review are:

- more information about chemical additives acting as slurry thinners,
- numeric information on acceptable frequency and duration of CO-trips, and
- associated BAT emission values for VOC, metals, HCl, HF, CO and PCDD/FS.

Lime industry

Lime is used in a wide range of products, for example as a fluxing agent in steel refining, as a binder in building and construction, and in water treatment to precipitate impurities. Lime is also used extensively for the neutralisation of acidic components of industrial effluent and flue gases. With an annual production of around 20 million tonnes of lime, the EU countries produce about 15% of sales-relevant world lime production.

1) See chapter 1.5 for qualifications about applicability and feasibility.
2) Emission levels are expressed on a daily average basis and standard conditions of 273 K, 101.3 kPa, 10% oxygen and dry gas.
3) See chapter 1.5 for details and justification of split views.

The lime making process consists of the burning of calcium and/or magnesium carbonates to liberate carbon dioxide and to obtain the derived oxide ($CaCO_3 \rightarrow CaO + CO_2$). The calcium oxide product from the kiln is generally crushed, milled and/or screened before being conveyed to silo storage. From the silo, the burned lime is either delivered to the end user for use in the form of quicklime, or transferred to a hydrating plant where it is reacted with water to produce slaked lime.

The term lime includes quicklime and slaked lime and is synonymous with the term lime products. Quicklime, or burnt lime, is calcium oxide (CaO). Slaked lime consist mainly of calcium hydroxide ($Ca[OH]_2$) and includes hydrated lime (dry calcium hydroxide powder), milk of lime and lime putty (dispersions of calcium hydroxide particles in water).

Lime production generally uses between 1.4 and 2.2 tonnes of limestone per tonne of saleable quicklime. Consumption depends on the type of product, the purity of the limestone, the degree of calcination and the quantity of waste products. Most of the balance is lost from the process as carbon dioxide emission to air.

The lime industry is a highly energy-intensive industry with energy accounting for up to 50% of total production costs. Kilns are fired with solid, liquid or gaseous fuels. The use of natural gas has increased substantially over the last few years. In 1995 the most commonly used fuels were natural gas (48%) and coal, including hard coal, coke, lignite and petcoke, (36%) followed by oil (15%) and other fuels (1%).

In 1995 there were approximately 240 lime-producing installations in the European Union (excluding captive lime production) and a total of about 450 kilns, most of which are other shaft kilns and parallel-flow regenerative shaft kilns. Typical kiln size lies between 50 and 500 tonnes per day.

The key environmental issues associated with lime production are air pollution and the use of energy. The lime burning process is the main source of emissions and is also the principal user of energy. The secondary processes of lime slaking and grinding can also be of significance. The key environmental emissions are dust, nitrogen oxides (NO_x), sulphur dioxide (SO_2) and carbon monoxide (CO).

Many lime plants have taken general primary measures such as process control optimisation. These measures are usually taken to improve product quality and lower production costs but they also reduce the energy use and air emissions.

The best available techniques for reducing dust emissions are a combination of general primary measures and efficient removal of particulate matter from point sources by application of fabric filters, electrostatic precipitators and/or wet scrubbers. The BAT emission level [4)] associated with the use of these techniques is 50 mg dust/m^3. The best available techniques also include minimisation and prevention of dust emissions from fugitive sources as described in section 1.4.7.3.

The best available techniques for reducing waste are the utilisation of dust, out-of-specification quicklime and hydrated lime in selected commercial products.

NO_x emissions depend mainly on the quality of lime produced and the design of kiln. Low-NO_x burners have been fitted to a few rotary kilns. Other NO_x reduction technologies have not been applied in the lime industry.

SO_2 emissions, principally from rotary kilns, depend on the sulphur content of the fuel, the design of kiln and the required sulphur content of the lime produced. The selection of fuels with low sulphur content can therefore limit the SO_2 emissions, and so can production of lime with higher sulphur contents. There are absorbent addition techniques available, but they are currently not applied in the lime industry.

Before an update of this reference document is carried out, it could be useful to make a survey of current abatement techniques, emissions and consumptions and of monitoring in the lime industry.

4) Emission levels are expressed on a daily average basis and standard conditions of 273 K, 101.3 kPa, 10% oxygen and dry gas, except for hydrating plants for which conditions are as emitted.

3.5.5 Ferrous metal industry

This guidance note was adopted on 28 September 2004

3.5.5.1 Guidance note

Introduction

Status of guidance note

This guidance note is intended to support the competent authorities in applying the BAT Reference (BREF) document for ferrous metal processing. It describes the field of application of the BREF, the changes in the Dutch legislation and the relationship between this BREF and other relevant legislation. The guidance not must be read in combination with the BREF document.

Status of BREF

The BREF has a comparable status as the NeR and the recommendations of the Commission on Integrated Water Management (CIW); it may only be departed from on duly stated grounds (for more information refer to the NeR (Chapter 2.12) and the Handbook on the use of permits under the Pollution of Surface Waters Act [WVO]).

Field of application

The content of the BREF for ferrous metal processing links up with the BREF for iron and steel, which deals with the manufacture of pig iron and steel up to an including the casting process. The BREF for ferrous metal processing deals with the hot rolling, cold rolling and drawing, thermal metal coating and the associated pre- and post-treatment of steel products.

Category 2.3.a of Annex I of Directive 96/61/EC only expressly mentions hot rolling mills (>20 t/h). Nevertheless, the BREF also considers cold rolling mills and associated processes, such as pickling and degreasing. Category 2.3.c of Annex I deals with the application of coatings of molten metal (>2 t/h). No distinction is made between continuous thermal coating of steel and thermal coating of manufactured steel products. As a result, discontinuous thermal coating of steel products, also called discontinuous galvanisation, is part of this document. Forges and iron foundries (category 2.3.b and 2.4 of Annex I) are not part of this document and also do not fall under the categories electrolytic coating or organic coating of steel. The production of ferrous metals used in the coating is described in the BREF for the non-ferrous metal industry.

The BREF consists of four parts. A through C deals with the different industrial subsectors of the ferrous metal processing industry. This structure has been chosen due to the large differences in scale and character of the activities that fall under the term 'ferrous metal processing'. It concerns the following subsectors, which provide an outline summary of the processes in the ferrous metal processing industry:

Part A, hot and cold deformation, including:
- Hot strip mills
- Cold strip mills
- Wire mills
- Acid treatment
- Annealing.

Part B, continuous coating, including:
- Continuous hot dip coating
- Aluminiumisation of sheet material
- Lead-tin coating of sheet material
- Coating of wire.

Part C, discontinuous galvanisation

Part D is not about an industrial subsector but contains the technical descriptions of a number of environmental measures used in more than one subsector. This method was chosen to prevent repetition for each subsector. The descriptions in part D must always be seen in relation to the more specific information on the application within the separate subsectors.

The BREF disregards environmental and safety aspects that do not relate directly to the ferrous metal processing. This concerns, for example, the environmental aspects of cooling systems; for these aspects, reference is made to the horizontal BREF documents for industrial cooling systems. Nor are aspects that are predominantly of a local nature, such as noise, vibration, odour, soil pollution and safety, dealt with in detail in the BREF.

At the moment of publication of this guidance note, both hot rolling, cold rolling and wire drawing are used as (dis)continuous coating in the Netherlands. The BREF is therefore in its entirety relevant for the issue of permits on the basis of the Environmental Protection Act and the Pollution of Surface Waters Act.

Conclusions and recommendations

The implementation of the BREF 'Ferrous Metals Processing' in the Dutch legislation means that:
- upon taking decisions on the basis of the Environmental Protection Act and the Pollution of Surface Waters Act, account must be taken of the Best Available Techniques as described in the BREF.

Supplementary to this, the following applies:
If emissions in the BREF are not expressly differentiated, the general stipulations of the NeR (latest version) apply and the emission policy for water (NW4 1998, CIW 1999). The negative environmental effects of, for example, the storage and transhipment of scrap and (hazardous) waste products are not considered in detail in the BREF. For the issue of permits, the special regulation of the NeR 'particulate emission from processing, preparation, transport, loading and unloading, and storage of drift-sensitive goods' can be used in this part.

- Process and burning installations used in the ferrous metal processing industry fall, upon entering into force, under the General Administrative Order on NO_x emission trading.
- There was agreement within the Technical Working Group TWG (concerning) the Best Available Techniques and the associated emission / consumption levels, except where expressly different views ('split views') were specified. Where there was such a 'split view', a choice was made by the Dutch government that is in line with the Dutch situation. The BREF for the ferrous metal processing industry contains, in any event, the following split views.

References

NeR	Netherlands Emission Guidelines for Air
NW4	*Fourth Policy Document on Water Management,* 1998
CIW May 1999	*Handbook on the use of permits under the Pollution of Surface Waters Act (WVO)* Commission on Integrated Water Management, May 1999
BREF	*Reference document on Best Available Techniques in the Ferrous Metals Processing Industry,* December 2001

Process component	Best Available Techniques	Split view	View of Dutch government
Hot rolling processes			
Scarfing	Masking of scarfing and particulate limitation by means of cloth filters	Different views on particulate level: • <5 mg/Nm^3 • <20 mg/Nm^3	• <5 mg/Nm^3
	Electrostatic precipitator if no cloth filter can be used because vapour is very moist	Different views on particulate level: • <10 mg/Nm^3 • 20–50 mg/Nm^3	• 20–50 mg/Nm^3
Grinding	Masking of machine grinding and separate cabins fitted with exhaust hoods for manual grinding and particulate limitation by means of cloth filters	Different views on particulate level: • <5 mg/Nm^3 • <20 mg/Nm^3	• <5 mg/Nm^3
Reheating and heat-treatment furnaces		Different views on particulate level: • limitation of the sulphur content of fuel to <1% is best available technique • reduction of sulphur limit value or additional SO_2 reduction measures is best available technique	• lower S content or additional SO_2 reduction measures is best available technique
		Different views: • SCR and SNCR are best available techniques • insufficient information for being able to decide whether or not SCR/SNCR are best available techniques	• SCR and SNCR are best available techniques (possibility to use SCR or SNCR is highly dependent on process circumstance and must be determined from case to case)
Finishing mill	Exhaust systems that purify the exhaust air with cloth filters and collected particulates are reused	Different views on particulate level: • <5 mg/Nm^3 • <20 mg/Nm^3	• <5 mg/Nm^3
Smoothing and welding	Exhaust hoods and subsequently emission limitation by means of cloth filters	Different views on particulate level: • <5 mg/Nm^3 • <20 mg/Nm^3	• <5 mg/Nm^3
Cold rolling processes			
Unwinding of coils	Exhaust systems that purify exhaustair with cloth filters and collected particulates are reused	Different views on particulate level: • <5 mg/Nm^3 • <20 mg/Nm^3	• <5 mg/Nm^3
Smoothing and welding	Exhaust hoods and subsequently emission limitation by means of cloth filters	Different views on particulate level: • <5 mg/Nm^3 • <20 mg/Nm^3	• <5 mg/Nm^3

3.5.5.2 Summary of BREF

This Reference Document on best available techniques in ferrous metals processing reflects an information exchange carried out according to Article 16(2) of Council Directive 96/61/EC. The document has to be seen in the light of the preface which describes the objectives of the document and its use.

This BREF document consists of 4 Parts (A–D). Parts A to C cover the different industrial sub-sectors of the Ferrous Metals Processing sector: A, Hot and Cold Forming; B, Continuous Coating; C, Batch Galvanizing. This structure was chosen because of the differences in nature and scale of the activities covered by the term FMP.

Part D does not cover an industrial sub-sector. It comprises the technical descriptions of a number of environmental measures which are techniques to be considered in the determination of BAT in more than one sub-sector. This was done to avoid repetition of technical descriptions in the three Chapters 4. These descriptions have to be viewed always in connection with the more specific information, referring to the application in individual sub-sectors, which is given in the relevant Chapter 4.

Part A Hot and Cold Forming

The hot and cold forming part of the ferrous metal processing sector comprises different manufacturing methods, such as hot rolling, cold rolling and drawing of steel. A great variety of semi-finished and finished products with different lines of production is manufactured. Products are: hot and cold rolled flats, hot rolled long products, drawn long products, tubes and wire.

Hot Rolling

In hot rolling the size, shape and metallurgical properties of steel are changed by repeatedly compressing the hot metal (temperature ranging from 1050 to 1300°C) between electrically powered rollers. The steel input for hot rolling varies in form and shape – cast ingots, slabs, blooms, billets, beam blanks – depending on the product to be manufactured. Products obtained from hot rolling are usually classified in two basic types according to their shape: flat and long products.

Total EU production in 1996 of hot rolled (HR) products was 127.8 million tonnes of which flats accounted for 79.2 million tonnes (ca. 62%) [Stat 97]. Germany is the largest manufacturer of the flats, with 22.6 million tonnes followed by France with 10.7 million tonnes, Belgium 9.9 million tonnes, Italy 9.7 million tonnes and UK 8.6 million tonnes. The vast majority of HR flat products is wide strip.

The remaining 38 % of HR products are long products with about 48.5 million tonnes in 1996. The two major manufacturing countries are Italy with about 11.5 million tonnes and Germany with 10.3 million tonnes; followed by UK (7 million tonnes) and Spain (6.8 million tonnes). The largest part of the long products sector in tonnage terms is the production of wire rod which stands for roughly a third of the total production followed by reinforcing bars and merchant bars with an approximate share of one quarter of the production each.

In steel tube manufacture, the EU, which produced 11.8 million tonnes in 1996, (20.9% of total world production) is the largest producer followed by Japan and the U.S. The European steel tube industry has a highly concentrated structure. Five countries – Germany (3.2 million tonnes), Italy (3.2 million tonnes), France (1.4 million tonnes), United Kingdom (1.3 million tonnes) and Spain (0.9 million tonnes) – account for roughly 90% of total EU production. In some countries, a single company can account for 50% or more of the national output. In addition to the major integrated steel tube manufacturers (mainly producing welded tubes), there are a relatively large number of small and medium-sized firms that are independent. Some manufacturers, often small in tonnage terms, operating in high value-added markets, concentrate on the manufacture of special dimensions and grades of tubes according to particular customer specifications.

Hot rolling mills usually comprise the following process steps: conditioning of the input (scarfing, grinding); heating to rolling temperature; descaling; rolling (roughing including width reduction, rolling to final dimension and properties) and finishing (trimming, slitting, cutting). They are classified by the type of product that they produce and by their design features: blooming and slabbing mills, hot strip mills, plate mills, bar and rod mills, structural and section mills and tube mills.

The main environmental issues of hot rolling are emissions to air, especially NO_x and SOx; the energy consumption of furnaces; (fugitive) dust emissions from product handling, rolling or mechanical surface treatment; oil- and solid-containing effluents and oil-containing wastes.

For NO_x emissions of reheating and heat treatment furnaces, industry reported concentrations of 200–700 mg/Nm^3 and specific emissions of 80–360 g/t; while other sources reported up to 900 mg/Nm^3 and – with combustion air preheating of up to 1000°C – of up to more than 5000 mg/Nm^3. SO_2 emissions from furnaces depend on the fuel used; ranges were reported from 0.6–1700 mg/Nm^3 and 0.3–600 g/t. The scattering of energy consumption for these furnaces was 0.7 to 6.5 GT/t; with a typical range being 1–3 GT/t.

As for dust emissions from product handling, rolling or mechanical surface treatment, very few data were submitted referring to the individual processes. The concentration ranges reported were:

- Scarfing: 5–115 mg/Nm^3
- Grinding: <30–100 mg/Nm^3
- Mill stands: 2–50 mg/Nm^3 and
- Coil handling: approximately 50 mg/Nm^3.

Emissions to water from hot rolling basically comprise oil- and solid-containing effluents in the range of 5 to 200 mg/l total suspended solids and 0.2–10 mg/l hydrocarbons. Oil-containing wastes from waste water treatment were reported ranging from 0.4–36 kg/t depending on the mill type.

For more details and for emission and consumption data for other process steps of hot rolling, refer to Chapter A3 where the available data are presented with qualifying information.

The key findings regarding BAT for individual process steps and different environmental issues of hot rolling are summarized in Table 1. All emission figures are expressed as daily mean values. Emissions to air are based on standard conditions of 273 K, 101.3 kPa and dry gas. Discharges to water are indicated as daily mean value of a flow-rate-related 24-hour composite sample or a flow-rate-related composite sample over the actual operating time (for plants not operated in three shifts).

There was consensus in the TWG on the best available techniques and associated emission/consumption levels presented in the table, except where a 'split view' is explicitly recorded.

Table 1 Hot rolling – key findings regarding BAT and associated emission/consumption levels

Best Available Techniques/ split views	Emission and consumption levels
Storing and handling of raw materials and auxiliaries	
• Collection of spillages and leakages by suitable measures,e.g. safety pits and drainage	
• Separation of oil from the contaminated drainage water and reuse of recovered oil	
• Treatment of separated water in the water treatment plant	
Machine scarfing	
• Enclosures for machine scarfing and dust abatement with fabric filters	Split view on dust level: • <5 mg/Nm^3 • <20 mg/Nm^3
• Electrostatic precipitator, where fabric filters cannot be operated because of very wet fume	Split view on dust level: • <10 mg/Nm^3 • 20–50 mg/Nm^3
• Separate collection of scale/swarf from scarfing	
Grinding	
• Enclosures for machine grinding and dedicated booths, equipped with collection hoods for manual grinding and dust abatement by fabric filters	Split view on dust level: • <5 mg/Nm^3 • <20 mg/Nm^3
All surface rectification processes	
• Treatment and reuse of water from all surface rectification processes (separation of solids)	
All surface rectification processes	
• Internal recycling or sale for recycling of scale, swarf and dust	
Re-heating and heat treatment furnaces	
• General measures, e.g. regarding furnace design or operation & maintenance, as described in chapter A.4.1.3.1	
• Avoiding excess air and heat loss during charging by operational measures (minimum door opening necessary for charging) or structural means (installation of multisegmented doors for tighter closure)	
• Careful choice of fuel and implementation of furnace automation/control to optimise the firing conditions. – for natural gas – for all other gases and gas mixtures – for fuel oil (<1% S)	SO_2 levels: • <100 mg/Nm^3 • <400 mg/Nm^3 • up to 1700 mg/Nm^3
Split view: • imitation of sulphur content in fuel to <1% is BAT • lower S limit or additional SO_2 reduction measures is BAT	
• Recovery of heat in the waste gas by feed stock pre-heating • Recovery of heat in the waste gas by regenerative or recuperative burner systems • Recovery of heat in the waste gas by waste heat boiler or evaporative skid cooling (where there is a need for steam)	Energy savings 25–50% and NO_x reductions potentials of up to 50% (depending on system)
• Second generation low-NO_x burners	NO_x 250–400 mg/Nm^3 (3% O_2) without air pre-heating reported NO_x reduction potential of about 65% compared to conventional
• Limiting the air pre-heating temperature. Trade-off energy saving vs. NO_x emission: Advantages of reduced energy consumption and reductions in SO_2, CO_2 and CO have to be weighed against the disadvantage of potentially increased emissions of NO_x	
Split view: • SCR and SNCR are BAT • Not enough information to decide whether or not SCR/SNCR are BAT	Achieved levels [1]: • SCR: NO_x <320 mg/Nm^3 • SNCR: NO_x <205 mg/Nm^3 • ammonia slip 5 mg/Nm^3
• Reduction of heat loss in intermediate products; by minimizing the storage time and by insulating the slabs/blooms (heat conservation box or thermal covers) depending on production layout. • Change of logistic and intermediate storage to allow for a maximum rate of hot charging, direct charging or direct rolling (the maximum rate depends on production schemes and product quality)	
• For new plants, near-net-shape casting and thin slab casting, as far as the product to be rolled can be produced by this technique	
Descaling	
• Material tracking to reduce water and energy consumption	
Transport of rolled stock	
• Reduce unwanted energy loss by coil boxes or coil recovery furnaces and heat shields for transfer bars	
Finishing train	
• Water sprays followed by waste water treatment in which the solids (iron oxides) are separated and collected for reuse of iron content	
• Exhaust systems with treatment of extracted air by fabric filters and recycling of collected dust	Split view on dust level: • <5 mg/Nm^3 • <20 mg/Nm^3

Table 1 Hot rolling (continued)

Best Available Techniques/ split views	Emission and consumption levels
Levelling and welding	
• Suction hoods and subsequent abatement by fabric filters	Split view on dust level: • <5 mg/Nm^3 • <20 mg/Nm^3
Cooling (machines etc.)	
• Separate cooling water systems operating in closed loops	
Waste water treatment/ scale- and oil-containing process water	
• Operating closed loops with recirculating rates of >95%	
• Reduction of emissions by using a suitable combination of treatment techniques (described in detail in Chapters A.4.1.12.2 and D.10.1)	• SS: < 20 mg/l • Oil: < 5 mg/l [2)] • Fe: < 10 mg/l • Crtot: < 0.2 mg/l [3)] • Ni: < 0.2 mg/l [3)] • Zn: < 2 mg/l
• Recirculation of mill scale collected in water treatment to the metallurgical process • Oily waste/sludge collected should be de-watered to allow for thermal utilisation or safe disposal	
Prevention of hydrocarbon contamination	
• Preventive periodic checks and preventive maintenance of seals, gaskets, pumps and pipelines. • Use of bearings and bearing seals of modern design for work- and back-up rolls, installation of leakage indicators in the lubricant lines (e.g. at hydrostatic bearings). • Collection and treatment of contaminated drainage water at the various consumers (hydraulic aggregates), separation and use of oil fraction, e.g. thermal utilisation by blast furnace injection. Further processing of the separated water either in the water treatment plant or in dressing plants with ultra filtration or vacuum evaporator	• Reduction in oil consumption by 50–70%
Roll shops	
• Use of water-based degreasing as far as technically acceptable for the degree of cleanliness required • If organic solvents have to be used, preference is to be given to non-chlorinated solvents • Collection of grease removed from roll trunnions and proper disposal, such as by incineration • Treatment of grinding sludge by magnetic separation for recovery of metal particles and recirculation into the steelmaking process • Disposal of oil- and grease-containing residues from grinding wheels, e.g. by incineration • Deposition of mineral residues from grinding wheels and of worn grinding wheels in landfills • Treatment of cooling liquids and cutting emulsions for oil/water separation. Proper disposal of oily residues, e.g. by incineration • Treatment of waste water effluents from cooling and degreasing as well as from emulsion separation in the hot rolling mill water treatment plant • Recycling of steel and iron turnings into the steelmaking process	

[1)] These are emission levels reported for the one existing SCR plant (walking beam furnace) and the one existing SNCR plant (walking beam furnace).
[2)] Oil based on random measurements.
[3)] 0.5 mg/l for plants using stainless steel.

Cold Rolling

In cold rolling, the properties of hot rolled strip products, e.g. thickness, mechanical and technological characteristics, are changed by compression between rollers without previous heating of the input. The input is obtained in the form of coils from hot rolling mills. The processing steps and the sequence of processing in a cold rolling mill depend on the quality of the steel treated. The following process steps are used for *low alloy and alloy steel (carbon steel)*: pickling; rolling for reduction in thickness; annealing or heat treatment to regenerate the crystalline structure; temper rolling or skin pass rolling of annealed strip to give desired mechanical properties, shape and surface roughness, and finishing.

The process route for *high alloy steel (stainless steel)* involves additional steps to that for carbon steels. The main stages are: hot band annealing and pickling; cold rolling; final annealing and pickling (or bright annealing); skin pass rolling and finishing.
Cold rolled products are mainly strips and sheets (thickness typically 0.16–3 mm) with high quality surface finish and precise metallurgical properties for use in high specification products.

Cold rolled wide strip production (sheets and plates) was about 39.6 million tonnes in 1996. [EUROFER CR]. The main producing countries were Germany with about 10.6 million tonnes, France with 6.3 million tonnes, Italy with 4.3, UK with 4.0 million tonnes and Belgium with 3.8 million tonnes.

Cold rolled narrow strip, obtained from cold rolling narrow hot strip or from slitting and cold rolling hot rolled sheet, amounted to about 8.3 millions tonnes in 1994 (2.7 million tonnes of cold rolled and 5.5 million tonnes of slit strip).
The cold rolled strip industry in the EU is both concentrated and fragmented. The largest 10 companies account for 50% of the production while another 140 companies account for the remaining 50%. The structure of the sector is marked by national differences in company size and industry concentration. Most of the largest companies are situated in Germany, which dominate the market with about 57% of EU production (1.57 million tonnes in 1994). The majority of companies, however, can be classified as small or medium-sized enterprises. [Bed95]

In 1994, Germany produced about 35% of the slit strip, with 1.9 million tonnes, followed by Italy and France each with a production of 0.9 million tonnes.

The main environmental issues of cold rolling are: acidic wastes and waste water; degreaser fume, acidic and oil mist emissions to air; oil-containing wastes and waste water; dust, e.g. from descaling and decoiling; NO_x from mixed acid pickling and combustion gases from furnace firing.

As for acid emissions to air from cold rolling, these may arise from pickling and acid regeneration processes. Emissions differ, depending on the pickling process used – basically the acid used. For hydrochloric acid pickling, HCl emissions of 1–145 mg/Nm³ maximum (up to 16 g/t) were reported; with the range reported by industry being 10 – <30 mg/Nm³ (~ 0.26 g/t). For sulphuric acid pickling, H_2SO_4 emissions of 1–2 mg/Nm³ and 0.05–0.1 g/t were reported.

For mixed acid pickling of stainless steel, HF emissions were reported in the range of 0.2–17 mg/m³ (0.2–3.4 g/t). Additionally to acidic air emissions, NO_x is generated. The scattering rang was reported to be 3– ~ 1000 mg/Nm³ (3–4000 g/t specific emission) with doubts being raised on the lower end levels.

Only little data was available for dust emissions from steel handling and descaling operations. Reported ranges for mechanical descaling are 10–20 g/t for specific emissions and concentration ranging from <1–25 mg/m³.

For more details and for emission and consumption data for other process steps of cold rolling, refer to Chapter A.3 where the available data are presented with qualifying information.

The key findings regarding BAT for individual process steps and different environmental issues of cold rolling are summarized in Table 2. All emission figures are expressed as daily mean values. Emissions to air are based on standard conditions of 273 K, 101.3 kPa and dry gas. Discharges to water are indicated as daily mean value of a flow-rate-related 24-hour composite sample or a flow-rate-related composite sample over the actual operating time (for plants not operated in three shifts).

There was consensus in the TWG on the best available techniques and associated emission/consumption levels presented in the table, except where a 'split view' is explicitly recorded.

Table 2 Cold rolling – key findings regarding BAT and associated emission/consumption levels

Best Available Techniques/ split views	Emission and consumption levels
Decoiling	
• Water curtains followed by waste water treatment in which the solids are separated and collected for reuse of iron content. • Exhaust systems with treatment of extracted air by fabric filters and recycling of collected dust	Split view on dust level: • <5 mg/Nm³ • <20 mg/Nm³
Pickling	
General measures to reduce acid consumption and waste acid generation as described in Chapter A.4.2.2.1. should be applied as far as possible, especially the following techniques: • Prevention of steel corrosion by appropriate storage and handling, cooling etc. • Reduction of load on pickling step by mechanical predescaling in a closed unit, with an extraction system and fabric filters. • Use of electrolytic pre-pickling. • Use of modern, optimised pickling facilities (spray or turbulence pickling instead of dip pickling). • Mechanical filtration and recirculation for lifetime extension of pickling baths. • Side-stream ion-exchange or electro-dialysis (for mixed acid) or other method for free acid reclamation (described in Chapter D.6.9) for bath regeneration	
HCl pickling	
• Reuse of spent HCl • or Regeneration of the acid by spray roasting or fluidised bed (or equivalent process) with recirculation of the regenerate; air scrubbing system as described in Chapter 4 for the regeneration plant; reuse of Fe2O3 by-product	• Dust: 20–50 mg/Nm³ • HCl: 2–30 mg/Nm³ • SO_2: 50–100 mg/Nm³ • CO: 150 mg/Nm³ • CO_2: 180000 mg/Nm³ • NO_2: 300–370 mg/Nm³
• Totally enclosed equipment or equipment fitted with hoods and scrubbing of extracted air	• Dust: 10–20 mg/Nm³ • HCl: 2–30 mg/Nm³
H_2SO_4 Pickling	
• Recovery of the free acid by crystallisation; air scrubbing devices for recovery plant	• H_2SO_4: 5–10 mg/Nm³ • SO_2: 8–20 mg/Nm³
• Totally enclosed equipment or equipment fitted with hoods and scrubbing of extracted air	• H_2SO_4: 1–2 mg/Nm³ • SO_2: 8–20 mg/Nm³
Mixed acid pickling	
• Free acid reclamation (by side-stream ion exchange or dialysis) • or acid regeneration – by spray roasting: – or by evaporation process:	 • Dust: <10 mg/Nm³ • HF: <2 mg/Nm³ • NO_2: <200 mg/Nm³ • HF: <2 mg/Nm³ • NO_2: <100 mg/Nm³
• Enclosed equipment/hoods and scrubbing, and additionally: • Scrubbing with H_2O_2, urea etc. • or NO_x suppression by adding H_2O_2 or urea to the pickling bath • or SCR	for all: • NO_x: 200–650 mg/Nm³ • HF: 2–7 mg/Nm³
• Alternative: use of nitric acid-free pickling plus enclosed equipment or equipment fitted with hoods and scrubbing	
Heating of acids	
• Indirect heating by heat exchangers or, if steam for heat exchangers has to be produced first, by submerged combustion. • Not using direct injection of steam	

Table 2 Cold rolling (continued)

Best Available Techniques/ split views	Emission and consumption levels
Minimization of waste water	
• Cascade rinsing systems with internal re-use of overflow (e.g. in pickling baths or scrubbing). • Careful tuning and managing of the 'pickling-acid regeneration-rinsing' system	
Waste water treatment	
• Treatment by neutralisation, flocculation, etc., where acidic water blow-down from the system cannot be avoided	• SS: <20 mg/l • Oil: <5 mg/l [1)] • Fe: <10 mg/l • Crtot:<0.2 mg/l [2)] • Ni: <0.2 mg/l [2)] • Zn: <2 mg/l
Emulsion systems	
• Prevention of contamination by regular checking of seals, pipework etc. and leakage control. • Continuous monitoring of emulsion quality. • Operation of emulsion circuits with cleaning and reuse of emulsion to extend lifetime. • Treatment of spent emulsion to reduce oil content, e.g. by ultrafiltration or electrolytic splitting	
Rolling and tempering	
• Exhaust system with treatment of extracted air by mist eliminators (droplet separator).	Hydrocarbons: • 5–15 mg/Nm^3
Degreasing	
• Degreasing circuit with cleaning and reuse of the degreaser solution. Appropriate measures for cleaning are mechanical methods and membrane filtration as described in chapter A.4. • Treatment of spent degreasing solution by electrolytic emulsion splitting or ultrafiltration to reduce the oil content; reuse of separated oil fraction; treatment (neutralisation etc.) of separated water fraction prior to discharge. • Extraction system for degreasing fume and scrubbing	
Annealing furnaces	
• For continuous furnaces, low NO_x burners • Combustion air pre-heating by regenerative or recuperative burners or • Pre-heating of stock by waste gas	NO_x: 250–400 mg/Nm^3 without air pre-heating, 3% O_2. Reduction rates of 60% for NO_x (and 87% for CO)
Finishing/Oiling	
• Extraction hoods followed by mist eliminators and/or electrostatic precipitators or • Electrostatic oiling	
Levelling and welding	
• Extraction hoods with dust abatement by fabric filters	Split view on dust level: • <5 mg/Nm^3 • <20 mg/Nm^3
Cooling (machines etc.)	
• Separate cooling water systems operating in closed loops	
Roll shops	
Refer to BATs listed for roll shops in hot rolling	
Metallic by-products	
• Collection of scrap from cutting, heads and tails and recirculation into the metallurgical process	

[1)] Oil based on random measurements.
[2)] For stainless steel <0.5 mg/l.

Wire Drawing

Wire drawing is a process in which wire rods/wires are reduced in size by drawing them through cone-shaped openings of a smaller cross section, called dies. The input is usually wire rod of diameters raging from 5.5 to 16 mm obtained from hot rolling mills in the form of coils. A typical wire drawing plant comprises the following process lines:

- Pre-treatment of the wire rod (mechanical descaling, pickling)
- Dry or wet drawing (usually several drafts with decreasing die sizes)
- Heat treatment (continuous-/discontinuous annealing, patenting, oil hardening)
- Finishing

The European Union has the world largest wire drawing industry, followed by Japan and North America. It produces about 6 million tonnes of wire per year. Including the various wire products, such as barbed wire, grill, fencing, netting, nails etc, the production of the sector reaches more than 7 million tonnes per year. The European wire drawing industry is characterised by a large number of medium sized, specialised companies. The industry's output, however, is dominated by a few large producers. It is estimated that about 5% of the companies account for 70% of the industry's output (25% of the companies for 90%).

Over the past 10 years, independent wire drawing companies have become increasingly vertically integrated. Approximately 6% of the wire drawers in Europe are integrated producers representing about 75% of the total production of steel wire (C.E.T).

The largest producer of steel wire is Germany with 32% (about 1.09 million tonnes) of EU wire production, followed by Italy (approx. 22%, 1.2 million tonnes), UK, Benelux (mainly Belgium), France and Spain.

The main environmental aspects of wire drawing are: air emissions from pickling, acidic wastes and waste water; fugitive soap dust (dry drawing), spent lubricant and effluents (wet drawing), combustion gas from furnaces and emissions and lead-containing wastes from lead baths.

For air emissions from pickling, HCl concentrations of 0–30 mg/Nm^3 were reported. In continuous annealing and patenting lead baths are used. Generating lead containing wastes, 1–15 kg/t for continuous annealing and 1–10 kg/t for patenting. Reported Pb air emissions for patenting are <0.02–1 mg/Nm^3 and Pb concentrations in quench water overflow 2–20 mg/l.

For more details and for emission and consumption data for other process steps of wire drawing, refer to Chapter A.3 where the available data are presented with qualifying information.

The key findings regarding BAT for individual process steps and different environmental issues of wire drawing are summarized in Table 3. All emission figures are expressed as daily mean values. Emissions to air are based on standard conditions of 273 K, 101.3 kPa and dry gas. Discharges to water are indicated as daily mean value of a flow-rate-related 24-hour composite sample or a flow-rate-related composite sample over the actual operating time (for plants not operated in three shifts).

There was consensus in the TWG on the best available techniques and associated emission/consumption levels presented in the table.

Table 3 Wire drawing – key findings regarding BAT and associated emission/consumption levels

Best Available Techniques	Emission and consumption levels
Batch pickling	
• Close monitoring of bath parameters: temperature and concentration. • Operating within the limits given in Part D, Chapter D.6.1 'Open Pickling Bath Operation'. • For of pickling baths with high vapour emission, e.g. heated or concentrated HCl-bath: installation of lateral extraction and possibly treating of the extraction air for both new and existing installations	• HCl: 2–30 mg/Nm^3
Pickling	
• Cascade Pickling (capacity >15,000 tonne wire rod per year) or • Reclamation of free acid fraction and reuse in pickling plant. • External regeneration of spent acid. • Recycling of spent acid as secondary raw material. • Non-acid descaling, e.g shot blasting, if quality requirements allow it. • Counter current cascade rinsing	
Dry drawing	
• Enclosing the drawing machine (and connecting to a filter or similar device when necessary), for all new machines with drawing speed ≥ 4 m/s	
Wet drawing	
• Cleaning and reuse of drawing lubricant. • Treatment of spent lubricant to reduce oil content in the discharge and/or to reduce waste volume, e.g. by chemical breaking, electrolytic emulsion splitting or ultrafiltration. • Treatment of discharge water fraction	
Dry and wet drawing	
• Closed cooling-water loops. • Not using once-through cooling water systems	
Batch annealing furnaces, continuous annealing furnaces for stainless steel and furnaces used in oil hardening and tempering	
• Burning of the protective gas purge	
Continuous annealing of low carbon wire and patenting	
• Good housekeeping measures, as described in chapter A.4.3.7 for the lead bath. • Separate storage of Pb-containing wastes, protected from rain and wind. • Recycling of Pb-containing wastes in non-ferrous metals industry • Closed loop operation of quench bath	• Pb: <5 mg/Nm^3 • CO: <100 mg/Nm^3 • TOC: <50 mg/Nm^3
Oil-hardening lines	
• Evacuation of the oil mist from quench baths and removal of the oil mists, when appropriate	

Part B Continuous Hot Dip Coating

In the hot dip coating process, steel sheet or wire is continuously passed through molten metal. An alloying reaction between the two metals takes place, leading to a good bond between coating and substrate.

Metals suitable for the use in hot dip coating are those which have a melting point low enough to avoid any thermal changes in the steel product; for example, aluminium, lead, tin and zinc.

The production of continuous hot dip coating lines in the EU was about 15 Mt in1997. The vast majority of coatings applied in continuous hot dip coating is zinc. Aluminium coatings and, especially, terne coatings played only a minor role.

Galvanized steel	81%
Galvannealed steel	4%
Galfan	4%
Aluminized steel	5%
Aluzinc	5%
Ternex	1%

In general, *continuous coating lines for sheet comprise* the following steps:

- Surface cleaning by means of chemical and/or thermal treatment
- Heat treatment
- Immersion in a bath of molten metal
- Finishing treatment

Continuous wire galvanizing plants involve the following steps:

- Pickling
- Fluxing
- Galvanizing
- Finishing

Main environmental issues concerning this sub-sector are acidic air emissions, wastes and waste water; air emissions and energy consumption of furnaces, Zinc-containing residues, oil- and chrome-containing waste waters.

For detailed emission and consumption data, refer to Chapter B.3 where the available data are presented with qualifying information.

The key findings regarding BAT for individual process steps and different environmental issues of continuous hot dip galvanizing are summarized in Table 4. All emission figures are expressed as daily mean values. Emissions to air are based on standard conditions of 273 K, 101.3 kPa and dry gas. Discharges to water are indicated as daily mean value of a flow-raterelated 24-hour composite sample or a flow-rate-related composite sample over the actual operating time (for plants not operated in three shifts).

There was consensus in the TWG on the best available techniques and associated emission/consumption levels presented in the table.

Table 4 Continuous hot dip galvanizing: key findings regarding BAT and associated emission/ consumption levels

Best Available Techniques	Emission and consumption levels
Pickling	
• Refer to the BAT chapter of Part A/Cold rolling Mills	
Degreasing	
• Cascade degreasing • Cleaning and recirculation of degreasing solution; appropriate measures for cleaning are mechanical methods and membrane filtration as described in chapter A.4. • Treatment of spent degreasing solution by electrolytic emulsion splitting or ultrafiltration to reduce the oil content; reutilisation of separated oil fraction, e.g. thermally; treatment (neutralisation etc.) of the separated water fraction. • Covered tanks with extraction and cleaning of extracted air by scrubber or demister. • Use of squeeze rolls to minimize drag-out	
Heat treatment furnaces	
• Low-NO_x burners • Air pre-heating by regenerative or recuperative burners • Pre-heating of strip • Steam production to recover heat from waste gas	• NO_x: 250–400 mg/Nm^3 (3% O_2) without air preheating • CO: 100–200 mg/Nm^3
Hot dipping	
• Separate collection and recycling in the non-ferrous metals industry for zinc-containing residues, dross or hard zinc	
Galvannealing	
• Low-NO_x burners • Regenerative or recuperative burner systems	• NO_x: 250–400 mg/Nm^3 (3% O_2) without air preheating
Oiling	
• Covering the strip oiling machine or • Electrostatic oiling	
Phosphating and passivation/chromating	
• Covered process baths • Cleaning and reuse of phosphating solution • Cleaning and reuse of passivation solution • Use of squeeze rolls. • Collection of skinpass/temper solution and treatment in waste water treatment plant	
Cooling (machines etc.)	
• Separate cooling water systems operating in closed loops	
Waste water	
• Waste water treatment by a combination of sedimentation, filtration and/or flotation/ precipitation/flocculation. Techniques described in Chapter 4 or equally efficient combinations of individual treatment measures (also described in part D). • For existing continuous water treatment plants which only achieve Zn <4 mg/l, switch to batch treatment	• SS: <20 mg/l • Fe: <10 mg/l • Zn: <2 mg/l • Ni: <0.2 mg/l • Crtot: <0.2 mg/l • Pb: <0.5 mg/l • Sn: <2 mg/l

Aluminizing of Sheet

Most BAT are the same as for hot dip galvanising. However, there is no need for a waste water treatment plant as only cooling water is discharged.

BAT for heating:

- Gas firing. Combustion control system

Table 5 Continuous lead-tin coating of sheet – key findings regarding BAT and associated emission/ consumption levels

Best Available Techniques	Emission and consumption levels
Pickling	
• Enclosed tanks and venting to a wet scrubber, treatment of waste water from the scrubber and pickling tank	• HCl: <30 mg/Nm^3 [1)]
Nickel plating	
• Enclosed process, ventilated to a wet scrubber	
Hot dipping	
• Air knives to control coating thickness	
Passivation	
• A no-rinse system and hence no rinse waters	
Oiling	
• Electrostatic oiling machine	
Waste water	
• Waste water treatment by neutralising with sodium hydroxide solution, flocculation/precipitation. • Filter cake de-watering and disposed to landfill	

[1)] Daily mean values, standard conditions of 273 K, 101.3 Pa and dry gas.

Coating of Wire

The key findings regarding BAT for individual process steps and different environmental issues of wire coating are summarized in Table 6. All emission figures are expressed as daily mean values. Emissions to air are based on standard conditions of 273 K, 101.3 kPa and dry gas. Discharges to water are indicated as daily mean value of a flow-rate-related 24-hour composite sample or a flow-rate-related composite sample over the actual operating time (for plants not operated in three shifts).

There was consensus in the TWG on the best available techniques and associated emission/consumption levels presented in the table.

Table 6 Wire coating – key findings regarding BAT and associated emission/consumption levels

Best Available Techniques	Emission and consumption levels
Pickling	
• Enclosed equipment or equipment fitted with hoods and scrubbing of extracted air. • Cascade pickling for new installations above a capacity of 15 000 tonne/year per line. • Recovery of free acid fraction. • External regeneration of spent acid for all installations • Reuse of spent acid as secondary raw material	• HCl: 2–30 mg/Nm^3
Water consumption	
Cascaded rinsing, possibly in combination with other methods to minimize water consumption, for all new and all large installations (>15 000 tonne/year)	
Waste water	
• Waste water treatment by physico-chemical treatment (neutralisation, flocculation, etc.)	• SS: <20 mg/l • Fe: <10 mg/l • Zn: <2 mg/l • Ni: <0.2 mg/l • Crtot: <0.2 mg/l • Pb: <0.5 mg/l • Sn: <2 mg/l
Fluxing	
• Good housekeeping with special focus on reducing iron carry-over and bath maintenance. • Regeneration of flux baths on site (side-stream iron removal). • External reutilisation of spent flux solution	
Hot dipping	
• Good housekeeping measures as described in Chapter B.4	• Dust: <10 mg/Nm^3 • Zinc: <5 mg/Nm^3
Zn-containing wastes	
• Separate storage and protection form rain and wind, and reuse in the non-ferrous metals industry	
Cooling water (after the zinc bath)	
• Closed loop or reuse of this relatively pure water as makeup water for other applications.	

Part C Batch Galvanizing

Hot dip galvanizing is a corrosion protection process in which iron and steel fabrications are protected from corrosion by coating them with zinc. Prevalent in batch hot dip galvanizing is job galvanizing – also referred to as general galvanizing – in which a great variety of input materials are treated for different customers. The size, amount and nature of the inputs can differ significantly. Galvanizing of pipes or tubes which is carried out in semi- or fullyautomatic special galvanizing plants is usually not covered by the term job galvanizing.

The items to be coated in batch galvanizing plants are steel fabrications, such as nails, screws and other very small items; lattice grates, construction parts, structural components, light poles and many more. In some cases tubes are also galvanized in conventional batch coating plants. Galvanized steel is used in construction, transport, agriculture, power transmission and everywhere that good corrosion protection and long life are essential.

The sector operates with short lead times and short order books to give enhanced service to customers. Distribution issues are important, and so plants are located close to market concentrations. Consequently, the industry consists of a relatively large number of plants (about 600 all over Europe), servicing regional markets in order to minimize distribution costs and increase economic efficiency. Only a few 'niche' operators are prepared to transport certain classes of fabrication for longer distances in order to exploit their special expertise or plant capability. Opportunities for these specialist operators are limited.

In 1997 the tonnage of galvanized steel was about 5 million. The largest share was produced by Germany with 1.4 million tonnes and 185 galvanizing plants (in 1997). Second largest producer was Italy with 0.8 million tonnes (74 plants), followed by UK and Ireland with 0.7 million tonnes (88 plants) and France 0.7 million tonnes (69 plants).

Batch galvanizing usually comprises the following process steps:

- Degreasing
- Pickling
- Fluxing
- Galvanizing (melt metal coating)
- Finishing

A galvanizing plant, essentially, consists of a series of treatment or process baths. The steel is moved between tanks and dipped into the baths by overhead cranes.

The main environmental issues for batch galvanizing are emissions to air (HCl from pickling, and dust and gaseous compounds from the kettle); spent process solutions (degreasing solutions, pickling baths and flux baths), oily wastes (e.g. from cleaning of degreasing baths) and zinccontaining residues (filter dust, zinc ash, hard zinc).

For detailed emission and consumption data, refer to Chapter 3 where the available data are presented with qualifying information.

The key findings regarding BAT for individual process steps and different environmental issues of batch galvanising are summarized in Table 7. All emission figures are expressed as daily mean values. Emissions to air are based on standard conditions of 273 K, 101.3 kPa and dry gas. Discharges to water are indicated as daily mean value of a flow-rate-related 24-hour composite sample or a flow-rate-related composite sample over the actual operating time (for plants not operated in three shifts).

There was consensus in the TWG on the best available techniques and associated emission/consumption levels presented in the table.

Table 7 Batch galvanizing – key findings regarding BAT and associated emission/consumption levels

Best Available Techniques	Emission and consumption levels
Degreasing	
• Installation of a degreasing step, unless items are totally grease free. • Optimum bath operation to enhance efficiency, e.g. by agitation. • Cleaning degreasing solutions to extend lifespan (by skimming, centrifuge, etc.) and recirculation, reutilization of oily sludge. • 'Biological degreasing' with in situ cleaning (grease and oil removal from degreaser solution) by bacteria.	
Pickling + stripping:	
• Separate pickling and stripping unless a downstream process for the recovery of values from 'mixed' liquors is installed on site or is available through a specialist external contractor. • Reuse of spent stripping liquor (external or internal e.g. to recover fluxing agent). *In case of combined pickling and stripping:* • Recovery of values from 'mixed' liquors, e.g. use for flux production, recovery of acid for re-use in the galvanizing industry or for other inorganic chemicals	
HCl pickling	
• Close monitoring of baths parameters: temperature and concentration. • Operating within the limits given in Part D/Chapter D.6.1 'Open Pickling Bath Operation'. • If heated or higher concentrated HCl-baths are used: installation of extraction unit and treatment of extracted air (e.g. by scrubbing). • Special attention to actual pickling effect of bath and use of pickling inhibitors to avoid over-pickling.	• HCl: 2–30 mg/Nm^3
HCl pickling	
• Recovery of free acid fraction from spent pickle liquor or external regeneration of pickling liquor. • Zn removal from acid. • Use of spent pickle liquor for flux production. • Not using spent pickle liquor for neutralisation. • Not using spent pickling liquor for emulsion splitting.	
Rinsing	
• Good drainage between pre-treatment tanks. • Implementation of rinsing after degreasing and after pickling. • Static rinsing or rinsing cascades. • Reuse of rinse water to replenish preceding process baths. Waste water-free operation (in exceptional cases where waste water is generated, waste water treatment is required).	
Fluxing	
• Control of bath parameters and the optimised amount of flux used are also important to reduce emission further down the process line. • For flux baths: internal and external flux bath regeneration.	
Hot dipping	
• Capture of emissions from dipping by enclosure of the pot or by lip extraction and dust abatement by fabric filters or wet scrubbers. • Internal or external reuse of dust, e.g. for flux production. The recovery system should ensure that dioxins, which may occasionally be present at low concentration due to upset conditions in the plant, do not build up as the dusts are recycled.	• Dust: <5 mg/Nm^3
Zn-containing wastes	
• Separate storage and protection form rain and wind, and reuse of contained values in the non-ferrous or other sectors.	

3.5.6 Glass-producing industry

This guidance note was adopted on 28 September 2004

3.5.6.1 Guidance note

Introduction

Status of guidance note

This guidance is intended to support the competent authorities in applying the BAT Reference (BREF) document for the glass-producing industry. It describes the field of application of the BREF, the changes in the Dutch legislation and the relationship between this BREF and other relevant legislation.

The guidance note must be read in combination with the BREF document. The full English-language version is the starting point.

Status of BREF

The BREF has a comparable status as the NeR and the recommendations of the Commission on Integrated Water Management (CIW); it may only be departed from on duly stated grounds (for more information refer to the NeR (Chapter 2.12) and the Handbook on the use of permits under the Pollution of Surface Waters Act [WVO]).

Field of application

The BREF relates to the following sectors:

- packaging glass
- sheet glass
- glass fibre
- table glass (incl. crystal)
- special glass
- glass wool
- mineral wool
- ceramic fibres
- frit (enamel flakes)
- glass fabric

The most important environmental aspects are emissions to the air and energy consumption. In some sectors, there are also process emissions to water. The BREF considers this extensively per sector.

This BREF disregards environmental and safety aspects that do not relate directly to the production of glass, mineral wool, ceramic fibre or frit. This concerns, for example, the environmental aspects of cooling systems and emissions from the storage and transhipment of feedstock. For these aspects, reference is made to the horizontal BREF documents for industrial cooling systems and Section 3.8.1 of the NeR on storage and transhipment of drift-sensitive goods. Nor are aspects, such as noise, vibration, odour, soil pollution, dealt with in detail in the BREF.

At the moment of publication of this BREF, all the products mentioned are manufactured in the Netherlands, with the exception of ceramic fibres. This production capacity of the logistics unit is an additional criterion in the assessment of whether a logistics unit falls under the scope of the BREF. In the BREF, the techniques have been assessed for furnaces capable of producing at least 20 tonnes of molten glass per day. For smaller furnaces, attention is required as to what extent the conclusions of the BREF apply to a scale of operations under 20 tonnes. See also Chapter 2.12.8 of the NeR.

The BREF devotes little attention to the production of enamel frits. The specific aspects in the production of these frits, such as the increased NO_x and fluorine emission due to the necessary addition of nitrates and fluorine, are not discussed. Nor is any mention made of the addition of boron and the specific problems arising from this.
This is further considered under 3.5.1.5. Glass and ceramics frits are not discussed at all.

The essence of the former special regulation 'C4 Production of glass'

The former special regulation 'C4 Production of glass', which was included in the NeR in 1993, contains an arrangement between the glass sector and the government concerning the emission values to be achieved in 2010. In the arrangement, both the objective and the way the objective can be achieved have been laid down. On the basis of the arrangement, companies can choose for two packages of measures and the time the measures should be taken is geared to the major furnace overhauls.
In package of measures 1, measures are taken no later than in 2003 to reduce the emission of SO_2, particulates, heavy metals, HCl and HF, and additional measures are taken no later than in 2010 to reduce the emission of NO_x.
In package of measures 2, oxyfuel technology is used no later than in 2003 to reduce the emission of NO_x and additional measures are taken no later than in 2010 to reduce the emission of SO_2, particulates, heavy metals, HCl and HF. The expected development of the emission factors as a result of taking measures is shown in the tables below.

Table 1 Expected development of emission factors arising from package of measures 1

Component	Level 1992		Until 2003	Until 2010
NO_x (kg/tonne molten glass)	5.0	(–20%)	4.0	p.m.
SO_2 (kg/tonne molten glass)	2.5	(–60%)	1.0	1.0

p.m.: The feasible emission reduction for measures against NO_x for the period 2003–2010 is strongly dependent on the technological developments and will be further specified later.

Table 2 Expected development of emission factors arising from package of measures 2

Component	Level 1992		Until 2003	Until 2010
NO_x (kg/tonne molten glass)	5.0	1.0		1.0
SO_2 (kg/tonne molten glass)	2.5	2.5	(–60%)	1.0
Stof (kg/tonne molten glass)	0.4	0.3		0.1

By gearing the measures to the major furnace overhauls and by introducing them in two phases (2003 and 2010) with clear objectives, the necessary investments will become clearer and more bearable.

Incidentally, the former BR did not apply to the production of sheet glass, glass fibre and glass wool. For taking measures in these sectors, the technologies mentioned were, in principle, declared applicable, with the exception of oxyfuel in the production of sheet glass.

Relation between BREF, the former BR 'C4 Production of glass' and the former BR 'C3 Production of mineral fibres'

The IPPC Directive states that all existing facilities must have an environmental permit no later than 31 October 2007, the conditions of which are based on the use of Best Available Techniques (BAT). New furnaces must immediately comply with BAT; furnaces undergoing a major overhaul must comply with BAT following modification.
The BREF provides a frame of reference for determining BAT and also specifies the associated indicative emission limit values.

A comparison between the 'feasible emission values' in the BREF and the expected emission factors for 2010 in the former special regulation reveals that most of the values mentioned do not significantly differ from another. The BREF also uses the starting point that dramatic changes to the installation should preferably coincide with major furnace overhauls. Moreover, the BREF covers more sectors and more components and contains more recent insights. This means the BREF broadens and improves the former BR 'C4 Production of glass', which can be retracted.

The special regulation 'C3 Production of mineral fibres' contains requirements for the components sulphur oxides, particulates and organic compounds. The BREF describes the emissions of NO_x, sulphur oxides, carbon monoxide, chlorides, fluorides and metals from the smelting process and presents BAT. The post-treatment (forming and hardening) is also described, and the techniques and associated indicative emission limit values. This means the BREF broadens and improves the former BR 'C3 Production of mineral fibres'.

Special points for attention and additions to the Glass BREF

In formulating or adapting the permit instructions, account should be taken of the following characteristic features of the glass industry.
Experiences with the BAT techniques described in the BREF are still limited in early 2003. That is why in all situations where these techniques are applicable not all expected results will be achieved. In many cases it is therefore desirable to establish the definitive permit requirements not in advance but afterwards on the basis of a measurement programme. The method of working avoids incorrect or unrealistic requirements being taken up in the permit.

- In the Dutch summary and in the BREF main document it is specified that the values are indicative and serve to compare the techniques. The values listed as feasible in the BREF are often obtained, in particular where a range is given, from measurements on new installations or installations that are stable and operate under optimal conditions. When laying down emission requirements in the permit, account must be taken of product and process variations, production speeds and age of furnaces, because these can lead to other emission levels or to variations in emission levels.
- The BREF pays no attention to the specific environmental aspects in the production of enamel fits such as emissions of NO_x, fluoride, boron and particulates. This means that no specific measures are described for the production of those frits in Chapter 5 of the BREF. In the production of enamel frits, the addition of nitrates as oxidation substance is necessary. Depending on the nature of the product, 18 kg nitrate per tonne of end-product is added. For each kg nitrate added per tonne of end-product, the NO_x emission increases by 0.5 kg NO_x per tonne of product. The BREF indicates that in oxygen-fired furnaces an NO_x value of 0.5–1.5 kg NO_x per tonne of product from the incineration emission of the fuel is feasible. It must be mentioned that this range is based on the values for continuous furnaces for the production of packaging glass. The frits industry, however, uses a batch production system with regular product changes and a non-continuous production system. During the period in which no production takes place, the furnace is kept at temperature. In those case, the NO_x is around 2,0 kg NO_x per tonne of product from incineration emissions. Boron can lead to higher emission values for particulates because this component condenses after passing through a cloth filter.

- In the glass industry, attention must be given expressly to an integral weighing of environmental and economic interests when determining feasible emission values or when considering a combination of BAT techniques.
  Illustration:
  - The use of stringent limit values for the emission of, for example, HCl, SO_2 and fluorides can put the ability to recycle these substances and waste glass at risk. A stringent limit value could make the reuse of the waste substances produced by flue gas cleaning impossible because accumulation of chloride, sulphur or fluoride may occur in the glass product.
  - A stringent limit value for a component can rule out the use of an emission-abatement technique for another component, or this can lead to, for instance, much extra energy being required to nevertheless use this technique due to having to reheat flue gases. The sector is precisely trying to reduce energy consumption as much as possible within the framework of long-term agreements on energy efficiency (MJAs).
  - The recovery of feedstock from mineral residual substances can lead to necessary additions (sodium nitrate) to the glass mixture. This produces an extra NO_x emission. For each kg nitrate added per tonne of end-product, the NO_x emission increases by 0.5 kg NO_x per tonne of product.
- Upon commissioning, the glass furnaces fall under the General Administrative Order on NO_x-emission trading. This order gives so-called PSR values for the different glass types. The moment of admission to the system of NO_x emission trading is also laid down. In the case of new building and rebuilding, furnaces must also comply with the emission requirements falling within the limits designated by the BREF as Best Available Techniques[1]. The possibilities of the system of emission trading should also be utilised as much as possible.
- In special cases, such as for oxygen-fired furnaces, the testing against emission concentrations consists of converting the measured emission in kg/tonne glass smelt per component to mg/Nm^3 waste gas, calculated back to the situation of air-fired furnaces. To that end, use can be made of the indicative conversion factors listed in Table 5.1 of Chapter 5 of the BREF.

Conclusions and recommendations

The implementation of the BREF for the glass-producing industry in the Netherlands means that:

- NeR special regulation 'C3 Production of mineral fibres' and 'C4 Production of glass' are cancelled and replaced by the complete Glass BREF and this guidance note. For NO_x the following applies: The glass furnaces fall under the General Administrative Order on NO_x emission trading upon entering into force. This order gives so-called PSR values for the different glass types. The moment of admission to the system of NO_x emission trading is also laid down. In the case of new building and rebuilding, furnaces must also comply with the emission requirements falling within the range designated by the BREF as Best Available Techniques. The possibilities of the system of emission trading should also be utilised as much as possible[2].
- The arrangements on phasing of the control of air emissions in line with the above-mentioned special regulation 'C4 Production of glass' can, in principle, be maintained.
- If measures are taken after 31 October 2007, the permit must duly state the reasons that these can be regarded as BAT in view of the cycle of furnace overhauls.
- In determining BAT, attention must be given to the integral weighing, that is to say, a fitting (combination of) techniques when all considerations have been included in the decision-making process.
- In those cases where insufficient experience has been gained with a certain technique in a specific situation, it may be desirable to establish the emission limit values afterwards on the basis of a measurement programme. In prescribing the measurement method and the measurement regime, account must be taken of the technical possibilities.
- In the issue of permits under the WVO, the CIW advises taking the Best Available Techniques into account as described in the BREF and this guidance note.

Supplementary to this, the following applies:
If emissions in the BREF are not expressly differentiated or mentioned in this guidance note, the general provisions of the NeR apply (latest version) and the emission policy on water (NW41998, CIW 1999). However, given the specific and complex character of flue gases in the glass industry it is possible that the mentioned values in the NeR cannot be applied just like that. See appended overview.

References

NeR	Netherlands Emission Guidelines for Air
NW4	*Fourth Policy Document on Water Management,* 1998
CIW May 1999	*Handbook on the use of permits under the Pollution of Surface Waters Act (WVO)* Commission on Integrated Water Management, May 1999
BREF	Reference Document on Best Available Techniques in the Glass Manufacturing Industry approved on 16/01/2002 by the European Commission (Pbl C12 of 16.01.02).
IPPC Directive	Directive 96/61/EC is the IPPC Council Directive of 24/09/96 (Publication L257 of 10/10/96).
BREF	*Reference document on Best Available Techniques in the Glass Manufacturing Industry,* December 2001

1) The head lines note on NO_x emission trading contains the following: Glass furnaces have been operating continuously for a long time, that is to say 6–8 years and often even 10 years and longer. That is why measures and provisions can only be applied in glass furnaces during a major overhaul. Since this often results in a completely new furnace, admission to the system of NO_x emission trading takes place per furnace, following each major overhaul and after the General Administrative Order on NO_x emission trading has entered into force. This means that from that moment the PSR-2010 immediately becomes effective for the new modified furnace. Furnaces that have undergone a major overhaul with significant de-NO_x measures before the General Administrative Order entered into force are admitted immediately to the system. Furnaces that will undergo a major overhaul after 2010 will first be admitted to the system of NO_x emission trading after 2010. From that moment, the PSR values of 2015 apply, which will probably be determined in 2006.
The Interprovincial Consultation (IPO) and the Ministry of Housing, Spatial Planning and the Environment (VROM) have now made the arrangement that, upon drawing up the Environmental Protection Act (Wm) permit, account must be taken of any Best Available Techniques included in the BREF for specific (process) installations. The inclusion of technical installation requirements in the Wm permit is, in light of the system of emission trading, undesirable because they will restrict the desired flexibility of the system. For new installations this will be no problem because the companies invest of their own accord in Best Available Technology. In the case of overhaul permits, however, the inclusion of technical installation requirements can lead to problems. Also the difference in approach of the Wm competent authorities can lead to legal inequality. That is why the following arrangement has been made:
– At the moment, the IPPC Directive makes it necessary for specific installations that technical installation requirements are included in the Wm permit. The Netherlands advocates that the IPPC be amended in such a way that this no longer applies to companies that fall under a system of emission trading;
– In the interim period, it is proposed that the competent authority imposes requirements that fit within the IPPC Directive but offers maximum room for emission trading.

2) The argument for this is that emission trading is a steering factor in the making of choices for the desired emission reductions. By using the starting point mentioned above, maximum room for emission trading is indeed created without deviating from the EU Directives that must be observed in the issue of permits.

Table 3a Overview of emission requirements for flue gases

Indicative values for feasible emission concentrations of metals, particulates and mineral wool for glass furnaces and mineral wool furnaces, other components for mineral wool furnaces	Concentration (mg/Nm^3)	Comment
Metals		
Metals class 1: Arsenic, Cobalt, Nickel, Selenium*, Chromium (VI) and their compounds	1	
*Selenium compounds in situations where selenium feedstock must be used	3 to 5	
Metals class 2: Antimony, Lead, Chromium (III), Copper, Manganese, Vanadium, Tin and their compounds	5	
Particulates		
Particulate emissions from borosilicate glass furnaces and special glass furnaces, including continuous glass fibres, glass wool, glass fabric, special glases and several frit types	30	To be measured in the chimney directly after the flue gas cleaning installation. Where the excepted boric acid condensate is produced after the flue gas cleaning installation
Particulate emissions from soda lime glass furnaces, including table glass, packaging glass and float glass	5 to 30	
Fluorides		
Fluoride (given as HF) compounds**	5	
**Fluoride (given as HF) compounds from the manufacture if glass types in which fluoride feedstock must be used, including continuous glass fibres and frits	15	
Chlorides		
Chlorine (given as HCl) compounds for mineral wool furnaces	30	
Hydrogen sulphide		
Measures as H_2S for mineral wool furnaces	5	
Carbon monoxide		
Measured as CO for mineral wool furnaces	200	
This data is based on the values stated in the BREF, with adjustment for selenium emissions from furnaces with selenium feedstock		*Nm^3 at 273.15 K, 1013 mbar, dry flue gas with 8 volume % oxygen for oxyfuel burning must be converted to kg per tonne smelt*

Table 3b Overview of emission requirements for flue gases

Indicative values for emissions of metals, organic components, particulates, ammonia and amines from packaging glass coating installations and from designing and hardening processes for glass fibre, glass wool and mineral wool	Concentration (mg/Nm^3)	Comment
Waste gasses from packaging glass coating installations (hot end)		
Tin	5	
Organotin	10	
Post-treatment of glass fibres		
Particulates from post-treatment of glass fibres: coatings and drying processes, reduction	20	
Volatile Organic Compounds from post-treatment of glass fibres	50	
Post-treatment of glass wool and mineral wool: combined emission upon forming or forming plus hardening		
Particulates and particles	50	
Phenol	15	
Formaldehyde	10	
Ammonia	65	
Amines	5	
Volatile Organic Components	50	
Post-treatment of glass wool: emissions from hardening furnaces		
Particulates and particles	50	
Phenol	10	
Formaldehyde	10	
Ammonia	65	
Amines	5	
Volatile Organic Components	50	
This data is based on the values mentioned in the BREF		*Nm^3 at 273,15 K, 1013 mbar dry flue gas*

3.5.6.2 Summary of BREF

Introduction

This reference document on best available techniques in the glass industry reflects an information exchange carried out according to Article 16 (2) of Council Directive 96/61/EC. The document has to be seen in the light of the preface that describes the objective of the document and its use.

This document covers the industrial activities specified in Sections 3.3 and 3.4 of Annex 1 of Directive 96/61/EC, namely:

3.3 Installations for the manufacture of glass including glass fibre with a melting capacity exceeding 20 tonnes per day.

3.4 Installations for melting mineral substances including the production of mineral fibres with a melting capacity exceeding 20 tonnes per day.

For the purposes of this document the industrial activities falling within these descriptions in the Directive are referred to as the glass industry, which is considered to be comprised of eight sectors. These sectors are based on the products manufactured, but inevitably there is some overlap between them. The eight sectors are: container glass; flat glass; continuous filament glass fibre; domestic glass; special glass (including water glass); mineral wool (with two subsectors, glass wool and stone wool.); ceramic fibre; and frits.

The document is made up of seven chapters and a number of annexes containing supplementary information. The seven chapters and four annexes are:

1 General Information
2 Applied Processes and Techniques
3 Present Consumption and Emission Levels
4 Techniques to Consider in the Determination of BAT
5 BAT Conclusions
6 Emerging Techniques
7 Conclusions and Recommendations
8 Annex 1 Example installation emission data
9 Annex 2 Example sulphur balances
10 Annex 3 Monitoring
11 Annex 4 Member State Legislation

The objective of the executive summary is to summarise the main findings of the document. Due to the nature of the main document it is impossible to present all of its complexities and subtleties in such a short summary. Therefore, references are made to the main text and it should be stressed that only the main document in its entirety should be used as a reference in the determination of BAT for any particular installation. To base such decisions on the executive summary alone could lead to the information being taken out of context and to a misinterpretation of the complexities of the issues.

The Glass Industry

Chapter 1 provides general background information on the glass industry. Its main purpose is to provide a basic understanding of the industry as a whole to help decision makers view the information provided later in the document in context with the wider influences affecting the industry.

The glass industry within the European Union (EU) is extremely diverse, both in the products made and the manufacturing techniques employed. Products range from intricate hand-made lead crystal goblets to huge volumes of float glass produced for the construction and automotive industries. Manufacturing techniques vary from small electrically heated furnaces in the ceramic fibre sector to cross-fired regenerative furnaces in the flat glass sector, producing up to 700 tonnes per day. The wider glass industry also includes many smaller installations that fall below the 20 tonnes per day threshold in Annex 1 to the Directive.

The glass industry is essentially a commodity industry, although many ways of adding value to high volume products have been developed to ensure the industry remains competitive. Over 80 % of the industry output is sold to other industries, and the glass industry as a whole is very dependent on the building industry, and the food and beverage industry. However, some of the smaller volume sectors produce high value technical or consumer products.

The total production of the glass industry within the EU in 1996 was estimated at 29 million tonnes (excluding ceramic fibres and frits), an indicative breakdown by sector is given in the table below.

Approximate sector based breakdown of glass industry production (excluding ceramic fibre and frit sectors)

Sector	% of Total EU Production (1996)
Container Glass	60
Flat Glass	22
Continuous Filament Glass Fibre	1.8
Domestic Glass	3.6
Special Glass	5.8
Mineral Wool	6.8

Chapter 1 provides information for each sector under the following headings: sector overview, products and markets, commercial and financial considerations, and main environmental issues. Due to the diversity of the industry the information given is very different for each sector. As an illustrative example the information given for the container glass sector is summarised in the paragraph below. Comparable information is provided for all sectors where available.

Container glass production is the largest sector of the EU glass industry, representing around 60% of the total glass production. The sector covers the production of glass packaging i.e. bottles and jars although some machine made tableware may also be produced in this sector. In 1997 the sector produced over 17.3 million tonnes of glass products from the 295 furnaces operating in the EU. There are approximately 70 companies with 140 installations. Container glass is produced in all Member States with the exception of Luxembourg. The beverage sector accounts for approximately 75% of the total tonnage of glass packaging containers. The main competition is from alternative packaging materials steel, aluminium, cardboard composites and plastics. A significant development within the sector has been the increased use of recycled glass. The average rate of utilisation of post consumer waste within the EU container glass sector is approximately 50% of total raw material input, with some installations utilising up to 90% waste glass.

Applied Processes

Chapter 2 describes the processes and manufacturing techniques commonly encountered in the glass industry. Most processes can be divided into five basic stages: materials handling; melting; forming; downstream processing and packaging.

The diversity of the glass industry results in the use of a wide range of raw materials. The techniques used for materials handling are common to many industries and are described in Section 2.1 of the BREF. The main issue is the control of dust from the handling of fine materials. The main raw materials for melting are glass forming materials (e.g. silica sand, cullet), intermediate/modifying materials (e.g. soda ash, limestone, feldspar) and colouring/decolouring agents (e.g. iron chromite, iron oxide).

Melting, the combination of the individual raw materials at high temperature to form a molten glass, is the central phase in the production of glass. The melting process is a complex combination of chemical reactions and physical processes, and melting can be divided into several stages: heating; primary melting; fining and homogenisation; and conditioning.

The main melting techniques are summarised below. Different techniques are used within the stone wool and frits sectors, and these techniques are described in detail in the main document. Glass making is a very energy intensive activity and the choice of energy source, heating technique and heat recovery method are central to the design of the furnace. The same choices are also some of the most important factors affecting the environmental performance and energy efficiency of the melting operation. The three main energy sources for glass making are natural gas, fuel oil and electricity.

Regenerative furnaces utilise regenerative heat recovery systems. Burners are usually positioned in or below combustion air/waste gas ports. The heat in the waste gases is used to preheat air prior to combustion, by passing the waste gases through a chamber containing refractory material, which absorbs the heat. The furnace only fires on one side at a time. After about twenty minutes, the firing is reversed and the combustion air is passed through the chamber previously heated by the waste gases. Preheat temperatures up to 1400°C may be attained leading to very high thermal efficiencies. In the cross-fired regenerative furnace, combustion ports and burners are positioned along the sides of the furnace, and the regenerator chambers are located either side of the furnace. In the end-fired regenerative furnace the principles of operation are the same, however, the two regenerative chambers are situated at one end of the furnace.

Recuperative furnaces utilise heat exchangers (termed recuperators) for heat recovery, with continuous preheat of combustion air by the waste gases. Air preheat temperatures are limited to around 800°C for metallic recuperators. The specific melting capacity (per unit of melter area) of recuperative furnaces is around 30% lower than for a regenerative furnace. The burners are located along each side of the furnace, transverse to the flow of glass, and fire continuously from both sides. This type of furnace is primarily used where high flexibility of operation is required with minimum initial capital outlay, particularly where the scale of operation is too small to make the use of regenerators economically viable. It is more appropriate to small capacity installations although higher capacity furnaces (up to 400 tonnes per day) are not uncommon.

Oxy-fuel firing involves the replacement of the combustion air with oxygen (>90% purity). The elimination of the majority of the nitrogen from the combustion atmosphere reduces the volume of the waste gases by about two thirds. Therefore, furnace energy savings are possible because it is not necessary to heat the atmospheric nitrogen to the temperature of the flames. The formation of thermal NO_x is also greatly reduced. In general, oxy-fuel furnaces have the same basic design as unit melters, with multiple lateral burners and a single waste gas exhaust port. However, furnaces designed for oxygen combustion do not utilise heat recovery systems to pre-heat the oxygen supply to the burners.

Electric furnaces consist of a refractory lined box supported by a steel frame, with electrodes inserted either from the side, the top or more usually the bottom of the furnace. Energy for melting is provided by resistive heating as the current passes through the molten glass. The technique is commonly applied in small furnaces particularly for special glass.

There is an upper size limit to the economic viability of electric furnaces, which depends on the cost of electricity compared with fossil fuels. The replacement of fossil fuels in the furnace eliminates the formation of combustion products.

Combined fossil fuel and electric melting can take two forms: predominantly fossil fuel firing with electric boost; or predominantly electrical heating with a fossil fuel support. Electric boosting is a method of adding extra heat to a glass furnace by passing an electric current through electrodes in the bottom of the tank. A less common technique is the use of gas or oil as a support fuel for a principally electrically heated furnace.

Discontinuous batch melters are used where smaller amounts of glass are required, particularly if the glass formulation changes regularly. In these instances pot furnaces or day tanks are used to melt specific batches of raw material. Many glass processes of this type would not fall under the control of IPPC because they are likely to be less than 20 tonnes per day melting capacity. Basically a pot furnace consists of a lower section to preheat the combustion air and an upper section which holds the pots and serves as the melting chamber. Day tanks are further developed from pot furnaces to have larger capacities, in the region of 10 tonnes per day. Structurally they more closely resemble the quadrangle of a conventional furnace, but are still refilled with batch each day.

Special melter designs have been produced to improve efficiency and environmental performance. The best known of this type of furnace are the LoNox melter and the Flex Melter. Aspects of the main process and techniques used within the industry are outlined for each sector in the paragraphs below.

Container glass is a diverse sector and almost all of the melting techniques described above are found. The forming process is carried out in two stages, the initial forming of the blank either by pressing with a plunger, or by blowing with compressed air, and the final moulding operation by blowing to obtain the finished hollow shape. These two processes are thus respectively termed 'press and blow' and 'blow and blow'. Container production is almost exclusively by IS (Individual Section) machines.

Flat glass is produced almost exclusively with cross-fired regenerative furnaces. The basic principle of the float process is to pour the molten glass onto a bath of molten tin, and to form a ribbon with the upper and lower surfaces becoming parallel under the influence of gravity and surface tension. From the exit of the float bath the glass ribbon is passed through the annealing lehr, gradually cooling the glass to reduce residual stresses. On-line coatings can be applied to improve the performance of the product (e.g. low emissivity glazing).

*Continuous filament glass fibr*e is produced using recuperative or oxy-fuel fired furnaces. The glass flows from the furnace to the forehearths where it is passes through bushings at the base. The glass is drawn through the bushing tips to form continuous filaments. The filaments are drawn together and pass over a roller or belt, which applies an aqueous coating to each filament. The coated filaments are gathered together into bundles (strands) for further processing.

Domestic glass is a diverse sector involving a wide range of products and processes. Ranging from intricate handmade lead crystal, to high volume, mechanised methods used for mass produced tableware. Almost all of the melting techniques, described above are used in the sector, from pot furnaces to large regenerative furnaces. The forming processes are automatic processing, hand made or semi-automatic processing, and following production the basic items can be subjected to cold finishing operations (e.g. lead crystal is often cut and polished).

Special glass is also a very diverse sector, covering a wide range of products that can differ considerably in composition, method of manufacture and use. The most common techniques are recuperative furnaces, oxy-gas furnaces, regenerative furnaces, electric melters and day tanks. The wide product range means that many forming techniques are used within the sector. Some of the most important are: press and blow production; rolling; pressing, ribbon process; tube extrusion; the drawing process; and dissolution (water glass).

Glass wool furnaces are usually either electric melters, gas fired recuperative furnaces, or oxyfuel furnaces. Molten glass flows along a forehearth and through single orifice bushings into rotary centrifugal spinners. Fiberising is by centrifugal action with attenuation by hot flame gases. An aqueous phenolic resin solution is sprayed onto the fibres. The resin coated fibre is drawn under suction onto a moving conveyor and then passes through an oven to dry and cure the product.

Stone wool is usually produced with the coke fired hot blast cupola. The molten material gathers in the bottom of the furnace and flows out along a short trough onto the spinning machine. Air is used to attenuate the fibres and to direct them onto the collection belts. An aqueous phenolic resin solution is sprayed onto the fibres by a series of spray nozzles. The remainder of the process is essentially as for glass wool.

Ceramic fibre is produced exclusively using electric furnaces. The melt is fiberised either by high speed wheels or a high pressure air jet, and the fibres are drawn on to a collection belt. The product can be baled at this point or processed into blanket to be baled as product or needle felted. Further downstream processing may also be carried out.

Frit production utilises both continuous furnaces and batch furnaces. It is common for small batches to be produced for a wide range of formulations. Frit furnaces are generally natural gas or oil fired, and many frit plants use oxy-fuel firing. Continuous furnaces can be cross-fired or endfired with a single burner. Discontinuous batch furnaces are box shaped or cylindrical refractory lined vessels, mounted to allow a degree of rotation. The melt can be quenched directly in a water bath, or can be cooled between water cooled rollers to produce a flake product.

Consumption and Emission Levels

Chapter 3 provides information on the ranges of consumption and emission levels that are encountered within the glass industry across the scope of processes and techniques described in Chapter 2. The inputs and outputs are discussed for the industry as a whole, and then a more specific consideration is made for each sector. The key emission characteristics, emission sources and energy issues are identified in this chapter. The information is intended to allow the emission and consumption figures for any particular installation being considered for a permit, to be viewed in context against other processes in the same sector or in the glass industry as a whole.

The core process inputs can be divided into four main categories: raw materials (those materials which form part of the product), energy (fuels and electricity), water, and ancillary materials (processing aids, cleaning materials, water treatment chemicals, etc). Glass industry raw materials are largely solid inorganic compounds, either naturally occurring minerals or manmade products. They vary from very coarse materials to finely divided powders. Liquids and gases are also widely used, both as ancillary materials and as fuels.

In the main document Table 3.1 lists the most common raw materials used for the production of glass. The raw materials used in product forming and other downstream activities (e.g. coatings and binders) are more specific to each sector and are discussed in later sections. The glass industry as a whole is not a major consumer of water, the main uses being cooling, cleaning and batch humidification. Glass making is an energy intensive process and therefore fuels can form a significant input to the processes. The main energy sources within the glass industry are fuel oil, natural gas and electricity. Energy and fuel issues are discussed in Section 3.2.3 and in the sector specific sections.

The core process outputs can be divided into five main categories: product, emissions to air, liquid waste streams, solid process residues, and energy.

All of the sectors within the glass industry involve the use of powdered, granular or dusty raw materials. The storage and handling of these materials represents a significant potential for dust emissions.

The major environmental challenges for the glass industry are emissions to air and energy consumption. Glass making is a high temperature, energy intensive activity, resulting in the emission of products of combustion and the high temperature oxidation of atmospheric nitrogen; i.e. sulphur dioxide, carbon dioxide, and oxides of nitrogen. Furnace emissions also contain dust and lower levels of metals. It is estimated that in 1997 the glass industry emissions to air consisted of: 9000 tonnes of dust; 103500 tonnes of NO_x; 91500 tonnes of SOx; and 22 million tonnes of CO_2 (including electrical generation). This amounted to around of 0.7% of total EU emissions of these substances. Total energy consumption by the glass industry was approximately 265 PJ. The main emissions arising from melting activities within the glass industry are summarised in the table below.

Summary of emissions to atmosphere arising from melting activities

Emission	Source / Comments
Particulate matter	Condensation of volatile batch components.
	Carry over of fine material in the batch.
	Product of combustion of some fossil fuels.
Oxides of Nitrogen	Thermal NOx due to high melter temperatures.
	Decomposition of nitrogen compounds in the batch materials.
	Oxidation of nitrogen contained in fuels.
Oxides of Sulphur	Sulphur in fuel.
	Decomposition of sulphur compounds in the batch materials.
	Oxidation of hydrogen sulphide in hot blast cupola operations.
Chlorides/HCl	Present as an impurity in some raw materials, particularly man made sodium carbonate. NaCl used as a raw material in some special glasses.
Fluorides/HF	Present as a minor impurity in some raw materials.
	Added as a raw material in the production of enamel frit to provide certain properties in the finished product.
	Added as a raw material in the continuous filament glass fibre industry, and in some glass batches to improve melting, or to produce certain properties in the glass e.g. opalescence.
	Where fluorides are added to the batch, typically as fluorspar, uncontrolled releases can be very high.
Heavy Metals (e.g. V, Ni, Cr, Se, Pb, Co, Sb,As, Cd)	Present as minor impurities in some raw materials, post consumer cullet, and fuels.
	Used in fluxes and colouring agents in the frit industry (predominantly lead and cadmium).
	Used in some special glass formulations (e.g. lead crystal and some coloured glasses).
	Selenium is used as a colorant (bronze glass), or as a decolourising agent in some clear glasses.
Carbon Dioxide	Combustion product.
	Emitted after decomposition of carbonates in the batch materials (e.g. soda ash, limestone).
Carbon Monoxide	Product of incomplete combustion, particularly in hot blast cupolas.
Hydrogen Sulphide	Formed from raw material or fuel sulphur in hot blast cupolas due to the reducing conditions found in parts of the furnace.

The emissions from downstream activities can vary greatly between the different sectors and are discussed in the sector specific sections. Although there are similarities in the melting techniques used in many sectors the downstream activities tend to be specific. Emissions to air can arise from: coating application and/or drying; secondary processing (e.g. cutting, polishing, etc); and from some product forming operations (e.g. mineral wool, and ceramic fibre).

In general, emissions to the water environment are relatively low and there are few major issues that are specific to the glass industry. However, there are activities undertaken in some sectors which require further consideration and are discussed in the sector specific sections, particularly domestic glass, special glass and continuous filament glass fibre.

A characteristic of most of the sectors is that the great majority of internally generated glass waste is recycled back to the furnace. The main exceptions to this are the continuous filament sector, the ceramic fibre sector and producers of very quality sensitive products in the special glass and domestic glass sectors. The mineral wool and frits sectors show a wide variation in the amount of waste recycled to the furnace ranging from nothing to 100 % for some stone wool plants.

Techniques for Consideration in the Determination of BAT

Many of the sectors within the glass industry utilise large continuous furnaces with lifetimes up to twelve years. These furnaces represent a large capital commitment and the continuous operation of the furnace and the periodic rebuild provide a natural cycle of investment in the process. Major changes of melting technology are most economically implemented if coincided with furnace rebuilds, and this can also be true for complex secondary abatement measures. However, many improvements to the operation of the furnace, including the installation of secondary techniques, are possible during the operating campaign.

This summary briefly outlines the main techniques for controlling each substance emitted from melting activities and from some of the downstream operations. It concentrates predominantly on emissions to air as these are generally the most significant emissions from glass processes. Chapter 4 gives detailed descriptions of each technique and explains the emission levels achieved, the applicability of the technique, financial issues and other associated considerations.

Particulate Matter

Techniques for controlling particulate emissions include secondary measures, generally electrostatic precipitators and bag filters, and primary measures.

The electrostatic precipitator (EP) consists of a series of high voltage discharge electrodes and corresponding collector electrodes. Particles are charged and subsequently separated from the gas stream under the influence of the electric field. EPs are very effective in collecting dust in the range 0.1 µm to 10 µm, and overall collection efficiency can be 95–99%. Actual performance varies depending mainly on waste gas characteristics and EP design. In principle, this technique is applicable to all new and existing installations in all sectors (except stone wool cupolas due to the risk of explosion). Costs are likely to be higher for existing plants, particularly where there are space restrictions.

In most applications a modern well designed two or three stage EP could be expected to achieve 20 mg/m^3. Where high efficiency designs are used or where favourable conditions exist lower emission levels are often possible. Costs vary greatly, depending heavily on required performance and waste gas volume. Capital costs (including acid gas scrubbing) are generally in the range 0.5 to 2.75 million euros, with operating costs 0.03 to 0.2 million euros annually.

Bag filter systems use a fabric membrane which is permeable to gas but which will retain the dust. Dust is deposited on and within the fabric, and as the surface layer builds up it becomes the dominating filter medium. The direction of gas flow can be either from the inside of the bag to the outside, or from the outside to the inside. Fabric filters are highly efficient and a collection efficiency of 95–99% would be expected. Particulate emissions between 0.1 mg/m^3 and 5 mg/m^3 can be achieved and levels consistently below 10 mg/m^3, could be expected in most applications. The ability to achieve such low levels can be important if dusts contain significant levels of metals, and low metal emissions must be achieved.
In principle, bag filters are applicable to all new and existing installations in all sectors. However, due to their potential to blind in certain circumstances, they are not the preferred choice in all applications. In most cases there are technical solutions to these difficulties, but there may be an associated cost. Capital and operating costs are broadly comparable with EPs.

Primary control techniques are based mainly on raw material changes and furnace/firing modifications. In most applications primary techniques cannot achieve emission levels comparable with bag filters and EPs.

Oxides of Nitrogen (NO_x)
The most appropriate techniques for controlling emissions of NO_x are generally: primary measures, oxy-fuel melting, chemical reduction by fuel, selective catalytic reduction and selective non-catalytic reduction.

Primary measures can be split into two main types 'conventional' combustion modifications and then special furnace designs or optimised combustion design packages. Oxy-firing is also a primary technique but is dealt with separately due to its specific nature. Conventional combustion modifications are usually based on: reduced air/fuel ratio, reduced preheat temperature, staged combustion and low NO_x burners; or a combination of these techniques. Capital costs are generally quite low and operating costs are often reduced due to reduced fuel usage and improved combustion. A great deal of progress has been made in this area, but the emission reductions achievable clearly depend on the starting point. NO_x reductions of 40–60% are not uncommon and emission levels of less than 650–1100 mg/Nm^3 have been achieved in some applications.

Special furnace designs have been developed which reduce NO_x emissions, e.g. the LONOx melter. These designs have been very successful but there are certain process constraints that limit their applicability. The FENIX process is a combustion optimisation package based on primary measures, that is tailored for a specific furnace. Results of 510 mg/Nm^3 and around 1.1 kg/tonne of melt have been reported, but the number of examples is limited at the time of writing.

Oxy-fuel firing involves the replacement of the combustion air with oxygen. The elimination of the majority of the nitrogen from the combustion atmosphere reduces the volume of the waste gases by about two thirds. Therefore, energy savings are possible because it is not necessary to heat the atmospheric nitrogen to the temperature of the flames. The formation of thermal NO_x is greatly reduced, because the only nitrogen present in the combustion atmosphere is the residual nitrogen in the oxygen/fuel, nitrogen from nitrate breakdown, and that from any parasitic air.

The principle of oxy-fuel firing is well established and in principle can be considered as applicable to the industry as a whole. However, the technique is still considered by some sectors (particularly flat glass and domestic glass), as a developing technology with potentially high financial risk. Considerable development work is being undertaken and the technique is becoming more widely accepted as the number of plants increases. The issues surrounding this technique are very complex and are discussed in detail in Chapter 4.

The economic competitiveness of the technique depends largely on the scale of energy savings (and the relative costs of alternative abatement techniques) compared with the cost of oxygen. Both the technical and economic viability of the technique are heavily dependent on site specific issues.

Chemical reduction by fuel describes those techniques where fuel is added to the waste gas stream to chemically reduce NO_x to N_2 through a series of reactions. The fuel does not burn but pyrolyses to form radicals which react with the components of the waste gas. The two main techniques that have been developed for use in the glass industry are the 3R process and the Reburning process. Both of these techniques are currently restricted to regenerative furnaces. The 3R process has been fully developed for application within the industry and the Reburning process has been run at full plant scale and has shown promising results. The 3R process can achieve emission levels of less than 500 mg/Nm^3 corresponding to an increase in fuel usage of 6–10%. The Reburning process is hoped to achieve comparable emission levels following development. The increased energy usage for both techniques can be greatly reduced by the use of energy recovery systems, and by combining the techniques with primary measures.

Selective catalytic reduction (SCR) involves reacting NO_x with ammonia in a catalytic bed generally at around 400°C. Most applications in the glass industry will require a 3-stage system including dust abatement and acid gas scrubbing. Systems are normally designed to achieve 75–95% reductions, and in general emission levels of less than 500 mg/Nm^3 are achievable. The cost of SCR depends mainly on the waste gas volume and the desired NO_x reduction. In general, capital costs (including EP and scrubbing) are in the range 1 million to 4.5 million euros with operating costs 0.075 to 0.5 million euros annually. In principle, SCR can be applied to most processes in the glass industry and to both new and existing processes. However, there are a number of issues that can limit the applicability of the technique in certain cases. For example, the technique has not been proven for heavy fuel oil fired glass furnaces, glass wool or continuous filament glass fibre.

Selective non-catalytic reduction (SNCR) operates on the same basis as SCR but the reactions take place at higher temperature (800–1100°C) without the need for a catalyst. SNCR does not require dust abatement or acid gas scrubbing. Reduction efficiencies of 30–70% are generally achievable, the critical factor is the availability of sufficient ammonia at the correct temperature window. Capital costs are in the range 0.2 to 1.35 million euros and operating costs from 23000 to 225000 euros per year, depending on furnace size. In principle, the technique is applicable to all glass processes including new and existing plants.

The main limitation to the applicability of SNCR is whether the reagent can be introduced at a point in the waste gas system where the correct temperature can be maintained for an adequate reaction time. This is of particular relevance in existing plants and for regenerative furnaces.

Oxides of Sulphur (SO_x)
The main techniques for controlling SO_x emissions are fuel selection, batch formulation and acid gas scrubbing.

In oil fired processes the main source of SO_x is the oxidation of sulphur in the fuel. The amount of SO_x derived from the batch materials varies depending on the glass type but in general wherever oil is burned the SO_x emissions from the fuel outweigh those from the batch materials. The most obvious way to reduce SO_x emissions is to reduce the sulphur content of the fuel. Fuel oil is available in various sulphur grades (<1%, <2%, <3% and >3%), and natural gas is essentially sulphur free. The conversion to a lower sulphur content fuel does not generally result in any increased costs except the higher fuel price. The conversion to gas firing requires different burners and a range of other modifications. The prices of the various fuels vary substantially with time and between Member States, but in general lower sulphur fuels are more expensive. As explained in Chapter 5 the financial and political issues associated with fuel pricing and availability are such that fuel selection is considered to be outside the scope of this document. However, where natural gas is burned SO_x emissions will usually be lower, and where oil is burned a sulphur level of 1% or less is considered BAT. Burning higher sulphur content fuels may also represent BAT if abatement is used to achieve equivalent emission levels.

In conventional glass making, sulphates are the main source of SO_x emissions from batch materials. Sulphates are the most widely used fining agents and are also important oxidising agents. In most modern glass furnaces the levels of batch sulphates have been reduced to the minimum practicable levels, which vary depending on the glass type. The issues surrounding the reduction of batch sulphates are discussed in Section 4.4.1.1 and the issues relating to the recycling of filter/EP dust are discussed in Section 4.4.3.3.

In stone wool production important sources of SO_2 emission (in addition to coke) are the use of blast furnace slag and cement bound briquettes in the batch. The availability of low sulphur coke and slag are restricted by very limited supply within economical transport distances. Slag can generally be eliminated from most batches, with the exception of the production of limited amounts of white fibre for specific applications.

The use of cement bound waste briquettes involves a balance between waste minimisation and SO_x emission reduction, which will often depend on specific priorities and must be considered in association with the use of acid gas scrubbing. This issue is discussed extensively in chapters 4 and 5 of the main document.

The operating principles of dry and semi-dry scrubbing are the same. The reactive material (the absorbent) is introduced to, and dispersed in the waste gas stream. This material reacts with the SOx species to form a solid, which must be removed from the waste gas stream by an electrostatic precipitator or bag filter system. The absorbents chosen to remove SOx are also effective in removing other acidic gases. In the dry process the absorbent is a dry powder (usually $Ca[OH]_2$, $NaHCO_3$, or $Na_2[CO]_3$). In the semi-dry process the absorbent (usually Na_2CO_3, CaO or $Ca[OH]_2$) is added as a suspension or solution and water evaporation cools the gas stream. The reductions achieved with the techniques depend on a number of factors including waste gas temperature, the amount and type of absorbent added (or more precisely the molar ratio between reactant and pollutants) and the dispersion of the absorbent. Section 4.4.3.3 outlines the efficiencies obtained with various absorbents and processes.

The complete recycling of filter dust, including the sulphated waste, is often considered to be a reasonable environmental and economic option, where it is technically possible. The overall reduction of SOx emissions is limited (by mass balance considerations) to the reduction at source obtained by substituting sulphate in the raw materials by filter dust. (Clearly this is in addition to other appropriate primary measures to reduce overall sulphur input.) Therefore, in order to reduce acid gas emissions, it may be necessary to consider an external disposal route for a portion of the collected material. The determination of what represents the best protection of the environment as a whole can often be site-specific and may involve balancing the potentially conflicting priorities of waste minimisation and SO_x emission reduction. Where this is the case a process sulphur balance will be essential in determining emission levels commensurate with BAT.

With closed loop filter dust recycling, the SO_x emission levels observed today, are generally in the range of 200–800 mg/Nm^3 for natural gas firing and 800–1600 mg/Nm^3 with 1% S fuel oil. The majority of installed SO_x scrubbing systems operate with dry lime scrubbing at a temperature of around 400°C, which is the waste gas temperature obtained from an efficient regenerative type furnace. At these temperatures, an SO_x reduction of around 50% can be achieved. An improved SO_x reduction rate can be reached at temperatures around 200°C and with a humid atmosphere but this involves further considerations.

SO_x scrubbing is an extremely complex area which generated a great deal of discussion within the technical working group. It is therefore essential that the discussion and explanation presented in chapters 4 and 5 are considered in full.

Fluorides (HF) and Chlorides (HCl)
HF and HCl emissions generally arise from the volatilisation of fluorides and chlorides in the batch materials, either present as impurities, or added intentionally to provide specific product or processing characteristics to the glass. The main techniques for the reduction of these emissions are batch modification or scrubbing. Where the halides are present as impurities emissions can generally be controlled by raw material selection, although scrubbing is often used either where raw material selection is not sufficient or where scrubbing is used to control other substances. Where halides are used to impart specific characteristics there are two main approaches scrubbing or batch reformulation to achieve the same characteristics by other means. Particular successes with reformulation have been achieved in continuous filament glass fibre.

Emissions from Non-Melting Activities
Emissions from downstream processing are sector specific and are described in some detail in Section 4.5 of the main document. With the exception of the mineral wool sector emissions are generally much lower than from the melting activities. Abatement techniques are generally based on conventional dust collection and wet scrubbing techniques with some thermal oxidation.

In mineral wool processes there is the potential for substantial emissions from the application and curing of organic resin based binder systems. The techniques for controlling these emissions are discussed in detail in Section 4.5.6 of the main document.

Emissions to Water
In general, emissions to the water environment are relatively low and there are few major issues that are specific to the glass industry. Water is used mainly for cleaning and cooling and can be readily recycled or treated using standard techniques. Specific issues of organic contamination can arise from mineral wool and continuous filament glass fibre processes. Issues of heavy metals (particularly lead) can arise from special glass, frits and domestic glass processes. The table below identifies the main potential techniques for controlling emissions to water.

List of potential wastewater treatment techniques for use in the Glass Industry

Physical/Chemical Treatment	Biological Treatment
• Screening	• Activated sludge
• Skimming	• Biofiltration
• Settlement	
• Centrifuge	
• Filtration	
• Neutralisation	
• Aeration	
• Precipitation	
• Coagulation and Flocculation	

Solid Waste
A characteristic of the glass industry is that most of the activities produce relatively low levels of solid waste. Most of the processes do not have significant inherent by-product streams. The main process residues are unused raw materials, waste glass that has not been converted into the product, and waste product. Other solid wastes include waste refractory and dust collected in abatement equipment or flues. Non-fibrous waste is generally readily recycled to the process and techniques are under development for recycling other wastes. The extent of waste recycling is increasing as financial incentives develop, particularly increased disposal costs. The main process residues encountered in the glass industry and the techniques used to control them are discussed in Section 4.7 of the main document.

Energy
Glass making is a very energy intensive process and the choices of energy source, heating technique and heat recovery method are central to the design of the furnace and to the economic performance of the process. The same choices are also some of the most important factors affecting the environmental performance and energy efficiency of the melting operation. In general, the energy necessary for melting glass accounts for over 75% of the total energy requirements of glass manufacture. The cost of energy for melting is one of the largest operational costs for glass installations and there is a significant incentive for operators to reduce energy use.
The main techniques for reducing energy usage are listed below and are discussed in detail in the main document:

- Melting technique and furnace design (e.g. regenerators, recuperators, electric melting, oxyfuel combustion, and electric boost).
- Combustion control and fuel choice (e.g. low NO_x burners, stoichiometric combustion, oil/gas firing).
- Cullet usage
- Waste heat boilers
- Cullet/batch preheating

Summary of BAT Conclusions
Chapter 5 presents the conclusions on the best available techniques to achieve integrated prevention and control of pollution in the glass industry. The chapter contains an introduction, a general section and then sector specific conclusions. It is intended that the 'general BAT' in Chapter 5 could be used to judge the current performance of an existing installation or to judge a proposal for a new installation and thereby assist in the determination of appropriate 'BAT' – based conditions for that installation. The figures presented are not emission limit values and should not be understood as such. The appropriate emission limit values for any specific case will need to be determined taking into account the objectives of the IPPC Directive and the local considerations.

Chapter 5 was written following a great deal of discussion and redrafting within the Technical Working Group. The context and subtleties of the conclusions are very important and it is difficult to summarise the chapter without compromising these issues and the effort and discussion that was required to get to the current position. This summary outlines the main conclusions of Chapter 5 but it is essential that the full document and particularly the full text of Chapter 5 are consulted for a full understanding.

This summary outlines some of the industry wide issues and then summarises the main general conclusions using a predominantly substance based approach. One important conclusion that came out of this work was that the glass industry is so diverse that it is often inappropriate to specify particular techniques. The general approach taken in Chapter 5 is to identify levels of performance that are indicative of the best available techniques, but at the same time acknowledging that the best way of achieving these levels of performance could differ from process to process.

General
An important characteristic of many installations in the glass industry is the periodic rebuild of the furnaces, although the extent of the rebuild can vary. There may be technical and economic advantages to co-ordinating the implementation of certain techniques until a rebuild, but this is not always the case. The rebuild cycle also means the age of a furnace is important in determining the appropriate course of action in terms of overall BAT.

The reference conditions for Chapter 5 are:
- For combustion gases: dry, temperature 0°C (273 K), pressure 101.3 kPa, 8% oxygen by volume (continuous melters), 13% oxygen by volume (discontinuous melters). For oxy-fuel fired systems the expression of the emissions corrected to 8% oxygen is of little value, and emissions from these systems should be discussed in terms of mass.
- For others gases (including emissions from curing and drying ovens without tail gas incineration): temperature 0°C (273 K), pressure 101.3 kPa with no correction for oxygen or water vapour concentration.

In the main document, emission levels associated with BAT are presented as ranges for both emission concentration (mg/m^3) and mass emission (kg/tonne of glass melted), to allow comparison between furnace techniques and to provide an indication of the relative environmental impact. For fossil fuel fired furnaces the relationship between mass and concentration depends predominantly on specific energy consumption for melting, but this varies considerably depending on a wide range of factors including melting technique, furnace size and glass type. For such a diverse industry it is very difficult to relate concentrations and mass emission figures directly without presenting ranges so wide as to diminish the value of numerical conclusions. Therefore, the approach taken is to give concentration figures as the basis of BAT and to use indicative conversion factors based on modern energy efficient furnaces to determine mass emission figures which 'generally equate to' these concentration levels.

For the purposes of this executive summary emission levels associated with BAT are given in concentration only. The exception to this is where techniques such as oxy-firing are discussed and mass emissions are the most meaningful way of describing the performance level. For the mass per tonne of glass melted reference should be made to the discussion on conversion factors in Section 5.2 and to the sector specific sections in Chapter 5.

Particulate Matter/Dust
The conclusion regarding dust emissions was broadly comparable for all sectors and is summarised in the paragraph below. There were two minor exceptions to this conclusion. For ceramic fibre the emission level associated with BAT was considered to be less than 10 mg/Nm^3 due to the nature of the particulate matter. For frit processes the general conclusion was as given below but it was acknowledged that for some installations a degree of development would be required to achieve these levels.

In general, BAT for controlling dust emissions from furnaces in the glass industry is considered to be the use of either an electrostatic precipitator or bag filter system, operating where appropriate, in conjunction with a dry or semi-dry acid gas scrubbing system. The BAT emission level associated with these techniques is 5–30 mg/Nm^3 which generally equates to less than 0.1 kg/tonne of glass melted. Values in the lower part of the range given would generally be expected for bag filter systems. These figures are based on a typical averaging period of not less than 30 minutes and not greater than 24 hours. In some cases the application of BAT for metals emissions may result in lower emissions levels for dust.

Some opinions within the Technical Working Group differed on whether the environmental benefits of secondary abatement of dust justified the higher costs in all cases. However, the general conclusion is that on balance secondary dust abatement represents BAT for most glass furnaces, unless equivalent emissions can be achieved with primary measures. The pros and cons of primary and secondary techniques are discussed extensively in Section 4.4.1.7 and 5.2.2.

Oxides of Nitrogen

This substance proved to be one of the most difficult on which to reach firm BAT conclusions. In particular, it is difficult to ascribe general emission levels that apply to more than one sector. It is therefore essential that the figures given in this section are only viewed as an indicative summary of the conclusions presented in Chapter 5. To base any consideration of BAT permit conditions on the information in this summary without reference to the main document would be to take the figures completely out of context. This could lead to unnecessarily stringent or lenient benchmarks being used for comparison.

For oxides of nitrogen the selection of techniques that represents BAT will depend very much on the site-specific issues, in particular the melting technique used and the age of the furnace. Certain techniques may achieve different results in different applications and may incur differing costs depending on site specific conditions.

For container glass, flat glass, special glass (including water glass), mineral wool and frit processes it is considered that the emission level for oxides of nitrogen (expressed as NO_2) associated with the techniques that will generally constitute BAT is 500–700 mg/Nm^3. Although the emission level associated with BAT is generally the same, the techniques that can be used to achieve these levels, their associated costs, and the relative difficulty of applying them vary between the sectors.

There are various situations where further considerations are necessary and the emission levels indicated above may not be appropriate. For example, where nitrates are needed, where certain recycled materials are used or where a furnace is nearing the end of its campaign. These considerations are very important and are discussed in the sector specific sections of Chapter 5.

At the time of writing the continuous filament sector is going through a transition period in NO_x control, which makes it difficult to form firm conclusions regarding BAT. The most promising technique appears to be oxy-fuel melting, although some good results have been achieved with primary measures and there are no overriding technical obstacles to the use of SNCR.

In general in this sector, BAT for oxides of nitrogen (expressed as NO_2) is considered likely to be oxy-fuel melting; and the emission level associated with BAT is considered to be 0.5–1.5 kg/tonne of glass melted. This statement is not a firm conclusion, rather a balanced judgement based on the information available at the time of writing. It is acknowledged that the technique still carries an element of financial risk, but it is expected that the technique will become more widely accepted as BAT in the medium term. Where other techniques are practicable a comparable BAT emission level for air fuel fired furnaces is considered to be 500–700 mg/Nm^3.

Similarly it is difficult to form firm conclusions for NO_x levels in the domestic glass sector. There are certain issues specific to the sector which affect the options for NO_x control. Some of these can be illustrated by a comparison with container glass e.g. potentially higher quality constraints; lower production volumes; smaller average furnace size; cullet restrictions; higher temperatures and longer residence times. All of these factors lead to higher specific energy consumption and increase the potential for NO_x formation. In general where electrical melting (either 100% or predominantly electrical) is economically viable, and particularly for lead crystal, crystal glass and opal glass production the technique is considered BAT. In this case, the emission level associated with BAT would generally be 0.2–1.0 kg/tonne of glass melted.

Where electrical melting is not economically viable a number of other techniques could be used. The domestic glass sector utilises a wide range of furnace types and the most appropriate technique will generally be installation specific. It is envisaged that given the necessary time for development and implementation of techniques, the emission level for oxides of nitrogen (expressed as NO_2) associated with BAT will be 500–700 mg/Nm^3 (or for oxy-fuel melting 0.5–1.5 kg/tonne of glass melted). This is based on the use of (or combinations of) primary measures (combustion modifications), oxy-fuel firing, SNCR, SCR or 3R/Reburning (regenerative furnaces only).

Stone wool cupolas do not generally give rise to substantial NO_x emissions and emissions less than 0.5 kg/tonne of melt can be achieved without specific controls. Where tank furnaces are used the emission level associated with BAT is considered to be equivalent to glass wool production. Ceramic fibre is produced exclusively with electric furnaces and NO_x emissions are generally significantly below 0.5 kg/tonne of melt.

Oxides of Sulphur

The determination of emission levels associated with BAT for each of the sectors is a complex subject with many inter-related and in some instances conflicting considerations. These issues are explained in detail in chapters 5 and 4 with the information presented here only an indicative summary.

A major influence is the choice of fuel and its sulphur level. Therefore, the circumstances for oil and gas firing are considered separately. Furthermore, certain formulations, particularly sodalime glasses, require the use of sulphates in the batch, and clearly such formulations will tend to show higher unabated SO_2 emissions.

It is envisaged that in most instances BAT for dust emissions will involve the use of a dust abatement system, which will often include acid gas scrubbing, and this is taken into account in the proposed emission levels associated with BAT in Chapter 5. The sulphated waste produced can generally be recycled with the furnace raw materials to avoid the generation of a solid waste stream. However, there is a limit to the extent to which the glass can act as a sink for the sulphur and the system can rapidly reach an equilibrium where a significant amount of the sulphur recycled is re-emitted. Therefore, with full dust recycling the desulphurisation effect of the scrubber can be limited by the capacity of the glass to absorb sulphur.

In order to reduce SO_2 emissions further it may be necessary to consider an external disposal route or if practicable to reduce fuel sulphur levels. The economically viable options for recycling the material off-site are extremely limited and the most likely disposal route is landfill, resulting in a solid waste stream. From an integrated environmental approach there is a need to consider the relative priorities of the reduction of SO_2 emissions and the potential generation of a solid waste stream. The most appropriate approach may differ from process to process and for this reason emission levels are presented for where SO_2 reduction is the priority and for where waste reduction is the priority. In practice there are many cases where the lower emission level can be achieved with full dust recycling.

The table below summarises the emission levels associated with BAT for each sector and for various situations. Again this is only an indicative summary and reference should be made to Chapter 5 to allow consideration of the complexities involved.

Indicative summary of oxides of sulphur emission levels associated with BAT (expressed as SO_2)

Sector	BAT emission levels ($mgSO_2/Nm^3$)		Comments
	Gas-firing	*Oil-firing*	
Container glass with SO_2 reduction as priority	200–500	500–1200	
Container glass with waste minimisation as priority	<800	<1500	Where mass balance does not allow the figures above to be achieved
Flat glass with SO_2 reduction as priority	200–500	500–1200	
Flat glass with waste minimisation as priority	<800	<1500	Where mass balance does not allow the figures above to be achieved
Continuous filament glass fibre	<200	500–1000	If sulphates in batch, gas-firing could be up to 800. For oil-firing, upper end of range relates to dust recycling
Domestic glass	200–500	500–1300	If low sulphate in batch, then <200 for gas-firing. Figures in upper part of ranges relate to dust recycling
Special glass including water glass	200–500	500–1200	Figures in upper part of ranges relate to dust recycling
Glass wool	generally <50	300–1000	Generally low sulphate glass
Stone wool (coke fired) with waste minimisation and recycling as priority	(a) <600 (b) <1100 (c) <1400		(a) Stone charge (b) 45% cement bound briquettes (c) Cement briquettes inc. filter dust
Stone wool (coke fired) with SO_2 reduction as priority	(a) < 200 (b) < 350 (c) < 420		(a) Stone charge (b) 45% cement bound briquettes (c) Cement briquettes inc. filter dust
Ceramic fibre (electric melting)	<0.5 kg/tonne melt		Electric furnaces only, concentration will be case specific
Frits	<200	500–1000	Oil firing is rare

Other Emissions from Melting
Each of the sector-specific sections in Chapter 5 has a subsection to cover those emissions from the melting operations other than dust, NO_x, and SOx. The most significant of these 'other emissions' are generally chlorides (expressed as HCl), fluorides (expressed as HF), and metals and their compounds. Certain metals are grouped together and termed either Group 1 or Group 2. Those metals, which fall outside of these groupings are either specified individually, due to their higher toxicity, or covered only within the category of dust, because their low toxicity does not justify specific consideration. The two Groups are given in the table below.

Classifications of metals and their compounds

Group 1 metals and their compounds	Group 2 metals and their compounds
• arsenicum	• antimoon
• Arsenic	• Antimony
• Cobalt	• Lead
• Nickel	• Chromium III
• Selenium	• Copper
• Chromium VI	• Manganese
	• Vanadium
	• Tin

The BAT conclusions for most sectors relating to these substances were generally equivalent. BAT for controlling these emissions is considered to be raw material selection to minimise emissions, combined with acid gas scrubbing, where appropriate. Acid gas scrubbing may not always be necessary either to protect the abatement equipment or to achieve the figures given for SOx. Where this is the case, acid gas scrubbing is considered to constitute BAT if the levels identified below cannot be achieved by primary measures.

The emission levels associated with BAT for the pollutants specified below are considered to be:

- Chlorides (expressed as HCl) <30 mg/Nm³
- Fluorides (expressed as HF) <5 mg/Nm³
- Metals (gas + solid phase) (Group 1 + Group 2) <5 mg/Nm³
- Metals (gas + solid phase) (Group 1) <1 mg/Nm³

In the frits and special glass sectors there are some cases with potential emissions of cadmium and thallium. The emission level associated with BAT for these metals and their compounds is <0.2 mg/Nm³. For the production of continuous filament glass fibre the fluoride emission level associated with BAT is 5–15 mg/Nm³. The lower end of this range relates to non-fluoride added compositions and the higher end relates to added fluoride compositions.

In the stone wool sector emission levels associated with BAT are also given for carbon monoxide and hydrogen sulphide. These are <200 mg/Nm³ and <5 mg/Nm³, respectively.

Downstream Processes
Downstream processes vary greatly depending on the specific sector and installations involved and reference should be made to the sector specific sections in Chapter 5. However, with the exception of mineral wool some indicative emission levels associated with BAT are given below. Not all substances will be encountered in all installations or sectors, and certain substances are addressed in some of the sector specific sections that are not covered here because they apply to only one sector. Notwithstanding these issues, there is some commonality in the types of techniques that could be used if secondary abatement was appropriate.

- Chlorides (expressed as HCl) <30 mg/Nm³
- Fluorides (expressed as HF) <5 mg/Nm³
- Particulates <20 mg/Nm³
- Metals (gas + solid phase) (Group 1 + Group 2) <5 mg/Nm³
- Metals (gas + solid phase) (Group 1) <1 mg/Nm³

Emissions to Water
Aqueous emissions from the activities in the glass industry are generally low and not specific to the industry. However, a number of activities can give rise to more significant aqueous emissions. The emission levels given below are generally considered to be appropriate to protecting the water environment and are indicative of the emission levels that would be achieved with those techniques generally considered to represent BAT. They do not necessarily represent levels currently achieved within the industry but are based on the expert judgement of the TWG.

- Suspended solids <30 mg/l
- Chemical oxygen demand[1)] 100–130 mg/l
- Ammonia (Kjeldahl) <10 mg/l
- Sulphate <1000 mg/l
- Fluoride 15–25 mg/l
- Arsenic <0.3 mg/l
- Antimony <0.3 mg/l
- Barium <3.0 mg/l
- Cadmium <0.05 mg/l
- Chromium (Total) <0.5 mg/l
- Copper <0.5 mg/l
- Lead[2)] <0.5 mg/l

1) For the continuous filament glass fibre sector this figure is considered to be 200 mg/l. In general, chemical oxygen demand is quite low and the actual level associated with BAT may depend on the receiving water. If the receiving water is particularly sensitive levels below this figure may be required.
2) For domestic glass processes utilising significant amounts of lead compounds, 1.0 mg/l is currently considered to be more appropriate. There are no overriding technical obstacles to the achievement of 0.5 mg/l, and given the necessary time for the development and implementation of appropriate techniques this figure will be achievable.

• Nickel	<0.5 mg/l
• Tin[3)]	<0.5 mg/l
• Zinc	<0.5 mg/l
• Phenol	<1.0 mg/l
• Boric acid	2–4 mg/l
• pH	6.5–9
• Mineral oil	<20 mg/l

Under certain circumstances, discharge to a sewage treatment works or to other off-site treatment may also constitute BAT. Where this approach is proposed consideration should be given to the suitability of the receiving facility.

Project Conclusions and Recommendations

This chapter is divided into three sections: information exchange, general conclusions and recommendations for further work. The first section outlines the timescales and mechanisms for the information exchange exercise. A great deal of information was made available from industry and Member States and was generally of high quality. The available information was refined and validated during the consultation processes. It is recommended that this document be reviewed in the next 4 to 5 years.

The main general conclusions are:

- That the information exchange was successful and a high degree of agreement was reached following the second meeting of the technical working group.
- The industry is extremely diverse and it is not generally appropriate to specify a single technique as BAT in most cases.
- A great deal has been achieved in recent years to improve the environmental performance of the industry. However, further developments/improvements are expected particularly with primary techniques but also with the application of secondary techniques that have been more commonly applied in other sectors.

The main recommendations for future work are:

- A more in depth (preferably semi-quantitative) assessment of cross media issues would be beneficial.
- A more detailed consideration of the costs of techniques would be useful in determining BAT.
- When the work is reviewed a more in-depth assessment of techniques to improve energy efficiency would be useful, taking into account more recently available information.
- When the work is reviewed the progress with primary emission control methods should be reassessed.
- When the work is reviewed a reassessment should be made of those techniques which currently have some issues unproven or contested, either for the glass industry as a whole or in certain applications. In particular, sulphur dioxide removal, oxy-fuel firing and SCR.

[3)] For container glass processes utilising aqueous scrubbers for treating downstream emissions an emission level of <3 mg/l is more appropriate.

3.5.7 Non-ferrous metal industry

This guidance note was adopted on 28 September 2004

3.5.7.1 Guidance note

Introduction

Status of guidance note

This guidance note is intended to support the competent authority in applying the BAT Reference (BREF) document for the non-ferrous metal industry. It describes the field of application of the BREF, the changes in the Dutch legislation as a result of this BREF and the relationship between this BREF and other relevant legislation.

The guidance note must be read in combination with the BREF document.

Status of BREF

The BREF has a comparable status as the NeR and the recommendations of the Commission on Integral Water Management (CIW); it may only be departed from on duly stated grounds (for more information refer to the NeR (Chapter 2.12) and the Handbook on the use of permits under the Pollution of Surface Waters Act [WVO]).

Field of application

The BREF relates to installations for the production of non-ferrous metals both from primary and secondary feedstock. The metals are divided into nine groups:

- copper (incl. Sn and Be) and its alloys
- aluminium
- zinc, lead and cadmium (+ Sb, Bi, In, Ge, Ga, As, Se, Te)
- precious metals
- mercury
- heat-resistant metals
- iron alloys
- alkali and alkaline earth metals
- nickel and cobalt

Carbon and graphite production are included as separate groups, because these products are used in the manufacture of non-ferro metals such as primary aluminium.

The BREF disregards environmental and safety aspects that do not relate directly to the non-ferrous metal industry. For example, the extraction and treatments of the ores at the mine are explicitly excluded from the BREF. At least 42 non-ferrous metals plus iron alloys and carbon and graphite are produced in Europe. The BREF applies to all of these processes. Not all these processes are relevant for the Netherlands.

Essence of the former special regulation 'D2 Production of primary aluminium' and 'Z2 Production of carbon anodes'

The former special regulation 'D2 Production of primary aluminium' gives emission requirements for particulates (general NeR requirements), for fluoride (0.1 mg/m^3 given as HF) and sulphur oxides. A study of the possibilities and cost effectiveness of the removal of sulphur oxide from the waste gases has been conducted. The SO_2 emission must be restricted by making efforts to use sulphur-low anodes.

The former special regulation 'Z2 Production of carbon anodes' includes limits for the waste gas of the furnaces (tar, particulates and PAHs). The NeR requirements apply to PAHs.

Special regulations D2 and Z2 are cancelled and replaced by the BREF and this guidance note.

Relation between the BREF, the former 'D2 Production of primary aluminium' and 'Z2 Production of carbon anodes'

The IPPC Directive states that all existing installations must have an environmental permit no later than 31 October 2007. The conditions of this permit are based on the application of the Best Available Techniques (BAT). New process components for the production of non-ferrous metals must comply with BAT; modifications of existing processes must comply with BAT following overhaul.

The BREF provides a frame of reference for the determination of BAT and also specifies the associated indicative emission target values.

Special points for attention and additions to the BREF for the non-ferrous metal industry

Chapters 3-12 of the BREF for the non-ferrous metal industry describes the different elements with associated processes. Each chapter is concluded with a selection of the Best Available Techniques (BAT) for the element in question along with the associated emission target values to the air and water (for chapter reference see the table at the end of this document).

A comparison between the 'feasible emission values' in the BREF and the emission requirements of the NeR and special regulations D2 and Z2 has shown that most of the values do not differ significantly from one another.

Some points for attention:

NO_x *emission trading:* emission trading applies only to large companies with a thermal capacity of over 20MW. In the ferrous-metal industry there are only a few such companies.

SO_2 / NEC Directive (national emission ceilings): In order to realise the SO_2 ceilings of the NEC Directive, primary aluminium production companies, in particular, must apply extra measures (in addition to the BREF).

Fluorine: a low fluorine emission will be realised through application of BAT.
Particulate emission requirements: for the non-ferrous metal industry this a key point for attention. The emission requirements to be achieved depend on the individual situation. The particulate requirement of 5 mg/m^3 or less can be achieved with a cloth filter, which is regarded as the Best Available Technique (BAT). There may be situations where this limit cannot be achieved.

Conclusions and recommendations

The implementation of the BREF for the non-ferrous metal in the Dutch legislation means that:

- the summary of the BREF illustrates the emissions to the air and water by naming a part of the emissions. More emissions are specified in the main document;
- special regulation D2 of the NeR 'Production of primary aluminium' has been cancelled and replaced by the BREF and this guidance note;
- special regulation Z2 of the NeR 'Production of carbon anodes' has been cancelled and replaced by the BREF and this guidance note;
- in determining BAT, attention must be devoted to integral weighing, that is to say, a fitting (combination of) techniques when all considerations have been included in the decision-making process;
- in the issue of WVO permits, the CIW advises taking Best Available Technology into account as described in the BREF and this guidance note;
- for the assessment of substances and preparations and the assessment of residual discharges, the General Assessment Method (ABM) and the immission test apply (CIW May 2000; CIW June 2000).

Supplementary to this, the following applies:
If emissions in the BREF are not expressly differentiated, the general stipulations of the NeR (latest version) apply, and the emission policy for water (NW4 1998, CIW 1999).

References

NeR — Netherlands Emission Guidelines for Air

CIW May 1999 — *Handbook on the use of permits under the Pollution of Surface Waters Act (WVO)* Commission on Integrated Water Management, May 1999

CIW May 2000 — The assessment of substances and preparations for the implementation of the emission policy for water, Commission on Integrated Water Management, May 2000

CIW June 2000 — *Emission-immission, priorising sources and the immission test,* Commission on Integrated Water Management, June 2000

NW4 — *Fourth Policy Document on Water Management,* 1998

BREF IPPC — *Reference Document on Best Available Techniques in the Non-Ferrous Metals Industries,* December 2001

Division of BREFs and win which chapter the BAT emission guidelines are specified

Production process	BREF chapter and page reference
Production of copper & its compounds, incl. Sn & Be of primary and secondary feedstocks	H3, pp. 255–272
Production of aluminium from primary and secondary feedstocks	H4, pp. 321–334
Production of lead, zinc and cadmium (+ Sb, Bi, In, Ge, Ga, As, Se & Te)	H5, pp. 392–403
Production of precious metals	H6, pp. 430–438
Production of mercury (Hg)	H7, pp. 448–453
Production of iron alloys	H8, pp. 493–498
Production of ferro alloys	H9, pp. 570–280
Production of alkali and alkaline	H10, pp. 610–615
Production of nickel and cobalt	H11, pp. 646–655
Production of carbon and graphite anodes	H12, pp. 680–688

3.5.7.2 Summary of BREF

This reference document on best available techniques in the non-ferrous metal industry reflects the information exchange carried out according to Article 16 (2) of Council Directive 96/61/EC. The document has to be seen in the light of the preface that describes the objective of the document and its use.

To deal with the complex area of the production of non-ferrous metals, an approach was adopted to cover production of the metals from both primary and secondary raw materials together in one document and to deal with the metals in 10 groups. Those groups are:

- Copper (including Sn and Be) and its Alloys.
- Aluminium.
- Zinc, Lead and Cadmium, (+ Sb, Bi, In, Ge, Ga, As, Se, Te).
- Precious Metals.
- Mercury.
- Refractory Metals.
- Ferro Alloys.
- Alkali and Alkaline Earth Metals.
- Nickel and Cobalt.
- Carbon and Graphite.

Carbon and graphite production was also included as a separate group as many such processes are associated with primary aluminium smelters. Processes for roasting and sintering of ores and concentrates and for the production of alumina were also included within these groups where applicable. Mining and ore treatment at the mine site are not covered in the document

In the document, information is presented in twelve chapters covering: general information in Chapter 1, common processes in Chapter 2 and then metallurgical production processes for ten groups of metals in Chapters 3 to 12. Chapter 13 presents the conclusions and recommendations. Annexes covering costs and international regulations are also included. The common processes in Chapter 2 are divided as follows:

- Use of the chapter – complex installations.
- Use and reporting of emission data.
- Management, design and training.
- Receipt, storage and handling of raw materials.
- Pre-processing and pre-treatment of raw materials and transfer to production processes.
- Metal production processes – furnace types and process control techniques.
- Gas collection and air abatement techniques.
- Effluent treatment and water reuse.
- Minimisation, recycling and treatment of process residues (including by-products and waste).
- Energy and waste heat recovery.
- Cross media issues.
- Noise and vibration.
- Odour.
- Safety aspects.
- De-commissioning.

Each of Chapters 2 to 12 includes sections on applied processes and techniques, present emission and consumption levels, techniques to consider in the determination of BAT and BAT conclusions. For Chapter 2 the BAT conclusions are only drawn for material handling and storage, process control, gas collection and abatement, dioxin removal, sulphur dioxide recovery, mercury abatement and effluent treatment/water reuse. The BAT conclusions contained in all of the chapters should be consulted for a complete understanding.

Non-Ferrous Metal Industry

At least 42 non-ferrous metals plus ferro alloys and carbon and graphite are produced in EU and are used in a variety of applications in the metallurgical, chemical, construction, transport and electricity generation/transmission industries. For example high purity copper is essential for electricity generation and distribution and small amounts of nickel or refractory metals improve the corrosion resistance or other properties of steel. They are also used in many high technology developments, particularly in the defence, computing, electronic and telecommunications industries.

Non-ferrous metals are produced from a variety of primary and secondary raw materials. Primary raw materials are derived from ores that are mined and then further treated before they are metallurgically processed to produce crude metal. The treatment of ores is normally carried out close to the mines. Secondary raw materials are indigenous scrap and residues and may also undergo some pre-treatment to remove coating materials.

In Europe, ore deposits containing metals in viable concentrations have been progressively depleted and few indigenous sources remain. Most concentrates are therefore imported from a variety of sources worldwide.

Recycling constitutes an important component of the raw material supplies of a number of metals. Copper, aluminium, lead, zinc, precious metals and refractory metals, among others, can be recovered from their products or residues and can be returned to the production process without loss of quality in recycling. Overall, secondary raw materials account for a high proportion of the production, thus reducing the consumption of raw materials and energy.

The product of the industry is either refined metal or what is known as semis or semi manufactures, i.e. metal and metal alloy cast ingots or wrought shapes, extruded shapes, foil, sheet, strip, rod etc.

The structure of the industry varies metal by metal. No companies produce all non-ferrous metals although there are a few pan-European companies producing several metals, e.g. copper, lead, zinc, cadmium etc.

The size of the companies producing metals and metal alloys in Europe varies from a few employing more than 5000 people and a large number having between 50 and 200 employees. Ownership varies between pan-European and national metals groups, industrial holdings groups, stand-alone public companies and private companies.

Some metals are essential as trace elements but at higher concentrations are characterised by the toxicity of the metal, ion or compounds and many are included under various lists of toxic materials. Lead, cadmium and mercury are of the greatest concern.

Environmental Issues for the Industry

The main environmental issues for the production of most non-ferrous metals from primary raw materials are the potential emission to air of dust and metals/metal compounds and of sulphur dioxide to if roasting and smelting sulphide concentrates or using sulphur-containing fuels or other materials. The capture of sulphur and its conversion or removal is therefore an important factor in the production of non-ferrous metals. The pyrometallurgical processes are potential sources of dust and metals from furnaces, reactors and the transfer of molten metal.
Energy consumption and the recovery of heat and energy are important factors in the production of non-ferrous metals. They depend on the efficient use of the energy content of sulphidic ores, the energy demand of the process stages, the type and supply method of energy used and the use of effective methods of heat recovery. Working examples are given in Chapter 2 of the document.

The main environmental issues associated with the production of non-ferrous metals from secondary raw materials are also related to the off-gases from the various furnaces and transfers that contain dust, metals and in some process steps, acid gases. There is also the potential for the formation of dioxins due to the presence of small amounts of chlorine in the secondary raw materials; the destruction and/or capture of dioxin and VOCs is an issue that is being pursued.

The main environmental issues for primary aluminium are the production of poly-fluorinated hydrocarbons and fluorides during electrolysis, the production of solid waste from the cells and the production of solid waste during the production of alumina.

The production of solid waste is also an issue for the production of zinc and other metals during the iron removal stages.

Other processes often use hazardous reagents such as HCl, HNO_3, Cl_2 and organic solvents for leaching and purification. Advanced processing techniques are able to contain these materials and recover and reuse them. Reactor sealing is an important issue in this respect.

In the majority of cases these process gases are cleaned in fabric filters and so the emissions of dust and metal compounds such as lead are reduced. Gas cleaning using wet scrubbers and wet electrostatic precipitators is particularly effective for process gases that undergo sulphur recovery in a sulphuric acid plant. In some cases where dust is abrasive or difficult to filter, wet scrubbers are also effective. The use of furnace sealing and enclosed transfers and storage is important in preventing fugitive emissions.

In summary the main issues for the production processes for each of the groups of metals comprise the following components:

- For the production of copper: SO_2, dust, metal compounds, organic compounds, wastewater (metal compounds), residues such as furnace linings, sludge, filter dust and slag. Dioxin formation during treatment of secondary copper materials is also an issue.
- For the production of aluminium: fluorides (incl. HF), dust, metal compounds, SO_2, COS, PAH, VOCs, green house gases (PFCs and CO_2), dioxins (secondary), chlorides and HCl. Residues such as bauxite residue, Spent Pot Lining, filter dust and salt slag and wastewater (oil and ammonia).
- For the production of lead, zinc and cadmium: dust, metal compounds, VOCs (including dioxins), odours, SO_2, other acid gases, wastewater (metal compounds), residues such as sludge, the iron rich residues, filter dust and slag.
- For the production of precious metals: VOCs, dust, metal compounds, dioxins, odours, NO_x, other acid gases such as chlorine and SO_2. Residues such as sludge, filter dust and slag and wastewater (metal compounds and organic compounds).
- For the production of mercury: mercury vapour, dust, metal compounds, odours, SO_2, other acid gases, wastewater (metal compounds), residues such as sludge, filter dust and slag.
- For the production of refractory metals, hardmetal powder and metal carbides: dust, solid hardmetal and metal compounds, wastewater (metal compounds), residues such as filter dust, sludge and slag. Process chemicals such as hydrogen fluoride (HF) are used for processing tantalum and niobium and are highly toxic. This needs to be taken into account in the handling and storage of these materials.
- For the production of ferro-alloys: dust, metal compounds, CO, CO_2, SO_2, energy recovery, wastewater (metal compounds), residues such as filter dust, sludge and slag.
- For the production of alkali and alkaline earth metals: chlorine, HCl, dioxin, SF6, dust, metal compounds, CO_2, SO_2, wastewater (metal compounds), residues such as sludge, aluminate, filter dust and slag.

- For the production of nickel and cobalt: VOCs, CO, dust, metal compounds, odours, SO_2, chlorine and other acid gases, wastewater (metal compounds and organic compounds), residues such as sludge, filter dust and slag.
- For the production of carbon and graphite: PAHs, hydrocarbons, dust, odours, SO_2, wastewater prevention, residues such as filter dust.

Applied Processes

The range of raw materials available to the various installations is wide and this means that a variety of metallurgical production processes is used. In many instances the process choice is governed by the raw materials. The following tables summarise the furnaces used for the production of non-ferrous metals:

Table 1 Drying, roasting, sintering and calcining furnaces

Furnace	Metals Used	Material Used	Comment
Steam coil dryer Fluid bed dryer Flash dryer	Cu and some others	Concentrates	
Rotary Kiln	Most metals for drying.	Ores, concentrates and various scrap and residues	Drying, calcining and fuming applications Use as an incinerator
	Fuming ZnO. Calcining alumina, Ni and ferro alloys.		
	Burning of photographic film for precious metal production.		
	De-oiling Cu and Al scrap		
Fluidised bed	Copper and zinc Al_2O_3	Concentrates $Al(OH)_3$	Calcining and roasting
Up Draught sintering machine	Zinc and lead	Concentrates and secondary	Sintering
Down Draft sintering machine	Zinc and lead	Concentrates and secondary	Sintering
Steel Belt sintering machine	Ferro-alloys, Mn, Nb	Ore	Other applications possible
Herreshoff	Mercury, Molybdenum (rhenium recovery)	Ores and concentrates	Roasting, calcining

Table 2 Smelting and refining furnaces

Furnace	Metals Used	Material Used	Comment
Enclosed refractory lined crucibles	Refractory metals, special ferro-alloys	Metal oxides	
Open Pit	Refractory metals, special ferro-alloys	Metal oxides	
Baiyin	Copper	Concentrates	
Electric Arc Furnace	Ferro alloys	Concentrates, ore	
Contop/Cyclone	Copper	Concentrates	
Submerged Electric Arc Furnace	Precious metals, copper, ferro alloys	Slag, secondary materials, concentrates	For the production of ferro-alloys the open, semi closed and closed types are used
Rotary	Aluminium, lead, copper, precious metals	Scrap and other secondary, blister copper	Oxidation and reaction with substrate
Tilting Rotary Furnace	Aluminium	Scrap and other secondary	Minimises salt flux use
Reverberatory	Aluminium, copper, others	Scrap and other secondary, black copper	Smelting of Cu concentrates elsewhere in the World
Vanyucov	Copper	Concentrates	
ISA Smelt/Ausmelt	Copper, lead,	Intermediates, concentrates and secondary materials	
QSL	Lead	Concentrates and secondary	
Kivcet	Lead, Copper	Concentrates and secondary	
Noranda	Copper	Concentrates	
El Teniente	Copper	Concentrates	
TBRC TROF	Copper (TBRC), Precious metals	Most secondary inc. slimes	
Mini Smelter	Copper/lead/tin	Scrap	
Blast Furnace and ISF	Lead, lead/zinc, copper, precious metals, high carbon ferromanganese	Concentrates, most secondary	For ferro-manganese production production it is only used together with energy recovery
Inco Flash Furnace	Copper, nickel	Concentrates	
Outokumpu Flash Smelter	Copper, nickel	Concentrates	
Mitsubishi process	Copper	Concentrates and anode scrap	
Peirce Smith	Copper (converter), Ferro-alloys, Metal Oxide Production	Matte and anode scrap	
Hoboken	Copper (converter)	Matte and anode scrap	
Outokumpu Flash Converter	Copper (converter)	Matte	
Noranda Converter	Copper (converter)	Matte	
Mitsubishi Converter	Copper (converter)	Matte	

Table 3 Melting Furnaces

Furnace	Metals Used	Material Used	Comment
Induction	Most	Clean metal and scrap	Induced stirring assists alloying. Vacuum can be applied for some metals
Electron Beam	Refractory metals	Clean metal and scrap	
Rotary	Aluminium, lead	Various scrap grades	Fluxes and salts used for complex matrices
Reverberatory	Aluminium (primary and secondary)	Various scrap grades	Bath or hearth configuration can vary. Melting or holding
Contimelt	Copper	Copper anode, clean scrap and blister copper	Integrated furnace system
Shaft	Copper	Copper cathode and clean scrap	Reducing conditions
Drum (Thomas)	Copper	Copper scrap	Melting, fire refining
Heated Crucibles (indirect kettles)	Lead, zinc	Clean scrap	Melting, refining, alloying
Direct heated crucibles	Precious metals	Clean metal	Melting, alloying

Table 4 Reported range of current emissions

Abatement Technique	component	Reported emissions minimum	maximum	Specific emission*
Fabric filter, hot EP and cyclone	Dust (Metals dependent on composition)	<1 mg/Nm^3	100 mg/Nm^3	100–6000 g/t
Carbon filter	Total C	<20 mg/Nm^3		
Afterburner (including temperature quench for dioxin)	Total C	<2 mg/Nm^3	100 mg/Nm^3	10–80 g/t
	Dioxin (TEQ)	<0.1 ng/Nm^3	5 ng/Nm^3	5–10 mg/t
	PAH (EPA)	<1 µg/Nm^3	2500 mg/Nm^3	
	HCN	<0.1 mg/Nm^3	10 mg/Nm^3	
Wet or semi-dry scrubber	SO_2	<50 mg/Nm^3	250 mg/Nm^3	
	Hydrocarbon	<10 mg/Nm^3	200 mg/Nm^3	
	Chlorine	<2 mg/Nm^3		
Alumina scrubber	Dust	<1 mg/Nm^3	<20 mg/Nm^3	
	Hydrocarbon	<1 mg/Nm^3	<50 mg/Nm^3	
	PAH (EPA)	<20 mg/Nm^3	<2000 mg/Nm^3	
Chlorine recovery	Chlorine	<5 mg/Nm^3		
Optimised Combustion Low NO_x burner	NO_x	10 mg/Nm^3	500 mg/Nm^3	
Oxidising scrubber	NO_x		<100 mg/Nm^3	
Sulphuric acid plant reported as conversion of SO_2	Double contact	99.3%	99.7%	
	Single contact	95%	99.1%	1–16 kg/t
Cooler, EP lime/carbon adsorption and fabric filter	PAH (EPA)	0,1 mg/Nm^3	6 mg/Nm^3	
	Hydrocarbons	20 mgC/Nm^3	200 mgC/Nm^3	

*) Amount per tonne of metal produced.

Hydrometallurgical processes are also used. Acids and alkalis (NaOH, sometimes also Na_2CO_3) are used to dissolve the metal content of a variety of calcines, ores and concentrates before refining and electro-winning. The material to be leached is usually in the form of the oxide, either as an oxidic ore or an oxide produced by roasting. Direct leaching of some concentrates or mattes is also performed at both elevated and atmospheric pressure. Some copper sulphide ores can be leached with sulphuric acid or other media, sometimes using natural bacteria to promote oxidation and dissolution, but very long residence times are used.

Air, oxygen, chlorine or solutions containing ferric chloride can be added to leaching systems to provide the appropriate conditions for dissolution. The solutions that are produced are treated in a number of ways to refine and win the metals.

Common practice is to return the depleted solutions to the leaching stage, where appropriate, to conserve acids and alkaline solutions.

Current Emissions and Consumption

The range of raw materials is also a significant factor and affects the use of energy, the amount of residues produced and the quantity of other materials used. An example is the removal of impurities such as iron into slags; the amount of impurity present governs the amount of slag produced and the energy used. Emissions to the environment depend on the collection or abatement systems that are used. The current ranges reported for a number of abatement processes during the exchange of information are summarised in table 4.

Process gases are captured and then cleaned in fabric filters to reduce the emissions of dust and metal compounds such as those of lead. Modern filter fabrics offer significant improvements in performance, reliability and life. Afterburners and carbon absorption are used to remove dioxins and VOCs.

Uncaptured gases or fugitive emissions, however, are not treated. Dust emissions also occur from storage, handling and the pre-treatment of raw materials where fugitive dust emissions also play an important role. This is true for both primary and secondary production, as their significance can be much greater than captured and abated emissions. Careful plant design and process operations are needed to capture and treat process gases where fugitive emissions are significant.

Table 5 shows that fugitive or uncaptured emissions are important issues:

Table 5 Comparison of abated and fugitive dust loads at a primary copper smelter

	Dust emission kg/a	
	Before additional secondary gas collection (1992)	After additional secondary gas collection (1996)
Anode production t/a	220000	325000
Fugitive emissions Total Smelter	66490	32200
Smelter roofline	56160	17020
Primary smelter stack emissions Smelter/acid plant	7990	7600
Stack-secondary hoods	2547	2116

Many processes use sealed cooling and process water systems but there is still the potential to discharge heavy metals to water. The methods to reduce water use and wastewater generation and to treat process waters are reviewed in Chapter 2.

The production of residues is also a significant factor in this industry, but the residues often have recoverable metal quantities and it is common practice to use residues on-site or in other installations to recover metals. Many slags that are produced are inert, non-leachable and are used in many civil engineering works. Other slags, such as salt slag, can be treated to recover other components for use in other industries, but the industry needs to ensure that these recovery operations are operated to a high environmental standard.

Key BAT Conclusions

The exchange of information during the preparation of the BREF for non-ferrous metal production has allowed conclusions on BAT to be reached for the production and associated processes. The sections in each of the chapters that describe BAT should therefore be referred to for a complete understanding of BAT and the associated processes and emissions.

The key findings are summarised below.

Up-stream Activities

Process management, supervision and the control of the process and abatement systems are very important factors. Good training practices and operator instruction and motivation are also important especially to prevent environmental pollution. Good techniques for raw material handling can prevent fugitive emissions. Other important techniques include:

- Consideration of the environmental implications of a new process or raw material at the earliest stages of the project with reviews at regular intervals thereafter.
- Design of the process to accept the anticipated range of raw material. Severe problems can result for example if gas volumes are too high or if the energy use of the material is higher than anticipated. The design stage is the most cost-effective time to introduce improvements in overall environmental performance.
- Use of an audit trail of the design and decision-making process to show how various processes and abatement options were considered.
- Planning of commissioning procedures for new or modified plant.

Table 6 summarises the techniques for raw material storage and handling on the basis of type and characteristics of the material.

Furnace design, the use of suitable pre-treatment methods and process control were identified as important features of BAT.

The use of raw material blending to optimise the process prevents inappropriate material being used and maximises process efficiency. Sampling and analysis of feed materials and the segregation of some materials are important factors in this technique.

Good design, maintenance and monitoring are important for all process and abatement stages. Sampling and monitoring of emissions to the environment should be carried out according to national or international standard methods. Important parameters that can be used for the control of process or abatement should be monitored. Continuous monitoring of key parameters should be carried out if practical.

Process control

Process control techniques that are designed to measure and maintain optimum parameters such as temperature, pressure, gas components and other critical process parameters etc are considered to be BAT.

Sampling and analysis of raw materials to control plant conditions. Good mixing of different feed materials should be achieved to get optimum conversion efficiency and reduce emissions and rejects.

Table 6 Summary of raw material and handling techniques

Raw material	Metal group	Method for handling	Method for storage	Comments
Concentrates:	All – if dust forming	Enclosed conveyors or pneumatic	Enclosed building	Prevention of water contamination
	All – if non dust forming	Covered conveyors	Covered store	
Fine grained material (e.g. metal powder)	Refractory metals	Enclosed conveyors or pneumatic. Covered conveyors	Closed drum, bins and hoppers	Prevention of water contamination and fugitive air emissions
Secondary raw materials:	All – Large items	Mechanical loader	Open	Prevention of water contamination or reactions with water. Oily drainage from swarf
	All – Small items	Charge skips	Covered bays	
	All – Fine material	Enclosed or agglomerated	Enclosed if dusty	
Fluxes	All – if dust forming	Enclosed conveyors or pneumatic	Enclosed building	Prevention of water contamination
	All – if non dust forming	Covered conveyors	Covered store	
Solid fuel & coke:	All	Covered conveyors If not dust forming	Certified storage If not dust forming	
Liquid fuels and LPG	All	Overhead pipeline	Certified storage Bunded areas	Back venting of delivery lines
Process gases	All	Overhead pipeline Reduced pressure pipeline (Chlorine, CO)	Certified storage	Pressure loss monitoring, Alarms for toxic gases
Solvents	Cu, Ni, Zn group, PM, Carbon	Overhead pipeline Manual	Drums, tanks	Back venting of delivery lines
Products – Cathodes, wire-rod, billets, ingots, cakes etc	All	Depends on conditions	Open, covered or enclosed depending on dust formation and reaction with water	Appropriate drainage system
Process residues for recovery	All	Depends on conditions	Open, covered or enclosed depending on dust formation and reaction with water	Appropriate drainage system
Wastes for disposal (e.g. furnace linings)	All	Depends on conditions	Open covered or enclosed bays or sealed (drums) depending on the material	Appropriate drainage system

The use of feed weighing and metering systems, the use of microprocessors to control material feed-rate, critical process and combustion conditions and gas additions allow process operation to be optimised. Several parameters can be measured to allow this and alarms provided for critical parameters, which include:

- On-line monitoring of temperature, furnace pressure (or depression) and gas volume or flow.
- Monitoring of gaseous components (O_2, SO_2, CO, dust, NO_x etc).
- On-line monitoring of vibration to detect blockages and possible equipment failure.
- On-line monitoring of the current and voltage of electrolytic processes.
- On-line monitoring of emissions to control critical process parameters.
- Monitoring and control of the temperature of melting furnaces to prevent the production of metal and metal oxide fume by overheating.

Operators, engineers and others should be continuously trained and assessed in the use of operating instructions, the use of the modern control techniques and the significance of alarms and the actions to be taken when alarms are given.

Optimisation of levels of supervision to take advantage of the above and to maintain operator responsibility.

Gas collection and abatement

The fume collection systems used should exploit furnace or reactor sealing systems and be designed to maintain a reduced pressure that avoids leaks and fugitive emissions. Systems that maintain furnace sealing or hood deployment should be used. Examples are: through electrode additions of material; additions via tuyeres or lances and the use of robust rotary valves on feed systems. Secondary fume collection is expensive and consumes a lot of energy, but is needed in the case of some furnaces. The system used should be an intelligent system capable of targeting the fume extraction to the source and duration of any fume.

Overall for dust and associated metal removal, fabric filters (after heat recovery or gas cooling) can provide the best performance provided that modern wear resistant fabrics are used, the particles are suitable and continuous monitoring is used to detect failure. Modern filter fabrics (e.g. membrane filter) offer significant improvements in performance, reliability and life and therefore offer cost savings in the medium term. They can be used in existing installations and can be fitted during maintenance. They feature bag burst detection systems and on-line cleaning methods.

For sticky or abrasive dusts, wet electrostatic precipitators or scrubbers can be effective provided that they are properly designed for the application.

Gas treatment for the smelting or incineration stage should include a sulphur dioxide removal stage and/or after-burning if this is considered necessary to avoid local, regional or long-range air quality problems or if dioxins may be present.

There may be variations in the raw materials that influence the range of components or the physical state of some components such as the size and physical properties of the dust produced. These should be assessed locally.

Prevention and the destruction of dioxins
The presence of dioxins or their formation during a process needs to be considered for many of the pyro-metallurgical processes used to produce non-ferrous metals. Particular instances are reported in the metal-specific chapters and in these cases the following techniques are considered to be BAT for the prevention of the formation of dioxins and the destruction of any that are present. These techniques may be used in combination. Some non-ferrous metals are reported to catalyse de-novo synthesis and it is sometimes necessary to have a clean gas prior to further abatement.

- Quality control of scrap inputs depending on the process used. The use of the correct feed material for the particular furnace or process. Selection and sorting to prevent the addition of material that is contaminated with organic matter or precursors can reduce the potential for dioxin formation.
- The use of correctly designed and operated afterburners and rapid quenching of the hot gases to <250°C.
- The use of optimum combustion conditions. The use of oxygen injection in the upper part of a furnace to ensure complete combustion of furnace gases if necessary to achieve this.
- Absorption onto activated carbon in a fixed bed or moving bed reactor or by injection into the gas stream, and removal as filter dust.
- Very high efficiency dust removal for example, ceramic filters, high efficiency fabric filters or the gas cleaning train prior to a sulphuric acid plant.
- The use of a catalytic oxidation stage or fabric filters that incorporate a catalytic coating.
- The treatment of collected dusts in high temperature furnaces to destroy dioxins and to recover metals.

The emission concentrations that are associated with the above techniques range from <0.1 to 0.5 ng/Nm^3 TEQ depending on the feed, the smelting or melting process and the techniques or combination of techniques that are used for dioxin removal.

Metallurgical Processes
The range of raw materials available to the various installations is wide and means that there is a need to include a variety of metallurgical production processes in the BAT sections of the majority of the metal groups. In many instances the process choice is governed by the raw materials, so the type of furnace has only a minor effect on BAT, provided that the furnace has been designed for the raw materials used and energy recovery is used where practicable.

There are exceptions. For example, the use of multiple point feeding of alumina to centre worked prebake cells was identified as BAT for primary aluminium, as was the use of sealed furnaces in the production of some ferro-alloys to allow collection of high calorific value gas.

For primary copper the reverberatory furnace is not considered to be BAT. The other major influences are the blending of the raw materials, process control, management and the collection of fume. The hierarchy in the choice of a new or changed process was identified as:

- Thermal or mechanical pre-treatment of secondary material to minimise organic contamination of the feed.
- The use of sealed furnaces or other process units to prevent fugitive emissions, allow heat recovery and allow the collection of process gases for other use (e.g. CO as a fuel and SO_2 as sulphuric acid) or for abatement.
- The use of semi-sealed furnaces where sealed furnaces are not available.
- The minimisation of material transfers between processes.
- Where such transfers are unavoidable, the use of launders in preference to ladles for molten materials.
- In some cases the restriction of techniques to those that avoid molten material transfers may prevent the recovery of some secondary materials that would then enter the waste stream. In these cases the use of secondary or tertiary fume collection is appropriate so that these materials can be recovered.
- Hooding and ductwork design to capture fume arising from hot metal, matte or slag transfers and tapping.
- Furnace or reactor enclosures may be required to prevent release of fume losses into the atmosphere.

- Where primary extraction and enclosure are likely to be ineffective, then the furnace can be fully closed and ventilation air drawn off by extraction fans to a suitable treatment and discharge system.
- The maximum use of the energy content of sulphidic concentrates.

Emissions to Air

Emissions to air arise from the storage, handling, pre-treatment, pyro-metallurgical and hydrometallurgical stages. Transfer of materials is particularly important. Data provided has confirmed that the significance of fugitive emissions in many processes is very high and that fugitive emissions can be much greater than those that are captured and abated. In these cases it is possible to reduce environmental impact by following the hierarchy of gas collection techniques from material storage and handling, reactors or furnaces and from material transfer points. Potential fugitive emissions must be considered at all stages of process design and development. The hierarchy of gas collection from all of the process stages is:

- Process optimisation and minimisation of emissions
- Sealed reactors and furnaces
- Targeted fume collection.

Roofline collection of fume is very energy consuming and should be a last resort.

The potential sources of emissions to air are summarised in table 7, which also gives a review of prevention and treatment methods. Emissions to air are reported on the basis of collected emissions. Associated emissions are given as daily averages based on continuous monitoring during the operating period. In cases where continuous monitoring is not practicable the value will be the average over the sampling period. Standard conditions are used: 273 K, 101.3 kPa, measured oxygen content and dry gas with no dilution of the gases.

Sulphur capture is an important requirement when sulphidic ores or concentrates are roasted or smelted. The sulphur dioxide produced by the process is collected and can be recovered as sulphur, gypsum (if no cross-media effects) or sulphur dioxide or can be converted to sulphuric acid. The process choice depends on the existence of local markets for sulphur dioxide. The production of sulphuric acid in a double contact sulphuric acid plant with a minimum of four passes, or in a single contact plant with gypsum production from the tail gas and using a modern catalyst, are considered to be BAT. Plant configuration will depend on the concentration of sulphur dioxide produced in the roasting or smelting stage.

Table 7 Summary of sources and treatment/abatement options

Process stage	Component in off-gas	Treatment method
Materials handling and storage	Dust and metals	Correct storage, handling and transfer. Dust collection and fabric filter if necessary
Grinding, drying	Dust and metals	Process operation. Gas collection and fabric filter
Sintering/roasting Smelting Converting Fire refining	VOCs, dioxins	Afterburner, adsorbent or activated carbon addition
	Dust and metal compounds	Gas collection, gas cleaning in fabric filter, heat recovery
	Carbon monoxide	Afterburner if necessary
	Sulphur dioxide	sulphuric acid plant (for sulphidic ores) or scrubber
Slag treatment	Dust and metals	Gas collection, cooling and fabric filter
	Sulphur dioxide	Scrubber
	Carbon monoxide	Afterburner
Leaching and chemical refining	Chlorine	Gas collection and re-use, wet chemical scrubber
Carbonyl refining	Carbon monoxide. Hydrogen	Sealed process, recovery and reuse. Afterburner and dust removal in fabric filter for tail gas
Solvent extraction	VOC. (depends on the solvent used and should be determined locally to assess the possible hazard)	Containment, gas collection, solvent recovery. Carbon adsorption if necessary
Thermal refining	Dust and metals Sulphur dioxide	Gas collection and fabric filter. Scrubber if necessary
Molten salt electrolysis	Fluoride, chlorine, PFCs	Process operation. Gas collection, scrubber (alumina) and fabric filter
Electrode baking, graphitisation	Dust, metals, SO_2, Fluoride, PAHs, tars	Gas collection, condenser and EP, afterburner or alumina scrubber and fabric filter. Scrubber if necessary for SO_2
Metal powder production	Dust and metals	Gas collection and fabric filter
Powder production	Dust, Ammonia	Gas collection and recovery. Acid medium scrubber
High temperature reduction	Hydrogen	Sealed process, re-use
Electro-winning	Chlorine. Acid mist	Gas collection and re-use. Wet scrubber. De-mister
Melting and casting	Dust and metals	Gas collection and fabric filter
	VOCs, dioxins (organic feed)	Afterburner (Carbon injection)

Dust arrestment using a fabric filter may require the removal of hot particles to prevent fires. Hot electrostatic precipitators would be used in a gas cleaning system prior to a sulphuric acid plant or for wet gases

A summary of the emission levels associated with abatement systems that are considered to be BAT for the non-ferrous metal processes is shown in table 8. More details are given in the BAT conclusions in the metal-specific chapters.

Table 8 Emissions to air associated with the use of BAT

Abatement	Technique	Associated Range Comment
Fabric filter	Dust 1–5 mg/Nm^3 Metals – dependent on dust composition	Depends on characteristics of dust
Carbon or Bio filter	Total organic C <20 mg/Nm^3	Phenol <0.1 mg/Nm3
Afterburner (including temperature quench for dioxin removal)	Total organic C <5–15 mg/Nm^3 Dioxin <0.1–0.5 ng/Nm^3 TEQ PAH (OSPAR 11) < 200μgCNm^3 HCN <2 mg/Nm^3	Designed for gas volume. Other techniques are available to reduce dioxins further by carbon/lime injection, catalytic reactors/filters
Optimised combustion conditions	Total organic C <5–50 mg/Nm^3	
Wet EP Ceramic filter	Dust <5 mg/Nm^3	Depends on characteristics e.g. dust, moisture or high temperature
Wet or semi-dry alkaline scrubber	SO_2 <50–200 mg/Nm^3 Tar <10 mg/Nm^3 Chlorine <2 mg/Nm^3	
Alumina scrubber	Dust 1–5 mg/Nm^3 Hydrocarbon <2 mg/Nm^3 PAH (OSPAR 11) <200 μgC/Nm^3	
Chlorine recovery	Chlorine <5 mg/Nm^3	Chlorine is re-used. Possible accidental fugitive releases
Oxidising scrubber	NO_x <100 mg/Nm^3	From use of nitric acid – recovery followed by removal of traces
Low NOx burner	<100 mg/Nm^3	Higher values are associated with oxygen enrichment to reduce energy use. In these cases gas volume and mass emission are reduced
Oxy-fuel burner	<100–300 mg/Nm^3	
Sulphuric acid plant	>99.7% conversion (double contact) >99.1% conversion (single contact)	Including mercury scrubber using Boliden/Norzink process or thiosulphate scrubber Hg <1 ppm in acid produced
Cooler, EP, lime/carbon adsorption and fabric filter	PAH (OSPAR 11) <200 μgC/Nm^3 Hydrocarbons (volatile) <20 mgC/Nm^3 Hydrocarbons (condensed) <2 mgC/Nm^3	

Collected emissions only. Associated emissions are given as daily averages based on continuous monitoring during the operating period and standard conditions of 273 K, 101.3 kPa, measured oxygen content and dry gas without dilution of the gases with air. In cases where continuous monitoring is not practicable the value will be the average over the sampling period. For the abatement system used, the characteristics of the gas and dust will be taken into account in the design of the system and the correct operating temperature used. For some components, the variation in raw gas concentration during batch processes may affect the performance of the abatement system.

Table 9 Overview of chemical treatment methods for some gaseous components

Process/Reagent Used	Component in off-gas	Treatment Method
Use of arsenic or antimony oxide. (refining of Zn/Pb)	Arsine/stibine	Permanganate scrubbing
Pitch etc	Tars and PAH	Afterburner, condenser and EP or dry absorber
Solvents, VOCs	VOC, Odour	Containment, condensation. Activated carbon, bio-filter
Sulphuric acid (+ sulphur in fuel or raw material)	Sulphur dioxide	Wet or semi-dry scrubber system. Sulphuric acid plant
Aqua Regia	NOCl, NO_x	Caustic scrubber system
Chlorine, HCl	Cl_2	Caustic scrubber system
Nitric acid	NO_x	Oxidise and absorb, recycle, scrubber system
Na or KCN	HCN	Oxidise with hydrogen peroxide or hypochlorite
Ammonia	NH_3	Recovery, scrubber system
Ammonium chloride	Aerosol	Recovery by sublimation, scrubber system
Hydrazine	N_2H_4 (possible carcinogen)	Scrubber or activated carbon
Sodium borohydride	Hydrogen (explosion hazard)	Avoid if possible in PGM processing (especially Os, Ru)
Formic acid	Formaldehyde	Caustic scrubber system
Sodium chlorate/HCl	Cl_2 oxides (explosion hazard	Control of process end point

Several specific reagents are used in chemical treatment of solutions of metals or in various metallurgical processes. Some of the compounds, sources and treatment methods of gases produced from the use of these reagents are given in table 9.

Emissions to water

Emissions to water arise from a number of sources and a variety of minimisation and treatment options are applicable depending on the source and the components present. In general the wastewaters can contain soluble and non-soluble metal compounds, oil and organic material. The following table summarises the potential wastewaters, the metals produced, minimisation and treatment methods.

Table 10 Overview of BAT for wastewater streams

Source of wastewater	Associated process	Minimisation methods	Treatment Methods
Process water	Alumina production, Lead-acid battery breaking. Pickling	Return to process as far as possible	Neutralisation and precipitation. Electrolysis
Indirect cooling water	Furnace cooling for most metals. Electrolyte cooling for Zn	Use of sealed or air cooling system. System monitoring to detect leaks	Settlement
Direct cooling water	Al, Cu, Zn castings. Carbon electrodes	Settlement Closed cooling system	Settlement. Precipitation if needed
Slag granulation	Cu, Ni, Pb, Zn, precious metals, ferro alloys		Settlement. Precipitation if needed
Electrolysis	Cu, Ni, Zn	Sealed system. Electro-winning of electrolyte bleed	Neutralisation and precipitation
Hydrometallurgy (blow-down)	Zn, Cd	Sealed system	Settlement. Precipitation if needed
Abatement system (blowdown)	Wet scrubbers. Wet EPs and scrubbers for acid plants	Re-use of weak acid streams if possible	Settlement. Precipitation if needed
Surface water	All	Good raw materials storage and prevention of fugitive emissions	Settlement. Precipitation if needed. Filtration

Wastewater treatment systems can maximise the removal of metals using sedimentation and possibly filtration. The reagents used for precipitation may be hydroxide, sulphide or a combination of both, depending on the mix of metals present. It is also practicable in many cases to reuse treated water.

Table 11 Example of emissions to water associated with the use of BAT

	Main components [mg/l]					
	Cu	Pb	As	Ni	Cd	Zn
Process-water	<0.1	<0.05	<0.01	<0.1	<0.05	<0.15

The associated emissions to water are based on a qualified random sample or a 24-hour composite sample. The extent of wastewater treatment depends on the source and the metals contained in the wastewater.

Table 12 Overview of residues and available options for dealing with them

Source of the residues	Associated Metals	Residue	Options for dealing with them metalen
Raw materials handling etc	All metals	Dust, sweepings	Feed for the main process
Smelting furnace	All metals	Slag	Construction material after slag treatment. Abrasive industry Parts of slag may be used as refractory material e.g. slag from the production of chromium metal
	Ferro-alloys	Rich slag	Raw material for other ferro-alloy processes
Converting furnace	Cu	Slag	Recycle to smelter
Refining furnaces	Cu	Slag	Recycle to smelter
	Pb	Skimmings	Recovery of other valuable metals
	Precious metals (PMs)	Skimmings and slag	Internal recycle
Slag treatment	Cu and Ni	Cleaned slag	Construction material. Matte produced
Melting furnace	All metals	Skimmings Slag and salt slag	Return to process after treatment. Metal recovery, recovery of salt and other material
Electro-refining	Cu	Electrolyte bleed Anode remnants Anode slime	Recovery of Ni. Return to converter Recovery of precious metals
Electro-winning	Zn, Ni, Co, PMs	Spent electrolyte	Re-use in leaching process
Fused salt electrolysis	Al	Spent Pot Lining Excess bath Anode stubs	Carburant or disposal Sale as electrolyte Recovery
	Na and Li	Cell material	Scrap iron after cleaning
Distillation	Hg	Residues (Hollines)	Re-use as process feed
	Zn, Cd	Residues	Return to process
Leaching	Zn	Ferrite residues	Safe disposal, re-use of liquor
	Cu	Residues	Safe disposal
	Ni/Co	Cu/Fe residues	Recovery, disposal
Sulphuric acid plant		Catalyst	Regeneration
		Acid sludges	Safe disposal
		Weak acid	Leaching, disposal
Furnace linings	All metals	Refractory	Use as slagging agent, disposal
Milling, Grinding	Carbon	Carbon and graphite dusts	Use as raw material in other processes
Pickling	Cu, Ti	Spent acid	Recovery
Dry abatement systems	Most – using fabric filters or EPs	Filter dust	Return to process Recovery of other metals
Wet abatement systems	Most – using scrubbers or wet EPs	Filter sludge	Return to process or recovery of other metals (e.g. Hg). Disposal
Wastewater treatment sludge	Most	Hydroxide or sulphide sludges	Safe disposal, re-use Re-use
Digestion	Alumina	Red mud	Safe disposal, re-use of liquor

Process Residues
Process residues are produced at various stages of the process and are highly dependent on the constituents of the raw materials. Ores and concentrates contain quantities of metals other than the prime target metal. Processes are designed to obtain a pure target metal and to recover other valuable metals as well.

These other metals tend to concentrate in the residues from the process and in turn these residues form the raw material for other metal recovery processes. Table 12 gives an overview of some process residues and the options available to deal with them.

Filter dusts can be recycled within the same plant or used for the recovery of other metals at other non-ferrous metal installations, by a third party or for other applications.

Residues and slags can be treated to recover valuable metals and render the residues suitable for other uses e.g. as construction material. Some components can be converted into saleable products.

Residues from water treatment may contain valuable metals and can be recycled in some cases.

The regulator and operator should satisfy themselves that the recovery of residues by a third party is carried out to high environmental standards and does not cause negative cross-media effects.

Toxic Compounds
Specific toxicity of some compounds that may be emitted (and their environmental impact or consequences) varies from group to group. Some metals have toxic compounds that may be emitted from the processes and so need to be reduced.

Energy recovery
Energy recovery before or after abatement is applicable in the majority of cases but local circumstances are important, for example, where there is no outlet for the recovered energy. The BAT conclusions for energy recovery are:

- Production of steam and electricity from the heat raised in waste heat boilers.
- The use of the heat of reaction to smelt or roast concentrates or melt scrap metals in a converter.
- The use of hot process gases to dry feed materials.
- Pre-heating of a furnace charge using the energy content of furnace gases or hot gases from another source.
- The use of recuperative burners or the pre-heating of combustion air.
- The use as a fuel gas of CO produced.
- The heating of leach liquors from hot process gases or liquors.
- The use of plastic contents in some raw materials as a fuel, provided that good quality plastic cannot be recovered and VOCs and dioxins are not emitted.
- The use of low-mass refractories where practicable.

Degree of Consensus and Recommendations for Future Work
This BREF has met a high level of support from the TWG and participants at the 7th meeting of the Information Exchange Forum. Critical remarks have mainly related to information gaps and presentational aspects (calls for more BAT associated emission and consumption levels to be included in the Executive Summary).

It is recommended that this document be revised in 4 years time. The areas where additional efforts should be made to establish a sound basis of information include, above all, fugitive emissions and also specific emission and consumption data, process residues, wastewater and aspects related to small and medium-sized companies. Chapter 13 contains further recommendations.