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Integrated Pollution Prevention and Control

Reference Document on Best Available Techniques in the

Cement, Lime and Magnesium Oxide Manufacturing Industries

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EXECUTIVE SUMMARY OF THE REFERENCE DOCUMENT ON BEST AVAILABLE TECHNIQUES IN THE CEMENT, LIME AND MAGNESIUM OXIDE MANUFACTURING INDUSTRIES

INTRODUCTION

The BAT (Best Available Techniques) Reference Document (BREF) entitled '**Cement, Lime and Magnesium Oxide Manufacturing Industries**' reflects an information exchange carried out under Article 17(2) of Directive 2008/1/EC of the European Parliament and of the Council (IPPC Directive). This Executive Summary describes the main findings, and provides a summary of the principal BAT conclusions and the associated consumption and emission levels. It should be read in conjunction with the Preface, which explains this document's objectives; how it is intended to be used and legal terms. This Executive Summary can be read and understood as a standalone document but, as a summary, it does not present all the complexities of the full document. It is therefore not intended as a substitute for this full document as a tool in BAT decision making.

SCOPE OF THIS DOCUMENT

This document addresses the industrial activities specified in Section 3.1 of Annex I to Directive 2008/1/EC, namely:
'3.1. Installations for the production of cement clinker in rotary kilns with a production capacity exceeding 500 tonnes per day or lime in rotary kilns with a production capacity exceeding 50 tonnes per day or in other furnaces with a production capacity exceeding 50 tonnes per day.'

Additionally to the cement and lime industry, this document covers the manufacture of magnesium oxide by using the dry process route.

This BREF document has three chapters, one for the cement industry, one for the lime industry and one for the manufacture of magnesium oxide by using the dry process route based on mined natural magnesite (magnesium carbonate $MgCO_3$). Each of these chapters has seven sections according to the general outline and guide for writing BREFs. In addition to the basic manufacturing activities of the three industrial activities mentioned above, this document covers the associated activities which could have an effect on emissions or pollution. Thus, this document includes activities from the preparation of raw materials to the dispatch of the finished products. Certain activities, e.g. quarrying/mining and shaft kilns for cement clinker production, are not covered because they are not considered to be directly associated with the primary activity.

CEMENT INDUSTRY

Key environmental issues

Cement is a basic material used for building and civil engineering construction. The production of cement in the European Union stood at 267.5 million tonnes in 2006, equivalent to about 10.5 % of world production.

In 2008 there were 268 installations producing cement clinker and finished cement in the European Union with a total of 377 kilns. In addition, there were a further 90 grinding plants (cement mills) and two clinker plants without mills. A typical kiln size has come to be around 3000 tonnes clinker/day.

The clinker burning process is the most important part of the process in terms of the key environmental issues for cement manufacture: energy use and emissions to air. Depending on the specific production processes, cement plants cause emissions to air and land (as waste). In specific rare cases, emissions to water may occur. Additionally, the environment can be affected by noise and odours. The key polluting substances emitted to air are dust, nitrogen oxides and sulphur dioxide. Carbon oxides, polychlorinated dibenzo-p-dioxins and dibenzofurans, total organic carbon, metals, hydrogen chloride and hydrogen fluoride are emitted as well. The type and quantity of air pollution depend on different parameters, e.g. inputs (the raw materials and fuels used) and the type of process applied.

To produce 1 tonne of clinker, the typical average consumption of raw materials in the EU is 1.52 tonnes. Most of the balance is lost from the process as carbon dioxide emissions to air in the calcination reaction ($CaCO_3 \rightarrow CaO + CO_2$).

Applied processes and techniques

After the mining, crushing, grinding and homogenisation of raw materials, the first step in cement manufacture is calcination of calcium carbonate followed by the reaction of 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. Several types of wastes can also be used as partial replacements for the natural raw materials.

The cement industry is an energy intensive industry with energy typically accounting for about 40 % of production costs (i.e. excluding capital costs but including electricity costs). Various conventional fossil and waste fuels can be used to provide the thermal energy demand required for the process. In 2006, the most commonly used fuels were petcoke, coal and different types of waste, followed by lignite and other solid fuels, fuel oil, and natural gas.

Basically, characteristics of the clinker burning process itself allow the use of wastes as raw materials and/or as fuels. 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. In 2008, about 90 % of Europe's cement production was from dry process kilns, a further 7.5 % of production was accounted for by semi-dry and semi-wet process kilns, with the remainder of European production, about 2.5 %, 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 process kiln systems.

LIME INDUSTRY

Key environmental issues

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. In 2004, the European production market represented almost 25 million tonnes of lime for a total European production of 28 million tonnes including commercial and captive lime production, which accounted for 20 % of the world’s total lime production.

In 2003, there were approximately 211 installations producing lime in the EU-27 (excluding captive lime production) and in 2006, there were a total of 597 kilns producing commercial lime, of which 551 (or about 90 %) were shaft kilns. Typical kiln size lies between 50 and 500 tonnes per day for shaft kiln types. 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 emissions to air.

The lime industry is a highly energy intensive industry with energy accounting for up to 60 % of total production costs. Kilns are fired with gaseous fuels (e.g. natural gas, coke oven gas), solid fuels (e.g. coal, coke/anthracite) and liquid fuels (e.g. heavy/light fuel oil). Furthermore, different types of wastes are used as fuels, e.g. oil, plastics, paper, animal meal, sawdust.

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. Depending on the specific production processes, lime plants cause emissions to air, water and land (as waste). Additionally, the environment can be affected by noise and odours. The key polluting substances emitted to air are dust, nitrogen oxides, sulphur dioxide and carbon monoxide. Polychlorinated dibenzo-p-dioxins and polychlorinated dibenzofurans, total organic carbon, metals, hydrogen chloride and hydrogen fluoride can be relevant depending on the raw materials and fuels used.

Applied processes and techniques

The term 'lime' includes quicklime and slaked lime and is synonymous with the term 'lime products'. Quicklime, or burned lime, is calcium oxide (CaO). Slaked lime consists 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).

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.

MANUFACTURE OF MAGNESIUM OXIDE (DRY PROCESS ROUTE)

Key environmental issues

Magnesium oxide (MgO/magnesia) is the most important industrial magnesium compound and is mainly used in the steel and refractory industry, but also in many other industrial sectors. Different types of magnesium oxide are produced by using the dry process route, such as dead burned magnesia (DBM), caustic calcined magnesia (CCM), fused magnesia (FM).

The world's production of magnesite was around 12.5 million tonnes in 2003. In the EU-27, about 2.3 million tonnes were produced in 2003 which was 18.4 % of the world's production. In 2003, the world's production of MgO by using the dry process route was around 5.8 million tonnes. In 2008 in the EU-27, on the basis of the information available, there were only nine producers of magnesium oxide (dry process route) using 14 plants. The number of kilns per plant was one to three, except for one producer who operates eight kilns in a single plant.

The manufacture of MgO is energy intensive as MgO, and particularly DBM, is manufactured at very high temperatures. The energy demand for MgO production ranges between 6 and 12 GJ/t MgO and is determined by different factors. In 2008, natural gas, petroleum coke and fuel oil were used as fuels.

The key environmental issues associated with magnesium oxide production are air pollution and the use of energy. The firing process is the main source of emissions and is also the principal user of energy. Depending on the specific MgO production processes, plants cause emissions to air, water and land (as waste). Additionally, the environment can be affected by noise and odours. The key polluting substances emitted to air are dust, nitrogen oxides, sulphur dioxide and carbon oxides (CO, CO_2).

Applied processes and techniques

Raw magnesite is mined, crushed, ground or milled and sieved before being fired. More than 98 % of the mined magnesite is used for the production of the different magnesia products. The chemical reaction of de-acidifying magnesite is endothermic and depends on a high firing temperature. Several firing processes and firing steps are needed to produce the different types of magnesium oxide CCM, DBM and/or FM. Several kiln types are used, such as multiple hearth furnaces, shaft kilns or rotary sintering kilns. For the production of fused magnesia special electric arc kilns are used.

CEMENT, LIME AND MAGNESIUM OXIDE INDUSTRY

Techniques to consider in the determination of BAT

Important issues for the implementation of IPPC in the cement, lime and magnesium oxide industries are reduction of emissions to air; efficient energy and raw material usage; minimisation, recovery and recycling of process losses/waste; as well as effective environmental and energy management systems.
The issues above are addressed by a variety of process integrated measures/techniques and end-of-pipe techniques, taking into account their applicability in the cement, lime or magnesium oxide sectors. The measures/techniques that are included in this document are those that are considered to have the potential to acAhieve, or to contribute to, a high level of environmental protection. In this context, for the cement industry approximately 36 techniques to consider for pollution prevention and control are presented (Section 1.4), for the lime industry approximately 24 techniques (Section 2.4) and for the magnesium oxide industry using the dry process route approximately 16 techniques (Section 3.4).

Best available techniques

The BAT sections (Sections 1.5, 2.5 and 3.5) identify those techniques that are BAT for the cement, lime or magnesium oxide industries in a general sense, based mainly on the information from Sections 1.4, 2.4 or 3.4, taking into account the definition of best available techniques (Art. 2(12) of the IPPC Directive) and the considerations listed in Annex IV to the IPPC Directive. The BAT sections also suggest consumption and emission values that are associated with the use of BAT. As described in the Preface, the BAT sections do not propose emission limit values. For installation covered by the IPPC Directive, it is up to the competent authority to determine the emission limit values in the permit on the basis of BAT.

It has to be noted that in this Executive Summary, the BAT conclusions of this document are only presented as summaries. To read the relevant full BAT conclusion, see Sections 1.5, 2.5 and 3.5 of this document. Furthermore, it has generally to be noted, when co-incinerating waste, the requirements of the Waste Incineration Directive (WID) have to be met [59, European Commission, 2000].

Summary of BAT for the cement industry	
Environmental management (BAT 1 in Section 1.5.1)	• implement and adhere to an Environmental Management System (EMS) that incorporates, as appropriate to the local circumstances, the features as listed in BAT 1 in Section 1.5.1
General primary measures/techniques (BAT 2, 3, 4 in Section 1.5.2)	• achieve a smooth and stable kiln process, operating close to the process parameter set points, that is beneficial for all kiln emissions as well as the energy use by applying the measures/techniques listed in BAT 2 a, b in Section 1.5.2 • carry out a careful selection and control of all substances entering the kiln in order to avoid and/or reduce emissions (BAT 3 in Section 1.5.2) • carry out monitoring and measurements of process parameters and emissions on a regular basis which are listed in BAT 4 a – e in Section 1.5.2
Process selection (BAT 5 in Section 1.5.3.1)	• for new plants and major upgrades, apply a dry process kiln with multistage preheating and precalcination. Under regular and optimised operational conditions, the associated BAT heat balance value is 2900 – 3300 MJ/tonne clinker (BAT 5 in Section 1.5.3.1)
Energy consumption (BAT 6, 7, 8, 9 in Section 1.5.3.2)	• reduce/minimise thermal energy consumption by applying a combination of the measures/techniques as listed in BAT 6 a – f in Section 1.5.3.2 • reduce primary energy consumption by considering the reduction of the clinker content of cement and cement products (BAT 7 in Section 1.5.3.2) • reduce primary energy consumption by considering cogeneration/combined heat and power plants if possible, on the basis of useful heat demand, within energy regulatory schemes where economically viable (BAT 8 in Section 1.5.3.2) • minimise electrical energy consumption by applying the measures/techniques individually or in combination as listed BAT 9 a, b in Section 1.5.3.2

Summary of BAT for the cement industry	
Waste quality control (BAT 10 a – c in Section 1.5.4.1)	• apply quality assurance systems to guarantee the characteristics of wastes and to analyse any waste that is to be used as raw material and/or fuel in a cement kiln for parameters/criteria listed in BAT 10 a I. – III. in Section 1.5.4.1 • control the amount of relevant parameters for any waste that is to be used as raw material and/or fuel in a cement kiln, such as chlorine, relevant metals (e.g. cadmium, mercury, thallium), sulphur, total halogen content (BAT 10 b in Section 1.5.4.1) • apply quality assurance systems for each waste load (BAT 10 c in Section 1.5.4.1)
Waste feeding into the kiln (BAT 11 a – f in Section 1.5.4.2)	• use the appropriate feed points to the kiln in terms of temperature and residence time depending on kiln design and kiln operation (BAT 11 a in Section 1.5.4.2) • feed waste materials containing organic components that can be volatilised before the calcining zone into the adequately high temperature zones of the kiln system (BAT 11 b in Section 1.5.4.2) • operate in such a way that the gas resulting from the co-incineration of waste is raised in a controlled and homogeneous fashion, even under the most unfavourable conditions, to a temperature of 850 °C for 2 seconds (BAT 11 c in Section 1.5.4.2) • raise the temperature to 1100 °C, if hazardous waste with a content of more than 1 % of halogenated organic substances, expressed as chlorine, is co-incinerated (BAT 11 d in Section 1.5.4.2) • feed wastes continuously and constantly (BAT 11 e in Section 1.5.4.2) • stop co-incinerating waste for operations such as start-ups and/or shutdowns when appropriate temperatures and residence times cannot be reached, as noted in BAT 11 a – d (BAT 11 f in Section 1.5.4.2)
Safety management for the use of hazardous waste materials (BAT 12 in Section 1.5.4.3)	• apply safety management for the handling, e.g. storage, and/or feeding of hazardous waste materials, such as using a risk based approach according to the source and type of waste, for the labelling, checking, sampling and testing of waste to be handled (BAT 12 in Section 1.5.4.3)
Diffuse dust emissions (BAT 13 a, b in Section 1.5.5.1)	• minimise/prevent diffuse dust emissions by applying the measures/techniques individually or in combination which are listed in BAT 13 a, b in Section 1.5.5.1 (measures/techniques for dusty operations and bulk storage areas)
Channelled dust emissions from dusty operations (BAT 14 in Section 1.5.5.2)	• apply a maintenance management system which especially addresses the performance of filters of these sources. Taking this management system into account, BAT is to reduce channelled dust emissions from dusty operations to less than 10 mg/Nm^3 (BAT-AEL), as the average over the sampling period (spot measurement, for at least half an hour) by applying dry exhaust gas cleaning with a filter. For small sources (<10000 Nm^3/h) a priority approach has to be taken into account
Dust emissions from kiln firing processes (BAT 15 in Section 1.5.5.3)	• reduce dust (particulate matter) emissions from flue-gases of kiln firing processes by applying dry exhaust gas cleaning with a filter. The BAT-AEL is <10 – 20 mg/Nm^3, as the daily average value. When applying fabric filters or new or upgraded ESPs, the lower level is achieved
Dust emissions from cooling and milling processes (BAT 16 in Section 1.5.5.4)	• reduce dust (particulate matter) emissions from flue-gases of cooling and milling processes by applying dry exhaust gas cleaning with a filter. The BAT-AEL is <10 – 20 mg/Nm^3, as the daily average value or average over the sampling period (spot measurements for at least half an hour). When applying fabric filters or new or upgraded ESPs, the lower level is achieved

<table>
<tr><th colspan="2">Summary of BAT for the cement industry</th></tr>
<tr><td>NO_x emissions (BAT 17, 18 in Section 1.5.6.1)</td><td>

- reduce the emissions of NO_x from the flue-gases of kiln firing processes by applying measures/techniques which are listed in BAT 17 a – d in Section 1.5.6.1 individually or in combination (i.e. primary measures/techniques and/or staged combustion (conventional or waste fuels), also in combination with a precalciner and the use of optimised fuel mix, SNCR, SCR, subject to appropriate catalyst and process development in the cement industry). The following emission levels of NO_x are BAT-AELs (BAT 17 in Section 1.5.6.1):

<table>
<tr><th>Kiln type</th><th>Unit</th><th>BAT-AEL
(daily average value)</th></tr>
<tr><td>Preheater kilns</td><td>mg/Nm³</td><td><200 – 450[2) 3)]</td></tr>
<tr><td>Lepol and long rotary kilns</td><td>mg/Nm³</td><td>400 – 800[1)]</td></tr>
<tr><td colspan="3">[1)] Depending on initial levels and ammonia slip
[2)] BAT-AEL is 500 mg/Nm³, where after primary measures/techniques the initial NO_x level is >1000 mg/Nm³
[3)] Existing kiln system design, fuel mix properties including waste, raw material burnability can influence the ability to be in the range. Levels below 350 mg/Nm³ are achieved at kilns with favourable conditions. The lower value of 200 mg/Nm³ has only been reported as monthly average for three plants (easy burning mix used)</td></tr>
</table>

- by applying SNCR (BAT 18 in Section 1.5.6.1),
  - apply measures/techniques which are listed in BAT 18 a and b in Section 1.5.6.1
  - keep the emissions of NH_3 slip from the flue-gases as low as possible, but below 30 mg/Nm³, as the daily average value. The correlation between the NO_x abatement efficiency and the NH_3 slip has to be considered. Depending on the initial NO_x level and on the NO_x abatement efficiency, the NH_3 slip may be higher up to 50 mg/Nm³. For Lepol and long rotary kilns, the level may be even higher (BAT 18 c in Section 1.5.6.1)

</td></tr>
<tr><td>SO_x emissions (BAT 19, 20 in Section 1.5.6.2)</td><td>

- keep the emissions of SO_x low or reduce the emissions of SO_x from the flue-gases of kiln firing and/or preheating/precalcining processes by applying one of the measures/techniques which are listed in BAT 19 a (absorbent addition) and b (wet scrubber) in Section 1.5.6.2. The following emission levels of SO_x are BAT-AELs (BAT 19 in Section 1.5.6.2):

<table>
<tr><th>Parameter</th><th>Unit</th><th>BAT-AEL[1)]
(daily average value)</th></tr>
<tr><td>SO_x expressed as SO_2</td><td>mg/Nm³</td><td><50 – <400</td></tr>
<tr><td colspan="3">[1)] The range takes into account the sulphur content in the raw materials</td></tr>
</table>

- optimise the raw milling processes (for the dry process) which act as SO_2 abatement for the kiln, as described in Section 1.3.4.3 (BAT 20 in Section 1.5.6.2)

</td></tr>
<tr><td>Reduction of CO trips (BAT 21 in Section 1.5.6.3.1)</td><td>

- when applying ESPs or hybrid filters, minimise the frequency of CO trips and keep their total duration to below 30 minutes annually, by applying of the measures/techniques which are listed in BAT 21 a – c in Section 1.5.6.3.1 in combination

</td></tr>
<tr><td>Total organic carbon emissions (BAT 22 in Section 1.5.6.4)</td><td>

- keep the emissions of TOC from the flue-gases of the kiln firing processes low by avoiding of feeding raw materials with a high content of volatile organic compounds into the kiln system via the raw material feeding route

</td></tr>
<tr><td>Hydrogen chloride (HCl) and hydrogen fluoride (HF) emissions (BAT 23, 24 in Section 1.5.6.5)</td><td>

- keep the emissions of HCl below 10 mg/Nm³ (BAT-AEL), as the daily average value or average over the sampling period (spot measurements, for at least half an hour), by applying the measures/techniques which are listed in BAT 23 a and b in Section 1.5.6.5 individually or in combination
- keep the emissions of HF below 1 mg/Nm³ (BAT-AEL) expressed as HF, as the daily average value or average over the sampling period (spot measurements, for at least half an hour), by applying the primary measures/techniques which are listed in BAT 24 a, b in Section 1.5.6.5 individually or in combination

</td></tr>
<tr><td>PCDD/F emissions (BAT 25 in Section 1.5.7)</td><td>

- avoid emissions of PCDD/F or keep the emissions of PCDD/F from the flue-gases of the kiln firing processes low by applying the measures/techniques which are listed in BAT 25 a – f in Section 1.5.7 individually or in combination: The BAT-AELs are <0.05 – 0.1 ng PCDD/F I-TEQ/Nm³, as the average over the sampling period (6 – 8 hours)

</td></tr>
<tr><td>Metal emissions (BAT 26 in Section 1.5.8)</td><td>

- minimise the emissions of metals from the flue-gases of the kiln firing processes by applying the measures/techniques which are listed in BAT 26 a – c in Section 1.5.8 individually or in combination. The following emission levels of metals are BAT-AELs:

<table>
<tr><th>Metals</th><th>Unit</th><th>BAT-AEL
(average over the sampling period
(spot measurements, for at least half an hour))</th></tr>
<tr><td>Hg</td><td>mg/Nm³</td><td><0.05[2)]</td></tr>
<tr><td>Σ (Cd, Tl)</td><td>mg/Nm³</td><td><0.05[1)]</td></tr>
<tr><td>Σ (As, Sb, Pb, Cr, Co, Cu, Mn, Ni, V)</td><td>mg/Nm³</td><td><0.5[1)]</td></tr>
<tr><td colspan="3">[1)] Low levels have been reported, see Sections 1.3.4.7, 1.3.4.7.1 and 1.4.7
[2)] Low levels have been reported (see Sections 1.3.4.7, 1.3.4.7.1 and 1.4.7). Values higher than 0.03 mg/Nm³ have to be further investigated. Values close to 0.05 mg/Nm³ require consideration of additional measures/techniques such as those described in Sections 1.3.4.13, 1.3.9.1 and 1.4.7</td></tr>
</table>

</td></tr>
</table>

Summary of BAT for the cement industry	
Process losses/ waste (BAT 27 in Section 1.5.9)	• re-use collected particulate matter in the process, wherever practicable, or utilise these dusts in other commercial products, when possible
Noise (BAT 28 in Section 1.5.10)	• reduce/minimise noise emissions from the cement manufacturing processes by applying a combination of the measures/techniques which are listed in BAT 28 a – h in Section 1.5.10

Summary of BAT for the lime industry	
Environmental management (BAT 29 in Section 2.5.1)	• implement and adhere to an Environmental Management System (EMS) that incorporates, as appropriate to the local circumstances, the features as listed in BAT 29 in Section 2.5.1
General primary measures/techniques (BAT 30, 31, 32 in Section 2.5.2)	• achieve a smooth and stable kiln process, operating close to the process parameter set points, that is beneficial for all kiln emissions as well as the energy use by applying the measures/techniques which are listed in BAT 30 a, b in Section 2.5.2 • carry out a careful selection and control of substances entering the kiln in order to reduce and/or avoid emissions (BAT 31 in Section 2.5.2). • carry out monitoring and measurements of process parameters and emissions on a regular basis as listed in BAT 32 a – d in Section 2.5.2
Energy consumption (BAT 33, 34 in Section 2.5.3)	• reduce/minimise thermal energy consumption by applying a combination of the measures/techniques which are listed in BAT 33 a – c in Section 2.5.3. The following thermal energy consumption levels are associated with BAT (BAT 33 in Section 2.5.3):

Kiln type	Thermal energy consumption[1)] GJ/t
Long rotary kilns (LRK)	6.0 – 9.2
Rotary kilns with preheater (PRK)	5.1 – 7.8
Parallel flow regenerative kilns (PFRK)	3.2 – 4.2
Annular shaft kilns (ASK)	3.3 – 4.9
Mixed feed shaft kilns (MFSK)	3.4 – 4.7
Other kilns (OK)	3.5 – 7.0

[1)] Energy consumption depends on the type of product, the product quality, the process conditions and the raw materials

(Energy consumption, continued)	• minimise electrical energy consumption by applying the measures/techniques which are listed in BAT 34 a – c in Section 2.5.3 individually or in combination (BAT 34 in Section 2.5.3)
Consumption of limestone (BAT 35 in Section 2.5.4)	• minimise limestone consumption by applying the measures/techniques which are listed in BAT 35 a, b in Section 2.5.4 individually or in combination
Selection of fuels (BAT 36 in Section 2.5.5)	• carry out a careful selection and control of fuels entering the kiln, such as selecting fuels with low contents of sulphur (for rotary kilns in particular), nitrogen and chlorine in order to avoid/reduce emissions
Waste quality control (BAT 37 a, b in Section 2.5.5.1.1)	• apply quality assurance systems to guarantee the characteristics of wastes and to analyse any waste that is to be used as fuel in a lime kiln for the parameters/criteria listed BAT 37 a I. – a III. in Section 2.5.5.1.1 • control the amount of relevant parameters for any waste that is to be used as fuel in a lime kiln, such as total halogen content, relevant metals (e.g. total chromium, lead, cadmium, mercury, thallium) and sulphur
Waste feeding into the kiln (BAT 38 a – e in Section 2.5.5.1.2)	• use appropriate burners for feeding suitable wastes depending on kiln design and kiln operation (BAT 38 a in Section 2.5.5.1.2) • operate in such a way that the gas resulting from the co-incineration of waste is raised in a controlled and homogeneous fashion and even under the most unfavourable conditions, to a temperature of 850 °C for 2 seconds (BAT 38 b in Section 2.5.5.1.2) • raise the temperature to 1100 °C if hazardous wastes with a content of more than 1 % of halogenated organic substances, expressed as chlorine, are co-incinerated (BAT 38 c in Section 2.5.5.1.2) • feed wastes continuously and constantly (BAT 38 d in Section 2.5.5.1.2) • stop co-incinerating waste for operations such as start-ups and/or shutdowns when appropriate temperatures and residence times cannot be reached, as mentioned in BAT 38 b – c (BAT 38 e in Section 2.5.5.1.2)
Safety management for the use of hazardous waste materials (BAT 39 in Section 2.5.5.1.3)	• apply safety management for the handling, e.g. storage, and/or feeding of hazardous waste materials (see Section 2.4.4) (BAT 39 in Section 2.5.5.1.3)
Diffuse dust emissions (BAT 40 in Section 2.5.6.1)	• minimise/prevent diffuse dust emissions by applying the measures/techniques which are listed in BAT 40 a, b in Section 2.5.6.1 individually or in combination

<table>
<tr><th colspan="2">Summary of BAT for the lime industry</th></tr>
<tr><td>Channelled dust emissions from dusty operations (BAT 41 in Section 2.5.6.2)</td><td>

- apply a maintenance management system which especially addresses the performance of filters of these sources. Taking this management system into account, BAT is to reduce channelled dust emissions from dusty operations to less than 10 mg/Nm^3 (BAT-AEL), as the average over the sampling period (spot measurements, for at least half an hour) by applying fabric filters or to <10 – 20 mg/Nm^3 (BAT-AEL), as the average over the sampling period (spot measurements, for at least half an hour) by applying wet scrubbers.
  Wet scrubbers are mainly used for hydrating lime plants. It has to be noted that for small sources (<10000 Nm³/h) a priority approach has to be taken into account

</td></tr>
<tr><td>Dust emissions from kiln firing processes (BAT 42 in Section 2.5.6.3)</td><td>

- reduce dust (particulate matter) emissions from the flue-gases of kiln firing processes by applying exhaust gas cleaning with a filter (see Section 2.4.5.3). By applying fabric filters, the BAT-AEL is less than 10 mg/Nm^3, as the daily average value. By applying ESPs or other filters, the BAT-AEL is less than 20 mg/Nm^3, as the daily average value.
  In exceptional cases where the resistivity of dust is high, the BAT-AEL could be higher, up to 30 mg/Nm^3, as the daily average value

</td></tr>
<tr><td>General primary measures/techniques for reducing gaseous compounds (BAT 43 in Section 2.5.7.1)</td><td>

- reduce the emissions of gaseous compounds (i.e. NO_x, SO_x, HCl, CO, TOC/VOC, metals) from the flue-gases of kiln firing processes by applying the primary measures/techniques which are listed in BAT 43 a – c in Section 2.5.7.1 individually or in combination

</td></tr>
<tr><td>NO_x emissions (BAT 44, 45 in Section 2.5.7.2)</td><td>

- reduce the emissions of NO_x from the flue-gases of kiln firing processes by applying the measures/techniques which are listed in BAT 44 a, b in Section 2.5.7.2 individually or in combination. The following emission levels of NO_x are BAT-AELs:

<table>
<tr><th>Kiln type</th><th>Unit</th><th>BAT-AEL
(daily average value, stated as NO_2)</th></tr>
<tr><td>PFRK, ASK, MFSK, OSK</td><td>mg/Nm³</td><td>100 – <350[1) 3)]</td></tr>
<tr><td>LRK, PRK</td><td>mg/Nm³</td><td><200 – <500[1) 2)]</td></tr>
<tr><td colspan="3">1) The higher ranges are related to the production of dolime and hard burned lime
2) For LRK and PRK with shaft producing hard burned lime, the upper level is up to 800 mg/Nm³
3) Where primary measures as indicated in a) I. above are not sufficient and where secondary measures are not available to reduce the NO_x emissions to 350 mg/Nm³, the upper level is 500 mg/Nm³, especially for hard burned lime</td></tr>
</table>

- when SNCR is applicable,
  - apply measures/techniques which are listed in BAT 45 a, b in Section 2.5.7.2
  - keep the emissions of NH_3 slip from the flue-gases as low as possible, but below 30[1)] mg/Nm^3, as the daily average value. The correlation between the NO_x abatement efficiency and the NH_3 slip has to be considered (see Section 2.4.6.1.4, Figure 2.50) (BAT 45 c in Section 2.5.7.2)

  1) This BAT-AEL is related to experiences taken from one lime installation (four kilns)

</td></tr>
<tr><td>SO_x emissions (BAT 46 in Section 2.5.7.3)</td><td>

- reduce the emissions of SO_x from the flue-gases of kiln firing processes by applying the measures/techniques which are listed in BAT 46 a – c in Section 2.5.7.3 individually or in combination. The following emission levels of SO_x are BAT-AELs:

<table>
<tr><th>Kiln type</th><th>Unit</th><th>BAT-AEL[1)]
(daily average value, SO_x expressed as SO_2)</th></tr>
<tr><td>PFRK, ASK, MFSK, OSK, PRK</td><td>mg/Nm³</td><td><50 – <200</td></tr>
<tr><td>LRK</td><td>mg/Nm³</td><td><50 – <400</td></tr>
<tr><td colspan="3">1) The level depends on the initial SO_x level in the exhaust gas and on the reduction measure/technique used</td></tr>
</table>

</td></tr>
<tr><td>CO emissions (BAT 47 in Section 2.5.7.4.1)</td><td>

- reduce the emissions of CO by applying the primary measures/techniques which are listed in BAT 47 a, b in Section 2.5.7.4.1 individually or in combination. The following emission levels of CO are BAT-AELs:

<table>
<tr><th>Kiln type</th><th>Unit</th><th>BAT-AEL[1)]
(daily average value)</th></tr>
<tr><td>PFRK, OSK, LRK, PRK</td><td>mg/Nm³</td><td><500</td></tr>
<tr><td colspan="3">1) Level can be higher depending on raw materials used and/or type of lime produced, e.g. hydraulic lime</td></tr>
</table>

</td></tr>
<tr><td>Reduction of CO trips (BAT 48 in Section 2.5.7.4.2)</td><td>

- when using electrostatic precipitators (ESPs), minimise the frequency of CO trips by applying the measurements/techniques which are listed in BAT 48 a – c in Section 2.5.7.4.2

</td></tr>
</table>

<table>
<tr><th colspan="2">Summary of BAT for the lime industry</th></tr>
<tr><td>Total organic carbon (BAT 49 in Section 2.5.7.5)</td><td>• reduce the emissions of TOC from the flue-gases of the kiln firing processes by applying the measures/techniques which are listed in BAT 49 a, b in Section 2.5.7.5 individually or in combination. The following emission levels of TOC are BAT-AELs:
<table>
<tr><th>Kiln type</th><th>Unit</th><th>BAT-AEL
(average over the sampling period)</th></tr>
<tr><td>LRK[1)], PRK[1)]</td><td>mg/Nm^3</td><td><10</td></tr>
<tr><td>ASK[1)], MFSK[1) 2)], PFRK[2)]</td><td>mg/Nm^3</td><td><30</td></tr>
<tr><td colspan="3">[1)] Level can be higher depending on the raw materials used and/or the type of lime produced, e.g. hydraulic lime
[2)] In exceptional cases, the level can be higher</td></tr>
</table></td></tr>
<tr><td>Hydrogen chloride (HCl) and hydrogen fluoride (HF) emissions (BAT 50 in Section 2.5.7.6)</td><td>• when using wastes, reduce the emissions of HCl and the emissions of HF by applying the primary measures/techniques as listed in BAT 50 a, b in Section 2.5.7.6.
The BAT-AEL for HCl is <10 mg/Nm^3, as the daily average value or the average value over the sampling period (spot measurements, for at least half an hour) and the BAT for HF is <1 mg/Nm^3, as the daily average value or the average value over the sampling period (spot measurements, for at least half an hour)</td></tr>
<tr><td>PCDD/F emissions (BAT 51 in Section 2.5.8)</td><td>• prevent or reduce the emissions of PCDD/F by applying the primary measures/techniques which are listed in BAT 51 a – c in Section 2.5.8 individually or in combination.
The BAT-AELs are <0.05 – 0.1 ng PCDD/F I-TEQ/Nm^3, as the average over the sampling period (6 – 8 hours)</td></tr>
<tr><td>Metal emissions (BAT 52 in Section 2.5.9)</td><td>• minimise the emissions of metals from the flue-gases of the kiln firing processes by applying the measures/techniques which are listed in BAT 52 a – d in Section 2.5.9 individually or in combination. When using wastes, the following emission levels of metals are BAT-AELs:
<table>
<tr><th>Metals</th><th>Unit</th><th>BAT-AEL
(average over the sampling period)</th></tr>
<tr><td>Hg</td><td>mg/Nm^3</td><td><0.05</td></tr>
<tr><td>∑ (Cd, Tl)</td><td>mg/Nm^3</td><td><0.05</td></tr>
<tr><td>∑ (As, Sb, Pb, Cr, Co, Cu, Mn, Ni, V)</td><td>mg/Nm^3</td><td><0.5</td></tr>
<tr><td colspan="3">Low levels were reported (see Sections 2.3.3.9, 2.3.3.10.1 and 4.3.4 when applying measures/techniques as mentioned in BAT 52)</td></tr>
</table></td></tr>
<tr><td>Process losses/waste (BAT 53 a, b in Section 2.5.10)</td><td>• re-use collected dust/particulate matter in the process wherever practicable (BAT 53 a in Section 2.5.10)
• utilise dust, off specification quicklime and hydrated lime in selected commercial products (BAT 53 b in Section 2.5.10)</td></tr>
<tr><td>Noise (BAT 54 in Section 2.5.11)</td><td>• reduce/minimise noise emissions from the lime manufacturing processes by applying a combination of the measures/techniques which are listed in BAT 54 a – o in Section 2.5.11</td></tr>
</table>

<table>
<tr><th colspan="2">Summary of BAT for the magnesium oxide industry</th></tr>
<tr><td>Environmental management (BAT 55 in Section 3.5.1)</td><td>• implement and adhere to an Environmental Management System (EMS) that incorporates, as appropriate to the local circumstances, the features as listed in BAT 55 in Section 3.5.1</td></tr>
<tr><td>General primary measures/techniques (BAT 56 in Section 3.5.2)</td><td>• carry out monitoring and measurements of process parameters and emissions on a regular basis as listed in BAT 56 a – c in Section 3.5.2</td></tr>
<tr><td>Energy consumption (BAT 57, 58 in Section 3.5.3)</td><td>• reduce thermal energy consumption depending on the process and the products to 6 – 12 GJ/t by applying a combination of the measures/techniques which are listed in BAT 57 a – c in Section 3.5.3
• minimise electrical energy consumption by applying the measures/techniques which are listed in BAT 58 a, b in Section 3.5.3 individually or in combination</td></tr>
<tr><td>Diffuse dust emissions (BAT 59 in Section 3.5.4.1)</td><td>• minimise/prevent diffuse dust emissions by applying measures/techniques for dusty operations individually or in combination</td></tr>
<tr><td>Channelled dust emissions from dusty operations (BAT 60 in Section 3.5.4.2)</td><td>• reduce channelled dust emissions from dusty operations to less than 10 mg/Nm^3 (BAT-AEL), as the average over the sampling period (spot measurements, for at least half an hour), by applying flue-gas cleaning with a filter. It has to be noted that for small sources (<10000 Nm^3/h), a priority approach has to be taken into account</td></tr>
<tr><td>Dust emissions from kiln firing process (BAT 61 in Section 3.5.4.3)</td><td>• reduce dust (particulate matter) emissions from the flue-gases of kiln firing processes to <20 – 35 mg/Nm^3 (BAT-AEL), as the daily average value or average over the sampling period (spot measurements, for at least half an hour), by applying exhaust gas cleaning with a filter</td></tr>
</table>

<table>
<tr><th colspan="2">Summary of BAT for the magnesium oxide industry</th></tr>
<tr><td>General primary measures/techniques for reducing gaseous compounds (BAT 62 in Section 3.5.5.1)</td><td>• reduce the emissions of gaseous compounds (i.e. NO_x, HCl, SO_x, CO) from flue-gases of kiln firing processes by applying the primary measures/techniques which are listed in BAT 62 a – c in Section 3.5.5.1 individually or in combination</td></tr>
<tr><td>NO_x emissions (BAT 63 in Section 3.5.5.2)</td><td>• reduce the emissions of NO_x from the flue-gases of kiln firing processes to <500 – <1500 mg/Nm^3 (BAT-AEL), as the daily average value stated as NO_2, by applying a combination of the measures/techniques which are listed in BAT 63 a, b in Section 3.5.5.2. The higher BAT-AEL values are related to the high temperature DBM process</td></tr>
<tr><td>CO emissions (BAT 64 in Section 3.5.5.3.1)</td><td>• reduce the emissions of CO from the flue-gases of kiln firing processes to <50 – 1000 mg/Nm^3 (BAT-AEL), as the daily average value by applying a combination of the measures/techniques which are listed in BAT 64 a – c in Section 3.5.5.3.1</td></tr>
<tr><td>Reduction of CO trips (BAT 65 in Section 3.5.5.3.2)</td><td>• by applying ESP, minimise the number of CO trips by applying the measures/techniques which are listed in BAT 65 a – c in Section 3.5.5.3.2</td></tr>
<tr><td>SO_x emissions (BAT 66 in Section 3.5.5.4)</td><td>• reduce the emissions of SO_x from the flue-gases of kiln firing processes by applying a combination of the primary and secondary measures/techniques which are listed in BAT 66 a - c in Section 3.5.5.4: The following emission levels of SO_x are BAT-AELs:
<table>
<tr><th>Parameter</th><th>Unit</th><th>BAT-AEL[1)3)]
(daily average value)</th></tr>
<tr><td>SO_x expressed as SO_2
Sulphur content in the raw material <0.10 %</td><td>mg/Nm^3</td><td><50</td></tr>
<tr><td>SO_x expressed as SO_2
Sulphur content in the raw material 0.10 – 0.25 %</td><td>mg/Nm^3</td><td>50 – 250</td></tr>
<tr><td>SO_x expressed as SO_2
Sulphur content in the raw material >0.25</td><td>mg/Nm^3</td><td>250 – 400[2)]</td></tr>
<tr><td colspan="3">1) The ranges depend on the content of sulphur in the raw materials, e.g. for the use of raw materials with a lower content of sulphur, lower levels within the ranges are BAT and for the use of raw materials with a higher content of sulphur, higher levels within the ranges are BAT
2) Related to raw material compositions, SO_2 emission levels could be higher than 400 mg/Nm^3 in exceptional cases
3) Cross media effects should be taken into account to assess the best combination of BAT to reduce SO_2 emissions</td></tr>
</table></td></tr>
<tr><td>Process losses/waste (BAT 67, 68, 69 in Section 3.5.6)</td><td>• re-use collected particulate matter (various types of magnesium carbonate dusts) in the process wherever practicable (BAT 67 in Section 3.5.6)
• when various types of collected magnesium carbonate dusts are not recyclable utilise these dusts in other marketable products, when possible (BAT 68 in Section 3.5.6)
• re-use sludge resulting from the wet process of the flue-gas desulphurisation in the process or in other sectors (BAT 69 in Section 3.5.6)</td></tr>
<tr><td>Noise (BAT 70 in Section 3.5.7)</td><td>• reduce/minimise noise emissions from magnesium oxide manufacturing processes by applying a combination of the measures/techniques which are listed in BAT 70 a – j in Section 3.5.7</td></tr>
<tr><td>Use of wastes as fuels and/or raw materials (BAT 71 in Section 3.5.8)</td><td>• when using wastes,
○ select suitable wastes for the process and the burner (BAT 71 a in Section 3.5.8)
○ apply quality assurance systems to guarantee the characteristics of wastes and to analyse any waste that is to be used for the criteria which are listed in BAT 71 b in Section 3.5.8
○ control the amount of relevant parameters for any waste that is to be used, such as total halogen content, metals (e.g. total chromium, lead, cadmium, mercury, thallium) and sulphur (BAT 71 c in Section 3.5.8)</td></tr>
</table>

Conclusions, recommendations, research and technical development

The conclusions and recommendations for the cement, lime and magnesium oxide industry contain information on the milestones in developing this document, the degree of consensus reached on the BAT proposals for the cement, lime and magnesium oxide industries and the information gaps that still exist. A high level of consensus was reached and no split views were recorded. The web-site of the European IPPC Bureau contains further information and guidance on the functioning of the information exchange and the procedure for BREFs review.

The EC is launching and supporting, through its RTD programmes, a series of projects dealing with clean technologies, emerging effluent treatment and recycling technologies and management strategies. Potentially these projects could provide a useful contribution to future BREF reviews. Readers are therefore invited to inform the European IPPC Bureau of any research results which are relevant to the Scope of this document (see also the Preface of this document).