EXECUTIVE SUMMARY

The BAT (Best Available Techniques) Reference Document (BREF) entitled ‘Ceramic Manufacturing (CER)’ reflects an information exchange carried out under Article 16(2) of Council Directive 96/61/EC (IPPC Directive). This executive summary describes the main findings, 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. It can be read and understood as a standalone document but, as a summary, it does not present all the complexities of this full document. It is therefore not intended as a substitute for this full document as a tool in BAT decision making and it has to be stressed again that this summary cannot correctly be interpreted unless it is read in conjunction with Chapters 4 and 5.

SCOPE OF THIS DOCUMENT

This document addresses the industrial activities specified in Section 3.5 of Annex I to Directive 96/61/EC, namely:

‘3.5. Installations for the manufacture of ceramic products by firing, in particular roofing tiles, bricks, refractory bricks, tiles, stoneware or porcelain, with a production capacity exceeding 75 tonnes per day, and/or with a kiln capacity exceeding 4 m^3 and with a setting density per kiln exceeding 300 kg/m^3’.

For the purposes of this document the industrial activities falling within this description will be referred to as the ‘ceramic industry’. The major sectors which are based on the ceramic products (ceramics) manufactured are as follows:

- wall and floor tiles
- bricks and roof tiles
- table- and ornamentalware (household ceramics)
- refractory products
- sanitaryware
- technical ceramics
- vitrified clay pipes
- expanded clay aggregates
- inorganic bonded abrasives.

In addition to the basic manufacturing activities, this document covers the directly 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 finished products. Certain activities, such as the quarrying of raw materials, are not covered because they are not considered to be directly associated with the primary activity.

THE CERAMIC INDUSTRY

Generally the term ‘ceramics’ (ceramic products) is used for inorganic materials (with possibly some organic content), made up of non-metallic compounds and made permanent by a firing process. In addition to clay based materials, today ceramics include a multitude of products with a small fraction of clay or none at all. Ceramics can be glazed or unglazed, porous or vitrified.

Firing of ceramic bodies induces time-temperature transformation of the constituent minerals, usually into a mixture of new minerals and glassy phases. Characteristic properties of ceramic products include high strength, wear resistance, long service life, chemical inertness and non-toxicity, resistance to heat and fire, (usually) electrical resistance and sometimes also a specific porosity.

Clay raw materials are widely distributed throughout Europe, so ceramic products like bricks which are relatively inexpensive (but which incur high transport costs due to their weight) are manufactured in virtually all Member States. Building traditions and heritage considerations result in different unit sizes from country to country. More specialised products which command higher prices tend to be mainly produced in a few countries, which have the necessary special raw materials and – equally important – traditions of skill and expertise.

KEY ENVIRONMENTAL ISSUES

Depending on the specific production processes, plants manufacturing ceramic products cause emissions to be released into air, water and land (waste). Additionally, the environment can be affected by noise and unpleasant smells. The type and quantity of air pollution, wastes and waste water depend on different parameters. These parameters are, e.g. the raw materials used, the auxiliary agents employed, the fuels used and the production methods:

- emissions to air: particulate matter/dust, soot, gaseous emissions (carbon oxides, nitrogen oxides, sulphur oxides, inorganic fluorine and chlorine compounds, organic compounds and heavy metals) can arise from the manufacture of ceramic products
- emissions to water: process waste water mainly contains mineral components (insoluble particulate matter) and also further inorganic materials, small quantities of numerous organic materials as well as some heavy metals
- process losses/waste: process losses originating from the manufacture of ceramic products, mainly consist of different kinds of sludge, broken ware, used plaster moulds, used sorption agents, solid residues (dust, ashes) and packaging waste
- energy consumption/CO_2 emissions: all sectors of the ceramic industry are energy intensive, as a key part of the process involves drying followed by firing to temperatures of between 800 and 2000 ºC. Today natural gas, liquefied petroleum gas (propane and butane) and fuel oil EL are mainly used for firing, while heavy fuel oil, liquefied natural gas (LNG), biogas/biomass, electricity and solid fuels (e.g. coal, petroleum coke) can also play a role as energy sources for burners.

APPLIED PROCESSES AND TECHNIQUES

The manufacture of ceramic products takes place in different types of kilns, with a wide range of raw materials and in numerous shapes, sizes and colours. The general process of manufacturing ceramic products, however, is rather uniform, besides the fact that for the manufacture of wall and floor tiles, household ceramics, sanitaryware and technical ceramics often a multiple stage firing process is used.

In general, raw materials are mixed and cast, pressed or extruded into shape. Water is regularly used for a thorough mixing and shaping. This water is evaporated in dryers and the products are either placed by hand in the kiln – especially in the case of periodically operated shuttle kilns – or placed onto carriages that are transferred through continuously operated tunnel or roller hearth kilns. For the manufacture of expanded clay aggregates, rotary kilns are used.

During firing a very accurate temperature gradient is necessary to ensure that the products obtain the right treatment. Afterwards controlled cooling is necessary, so that the products release their heat gradually and preserve their ceramic structure. Then the products are packaged and stored for delivery.

EMISSIONS AND CONSUMPTIONS

Emissions

The processing of clays and other ceramic raw materials inevitably leads to dust formation – especially in the case of dry materials. Drying, (including spray drying), comminution (grinding, milling), screening, mixing and conveying can all result in a release of fine dust. Some dust also forms during the decorating and firing of the ware, and during the machining or finishing operations on the fired ware. Dust emissions are not only derived from the raw materials as described above, but also the fuels contribute to these emissions to air.

The gaseous compounds released during drying and firing are mainly derived from the raw materials, but fuels also contribute gaseous pollutants. In particular these are SO_X, NO_X, HF, HCl, VOC and heavy metals.

Process waste water is generated mainly when clay materials are flushed out and suspended in flowing water during the manufacturing process and equipment cleaning, but emissions to water also occur during the operation of wet off-gas scrubbers. The water added directly to ceramic body mixes is subsequently evaporated into the air during the drying and firing stages.

Process losses can often be recycled and re-used within the plant due to product specifications or process requirements. Materials, which cannot be recycled internally, leave the plant to be used in other industries or to be supplied to external waste recycling or waste disposal facilities.

Consumptions

The primary energy use in ceramic manufacturing is for kiln firing and, in many processes, drying of intermediates or shaped ware is also energy intensive.

Water is used in virtually all ceramic processes and good quality water is essential for the preparation of clays and glaze slips, clay bodies for extrusion, 'muds' for moulding, preparation of spray dried powders, wet grinding/milling and washing or cleaning operations.

A vast range of raw materials is consumed by the ceramic industry. These include the main body forming materials, involving high tonnages, and various additives, binders and decorative surface-applied materials which are used on a lesser scale.

TECHNIQUES TO CONSIDER IN THE DETERMINATION OF BAT

Important issues for the implementation of IPPC in the ceramic industry are reduction of emissions to air and water, efficient energy, raw material and water usage, minimisation, recovery and recycling of process losses/waste and process waste water, as well as effective management systems.

The issues above are addressed by a variety of process-integrated and end-of-pipe techniques, taking into account the applicability in the nine individual ceramic sectors. In this context, approximately 50 techniques for pollution prevention and control are presented in this document, under the following seven thematic headings:

Reduction of energy consumption (energy efficiency)

The choices of energy source, firing technique and heat recovery method are central to the design of the kiln and are also some of the most important factors affecting the environmental performance and energy efficiency of the manufacturing process.

The main techniques for reducing energy usage, which can be applied individually or in combination, are listed below and are discussed in detail in this document:

- improved design of kilns and dryers
- recovery of excess heat from kilns
- cogeneration/combined heat and power plants
- substitution of heavy fuel oil and solid fuels by low emission fuels
- modification of ceramic bodies.

Emissions of dust (particulate matter)

To prevent diffuse and channelled dust emissions, techniques and measures are described, which can be applied individually or in combination. These are:

- measures for dusty operations
- measures for bulk storage areas
- separation/filter systems.

Gaseous compounds

To prevent emissions of gaseous air pollutants (in particular SO_{Xx}, NO_{Xx}, HF, HCl, VOC), primary and secondary measures/techniques are described, which can be applied individually or in combination. These are:

- reduction of pollutant precursor input
- addition of calcium rich additives
- process optimisation
- sorption plants (adsorbers, absorbers)
- afterburning.

Process waste water

Objectives and solutions for the reduction of process waste water (emissions and consumption) are presented in the form of process optimisation measures and process waste water treatment systems. For the reduction of process waste water emissions and lower water consumption, combinations of these measures are usually applied.

Process losses/waste

Objectives and solutions for the reduction of process losses/waste are presented regarding sludge arising in the manufacture of ceramic products and solid process losses/solid waste in the form of process optimisation, recycling and re-use measures/techniques. For the reduction of process losses/waste, combinations of these measures/techniques are usually applied.

General considerations concerning noise

Possibilities for the reduction of noise occurring in the several steps during the manufacturing processes of ceramic products are demonstrated. A general summary and overview for the reduction of noise is presented.

Environmental management tools/environmental management systems (EMS)

EMS are essential for minimising the environmental impact of industrial activities in general, with some measures that are specifically important to ceramics. Therefore EMS are presented in this document as tools that operators can use to address these design, construction, maintenance, operation and decommissioning issues in a systematic, demonstrable way.

BAT FOR CERAMIC MANUFACTURING

The BAT chapter (Chapter 5) identifies those techniques that are considered to be BAT in a general sense, based mainly on the information in Chapter 4, taking into account the Article 2(11) definition of best available techniques and the considerations listed in Annex IV to the Directive. As described more fully in the Preface, the BAT chapter does not set or propose emission limit values but suggests consumption and emission values that are associated with the use of BAT as well as a selection of BAT. The determination of appropriate permit conditions will involve taking account of local, site-specific factors such as the technical characteristics of the installation concerned, its geographical location and the local environmental conditions. In the case of existing installations, the economic and technical viability of upgrading them also needs to be taken into account.

The following paragraphs summarise the key BAT conclusions for the ceramic manufacturing industry relating to the most relevant environmental issues. The BAT conclusions are set out on two levels. Section 5.1 presents generic BAT conclusions, i.e. those that are generally applicable to the whole ceramic industry. Section 5.2 contains more specific BAT conclusions, i.e. those for the nine major ceramic sectors under the scope. ‘Best Available Techniques’ for a specific installation will usually be the use of one individual or a combination of the techniques and measures listed in the relevant chapter under the generic and sector specific sections.

It has to be noted, that in this Executive Summary, the BAT conclusions of this document are summarised as short versions. To read the relevant full BAT conclusions, see the corresponding sections in Chapter 5 of this document.

Generic BAT

The generic BAT section contains general BAT conclusions regarding all nine sectors explained and described in detail in this document.

It has to be noted, that in this Executive Summary, the BAT conclusions of this document are summarised as short versions. It has to be stressed again that this BAT summary as well as the associated BAT AEL ranges mentioned in the summary, cannot correctly be interpreted unless it is read in conjunction with Chapter 4 and the relevant full BAT conclusions in Chapter 5 of this document.

Environmental management:

Implement and adhere to an Environmental Management System (EMS) that incorporates, as appropriate to individual circumstances, the features listed in Section 5.1.1 of this document.

Energy consumption:

Reduce energy consumption by applying a combination of several techniques, which are listed in Section 5.1.2.a of this document and can be summarised as:

- improved design of kilns and dryers
- recovery of excess heat from kilns, especially from their cooling zone
- applying a fuel switch in the kiln firing process (substitution of heavy fuel oil and solid fuels by low emission fuels)
- modification of ceramic bodies.

Reduce primary energy consumption by applying cogeneration/combined heat and power plants on the basis of useful heat demand, within energy regulatory schemes which are economically viable.

Diffuse dust emissions:

Reduce diffuse dust emissions by applying a combination of several techniques, which are listed in Section 5.1.3.1 of this document and can be summarised as measures for dusty operations and bulk storage area measures.

Channelled dust emissions from dusty operations other than from drying, spray drying or firing:

Reduce channelled dust emissions from dusty operations to 1 – 10 mg/m^3, as the half hourly average value, by applying bag filters. The range may be higher depending on specific operating conditions.

Dust emissions from drying processes:

Keep dust emissions from drying processes in the range 1 – 20 mg/m^3 as the daily average value by cleaning the dryer, by avoiding the accumulation of dust residues in the dryer and by adopting adequate maintenance protocols.

Dust emissions from kiln firing processes:

Reduce dust emissions from the flue-gases of kiln firing processes to 1 – 20 mg/m^3 as the daily average value by applying a combination of several techniques, which are listed in Section 5.1.3.4 of this document. These techniques can be summarised as utilisation of low ash fuels and minimisation of dust formation caused by the charging of the ware to be fired in the kiln.

By applying dry flue-gas cleaning with a filter, a dust emission level of less than 20 mg/m^3 in the cleaned flue-gas is BAT and by applying cascade-type packed bed adsorbers, a dust emission level of less than 50 mg/m^3 in the cleaned flue-gas is BAT (for expanded clay aggregates, see the sector specific BAT).

Gaseous compounds, primary measures/techniques:

Reduce the emissions of gaseous compounds (i.e. HF, HCl, SO_X, VOC, heavy metals) from flue-gases of kiln firing processes by applying one or a combination of several techniques, which are listed in Section 5.1.4.1 of this document. These techniques can be summarised as reducing the input of pollutant precursors and heating curve optimisation.

Keep the emissions of NO_X from flue-gases of kiln firing processes below 250 mg/m^3, as the daily average value stated as NO_2, for kiln gas temperatures below 1300 ºC, or below 500 mg/m^3, as the daily average value stated as NO_2, for kiln gas temperatures of 1300 ºC and higher, by applying a combination of primary measures/techniques as listed in Sections 4.3.1 and 4.3.3 of the document (for expanded clay aggregates, see the sector specific BAT).

Keep the emissions of NO_X from off-gases of cogeneration engines below 500 mg/m^3, as the daily average value stated as NO_2, by applying process optimisation measures.

Gaseous compounds, secondary measures/techniques and in combination with primary measures/techniques:

Reduce the emissions of gaseous inorganic compounds from flue-gases of kiln firing processes by applying one of several techniques which are listed in Section 5.1.4.2 of this document and can be summarised as cascade-type packed bed adsorbers and dry flue-gas cleaning with a filter.

The following table from Section 5.1.4.2 shows BAT emission levels for gaseous inorganic compounds from flue-gases of kiln firing processes by applying a combination of primary measures/techniques as stated in Section 5.1.4.1.a and/or secondary measures/techniques as stated in Section 5.1.4.2 of this document.

Parameter	Unit, as a daily average value	BAT AEL 1)
Fluoride stated as HF	mg/m^3	1 – 10 2)
Chloride stated as HCl	mg/m^3	1 – 30 3)
SO_X stated as SO_2 Sulphur content in raw material ≤0.25 %	mg/m^3	<500
SO_X stated as SO_2 Sulphur content in raw material >0.25 %	mg/m^3	500 – 2000 4)
1) The ranges depend on the content of the pollutant (precursor) in the raw materials, i.e. for firing processes of ceramic products with a low content of the pollutant (precursor) in the raw materials, lower levels within the range are BAT and for firing processes of ceramic products with a high content of the pollutant (precursor) in the raw materials, higher levels within the range are BAT AELs.		
2) The higher BAT level can be lower depending on the characteristics of the raw material.		
3) The higher BAT level can be lower depending on the characteristics of the raw material. Also, the higher BAT AEL should not prevent the re-use of waste water.		
4) The higher BAT level only applies to raw material with an extremely high sulphur content.		

Process waste water (emissions and consumption):

Reduce water consumption by applying several process optimisation measures as listed in Section 4.4.5.1 of this document, which can be applied individually or in combination.

Clean process waste water by applying several process waste water treatment systems as listed in Section 4.4.5.2 of this document, which can be applied individually or in combination to ensure that the water is adequately cleaned to be re-used in the manufacturing process or to be discharged directly into watercourses or indirectly into a municipal waste water sewerage system.

The following table from Section 5.1.5 shows BAT associated emission levels of pollutants in waste water discharges:

Parameter	Unit	BAT AEL (2 hours composite sample)
Suspended solids	mg/l	50.0
AOX	mg/l	0.1
Lead (Pb)	mg/l	0.3
Zinc (Zn)	mg/l	2.0
Cadmium (Cd)	mg/l	0.07

If more than 50 % of the process water is re-used in the manufacturing processes, higher concentrations of these pollutants may still be BAT AELs, as long as the specific pollutant load per production amount (kg of processed raw material) is not higher than the pollutant load resulting from a water recycling rate of less than 50 %.

Sludge:

Recycle/re-use sludge by applying sludge recycling systems and/or sludge re-use in other products.

Solid process losses/solid waste:

Reduce solid process losses/solid waste by applying a combination of several techniques, which are listed in Section 5.1.7 of this document and can be summarised as:

- feedback of unmixed raw materials
- feedback of broken ware into the manufacturing process
- use of solid process losses in other industries
- electronic controlling of firing
- applying optimised setting.

Noise:

Reduce noise by applying a combination of several techniques, which are listed in Section 5.1.8 of this document and can be summarised as:

- enclosure of units
- vibration insulation of units
- using silencers and slow rotating fans
- situating windows, gates and noisy units away from neighbours
- sound insulation of windows and walls
- closing windows and gates
- carrying out noisy (outdoor) activities only during the day
- good maintenance of the plant.

Sector specific BAT

The sector specific BAT section contains specific BAT conclusions regarding each of the nine sectors explained and described in this document. It has to be stressed again that this BAT summary as well as the associated BAT AEL ranges mentioned in the summary, cannot correctly be interpreted unless it is read in conjunction with Chapter 4 and the relevant full BAT conclusions in Chapter 5 of this document.

Channelled dust emissions:

Wall and floor tiles, household ceramics, sanitaryware, technical ceramics, vitrified clay pipes:

Reduce channelled dust emissions from spray glazing processes to 1 – 10 mg/m^3, as the half hourly average value, by applying bag filters or sintered lamellar filters.

Wall and floor tiles, household ceramics, technical ceramics:

Reduce channelled dust emissions from spray drying processes to 1 – 30 mg/m^3, as the half hourly average value, by applying bag filters, or to 1 – 50 mg/m^3 by applying cyclones in combination with wet dust separators for existing installations, if the rinsing water can be re-used.

Expanded clay aggregates:

Reduce channelled dust emissions from hot off-gases to 5 – 50 mg/m^3, as the daily average value, by applying electrostatic precipitators or wet dust separators.

Dust emissions from kiln firing processes:

Wall and floor tiles:

Reduce dust emissions from flue-gases of kiln firing processes to 1 – 5 mg/m^3, as the daily average value, by applying dry flue-gas cleaning with a bag filter.

Gaseous compounds/primary measures/techniques:

Bricks and roof tiles:

Reduce the emissions of gaseous compounds (i.e. HF, HCl, SO_X,) from the flue-gases of kiln firing processes by the addition of calcium rich additives.

Expanded clay aggregates:

Keep the emissions of NO_X from the flue-gases of rotary kiln firing processes below 500 mg/m^3, as the daily average value stated as NO_2, by applying a combination of primary measures/techniques.

Gaseous compounds/secondary measures/techniques:

Wall and floor tiles, household ceramics, sanitaryware, technical ceramics:

Reduce the emissions of gaseous inorganic compounds from the flue-gases of kiln firing processes by applying module adsorbers, especially for lower flue-gas flowrates (below 18000 m^3/h) and when raw gas concentrations of inorganic compounds other than HF (SO_2, SO_3, HCl) and of dust are low.

Wall and floor tiles:

Reduce the emissions of HF from the flue-gases of kiln firing processes to 1 – 5 mg/m^3, as the daily average value, by applying, e.g. dry flue-gas cleaning with a bag filter.

Volatile organic compounds:

Bricks and roof tiles, refractory products, technical ceramics, inorganic bonded abrasives:

Reduce the emissions of volatile organic compounds from the flue-gases of firing processes – with raw gas concentrations of more than 100 to 150 mg/m^3, depending on the raw gas characteristics, e.g. composition, temperature – to 5 – 20 mg/m^3, as the daily average value stated as total C, by applying thermal afterburning either in a one or a three chamber thermoreactor.

Refractory products treated with organic compounds:

Reduce the emissions of volatile organic compounds in low off-gas volumes from the treatment with organic compounds by applying activated carbon filters. For high off-gas volumes, BAT is to reduce the emissions of volatile organic compounds from the treatment with organic compounds by applying thermal afterburning to 5 – 20 mg/m^3.

Re-use of process waste water:

Wall and floor tiles, household ceramics, sanitaryware:

Re-use process waste water in the manufacturing process with process waste water recycling ratios of 50 – 100 % (for wall and floor tiles, depending on the type of tile to be manufactured), or of 30 – 50 % (for household ceramics and sanitaryware), by applying a combination of process optimisation measures and process waste water treatment systems.

Re-use of sludge:

Wall and floor tiles:

Re-use the sludge arising from process waste water treatment in the ceramic body preparation process in a ratio of 0.4 – 1.5 % per weight of added dry sludge to the ceramic body, by applying a sludge recycling system, when applicable.

Solid process losses/solid waste:

Household ceramics, sanitaryware, technical ceramics, refractory products:

Reduce the amount of solid process losses/solid waste in the form of used plaster moulds from the shaping by applying one individual or a combination of the following measures:

- replacing plaster moulds by polymer moulds
- replacing plaster moulds by metal moulds
- use of vacuum plaster mixers
- re-use of used plaster moulds in other industries.

EMERGING TECHNIQUES

Some new techniques for the minimisation of environmental impacts are under development or in limited use and are considered emerging techniques. Five of these are discussed in Chapter 6:

- radiant-tube burners
- microwave assisted firing and microwave dryers
- a new type of drying system for refractory products
- advanced process waste water management with integrated glaze recovery
- lead-free glazing of high quality table porcelain.

CONCLUDING REMARKS

The Concluding Remarks Chapter contains information on the milestones in developing this document, the degree of consensus reached on the BAT proposals for the ceramic industry and the information gaps that still exist, in particular regarding data which were not provided within the time period of the information exchange and, therefore, could not be taken in consideration. Recommendations for further research and information gathering are given and, finally, recommendations for updating the BREF on ceramic manufacturing.

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 EIPPCB of any research results which are relevant to the scope of this document (see also the preface of this document).