7.14 Ceramics

7.14.1 Coverage

The sector addresses industrial 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 m³ and with a setting density per kiln exceeding 300 kg/m³. [6]

7.14.2 Emission sources

The manufacture of ceramic products takes place in different types of kilns, with a wide range of raw materials. The general process of manufacturing ceramic products, however, is rather uniform except that for some products a multistage firing process is used. [1]

The main process steps are:

- Raw material preparation and component mixing
- Forming and shaping of ware, decoration
- Drying ware
- Firing ware
- Product finishing
- Addition of auxiliary materials [2]

In general, raw materials are mixed and cast, pressed or extruded into shape. The water used for a thorough mixing and shaping is evaporated in dryers and the products are placed either by hand in the kiln (especially for 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. Today natural gas, liquefied petroleum gas and light fuel oil are mainly used for firing, while heavy fuel oil, liquefied natural gas, biogas/biomass electricity and solid fuels can also play a role as energy source for burners. The main environmental issues are emissions to air as dust and gaseous emissions (carbon oxides, nitrogen oxides, sulphur oxides and others). [1] [3]

7.14.3 BAT, Associated Emission Levels (AEL)

For all following pollutants, reductions can be achieved by reducing the energy consumption. In order to achieve this, it is BAT to apply a combination of the following techniques:

- 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)
- Modification of ceramic bodies

It is furthermore considered BAT to reduce primary energy consumption by applying cogeneration on the basis of useful heat demand, within energy regulatory schemes, which are economically viable. [1]

7.14.3.1 SO2

The emissions of SO_2 in ceramic kiln exhaust gas depend on the sulphur content of the fuel and certain raw materials (gypsum, pyrite, etc). The presence of carbonates in raw materials however may reduce sulphur emissions. In general, techniques for reducing SO emissions include the use of low sulphur content fuels (such as natural gas or LPG), of low-sulphur raw materials and low sulphur body-additives. Further reductions are possible by optimising the heating process and lowering the firing temperature and the use of dry or wet scrubbers. [4]

Table 1: SO_2 emission levels associated with BAT for ceramics production [1]

Emission Source	BAT associated emission levels[1] mg/Nm^3	Comments
Flue gas from kiln firing	< 500 500-2000	Sulphur content in raw material <0.25% Sulphur content in raw material >0.25%; the higher level only applies to raw material with an extremely high sulphur content [Comment: IFC guideline gives a general value of 400 for kiln operations at 10% O_2]

[1] The BAT associated emission levels are based on a daily average, standard conditions and represents a typical load situation. For peak load, start up and shut down periods, as well as for operational problems of the flue gas cleaning systems, short-term peak values, which could be higher, have to be regarded.

Reference conditions: Oxygen content 18 %

7.14.3.2 NOX

The techniques for reducing emissions of gaseous compounds in ceramics manufacturing can be summarized as reducing the input of pollutant precursors (raw materials and additives) and heating curve optimisation (optimal peak flame temperatures, computerized control of kiln firing).
For expanded clay aggregates, it is BAT to keep the emissions from rotary kiln firing below the given BAT value by applying a combination of primary measures/techniques. [1] [4]

Table 2: NO_X emission levels associated with BAT for flue gas from kiln firing in ceramics production [1]

Emission source	BAT associated emission levels[1] mg/Nm3	Comments
Flue gas from kiln firing	< 250 < 500	Daily average value stated as NO_2 for kiln gas temperatures below 1300 °C Daily average value stated as NO_2 for kiln gas temperatures of 1300 °C or above [Comment: IFC guideline gives a general value of 600 for kiln operations at 10% O_2]
Flue gas from kiln firing (expanded clay aggregates)	< 500	Daily average value

[1] The BAT associated emission levels are based on a daily average, standard conditions and represents a typical load situation. For peak load, start up and shut down periods, as well as for operational problems of the flue gas cleaning systems, short-term peak values, which could be higher, have to be regarded.

Reference conditions: Oxygen content 18 %

7.14.3.3 Dust

General BAT

The processing of clay and other ceramic raw materials inevitably leads to dust formation, especially drying, grinding, milling, screening mixing and conveying can all result in the emission of fine dust; the fuels also contribute to these emissions. While diffuse dust emissions should be minimized by appropriate measures (use of silos for all bulk storage of dusty materials or use of confined storage areas within buildings or use of enclosed containers/packaging), for channelled dust emissions, it is BAT to use fabric filters.
For drying processes, it is BAT to clean the dryer, to avoid the accumulation of dust residues in the dryer and to adopt adequate maintenance protocols.
For kiln firing, it is considered BAT to use low ash fuels, to minimise dust formation caused by the charging of the ware to be fired in the kiln and to use flue-gas cleaning by filters or packed bed absorbers. [1] [2]

Sector specific BAT

For wall and floor tiles, household ceramics, sanitaryware, and technical ceramics, vitrified clay pipes it is considered BAT to reduce channelled dust emissions from spray glazing processes by applying fabric filters or sintered lamellar filters.
For wall and floor tiles, household ceramics, technical ceramics it is BAT to reduce channelled emissions from spray drying processes by applying fabric filters, or alternatively cyclones in combination with wet dust separators for existing installations, if the rinsing water can be reused.
For expanded clay aggregates, it is considered BAT to reduce channelled emissions from hot off-gases by applying electrostatic precipitators or wet dust separators.
For wall and floor tiles, it is BAT to reduce dust emissions from flue-gases of kiln firing processes, by applying flue-gas cleaning with a fabric filter. [1]

Table 3: Dust emission levels associated with BAT for ceramics production [1]

Emission source	BAT associated emission levels[1] mg/Nm3	Comments
General BAT		
Channelled emissions from operations other than drying, spray drying or firing	1-10	Half hourly average value by applying fabric filter; may be higher on specific conditions
Drying processes	1-20	Daily average
Kiln firing	1-20 < 50	Daily average; flue gas cleaning with filter Daily average; flue gas cleaning with cascade-type-packed bed absorbers
Sector specific BAT		
Spray glazing (For wall and floor tiles, household ceramics, sanitaryware, technical ceramics, vitrified clay pipes)	1-10	
Spray drying (For wall and floor tiles, household ceramics, technical ceramics)	1-30 1-50	Half hourly average; fabric filters Cyclones in combination with wet dust separators for existing installations, if the rinsing water can be reused
Expanded clay aggregates	5-50	Daily average
Kiln firing (for wall and floor tiles)	1-5	Daily average

[1] The BAT associated emission levels are based on a daily average, standard conditions and represents a typical load situation. For peak load, start up and shut down periods, as well as for operational problems of the flue gas cleaning systems, short-term peak values, which could be higher, have to be regarded.
Reference conditions: Oxygen content 18 %

7.14.3.4 VOC

Emissions of volatile organic compounds (VOC) result from incomplete combustion and from the organic material in the raw materials (e.g., binders, plasticizers, lubricants).

For bricks and roof tiles, refractory products, technical ceramics, inorganic bonded abrasives it is considered BAT to reduce the emissions of VOCs from the flue-gases of firing processes – with raw gas concentrations of more than 100 to 150 mg/m³, depending on the raw gas characteristics, e.g., composition, temperature – to the given BAT value by applying thermal afterburning either in a one or a three chamber thermo-reactor.

For refractory products treated with organic compounds it is BAT to reduce the emissions in low off-gas volumes from the treatment with organic compounds by applying activated carbon filters. For high off-gas volumes it is BAT to reduce the emissions of VOCs from the treatment with organic compounds by applying thermal afterburning. [1] [5]

Table 4: VOC emission levels associated with BAT for ceramics production [1]

Emission source	BAT associated emission levels[1] mg/Nm3	Comments
Flue gases of firing processes for bricks and roof tiles, refractory products, technical ceramics, inorganic bonded abrasives	5-20	For raw gas concentrations of more than 100-150 mg/m³; as daily average (total C); by application of afterburning, in a 1 or 3 chamber thermo-reactor
Refractory products	5-20	Thermal afterburning

[1] The BAT associated emission levels are based on a daily average, standard conditions and represents a typical load situation. For peak load, start up and shut down periods, as well as for operational problems of the flue gas cleaning systems, short-term peak values, which could be higher, have to be regarded.

7.14.3.5 Cross Media Effects

For all mentioned emission reduction and abatement techniques, the cross-media transfer of pollutants and the full range of environmental effects and improvements should be considered. For example additional energy consumption and increased quantities of waste or wastewater residuals may result from individual efforts for pollutant prevention, reduction, or removal.

7.14.4 Emerging techniques

The use of radiant tube burners (flame place inside a heat resistant tube, still under development) can reduce HF and SO_2 emissions. Microwave assisted firing and microwave dryers aim at shorter firing cycles and less excess heat. Large refractory products can be dried more efficiently by placing steel foils or carbon fibres as the heating element into the refractory mix. [1]

7.14.5 Cost data for emission reduction technologies

Table 5: Cost data for different emission reduction techniques for ceramics production [1]

Cleaning system/type	Field of Application	Absorbent /adsorbent	Common sizes/ flowrates for the ceramic industry (Am3/h)[1]	Rough investment guideline (EUR)	Maintenance (EUR/yr)	Sorbent cost (EUR/tonne) (EUR/yr)	Operation cost EUR/t
Dust abatement							
Fabric filter/bag house	Complete areas in the plant, preparation, conveying, storage, forming area, handing over locations, etc.		900 to 70000	6000 – 150000 (Depending on size and amount of ductwork)			0.03 – 0.1
Central vacuum cleaner	Complete areas in the plant, preparation, conveying, storage, forming area, handing over locations, Kiln cars etc.		900 to 1000	25000 – 65000 (Depending on amount of ductwork/pipes)			
Kiln car cleaning system (In different execution: Fixed nozzle, moving nozzle, lifting and adjusting of the plateau)	Kiln cars		8000 to 30000	40000 –200000 (Depending on size and execution)			
Electrostatic precipitator	Dust abatement for hot and large offgas streams		Up to 100000	1000000 – 3000000			0.1 – 0.2

Inorganic gaseous compounds abatement							
Module system	Mainly HF reduction	Ca(OH)2 Honeycomb	Very low flowrates	45000 – 100000	~500	~46000 EUR/yr	
Cascade type packed bed absorber	Mainly HF reduction	CaCO3	2500 to 140000 (no lower or upper limit)	40000 – 500000	~2000	30 – 55 EUR/tonne (delivered) 4000 – 30000 EUR/yr	23400 – 4800
Cascade type packed bed absorber	Mainly HF, HCl and SO_2 reduction	Modified/fabricated absorbent	2500 to 140000 (no lower or upper limit)	40000 – 500000	~2000	95 – 110 EUR/tonne (delivered) up to 60000 EUR/yr	
Countercurrent type packed bed absorber/ series modules	Mainly HF, HCl, and SO_2 reduction	$CaCO_3$ and modified/ fabricated absorbent	2500 to 140000 (no lower or upper limit)	80000 – 800000	~2500	30 – 55 EUR/tonne (delivered) respectively 95 – 110 EUR/tonne (delivered)	
Dry sorption with fabric filter (fly stream system)	Mainly HF, HCl, SO_2 Particulate reduction	$Ca(OH)_2$ in different qualities	2500 to 140000 (no lower or upper limit)	80000-1000000	~4000	95 – 110 EUR/tonne (delivered) 8000 – 45000 EUR/yr	107500 – 130700
Dry sorption with fabric filter (fly stream system) with conditioning of the reaction product	Mainly HF, HCl, and SO_2 Particulate reduction	$Ca(OH)_2$ in different qualities (with little water added)	2500 to 140000 (no lower or upper limit)	200000 – 1600000	~6500	95 – 110 EUR/tonne (delivered) 8000 – 45000 EUR/yr	107500 – 130700

Wet scrubber	Mainly HCl and SO_2 reduction	Alkali water	2500 to 140000 (no lower or upper limit)	400000 – 2000000	up to 8000	95 – 110 EUR/tonne (delivered) 8000 – 45000 EUR/yr +water	
VOC abatement							
Thermal afterburning in a thermoreactor (external)	VOC reduction		10000 – 50000	180000 – 420000	500 – 4500		
Internal carbonization gas combustion	VOC reduction			42000 – 300000	500 – 8000		

Note: In the column 'common sizes/flowrates' and in the column 'rough investment guideline' there are ranges. It is reasonable to assume that the small Am3/h-figures correspond to the low investment figure in EUR and that the high Am3/h figure corresponds to the high investment figure in EUR. In between the increase is not linear, normally the more Am3/h are treated, and the lower the investment per Am3 is.

[1]) The flowrates are given in 'actual m3' (Am3, as opposed to normal m3, standard condition) because actual flue-gas has to be treated.

7.14.6 References used in chapter 7.14

[1] European Commission. 2007: "Integrated Pollution Prevention and Control (IPPC) Reference Document on Best Available Techniques in the Ceramics Manufacturing Industry." http://eippcb.jrc.es/pages/FActivities.htm

[2] DEFRA 2007: Sector Guidance Note IPPC SG7 - Secretary of State's Guidance for the A2 Ceramics Sector including Heavy Clay, Refractories, Calcining Clay and Whiteware. http://www.defra.gov.uk

[3] Rentz, O., A. Schmittinger, R. Jochum and F. Schultmann (2002): Exemplarische Untersuchung der praktischen Umsetzung des integrierten Umweltschutzes in der Keramischen Industrie unter Beachtung der IVU-Richtlinie und der Erstellung von BVT-Merkblättern, DFIU-IFARE Karlsruhe, report on behalf of Umweltbundesamt, Germany, 221 pp.

[4] IFC 2007. International Finance Corporation (World Bank Group): Environmental, Health, and Safety Guidelines for Ceramic Tile and Sanitary Ware Manufacturing

[5] US Environmental Protection Agency (US EPA). 1995. "AP-42 Section 11.15, Glass Manufacturing." Washington, DC.

General References

US Environmental Protection Agency (US EPA). Standards of Performance for New Stationary Sources. Subpart CC – Standards of Performance for Glass Manufacturing Plants, 40 CFR Part 60. Washington, DC.

US EPA 1995 .Glass Manufacturing Point Source Category. Subpart E – Float Glass Manufacturing Subcategory40 CFR Part 426. Washington, DC.

Beerkens 2007 Evaluation of costs associated with air pollution control for glass melting furnaces – A study to support the revision of the IPPC reference document on best available techniques in the glass manufacturing industry 2008, Ordered by CPIV, Brussels, Belgium.

European Commission. 2007: Proposal for a Directive of the European Parliament and of the Council on Industrial Emissions (Integrated Pollution Prevention and Control) (Recast)