7.10 Cement production

7.10.1 Coverage

The emissions from cement plants which cause the greatest concern are nitrogen oxides (NO_x) and dust (TSP). Sulphur dioxide (SO_2) emissions, which are lower, are also considered. This chapter covers installations for production of cement clinker in rotary kilns with a production capacity exceeding 500 tonnes per day, or in other furnaces with a production capacity exceeding 50 tonnes per day [as it is the BREF document]. [12]

7.10.2 Emission sources

The cement manufacturing process can be divided in 3 steps. The first step is the calcination, in which calcium carbonate ($CaCO_3$) is decomposed to form calcium oxide (CaO). The following step is the clinker burning in which calcium oxide reacts with silica, alumina, and ferrous oxides to form the clinker, which is then cooled. Finally the clinker is ground with gypsum and other additives to produce cement.
The clinkering process groups the calcination step and the clinker burning step. It is the largest source of emissions in terms of NO_x, SO_2 and dust emissions. The clinkering process takes place in a kiln. Most of the kilns used are rotary kilns. There are different processes used for the clinker production, the dry process, semi-dry process, semi-wet process, wet process. Preheater or precalciner can be added to the process.
More than 75 % of the European clinker production is carried out with dry processes.
In the clinkering process, the raw meal is fed into the rotary kiln system where it is dried, pre-heated, calcined and sintered to produce cement clinker. The clinker is then cooled and stored before being mixed with gypsum to produce cement. [12].

Different preheating technologies are available for the clinkering process.

- **Grate preheater** takes place outside of the kiln. With grate preheater rotary kiln becomes shorter, heat losses are reduced and energy efficiency is increased.
- **Suspension preheating** consists in maintaining the meal in suspension with flue hot gas from the rotary kiln. The considerably larger contact surface enables almost complete heat exchange, at least theoretically
- **Precalcination system** divides the combustion in two points. The first burning occurs in the kiln burning zone and the secondary burning takes place in a special combustion chamber between the rotary kiln and the preheater.

The exhaust gases finally go through different cleaning devices to be dedusted and/or desulphurized. [12].

Cogeneration can now be applied in Cement plants. The excess heat from the cement production can be used to generate electrical power. [12]

7.10.3 BAT, Associated Emission Levels (AEL)

If not stated otherwise, emission levels given in this section are expressed on a daily average basis and standard conditions of 273 K, 101.3 kPa, 10% oxygen and dry gas.

SO_2:

In cement production, SO_2 emissions are mainly influenced by content of volatile sulphur in the raw materials. Thus the main measure to reduce SO_2 emissions is the use of sulphur free fuel or fuel with low sulphur content. SO_2 emissions of cement kiln may be very low without any measure at all: when low sulphur raw material and low sulphur fuels are used. [10]
However, different flue gas cleaning systems can be used when initial SO_2 emission levels are not very low.
The addition of absorbents such as slaked lime ($Ca(OH)_2$), quicklime (CaO) or activated fly ash with high CaO content to the flue gas can absorb a portion of the SO_2, it is BAT. This injection can be carried out under dry or wet form. The use of $Ca(OH)_2$ based absorbents with a high specific surface

area and high porosity is recommended. The low reactivity of these absorbents implies to apply a Ca/S molar ratio of between 3 and 6.
Wet scrubbing is BAT for desulphurization. In wet scrubbing technologies, the flue gas is first dedusted then cleaned by an atomized solution of alkali compounds. SO_2 reacts with this solution to form different by-products, which can be upgraded as sulphuric acid, sulphur, gypsum or scrubbing agent. A SO_2 reduction of more than 90 % can be expected.[12]
The BAT AEL can be met by applying absorbent addition or wet scrubber.
Regarding the absorbent addition it should be taken into account that the cost of absorbents implies increasing operational costs for increasing SO_2 concentrations, so that this measure might not be cost effective anymore for initial SO2 emissions levels above 1.200 mg/m³.

In cement industry values in the range of 50-400 mg/Nm^3 are expected when using adapted technologies. The following table gives an overview of BAT associated SO_2 emission levels for cement manufacturing.

Table 1: **BAT Associated SO_2 emission levels to reduce emissions in cement Industry**. [12]

Parameters	Techniques	Associated emission level with BAT[1] (mg/Nm^3) (daily average value)
Sulphur in fuel	Absorbent addition Wet scrubbing system	**SO_2**: <50 – <400

[1]these values are daily average values and the range takes into account the sulphur content in the raw material

NO_x:

In cement production, NO_x emissions are influenced by different parameters: the type of fuel, the type of combustion, the combustion air-ratio and the flame temperature. Thus, to reduce NO_x emissions, several measures can be taken.
Among primary measures, flame cooling, low NO_x burners, staged combustion, mid kiln firing and addition of mineralisers to the raw material are the main techniques used in cement plants:

Flame cooling can be achieved by an addition of water to the fuel or directly to the flame. It drops the temperature and so limits NO_x formation.
The addition of mineralisers, such as fluorine, to the raw material enables also the reduction of the sintering zone temperature and thus NO_x formation.
Low NO_x burners enable to reduce NO_x emissions during combustion processes. Combustion with low NO_x burner consists in a cold combustion with an internal or external flue gas recirculation. NO_x reductions up to 30% are achievable in successful installations and emission levels of 600-1000 mg/Nm^3 have been reported with the use of this technology. **Erreur ! Source du renvoi introuvable.**
In **staged combustion**; the first combustion stage takes place in the rotary kiln. The second combustion stage is a burner at the kiln inlet; it decomposes nitrogen oxides generated in the first stage. In the third combustion stage the fuel is fed into the calciner with an amount of tertiary air. This system reduces the generation of NO_x from the fuel, and also decreases the NO_x coming out of the kiln. In the fourth and final combustion stage, the remaining tertiary air is fed into the system as 'top air' for residual combustion. Staged firing technology can in general only be used with kilns equipped with a precalciner. [12]
Mid-kiln firing is applied in long wet or dry kilns. It creates a reducing zone by injecting fuel at an intermediate point in the kiln system. In some installations using this technique, NO_x reductions of 20 – 40% have been achieved.

Primary measures are efficient nevertheless secondary measures can be used to achieve larger NO_x emission reductions. Among them, selective catalytic reduction (SCR) and selective non-catalytic reduction (SNCR) are the main techniques considered in cement plants **Erreur ! Source du renvoi introuvable.** [6].. In SNCR, the conversion rate is lower: 10 – 50 % is obtained in cement plants.

In cement industry the BAT for NO_x emissions reduction are primary measures combined with staged combustion or a SNCR. Emission values in the range of 200-500 mg/Nm^3 are achievable when using these technologies.
Selective Catalytic Reduction (SCR) is BAT, subject to appropriate catalyst and process developments in the cement industry. Large reduction (85 – 95 %) can be expected. At least 2 suppliers in Europe guarantee emissions in the range of 100-200 mg/Nm^3, when using this technique. However, investment for this technique is still significantly higher than for SNCR. [12]
The following table gives an overview of BAT associated NO_x emission levels for cement manufacturing. [12]
If co-incineration waste is used, the requirements of the Waste Incineration Directive (WID) have to be met. [12]

Table 2: BAT Associated NO_x emission levels to reduce emissions in cement industry. [12]

Emission source	Techniques	Associated emission level with BAT (mg/Nm^3)
Preheater kilns	Combination of: primary measures (flame cooling, low NO_x burner, mid kiln firing, addition of mineralisers...), staged combustion (also in combination with a precalciner and the use of optimised fuel mix), SNCR,SCR.	<200 – 450[1 2]
Lepol and long rotary kilns		400 – 800[3]

[1]BAT-AEL is 500 mg/Nm^3, where after primary measures techniques the initial NO_x level is <1000mg/Nm^3
[2]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/Nm^3 are achieved at kilns with favourable conditions. The lower value of 200 mg/Nm^3 has only been reported as monthly average for three plants (easy burning mix used);
[3]Depending on initial levels and ammonia slip.

Dust:
In cement production, stack dust emissions come from three main sources; the kiln, the clinker cooler and the cement mills. Diffuse emissions come from handling and storage of materials. The crushing and grinding of raw materials and fuels handling can also be significant.
Electrostatic precipitators (ESP) and fabric filters are used to control dust emissions in cement production.
The fabric filter should have multiple compartments which can be individually isolated in case of bag failure and they should be sufficiently designed to allow adequate performance to be maintained if a compartment is taken off line. As the dust is collected the resistance to the gas flow increases and so is the pressure inside the filter. There should be 'burst bag detectors' on each compartment to indicate the need for maintenance when this happens.
Emissions below 5 mg/m^3 can be achieved by well designed and well maintained fabric filters.
Sufficiently dimensioned electrostatic filters, with both good air conditioning and optimised ESP cleaning regime, can reduce dust emission levels below 10 mg/Nm^3 (daily average value).
Control of CO level is necessary for the use of ESP. Concentration of CO has to be kept below the lower explosive limit to avoid any critical problem.
Roads used by lorries needs to be paved and periodically cleaned to avoid diffuse dust emissions. In addition, spraying water at the installation site is used to avoid dust emissions. Chemical agents can also be added to water to improve the efficiency of the agglomeration of dust. As far as possible, material handling should be conducted in closed area, where air need to be collected and cleaned through fabric filters. [12]

In cement industry the BAT for dust emissions reduction are ESP and fabric filters. Concentration values in the range of 5 – 50 mg/Nm^3 of dust are achieved when using these technologies. With the use of hybrid filters (combination of both FF and ESP), values in the range of 10 – 30 mg/Nm^3 of dust are achieved. The following table gives an overview of BAT associated dust emission levels for cement manufacturing.

Table 3: BAT Associated dust emission levels to reduce emissions in cement Industry. [4] [12]

Emission source	Techniques	Associated emission level with BAT (mg/Nm^3)
All kiln system Clinker cooler Cement mills	Fabric filters or ESP	**Dust:** <10 – 20
Dusty operations[1]	Dry exhaust gas cleaning with a filter	**Dust:** <10

[1]It has be noted that for small sources (<10000 Nm^3/h) a priority approach has to be taken into account.

7.10.4 Emerging techniques

As in cement production, the most concerning emissions are NO_x emissions, emerging techniques presented are techniques to reduce NO_x.
Fluidised bed combustion, and staged combustion combined with SNCR are emerging techniques to reduce NO_x emission levels.
Using fluidised bed combustion, NO_x emissions vary from 115 mg/Nm^3 to 190 mg/Nm^3 when heavy oil is used and from 440 mg/Nm^3 to 515 mg/Nm^3 when pulverised coal is used as fuel.
In theory, the combination of staged combustion and SNCR results in similar performance as SCR technology in terms of NO_x emission levels.

7.10.5 Cost data for emission reduction techniques

The following tables give an overview of the costs for different abatement techniques in cement industry. [12] [2]

Table 4: Cost of techniques for controlling NO_x in cement Industry. [12]

Technique	Kiln systems applicability	Reduction efficiency	Reported costs [1]	
			Investment (in 10^6 euros)	Operating (euros/tonne of clinker)
Flame cooling	All	0-35 %	Up to 0.2	Up to 0.5
Low-NO_x burner	All	0-35 %	Up to 0.45	0.07
Staged combustion	Precalciner	10-50 %	0.1 – 2	0
	Preheater		1 – 4	0
SNCR	Preheater and Precalciner	30 – 90 %	0.5 – 1.2	0.1 – 1.7
	Grate preheater	35 %	0.5	0.84
SCR[6]	Possibly all	43 – 95 %	2.2 – 4.5	0.33 – 3.0

[1] Investment cost and operating cost in, referring to a kiln capacity of 3000 tonne clinker/day and initial emission up to 2000 mg NO_x/m^3
[6] Costs data based on a kiln capacity of 1500 tonne clinker/day

Table 5: Cost of techniques for controlling SO_2 in cement Industry.

Technique	Kiln systems applicability	Reduction efficiency	Reported costs	
			Investment (in 10^6 euros)	Operating (euros/tonne of clinker)
Absorbent addition	All	60-80 %	0.2 – 0.3	0.1 – 0.4
Wet scrubber	All	> 90 %	5.8 – 23	0.5 – 2
Activated carbon	Dry	up to 95 %	15 [2]	No info.

[2] This cost also includes an SNCR process, referring to a kiln capacity of 2000 tonne clinker/day and initial emission of 50-600 mg SO2/m3

Table 6: Cost of techniques for controlling dust emissions in cement Industry. [12]

Technique	Applicability	Cost [1]	
		Investment (in 10^6 euros)	Operating (euros/tonne of clinker)
Electrostatic precipitators	All kiln systems clinker coolers cement mills	2.1 – 6.0 0.8 – 1.2 0.8 – 1.2	0.1 – 0.2 0.09 – 0.18 0.09 – 0.18
Fabric filters	All kiln systems clinker coolers cement mills	2.1 – 6.0 1.0 – 1.4 0.3 – 0.5	0.15 – 0.35 0.1 – 0.15 0.03 – 0.04

[1] Investment cost and operating cost to reduce the emission to 10-50 mg/m^3, normally referring to a kiln capacity of 3000 tonne clinker per day and initial emission up to 500 g dust/m^3

7.10.6 References used in the chapter 7.10

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