SO_X emission reduction in the ceramic industry: BAT and beyond

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Abstract

The ceramic industry in Flanders (Belgium) consists of ca. 30 plants producing mainly bricks, but also roof tiles, vitrified clay pipes and expanded clay aggregates. The clay minerals that are used as raw materials in these plants often contain high levels of sulphur. As a result, the ceramic industry is an important source of SO_X emissions in Flanders. In 2004, the SO_X emissions of the ceramic industry were estimated at 11,247 ton, or more than 10% of the total SO_X emissions in Flanders. In order to meet the objectives of the EU NEC-Directive (2001/81/EC), the Flemish authorities aim at reducing the SO_X emission of the ceramic industry to 5,460 ton by 2010.

In this context, the Flemish authorities (Flemish Institute for Technological Research) asked VITO to determine the Best Available Techniques (BAT) for reducing SO_X emissions in the ceramic industry. The selection of the BAT was based on a detailed evaluation of different emission reduction measures, such as addition of low sulphur and/or Ca-rich raw materials and different end-of-pipe techniques. Aspects that were considered in the evaluation of the measures included: technical applicability, achievable SO_X emission levels, cross-media aspects and associated costs. SO_X emission limit values were suggested based on the BAT selection and the associated SO_X emission reductions were estimated. The analysis showed that application of BAT cannot guarantee the Flemish ceramic industry reaching the desired SO_X emission level of 5,460 ton SO_X in 2010. Therefore, the study also examined strategies that go beyond BAT, in order to achieve further emission reductions.
Keywords: ceramic industry, SO_X emissions, Best Available Techniques, IPPC-Directive, NEC-Directive.

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1 Introduction

The IPPC-Directive (96/61/EC) [1] has introduced a framework requiring EU Member States to issue operating permits for industrial installations carrying out activities described in Annex 1 of the directive. These permits must contain conditions that are based on 'Best Available Techniques' (BAT), in order to achieve a high level of protection of the environment as a whole. BAT are defined as technologies and organisational measures that minimise the overall environmental impact and are available at an acceptable cost (cf. art. 2).

In Belgium environmental permit legislation is part of the individual competency of the three regions: Flanders, Wallonia and Brussels Capital Region. In Flanders, the environmental legislation lists the activities that require an environmental permit (broader than Annex 1 of the IPPC Directive) and includes the procedures to obtain such a permit. It also contains a list of general conditions, sectoral conditions per industry and emission limit values that should be used as minimum conditions in granting environmental permits. Environmental permit conditions should be based on (i) BAT, and (ii) local environmental quality objectives. The translation of BAT into permit conditions is usually carried out at sector level. The sectoral emission limit values are based on sectoral BAT.

In 1995, the Flemish government established a dedicated BAT-centre within VITO (Flemish Institute for Technological Research). The BAT-centre selects BAT at sector level and supports the authorities and the companies to put BAT into practice for many industrial activities [2]. One of the more recent reports published by the BAT-centre deals with the BAT for reducing the SO_X emissions of the ceramic industry in Flanders. The methodology and main conclusions of this report are presented in this paper.

2 SO_X emissions of the ceramic industry in Flanders

The ceramic industry in Flanders consists of ca 30 plants producing mainly bricks, but also roof tiles, vitrified clay pipes and expanded clay aggregates. The clay minerals used as raw materials in these plants often contain high levels of sulphur. As a result, the ceramic industry is an important source of SO_X emissions in Flanders.

For the purpose of the BAT analysis, the Flemish ceramic industry is divided into four groups, based on the S-content of the raw materials:

- Group 1: < 0.25 % S (11 plants, 30 production lines);
- Group 2: 0.25-0.50 % S (3 plants, 4 production lines);
- Group 3: 0.50-0.75 % S (5 plants, 7 production lines);
- Group 4: > 0.75 % S (9 plants, 14 production lines).

Based on data reported by the plants in their annual environmental reports, the total SO_X emissions of the Flemish ceramic industry in 2004 are estimated at ca 11,247 ton, which is more than 10% of the total SO_X emissions in Flanders. As shown in Figure 1, more than 85% of the total SO_X emissions of the Flemish ceramic industry originate from plants in group 3 and 4. This is explained by the strong correlation between the S-content of the raw materials and the SO_X emission levels.

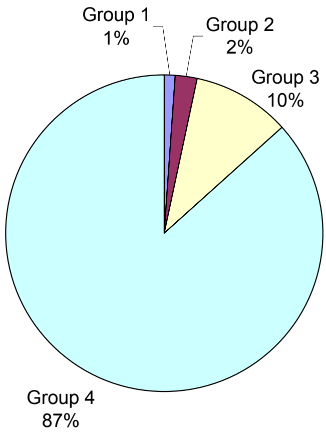

Figure 1: Contribution of the different groups to the total SO_X emissions of the Flemish ceramic industry in 2004 (based on data reported by the plants in their annual environmental reports).

In order to meet the objectives of the EU NEC-Directive (2001/81/EC) [3], the Flemish authorities aim at reducing the SO_X emissions of the ceramic industry to 5,460 ton by 2010. This is equivalent to an emission reduction of 51.5 % compared to 2004.

In this context, the Flemish authorities asked VITO (Flemish Institute for Technological Research) to determine the BAT for reducing the SO_X emissions of the ceramic industry. The BAT-study aims at:

- evaluating the different abatement measures for reducing the SO_X emissions of the Flemish ceramic industry and selecting the BAT (see paragraph 3);
- suggesting BAT based emission limit values (ELV's) for the sector and estimating the reduction of SO_X that can be reached by applying BAT (see paragraph 4);
- proposing and assessing strategies/scenarios that go beyond BAT, in order to achieve further emission reductions (see paragraph 5).

3 Evaluation of abatement measures and BAT selection

According to the IPPC Directive [1], European member states are required to take BAT into account when determining permit conditions, e.g. emission limit values. The BAT for the ceramic industry are discussed in the European BAT Reference Document (BREF) on the Ceramic Industry [4]. In this paper, the

BAT for SO_X emission reduction in the ceramic industry are determined for the Flemish situation. The methodology for the BAT selection is described in [2] and includes an evaluation of different candidate BAT with respect to their technical feasibility, environmental benefit and economic aspects.

3.1 Abatement measures considered in the evaluation

Both process integrated measures and end-of-pipe techniques are considered in the BAT evaluation for the Flemish ceramic industry.

3.1.1 Process integrated measures

According to the BREF [4], several process integrated measures are considered as BAT for reducing SO_X emissions in the ceramic industry [4]. The following abatement measures are evaluated for the ceramic industry in Flanders:

- the use of low sulphur fuels, e.g. natural gas;
- optimisation of the heating curve;
- in the case of sulphur rich raw materials: addition of low sulphur body additives (e.g. sand) or low sulphur clay to the raw materials;
- in the case of sulphur rich raw materials: addition of Ca-rich additives to the raw materials.

Practical experience in the Flemish ceramic industry has shown that up to 25% of the sulphur rich raw materials can be substituted by low sulphur and high calcium materials (e.g. loams). Higher substitution degrees result in insufficient product quality (decreased product strength). Another factor limiting the applicability of these measures is the availability of low sulphur and high calcium loams. The latter is related to social and environmental acceptance of additional loam pits in Flanders.

3.1.2 End-of-pipe techniques

Different end-of-pipe techniques can be considered for reducing SO_X emissions in the ceramic industry [4]. The following abatement measures are evaluated for the ceramic industry in Flanders:

- cascade type packed bed adsorbers (adsorption of SO_X on a packed bed of $CaCO_3$ granules);
- dry flue gas cleaning with a filter (adsorption of SO_X on $CaCO_3$ powder that is blown into and subsequently filtered from the flue gas stream);
- wet or semi-wet flue gas cleaning (absorption of SO_X in an alkaline water phase).

Both cascade type packed bed adsorbers and dry flue gas cleaning with a filter are considered as BAT in the BREF [4]. Wet or semi-wet flue gas cleaning is not generally considered as BAT because of the cross-media effects and the high investment and maintenance costs.

3.2 Technical feasibility and environmental benefit

3.2.1 Currently applied emission reduction techniques

The assessment of the currently applied emission reduction techniques is based on information received from ca. 30 production lines in the Flemish ceramic industry. As a result of a new emission regulation that came into force in Flanders in 2004, most of these plants recently implemented emission reduction techniques. The applied techniques and the achieved SO_X emission levels are summarised in Table 1. Apart from SO_X emission reduction, the implemented measures also result in reduction of HF emissions, which will not be discussed in this paper.

Table 1: Applied techniques and achieved SO_X emission levels in Flemish ceramic plants.

	% S in the raw materials	Implemented emission reduction technique(s)	SO_X-emissions (mg/Nm³)	
			before implementation of the emission reduction technique(s)	after implementation of the emission reduction technique(s)
Group 1	< 0.25%	cascade type packed bed adsorbers	18-233	5-186
Group 2	0.25-0.50%	no data available	no data available	no data available
Group 3	0.50-0.75%	cascade type packed bed adsorbers combined with primary measures	247-1938	99-998
Group 4	> 0.75%	cascade type packed bed adsorbers combined with primary measures, or dry flue gas cleaning with filter	425-3376	71-2192

3.2.2 Possible additional emission reduction techniques

For groups 1 and 2, no additional emission reduction techniques need to be considered, since the contribution of these groups to the total SO_X emissions of the ceramic industry is very limited (see Figure 1). For groups 3 and 4, the following additional emission reduction techniques can be considered:

- for plants equipped with a cascade type packed bed adsorber: use of a modified type of $CaCO_3$ adsorbent with higher SO_X adsorbing efficiency;
- for plants equipped with dry flue gas cleaning with filter: increase of the amount of $CaCO_3$ that is blown into the flue gas stream;
- for all plants: switch from dry flue gas cleaning to wet or semi-wet flue gas cleaning.

3.2.3 Achievable SO_X emission reduction

Since the additional abatement techniques are not yet applied in Flanders, the achievable SO_X emission levels are estimated based on literature data [4] and suppliers' information (see Table 2).

3.3 Economic aspects

Economic aspects play an essential role in the BAT selection, since a BAT should be 'available' under economically viable conditions. In order to evaluate the economic feasibility of the different emission reduction techniques, the total annual costs are calculated for a hypothetical 'average' company. For the techniques that are already implemented (see paragraph 3.2), the cost calculations are based on actual cost data. For the additional techniques to be considered (see paragraph 3.3) the cost calculations are based on suppliers' information and own calculations (e.g. for adsorbent consumption). Figure 2 shows the total annual costs for the different emission reduction techniques for an 'average' company in group 4.

Table 2: Achievable SO_X emission levels in Flemish ceramic plants after implementation of additional emission reduction techniques.

	% S in the raw materials	Additional emission reduction technique	Achievable SO_X-emissions (mg/Nm³)
Group 3	0.50-0.75%	cascade type packed bed adsorbers (modified $CaCO_3$) combined with primary measures	< 500 mg/Nm³
		wet or semi-wet flue gas cleaning	< 500 mg/Nm³
Group 4	> 0.75%	cascade type packed bed adsorbers (modified $CaCO_3$) combined with primary measures or dry flue gas cleaning with filter (increased amount of $CaCO_3$)	< 850 mg/Nm³
		wet or semi-wet flue gas cleaning	< 500 mg/Nm³

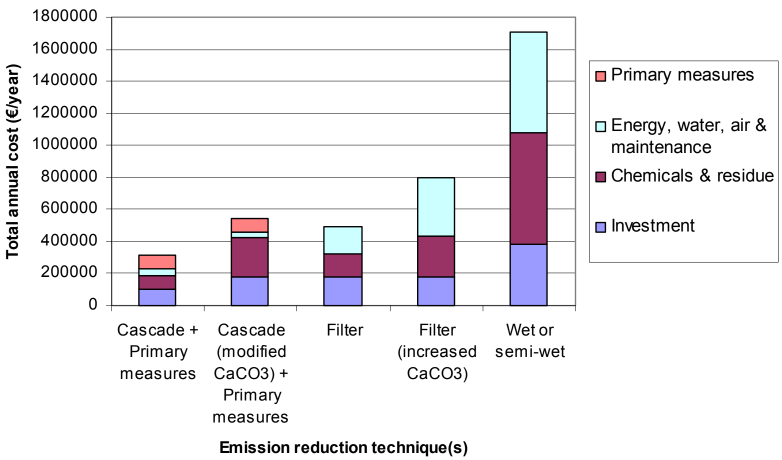

Figure 2: Total annual costs of different emission reduction techniques for an average company in group 4.

In Figure 2, the total annual costs are split into:

- investment costs: annual investment costs for end-of-pipe techniques as well as for primary measures (if the latter are relevant);

- chemical and residue costs: costs related to adsorbent or absorbent consumption, disposal or processing of used adsorbent or absorbent streams;
- energy, air, water and maintenance costs;
- costs of primary measures: additional costs for low sulphur and high calcium materials (if relevant).

These total annual costs are compared to the turnover, profits and added value of a hypothetical 'average' company. Using the indicative reference values in Table 3 combined with expert judgement, the economic feasibility of the different techniques is assessed (see Table 4).

Table 3: Indicative reference values for economic feasibility [5].

Compare total annual costs to …	Acceptable	To be judged	Not acceptable
turnover	< 0.5%	0.5-5%	> 5%
profits	< 10%	10-100%	> 100%
added value	< 2%	2-50%	> 50%

Table 4: Assessment of the economic feasibility of the different emission reduction techniques for an average company in group 4.

Emission reduction technique	Already applied in Flanders?	Total annual cost as a percentage of …			Global assessment of economic feasibility
		Turnover	Profits	Added Value	
Cascade type packed bed adsorbers combined with primary measures	Yes	2.96% (to be judged)	8.39% (to be judged)	n.a.*	Feasible
Cascade type packed bed adsorbers (modified $CaCO_3$) combined with primary measures	No	5.16% (not acceptable)	14.66% (to be judged)	n.a.*	Limited
Dry flue gas cleaning with filter	Yes	4.64% (to be judged)	13.16% (to be judged)	n.a.*	Limited
Dry flue gas cleaning with filter (increased amount of $CaCO_3$)	No	7.55% (not acceptable)	21.44% (to be judged)	n.a.*	Limited
Wet or semi-wet flue gas cleaning	No	16.06% (not acceptable)	45.60% (to be judged)	n.a.*	Not feasible

*: the average added value for the years 2000-2003 was negative.

3.4 BAT conclusions

Based on the evaluation in paragraphs 3.2 and 3.3, it may be concluded that the BAT for reduction of SO_X emissions in the Flemish ceramic industry is a combination of primary measures and end-of-pipe techniques:

- Primary measures:
  - The use of low sulphur fuels, e.g. natural gas;
  - Optimisation of the heating curve;
  - In the case of sulphur rich raw materials: addition of low sulphur body additives (e.g. sand) or low sulphur clay to the raw materials;
  - In the case of sulphur rich raw materials: addition of Ca-rich additives to the raw materials.
- End-of-pipe techniques:
  - cascade type packed bed adsorbers with standard or modified $CaCO_3$; or
  - dry flue gas cleaning with a filter.

Wet or semi-wet flue gas cleaning is not generally considered as BAT, because of the cross-media effects and the high investment and maintenance costs. These techniques can however play a role in scenarios that reduce the SO_x emissions of the ceramic industry in Flanders beyond the levels that are achievable with BAT (see paragraph 5).

4 BAT based ELV's and associated SO_x emissions

By applying BAT as defined in paragraph 3.4, ceramic plants in groups 1, 2 and 3 should be able to comply with an emission limit value (ELV) of 500 mg/Nm³. For plants in group 4 however, an ELV of 500 mg/Nm³ can only be met by applying wet or semi-wet flue gas cleaning, which is not BAT. For this group an ELV of 1,000 mg/Nm³ is judged to be in accordance with BAT.

Primary measures (addition of low sulphur, calcium rich materials) play an essential role in meeting these ELV's, especially for plants in groups 3 and 4. As discussed in paragraph 3.1.1, the applicability of these measures to the Flemish ceramic industry is limited by the availability of low sulphur and high calcium loams. This is related to the limited social and environmental acceptance of additional loam pits in Flanders. In scenarios with very limited availability of loam, ELV's up to 1,500 mg/Nm³ are judged to be in accordance with BAT, as is shown in Table 5.

Table 5: Scenarios with BAT based ELV's.

	Scenario	BAT-sufficient loam availability	BAT-limited loam availability	BAT-very limited loam availability
Emission limit value (mg/Nm³)	Group 1	500	500	500
	Group 2	500	500	500
	Group 3	500	750	1000
	Group 4	1000	1250	1500
Total SO_X emissions (kton/year)		5.80	7.12	8.29

Table 5 also shows the total SO_X emissions that will be attained by the Flemish ceramic industry if the plants comply with the proposed ELV's. These total SO_X emissions are calculated based on SO_X emission and concentration data reported by the individual plants in 2004, using the following formula:

$$SO_{X\ BAT}\ (kg) = \frac{ELV_{BAT}\ (mg/Nm^3)}{SO_X\ concentration_{2004}\ (mg/Nm^3)} \times SO_{X\ 2004}\ (kg)$$

Table 5 shows that, by imposing BAT based ELV's, the SO_X emissions of the Flemish ceramic industry can be reduced to 5.80 kton/year in the best case (i.e. when assuming sufficient loam availability). These BAT based ELV's do not allow to reach the maximum of 5.46 kton which was set as a goal for the ceramic industry in 2010 by the Flemish authorities, in order to reach the objectives of the EU NEC-Directive.

5 Scenarios beyond BAT

In order to reach the objectives of the EU NEC Directive [3], abatement measures beyond BAT will need to be implemented. Two basic types of scenarios can be considered:

- Scenarios with sectoral ELV's beyond BAT;
- Scenarios with BAT-based ELV's, in combination with voluntary agreements to reach further emission reductions in a limited number of plants.

An example of a scenario with sectoral ELV's beyond BAT is presented in Table 6. In this scenario, plants in group 4 implement emission reduction measures beyond BAT in order to meet the imposed ELV. In theory, this scenario would decrease the total SO_X emission of the Flemish ceramic industry to 4.63 kton per year, which is well below the goal of 5.46 kton. However, this scenario is expected to have undesirable socio-economic consequences, with possibly several plants in group 4 closing down, because the required emission reduction measures are not economically feasible for an 'average' company.

Table 6: Scenarios with ELV's beyond BAT.

	Scenario	Beyond BAT
Emission limit value (mg/Nm^3)	Group 1	500
	Group 2	500
	Group 3	500
	Group 4	750
Total SO_X emissions (kton/year)		4.63

The emission goal of 5.46 kton can also be reached by imposing BAT-based ELV's on the sector as a whole, in combination with the implementation of wet or semi-wet flue gas cleaning in a limited number of plants in group 4. These plants should preferably be large plants with very high SO_X emissions. In such plants, emission reduction measures that go beyond BAT for the sector as a whole, can be implemented under more economically feasible conditions. Table 7 lists some potential scenarios and the associated SO_X emissions. Scenarios such as those in table 7 can be stipulated in voluntary agreements between the industry and the authorities. Compared to scenarios with sectoral

ELV's beyond BAT (Table 6), these scenarios offer a more realistic option to reach the emission reduction goal for the sector under economically feasible conditions and without unacceptable socio-economic consequences.

Table 7: Scenarios with BAT based ELV's and implementation of techniques beyond BAT in a limited number of plants.

	Scenario	BAT*	BAT*	BAT*
Emission limit value (mg/Nm^3)	Group 1	500	500	500
	Group 2	500	500	500
	Group 3	500	750	1000
	Group 4	1000	1250	1500
Number of plants with wet or semi-wet flue gas cleaning		1	2	3
SO_X emissions (kton/year)		5.03	5.29	5.25

6 Conclusions

Due to the high sulphur content of raw materials, the ceramic industry is an important source of SO_X emissions in Flanders. In order to reach the goals set by the European NEC-Directive, significant SO_X emission reductions are required. Implementation of BAT, which is a combination of primary measures and dry flue gas cleaning techniques, is not sufficient to reach the required emission reductions. Compared to scenarios with sectoral ELV's beyond BAT, voluntary agreements between industry and authorities offer a more realistic option to reach the emission reduction goal for the sector under economically feasible conditions and without unacceptable socio-economic consequences.

References

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