

Environment and Plant Technology



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Assessment of potential emission abatement techniques for the Alpacem Anhovo Cement Plant

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List of Abbreviations:

AEL:	Associated Emission Level
BAT:	Best Available Technique
BREF:	BAT Reference (Document)
ELV:	Emission Limit Value
HD:	High-Dust
IED:	Industrial Emissions Directive
LD:	Low-Dust
PCDD/F:	Polychlorinated dioxins and furans
RDF:	Refuse Derived Fuel
RTO:	Regenerative Thermal Oxidation or Regenerative Thermal Oxidizer
SCR:	Selective Catalytic Reduction
SNCR:	Selective Non-Catalytic Reduction
s.t.p.:	Standard Temperature and Pressure
TOC:	Total Organic Carbon
VDZ:	Verein Deutscher Zementwerke (German Cement Works Association)

1 Introduction

Alpacem Cement, d.d. operates in the Alpe-Adria region, specializing in the production of cement and other binders, concrete, and aggregates such as sand and gravel. In Slovenia, their Anhovo cement plant has an annual production capacity of approximately 1.3 Mio. tons of cement.

The cement plant at Anhovo must adhere to national emission limits for key flue gas components, which are primarily based on the European Industrial Emissions Directive (IED), specifically the regulations for cement plants that co-incinerate waste [IED, 2010].

Previously, the existing emission abatement methods were sufficient to meet these limits. However, the Slovenian Parliament has worked towards aligning emission limits for both co-incineration and incineration plants. This effort resulted in a new Regulation on Waste Incineration Plants and Co-Incineration Plants [REG, 2025], adopted in June 2025, which imposes significantly stricter emission limit values for several flue gas components. Some of these new limits exceed the regulations set by the IED and are on a level for which there are no comparable cases in the European cement industry to date. Though the Alpacem Anhovo cement plant already employs "Best Available Techniques" (BAT's) for the production of cement [BAT, 2013], it is likely that meeting the stricter limit values will not be possible in all cases. In particular, for the air pollutants NO_x , NH_3 , TOC (ΣC), CO and Hg, processes with higher reduction potential will be required in future in order to comply with the new limit values. Some of these potential mitigation measures go beyond the BAT Reference (BREF) Document [BAT, 2013] for cement plants and the achievable emission levels specified therein. Nevertheless, it may be necessary to apply for derogations for certain limit values in order to enable safe kiln operation. Against this background, Alpacem Cement, d.d. has developed in co-operation with a technology provider a concept that could largely meet future emission reduction requirements.

VDZ Technology gGmbH was commissioned by Alpacem Cement, d.d. to assess the current emission situation and the potential emission abatement techniques in or beyond the status of BAT for cement plants. By this, the state-of-the-art in the cement industry shall be considered and the proportionality of measures to enable the production of cement clinker that is justifiable from a technical and economic point of view.

2 Description of cement production at Alpacem Anhovo cement plant

2.1 Kiln system

The kiln system of the Alpacem Anhovo cement plant includes a rotary kiln with a five-stage suspension preheater, an in-line calciner (including a so-called “hot disc”), a bypass, and a downstream clinker cooler (see **Figure 2-1**). After the preheater, the exhaust gas flow is split into two separate flows that pass through two raw mills and two fabric filters. The maximum kiln capacity according to the environmental permit is 3,180 t_{clt}/d.

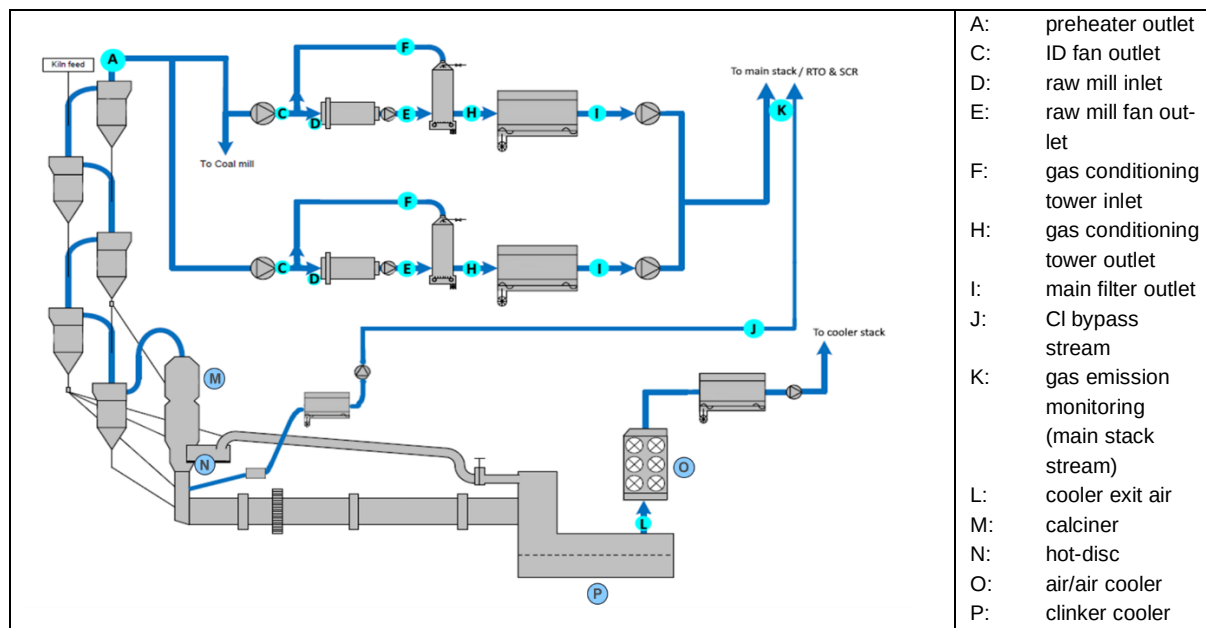


Figure 2-1 Process scheme of the clinker production

Fuels such as natural gas, petcoke and RDF (Refuse Derived Fuel) are burned in the main firing while used tyres, petcoke and RDF are used as fuels in the hot-disc calciner (see **Figure 2-1**).

2.2 Flue gas paths and modes of operation

The kiln exhaust gas passes through the precalciner and preheater, then is split into two partial flows after exiting the preheater. Subsequently, the preheater exit gas (raw gas) is used for drying the raw material in the raw mills. Most of the time the kiln plant is operated in the so-called “compound mode” (two raw mills in operation) or in “semi-direct mode” (only one raw mill in operation). In the so-called “direct operation” (no raw mill in operation) the raw gas is cooled down in conditioning towers and is dedusted in the fabric filters. This mode of operation accounts for only 1% of the annual operating time. In this mode of operation, the raw gas bypasses raw mills and is cooled down. The combined gas stream is emitted into the atmosphere via the main stack.

The bypass gas is dedusted in a separate filter and is merged with the main flue gas stream. The separated bypass dust is stored in a silo and can be utilized in the cement grinding process.

The cooler exit air is cooled down in an air/air cooler, dedusted and emitted into the atmosphere via a separate stack.

2.3 Emission abatement measures

The rotary cement kiln of the Alpacem Anhovo cement plant is equipped with various emission abatement measures. Modern bag filters are installed in both flue gas lines, in the cooler exit air and in the

bypass gas stream to reduce the dust emissions (see **Figure 2-1**). For NO_x reduction, a low-NO_x burner and an in-line calciner (staged combustion) are employed as "primary measures". Furthermore, the SNCR process (Selective Non-Catalytic Reduction) is used as a "secondary measure" for NO_x reduction. If necessary, the concentration of sulphur oxides in the flue gas can be reduced by injecting dry sodium bicarbonate (NaHCO₃). All these control measures are classified as "Best Available Techniques" (BAT) for emission abatement in the cement industry [BREF, 2013] (see **chapter 4**).

2.4 Utilization of alternative fuels

At the Anhovo rotary kiln, fossil fuels like natural gas and petcoke are utilized in the main firing and in the hot disc. In addition, also waste fuels or so-called "alternative fuels" are used. According to this, the regulations of the European Industrial Emissions Directive (IED) and of the Slovenian environmental legislation for cement plants co-incinerating waste apply (see **chapter 3.1**).

3 Emission limit values and current emission situation

3.1 Emission limit values on European and national level

The Industrial Emissions Directive (IED) is the most important European regulation to control the emissions of industrial installations. The competent authorities must issue permits and set emission limit values based on the application of Best Available Techniques (BAT's) for the individual industrial sectors. At the moment there are BAT Reference Documents (BREF Documents) for 37 industrial and agricultural processes. The BREF Document contains a description of the individual process, the formation of different pollutants and different measures to control the release of the pollutants into the environment. Finally, selected emission abatement techniques are classified as BAT and a BAT associated emission level (BAT-AEL) is defined which can be achieved when a BAT is applied at the respective process. The so-called BAT Conclusions [CON, 2013] are shorter and more condensed documents and contain the most important information about BAT's and the achievable emission levels for the respective industrial sector.

In the European BREF Document for the cement industry [BAT, 2013] several emission abatement techniques have been classified as BAT. Furthermore, the BAT-AEL's have been defined for the abatement of several air pollutants. The following **chapter 4** contains a short description of the BAT's for the abatement of the relevant air pollutants (NO_x, NH₃, TOC, CO, Hg) and, if available, the BAT-AEL's.

The regulations of European Directives like the IED have to be implemented into the national legislation of the member states. In Slovenia, the IED has been implemented in the Environmental Protection Act and the Regulation on Waste Incineration Plants and Co-Incineration Plants [REG, 2025].

3.2 Emission limit values in Slovenia

The currently prescribed national emission limit values for the Alpacem Anhovo cement plant are listed in **Table 3-1** below. In addition, the emission limit values (for cement plants co-incinerating waste) of the European IED [IED, 2010] are shown in the right-hand column.

Table 3-1 Current emission limit values for the Alpacem Anhovo cement kiln compared to the values of the IED

Pollutant	Unit	Current ELV	Emission limit values according to IED
Dust	mg/m ³ (s.t.p., ref. to 10 % O ₂)	20	30
NO _x		500	500
TOC (ΣC)		50	10*
CO		/	***
NH ₃		50	/
SO _x		50	50*
HCl		10**	10
HF		1**	1
Hg		0,05**	0,05
Cd and Tl		0,05**	0,05
Other heavy metals / trace elements (Sb, As, Pb, Cr, Co, Cu, Mn, Ni, V)		0,5**	0,5 (Total value)
PCDD/F	ng I-TEQ/m ³	0,1**	0,1

* The competent authority may grant derogations for emission limit values set out in this point in cases where TOC and SO₂ do not result from the co-incineration of waste

** Spot measurements

*** The competent authority may set an emission limit value for CO.

The currently applicable limit values are largely based on the specifications of the European IED, but there are differences for individual components:

- For the dust component the limit value was lower than in the IED.
- For TOC (ΣC) a higher limit was set in accordance with the IED regulations.
- In contrast to the regulations of the IED (see No. 2.4 of annex VI), no limit value has yet been set for CO.
- A limit value of 50 mg/m³ had to be met for NH₃ although the IED does not yet provide a limitation for this component.

In 2024, Slovenia adopted a revised Environmental Protection Act requiring cement plants, which are co-incinerating waste, to comply with the same emission limit values like waste incineration plants. This alignment was further detailed and formalized in 2025 through the adoption of a new Regulation on Waste Incineration Plants and Co-Incineration Plants [REG, 2025], which explicitly defines the applicable emission limit values and sets out the conditions under which derogations may be granted.

The new emission limit values are much stricter than the currently applicable limit values and are based on the achievable emission levels of the waste incineration BREF [BAT, 2019] and not on the achievable emission levels (BAT-AEL's) of the cement BREF [BAT, 2013]. The new decree also provides emission limit values in the half-hourly average and also annual average limit values for TOC (ΣC) and Hg (see **Table 3-3**). The new limit values are contained in Annex 4, No. 1.2 of the new Regulation for cement plants co-incinerating waste [AN4, 2025].

Table 3-2 New Slovenian emission limit values for cement plants co-incinerating waste [AN4, 2025]

Annex 3.2. Emission limit values for cement plants co-incinerating waste [g/h, 2020]					
Pollutant	Unit	Emission limit values (ELV's)			
		Daily average	ELV for all half-hourly averages	ELV for 97 % of the measured values	Annual average
Dust	mg/m ³ (s.t.p., dry, ref. to 10 % O ₂)	5	30	15	/
NO _x		150	500	400	/
TOC (ΣC)		10	80	50	10
CO		50	/	100	/
NH ₃		10	/	/	/
SO _x		40	200	75	/
HCl		8	40	30	/
HF		1	4	2	/
Hg		0,02	/	/	0,02
		Emission limit values over sampling period			
Cd and Tl	mg/m ³ (s.t.p., dry, ref. to 10 % O ₂)	0,02			
Other heavy metals / trace elements (Sb, As, Pb, Cr, Co, Cu, Mn, Ni, V)		0,3			
PCDD/F	ng I-TEQ /m ³ (s.t.p., dry, ref. to 10 % O ₂)	0,06			

The new limit values are not aligned with the BAT-AEL's of the cement BREF, but with the upper end of the ranges (BAT-AEL's) of the waste incineration BREF [BAT, 2019]. The new limit values represent a significant tightening of standards for nearly all exhaust gas components and are among the lowest limit values for cement plants in Europe. With the current emission control measures in place, it would be challenging to consistently meet these more stringent requirements. Therefore, emission reduction measures with a higher reduction potential should be envisaged. The following **chapter 4** contains a description of abatement techniques, which had been classified as BAT for the cement sector, and of additional (emerging) techniques, which are beyond the status of BAT.

3.3 Options to apply for derogations

The European IED offers operators of cement kilns, in which waste is co-incinerated, the possibility of applying for exemptions from the limit values for SO₂ and TOC if the emissions of these components do not originate from the incineration of waste (see Annex VI, Part 4, No. 2.3 of the IED).

This possibility has also been incorporated into Slovenian Regulation on Waste Incineration Plants and Waste Co-Incineration Plants (see Article 8) [REG, 2025]. In other countries, e.g. in Germany, it is also possible to apply for derogations for CO, NH₃ and Hg if the emissions are predominantly due to the composition of the raw material (raw-material-generated emissions).

VDZ has recently carried out laboratory measurements [VDZ, 2025] with raw material samples from the Alpacem Anhovo cement plant and determined the raw-material-generated emissions of several flue gas components. The investigations have shown that the new emission limits for several components could not be met with the best proven emission reduction measures due to the emissions from the raw material alone.

In addition, the provisions in Annex 5, Section 3.3 of the above mention Slovenian Regulation [AN5, 2025] allow derogations to be granted in cases where the technology that would enable compliance with the limit values is not available on the market. Taking into account the current state-of-the-art in emission reduction processes, compliance with the new limits would be extremely challenging for any cement plant.

3.4 Average emission concentration 2023 and 2024 and required abatement rates

The annual averages of the flue gas components for 2023 and 2024, which are measured continuously, are listed in the following **Table 3-3**. Furthermore, the required abatement rate to meet the future emission limit values for NO_x, NH₃, TOC and CO are listed – compared to the emission situation in 2024.

Table 3-3 Emission concentration (main stack) of different flue gas components in 2023 and 2024 (annual averages; measurement uncertainty not considered)

Parameter	Annual averages		New emission limit value	Required abatement rate
	2023	2024		
	[mg/m ³] (s.t.p., 10 % O ₂)			[%]
Dust	0,99	1,1	5	
SO _x	8,4	8,6	40	
NO _x	502	479	150	> 69
NH ₃	29,9	28,4	10	> 65
TOC	30,9	28,1	10	> 64
CO	339	267	50	> 81

The annual average values for dust and SO₂ in 2023 and 2024 were well below the new emission limits. For the component NH₃, the annual average is significantly above the new limit value of 30 mg/m³. Safe compliance with a daily average value of this magnitude is not possible. For NO_x, TOC and CO, the current annual average emission concentrations are well above the new limit values. If these stricter emission limits were introduced, high reduction rates would be required to meet to limit values. The following **chapter 4** gives a short overview about available abatement techniques for the respective air pollutants and the achievable emission levels.

4 State of emission abatement in the cement industry for NO_x, NH₃, TOC, CO and Hg

4.1 NO_x and NH₃

A reduction of NO_x emissions (NO and NO₂, expressed as NO₂) from the clinker burning process is possible by so-called primary (process-integrated) measures and secondary measures. According to the BREF Document for the cement industry the following measures have been classified as BAT:

Primary measures:

- flame cooling
- low-NO_x burners
- mid-kiln firing
- addition of mineralisers
- process optimisation

Secondary measures:

- selective non-catalytic reduction (SNCR)
- selective catalytic reduction (SCR)

High NO_x reduction rates are only achievable by the application of secondary measures like the SNCR, SCR and the RTO-SCR (combination of low-dust SCR with a Regenerative Thermal Oxidizer) process. In all three processes ammonia solution can be used as reducing agent for nitrogen oxides. The SCR process can be installed in different configurations, namely as High-Dust-SCR (HD-SCR) and Low-Dust-SCR (LD-SCR). Another configuration of the SCR process (Semi-Dust-SCR) has been installed once in an Austrian cement plant [KÖC, 2014]. The status of BAT for the SCR process was subject to a restriction, namely that the applicability of selective catalytic reduction “is subject to appropriate catalyst and process development in the cement industry” [BAT, 2013]. However, this classification reflects the state of knowledge in 2010. Since then, SCR demonstration projects have been carried out in the German cement industry. Within the demonstration projects long-term experiences have been gained with the operation of the HD-SCR process, the LD-SCR process and the RTO-SCR process. The results have been summarized in extensive Technical Reports [BMU, 2014], [BMU, 2015], [BMU, 2022]. Meanwhile, there are more than 20 SCR plants in operation in the German cement industry and more in Austria and Italy. Therefore, the SCR process can be seen as state-of-the art technology in the cement industry. The current state of knowledge regarding the application of the SCR process in the cement industry has been summarised in specialist publications in recent years [HOP, 2019], [HOE, 2024]. The obtained long-term results have shown that a NO_x emission level below 200 mg/m³ and a NH₃ emission level below 30 mg/m³ (as daily averages) can be achieved. However, it has not been proven that NO_x emission levels below 150 mg/m³ or NH₃ emission levels below 10 mg/m³ (as daily averages) can be safely maintained. Furthermore, the available operational experiences from many SCR projects have shown that SCR catalysts have a certain abatement potential for TOC (ΣC), but not for CH₄ and other C₁/C₂ components and not for CO.

Meanwhile, a revision process for the cement BREF is being prepared. However, the actual work will not begin before 2027. It is likely that the amended cement BREF Document will classify the SCR process as BAT without restrictions.

According to the cement BREF Document the NO_x and NH₃ emission levels, which are listed in **Table 4-1**, can be achieved by the application of BATs at cement kilns.

Table 4-1 BAT-AEL's for NO_x and NH₃

Parameter	Unit (s.t.p, 10 % O ₂)	BAT-AEL (daily average)	Remark
NO _x	mg/m ³	< 200 - 450	for preheater kilns
NH ₃		< 30 - 50	if SNCR process is applied

4.2 CO and TOC

The cement BREF Document, which reflects the state of emission abatement in 2010, contains very little information on reducing CO and TOC emissions. The only BAT for reduction of TOC emissions is “to avoid feeding raw materials with a high content of volatile organic compounds (VOC) into the kiln system via the raw material feeding route” [BAT, 2013]. Regarding carbon monoxide only the reduction of CO trips is discussed in the BREF Document. At that time, there were no operational experiences available in the cement industry with downstream emission reduction measures based on the combustion/oxidation of TOC and CO. Therefore, BAT-AEL's have not been specified in the cement BREF Document.

The German VDI Guideline 2094 [VDI, 2021] is a more recent document and contains descriptions of cement production technologies, the utilization of waste in the cement industry and of emissions from the cement production process and emission control measures. Furthermore, so-called “emerging techniques” are covered in the document.

To control the emissions of CO only primary (process-integrated) measures are mentioned which exhibit only a limited reduction potential and which are not suitable to achieve very low CO emission levels. To control the emissions of organic compounds (TOC) it is noted that no raw materials with high VOC content should be fed into the kiln system via the raw material feeding route (see above). Furthermore, operational experiences from the SCR demonstration projects and other SCR projects are mentioned according to which a 40 - 70 % reduction of TOC can be achieved with the SCR catalyst. However, the reduction rate for C₁/C₂ components is much lower and CH₄ is not decomposed at the SCR catalyst.

Downstream (tail-end) abatement measures to control the emissions of CO and TOC are mentioned in the chapter about “emerging techniques”. The so-called Regenerative Thermal Oxidation (RTO) is an appropriate measure to reduce the CO and TOC emissions. The dedusted flue gas is heated up to temperatures of at least 850 °C to achieve an almost complete oxidation of both components. Long-term operational experiences have been gained in an Austrian cement plant [PHI, 2013] and high reduction rates of about 99 % for both components could be achieved. By this, an CO emission level below 100 mg/m³ and a TOC emission level below 20 mg/m³ was complied with.

Furthermore, the RTO-SCR process has been classified as “emerging technique” in the VDI guideline. The RTO-SCR process is a multicomponent abatement measure, namely a combination of a Low-Dust SCR system and a Regenerative Thermal Oxidizer. By this, a reduction of NO_x, NH₃, CO and TOC is achievable. Operational experiences are available from cement plants in Austria [MAU, 2018] and Germany. In addition, extensive operational experiences are available from a demonstration project in a German cement plant [BMU, 2022]. The demonstration project has shown that a CO emission level below 100 mg/m³ and a TOC emission level below 10 mg/m³ could be met.

4.3 Hg

The cement BREF Document contains very little information about measures to control the emission of trace elements. The only measure, which has been classified as BAT, is to select materials with low content of the relevant metals and to limit the content of the relevant metals in the input material

streams, especially the input of mercury due to its high volatility. Despite the apparent lack of options for controlling Hg emissions, a BAT-AEL of $< 0.05 \text{ mg/m}^3$ was set.

Table 4-2 BAT-AEL's for Hg

Parameter	Unit (s.t.p, 10 % O ₂)	BAT-AEL (daily average)	Remark
Hg	mg/m ³	$< 0,05$ *	

* values close to $0,05 \text{ mg/m}^3$ require consideration of additional techniques (e.g. lowering of the flue gas temperature, activated carbon)

The German VDI standard 2094 [VDI, 2021] specifies further measures for limiting Hg emissions from cement kilns. As stated in the cement BREF document, it is recommended to avoid the use of raw materials and fuels with high mercury content in the clinker burning process. Furthermore, the removal of filter dust and the utilisation of dust during cement grinding are mentioned. SCR projects in the cement industry have shown that some of the elemental mercury in the exhaust gas stream is converted to ionic mercury at the catalyst. This enables increased separation as particle-bound mercury during the dedusting of the kiln exhaust gas. The injection of adsorbents such as activated carbon or hearth furnace coke is also described in the VDI guideline.

The chapter on emerging techniques also mentions two newer methods for Hg reduction, namely the XMercury process and the SPC (Sorbent Polymer Catalyst Composite) process. The XMercury process has been tested in cement plants in Austria and Germany [KER, 2015], [BMU, 2022]. In this process, Hg is expelled from part of the filter dust and then adsorbed on activated carbon or coke. This measure leads to a relieve of Hg cycles and thus also to a reduction in Hg emissions.

The SPC process is based on modules with polymer matrices into which catalytically active compounds are incorporated. Dust and water are deposited on the surface of the composite material, while gaseous pollutants penetrate into the composite material. SO₂ is oxidised to sulphuric acid, which drips off and can be recycled later. Elemental and ionic Hg is adsorbed on the surface and thus loaded onto the module. Regeneration of the modules is not planned, i.e. the loaded modules must be disposed of. The SPC process should enable Hg separation rates of over 85 % to be achieved. There is little operational experience from the cement industry to date – there are only a few results from a pilot test in an American cement plant.

5 Alpacem's concept to meet future emission limit values for NO_x, NH₃, TOC, CO and Hg

In co-operation with a technology provider, Alpacem Cement, d.d. has developed a concept in order to meet future emission reduction requirements. The installation of an RTO-SCR system (combination of Low-NO_x SCR and Regenerative Thermal Oxidizer; see **chapter 4.1** and **4.2**) is planned, which will achieve high reduction rates for NO_x, NH₃, CO and TOC (ΣC) components. Due to the high exhaust gas flow rate, the installation of a 7-tower variant is planned (see **Figure 5-1**).

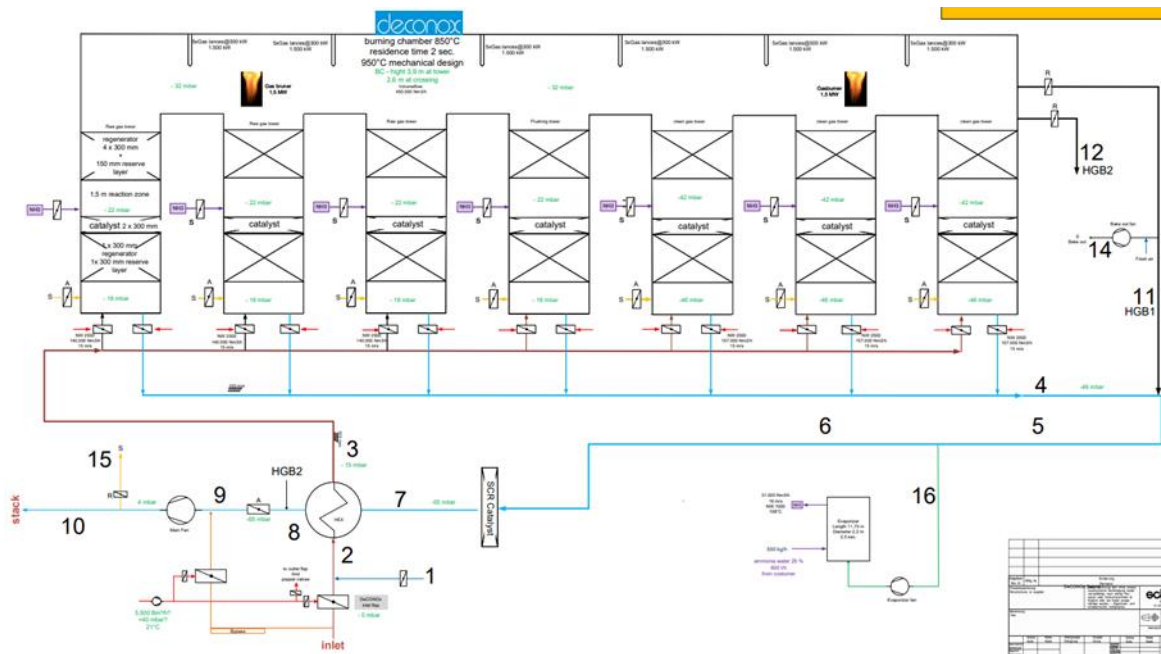


Figure 5-1 Flowsheet of an RTO-SCR plant (7-tower version); (Source: Scheuch GmbH, Auroldmünster, Austria)

NO_x reduction takes place at the SCR catalyst using the NH₃ present in the exhaust gas stream as a reducing agent. If necessary, additional ammonia water is injected as a reducing agent. During operating phases in which there is only a very low NO_x concentration and NH₃ is present in excess, increased NH₃ emissions may occur. Therefore, it cannot always be guaranteed that a very low NH₃ limit value (e.g. 10 mg/m³) can be reliably complied with. However, the existing operational experiences from plants in Austria and Germany have shown that an NH₃ emission level below 30 mg/m³ can be met.

With regard to NO_x reduction, it can be stated that an emission level below 200 mg/m³ (as daily average) can be reliably complied with using an RTO-SCR system. The objective of the German demonstration project was not to identify the maximum NO_x reduction potential. Operational experiences from an Austrian project have shown that a NO_x level around 150 mg/m³ can be maintained with a low NH₃ escape at the same time [MAU, 2018]. Whether an emission level below 150 mg/m³ (as daily average) could also be reliably complied with has not been investigated in the projects carried out to date.

The abatement of CO and TOC (ΣC) is carried out in a combustion chamber at a minimum temperature of 850 °C. The aim is to carry out oxidation in an autothermal process. If this is not achievable, the combustion chamber can also be fired with natural gas. However, there is not yet sufficient operating experience to assess whether an emission limit value of 50 mg/m³ for CO and 10 mg/m³ for TOC (ΣC) can be reliably complied with.

Operational experiences with SCR and RTO-SCR projects to date have shown that a period of at least 2 - 3 years should be allowed for optimising the system. During this time, frequent downtimes of the

system are to be expected, for which higher emission limits for the components NO_x, NH₃, CO and TOC (ΣC) must be specified.

The concept of Alpacem Cement, d.d. for Hg reduction combines several complementary primary and secondary measures which can be regarded as state-of-the-art in the cement industry:

- selection of input material with low Hg content and implementation of a quality assurance system for the raw materials and fuels used
- optimization of the conditioning tower and reduction of the operating temperature of the dust filter from 150 to 130 °C
- application of dust shuttling during direct operation (raw mill off) of the kiln system
- injection of activated carbon upstream of the main dust filter if necessary to cut short-term Hg peaks.

Based on the technical configuration of the Anhovo cement plant the installation of the XMercury process would not be appropriate and not feasible for technical and economic reasons. The extremely high volume of filter dust (approximately 30 - 35 t/h) would require a system several times larger than existing reference plants. This would lead to an excessive energy demand and operational complexity. Under such conditions, the application of this process is not advisable.

Therefore, while further Hg reduction measures are being pursued, it should be emphasised that setting a very low emission limit value (e.g. 0,02 mg/m³) at this stage (before full implementation and optimisation of the planned Hg reduction measures) would pose a significant compliance risk. A stepwise approach, based on demonstrated performance data, would be more appropriate in this case.

6 Summary and outlook

Alpacem Cement, d.d. operates a rotary kiln plant for the production of cement clinker at its Anhovo site in Slovenia. Until now, the plant had to comply with emission limits that were largely based on the European Industrial Emissions Directive (IED). To reduce emissions of various air pollutants, processes have been used that had been classified as Best Available Techniques (BAT) for plants in the cement industry.

A change in the national environmental legislation has now significantly tightened the emission limits for some components. The new limits are now based on the upper end of the BAT Associated Emission Levels (BAT-AEL) from the BAT Reference Document (BREF Document) for waste incineration plants. This is intended to harmonise the Slovenian regulations for incineration plants and co-incineration plants.

Some of the new emission limits are significantly below the BAT Associated Emission Levels (BAT-AEL) for cement plants and are unprecedented in the European cement industry. These limits are almost impossible to comply with using existing emission reduction processes. Further measures are required in order to comply with the new limits, particularly for the air pollutants NO_x , NH_3 , TOC (ΣC), CO and Hg.

In order to meet the new requirements, Alpacem Cement, d.d. has co-operated with a technology provider to develop a concept for future emission reduction. This involves the installation of an RTO-SCR plant, which can achieve high reduction rates for the air pollutants NO_x , NH_3 , TOC and CO. To reduce Hg emissions, a combination of various primary measures and the injection of activated coal containing adsorbents will be used in future.

RTO-SCR plants are not yet BAT or state-of-the-art in the cement industry. Operating experiences are available from individual plants in Austria and Germany. In addition, an extensive demonstration project on the application of an RTO-SCR plant was carried out in a German cement plant. However, it has not yet been proven that the low limit values that are to apply to the cement plant in Anhovo can be reliably complied with using this multi-component abatement technique.

It is also questionable whether a Hg limit value of $0,02 \mu\text{g}/\text{m}^3$ can be reliably complied with using the planned reduction measures. Operational experiences with so-called "Emerging Techniques" for Hg reduction are limited, and in many cases their application is not possible or practical for technical and economic reasons. Furthermore, it can be stated that based on the technical configuration of the Anhovo cement plant the installation of the XMercury process would not be feasible for technical and economic reasons. The extremely high volume of filter dust (30 – 35 t/h) would require a system several times larger than existing reference plants. This would lead to an excessive energy demand and operational complexity. Under such conditions, the application of this process is not advisable.

Therefore, derogations should be requested for certain air pollutants and limit values should be set that can be complied with using proven emission reduction methods. Slovenian environmental law provides the possibility for the application of such derogations, but explicitly only for the components SO_2 and TOC (ΣC). However, an additional possibility for granting exemptions is foreseen in Annex 5 of the Regulation on Waste Incineration Plants and Co-Incineration Plants [AN5, 2025]. This possibility exists, if the technology, which would enable to meet the emission limit values, is not available on the market. To date, there is insufficient operational experience with the use of advanced emission reduction techniques to show that the new limits for NO_x , NH_3 , CO, TOC and Hg can be reliably complied with. It is therefore recommended to use the results of the multi-year demonstration project at the Allmendingen cement plant (see **Table 6-1**) as a guide and to set corresponding emission limits for the Alpacem Cement kiln plant. For the flue gas component Hg, reduction measures like dust shuttling, injection of adsorbents and process optimisation are being pursued. It should be emphasized that setting a very low emission limit value (e.g. $0,02 \text{ mg}/\text{m}^3$) at this stage (before full implementation and

optimisation of the planned measures) would pose a significant compliance risk. A stepwise approach, based on demonstrated performance data, would be more appropriate in the case.

Table 6-1 Achievable emission limit values according to the long-term demonstration project in the Allmendingen cement works [BMU, 2022]

Component	Achievable emission limit (as daily average)
	[mg/m ³] (10 % O ₂)
NO _x	200
NH ₃	30
CO	100
TOC (ΣC)	10
Hg	0,03 *

* According to operational experiences from many cement works with the application of BAT's for Hg abatement

In several European countries, however, such derogations are also granted for other components if the emissions originate predominantly from the raw material. To this end, VDZ recently carried out raw material investigations with expulsion tests to determine the extent of "raw material-generated emissions" of certain flue gas components [VDZ, 2025]. The results of these laboratory investigations are summarized in a separate Technical Report [VDZ, 2024].

In principle, it is to be expected that the implementation of the planned emission reduction measures will lead to a further improvement of the environmental situation in the vicinity of the cement plant.

However, operational experiences from other SCR and RTO-SCR projects show that a sufficiently long period of time must be allowed for the optimisation of the new plants. It is to be expected that this will also result in frequent shutdowns of the emission reduction plants, during which modifications and maintenance work can be carried out. Emission limits must be set for these periods that can be complied with using conventional measures.

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8 VDZ reference list

As an international technical and scientific service provider for the cement and building materials industry, VDZ offers comprehensive services in the fields of cement, concrete and environmental protection.

For many years, VDZ has been supporting cement companies in research and consulting projects for the introduction of advanced emission reduction technologies. VDZ is active in various national and international committees and also involved in the upcoming revision of the BREF document for the cement industry.

Below are some examples of the VDZ's activities in this field:

- SNCR demonstration projects (1990s and 2000s) und optimization of SNCR plants in many cement plants
- SCR demonstration projects in Germany (conduction of operational trials, reporting):
 - HD-SCR Project Mergelstetten
 - LD-SCR Project Rohrdorf
 - DeCONOX (RTO-SCR) Project Allmendingen
 - HGF-SCR Project Otterbein
- Long-term work and exchange of operational experiences in VDZ Committee "NO_x abatement" (SNCR, SCR, DeCONOX/RTO-SCR)
- Advising cement plants on the planning of emission abatement facilities
- Consulting of the Swiss BAFU about the state of emission abatement in the cement industry
- Consulting of BAFU and the Swiss cement industry about the NO_x reduction potential of Swiss cement plants
- Involvement as industry representative in the preparation of the cement BREF document
- Involvement as industry representative in the revision of legal regulations on emission control at European and national level