Three DeNOx solutions are appropriate for cement plants: SCR (shown here), SNCR and catalytic bags

FACING TOUGHER REGULATIONS

Giuliamaria Meriggi, Redecam, presents the evolution of flue gas treatment in cement manufacture.

When Redecam Group was founded 30 years ago, removing dust at stack via air filtration was the only consideration for cement plants in order to abide by air emissions regulations. Over the years, global pollution increased exponentially and research became more conclusive regarding pollution's devastating effects on the environment, as well as on human and animal health. The result: a wide variety of lobby groups and local populations increased their advocacy and world leaders implemented increasingly strict legislation on a wide variety of pollutants. Whereas 20 years ago, Redecam's main flue gas treatment (FGT) clients were in the biomass and power sectors, today the cement industry has become a consumer of FGT technology as well. Cement plants already face tougher FGT regulations in many countries and should be prepared for the implementation of even stricter environmental legislation over the coming years.

Some governments have indeed been cracking down on facilities defying regulations: several cement plants in the US have faced millions of dollars in fines and have been threatened with closure if adequate FGT systems to reduce nitric oxides and sulfur dioxide are not effectively integrated.

In contrast, many other countries seem to currently face compliance enforcement challenges. China is a prime example, but is certainly not alone. It faces nearly crippling pollution and smog and has proven good intentions by introducing tough legislation to reduce NO_x and SO_x, among other pollutants. However, like most other jurisdictions, it seems unequipped to force compliance. Cement producers should get ready for that to change, as compliance enforcement will be on the rise.

Redecam has developed methods tailored to the cement industry to reduce nitric oxides, sulfur dioxide and mercury, among others. As more jurisdictions adopt stricter pollutant regulations and improve their enforcement, these technologies will be increasingly required.

Pollutant: NO_x

Nitrogen Oxides (NO_x) – poisonous, highly reactive gases formed when fuel is burned at high temperatures – are emitted by cement kilns and react with volatile organic compounds (VOCs) to produce ozone (smog). They contribute to acid rain, global warming and water quality deterioration. NO_x also affects human health, reacting with ammonia, moisture, and other compounds to form small particles that penetrate deep into sensitive parts of the lungs. These particles can cause or worsen respiratory disease, such as emphysema and bronchitis, and can aggravate existing heart disease, leading to premature death.[1]

A Redecam DeNOx SCR system, able to achieve up to 95% NOx reduction, with a bypass.

This plant ordered DID, MAS and SCR systems in order to ensure compliance with all future regulations.

Countries around the world currently have highly differing limits on NO_x emissions, most ranging from 200 mg/Nm³ to 2500 mg/Nm³. Some countries, such as Brazil, have no regulations regarding NO_x at all. The US limits became stricter as of 2015 to 1.5 lb/t of clinker.[2] China reduced its NO_x emission limit in 2014 to 400 mg/m³ – a start as the previous limit was 800 mg/m³.[3] The idea was to push cement producers to incorporate end-of-pipe control (ex: SNCR) to reduce NO_x emissions.[4]

In the coming years, cement plants in many areas will have to consider additional NO_x abatement technologies. Germany will impose a NO_x limit of just 200 mg/Nm³ in 2018[5] – a move that could push others to follow suit. Indeed, while the European Union's Industrial Emission Directive (IED) has not yet reduced emissions limits for NO_x to 200 mg/Nm³ (it may after 2016[6]), as organisations such as the European Environmental Bureau had advocated, it did reduce emissions requirements for cement plants to 500 mg/Nm³.[7] India has also been discussing imposing NO_x emission limits for several years.

NO_x abatement solutions

Two Best Available Technique (BAT) $DeNO_x$ solutions are appropriate for the cement industry: Selective Catalytic Reduction (SCR) and Selective Non-Catalytic Reduction (SNCR). Catalytic bags are also an option, although a newer technology.

Selective Catalytic Reduction (SCR)

SCR is the optimal NO_x control system, able to achieve up to 95% NO_x reduction in combustion processes. It can therefore meet stricter incoming legislation.

SCR converts NO_x into diatomic nitrogen, N_2, and water, H_2O, with the aid of a catalyst. A gaseous reductant, typically anhydrous ammonia, aqueous ammonia or urea, is added to a stream of flue or exhaust gas before the gas enters the catalyst chamber. SCR takes place at the end of the air pollution control process, after air filtration has taken place. Urea or ammonia can be used as reagents.

Facts about Redecam's SCR system:

- Both Tail-End and High-Dust $DeNO_x$ systems are available.
- Catalytic chambers are tailored to the plant's needs and designed for mechanical stability and

a long service life, resulting in lower Capex and lower Opex than other such systems.

- Reactions are carefully studied with computational fluid dynamics (CFD) modelling to provide low reagent consumption and engineers ensure field results reproduce theoretical CFD analyses.
- Choice of catalyst is of utmost importance to offer a low regeneration cycle.
- Operation occurs above dew point, meaning no corrosion.

Selective Non-Catalytic Reduction (SNCR)

SNCR can easily reduce NO_x emissions by up to 65%. It is a good option for cement plants in several areas, as in many instances this reduction percentage is sufficient to meet emissions regulations.

- Can be added to the existing air filtration system without major modifications.
- Economical in terms of Capex.
- Smaller footprint.
- An ID fan is not needed, saving on energy costs.

Facts about SNCR system:

- Reduces emissions by up to 65%. On-site tests have proven a reduction to 200 mg/Nm³.
- Reagent is optimised: the system's high temperature converts urea to ammonia without the need to install external burners to transform the reagent.
- The fully automated system monitors and optimises the SNCR process remotely and can send any malfunction data directly to the control room of the plant.
- Modules are pre-commissioned off-site. Often installation does not require any plant downtime.

Pollutant: SO_x

SO_x refers to all sulfur oxides, the two major ones being sulfur dioxide (SO_2) and sulfur trioxide (SO_3) (formed when SO_2 combines with oxygen). SO_x are a main contributor to greenhouse gas. They react with water vapour and form sulfuric acid (H_2SO_4) – one of the culprits in the creation of acid rain, harming bodies of water, forests and crops. In high concentrations, SO_2 can affect breathing and may aggravate existing respiratory and cardiovascular disease.

Cement plants emit SO_2 mainly for two reasons: the limestone and other raw materials used can contain sulfite impurities; and the fuels used, particularly coal and some alternative fuels, can contain elemental sulfur.

More developed economies have been reducing their emissions of SO_2 for several years. Germany has the lowest SO_2 emission limit in the world at 50 mg/Nm³ (although the state of South Wales, Australia has the same limit). Other countries with

DID with in-duct lances is an ideal SO_x removal solution for retrofits, as it allows plants to keep existing air filtration and ancillary equipment.

Cement plants in many jurisdictions should be contemplating adding FGT to their air filtration in order to meet incoming legislation.

relatively low SO_2 emissions limits are Norway (400 – 500 mg/Nm³), Austria (350 mg/Nm³), Egypt (400 mg/Nm³), Colombia (200 – 550 mg/Nm³) and South Africa (50 – 250 mg/Nm³).[8] The US limits SO_2 for cement plants at 0.4 lb/t clinker, as of September 2015.[9] China has also been taking a more environmentally conscious turn. Its 12th Five-Year

Plan aims to reduce ambient SO_2 concentrations by 10%, and in key regions by 12%, by 2015.[10]

Desulfurisation solutions

Traditionally, wet scrubbing and semi-wet desulfurisation have dominated the market. However, that is expected to change in the coming years, as the advantages of Dry Injection Desulfurisation (DID) become better known. Redecam considers DID to be the state-of-the-art technology and as its price tag has fallen, it is the only desulfurisation system Redecam offers. DID removes SO_2, SO_3, HCl (hydrochloric acid) and HF (hydrogen fluoride).

Advantages of DID:

- Cost-effective in terms of Capex.
- More compact.
- Lower installation costs due to use of carbon steel instead of alloy metals.
- Lower maintenance costs due to fewer moving parts.
- Captures more pollutants due to better mixing.
- Minimises the production of nitrogen oxides due to low operating temperatures.

Redecam key facts:

- Up to 98% effective.
- The residence time of the gas with the reagent and the mixing technology allows for an optimised reaction.
- The byproduct can be used as filler (e.g. road construction or mine reclamation) or landfilled. In-house simulation software helps calculate optimal injection points.
- Two models are recommendable for the cement industry:
  - DID with in-duct lances (ideal for retrofit applications as no extra-footprint is required).
  - DID-R – with reaction tower (for facilities needing high performance systems).

Pollutants: mercury and other heavy metals

Mercury and several of its compounds are extremely toxic. Research shows that mercury in the air may settle into water bodies, transforming into methylmercury. Methylmercury accumulates in fish at levels that may not only harm the fish, but also those who eat them.

Mercury enters the cement production process via impurities in the limestone raw material and minor impurities in fuel sources like coal and selected alternative fuels. Mercury becomes concentrated within cement plants but a portion is constantly emitted. Spikes in emissions occur upon start-up and shutdown, especially when the shutdown is unexpected.

Where emission limit values are in place, they range (with few exceptions) between 0.03 – 0.1 mg/m³ as a daily average. This range applies to emissions from cement plants in places as diverse as Germany (0.03 mg/Nm³), Egypt, Brazil, Nigeria, Australia, Chile and South Africa. China implemented new mercury regulations in 2014, but there remain many countries without mercury emission limits. These include the major markets of India, Turkey (for non-AF burning plants), the UAE, Saudi Arabia and Lebanon.[11]

In the EU, industrial mercury emissions are covered by the IED and are limited to 0.05 mg/m³ for furnaces co-incinerating waste fuels. In the US, new mercury emission limit values came into effect in September 2015. Emissions for existing kilns are now limited to 27.5 kg per million t of clinker. For new kilns, the limit is 11.5 kg per million t of clinker. These emission limits are so low that the local cement industry is being required to examine new methods of mercury control.[12]

Mercury reduction solutions

Best Available Techniques propose a primary solution: carefully selecting and controlling all substances entering the kiln in order to reduce mercury input.[13] When that is not enough – or not viable – secondary mercury reduction techniques are available: dust-shuttling, dust-shuttling with sorbent injection and sorbent injection with a polishing filter.

Advantages and limitations:[14]

- Dust-shuttling:
  - Least expensive in terms of Capex.
  - Mercury reduction of only 10 – 35%.
  - Limited applicability as low gas temperatures needed to be effective.
- Dust-shuttling with sorbent:
  - Mercury reduction of 70 – 90%.
  - Option to cut peak emissions. Continuous sorbent injection can compromise quality of cement.
- Sorbent injection with polishing filter:
  - Most effective technique, up to 90% mercury reduction.
  - Sorbent can be injected continuously or for cutting peak emissions.

Redecam offers sorbent injection with a polishing filter – its Mercury Adsorption System (MAS). Powdered activated carbon (PAC) is pneumatically injected downstream of the main particulate control, with a polishing filter to remove the mercury laden sorbent.

MAS is comparatively cost-efficient in terms of Capex. It can be installed as a retrofit, added into existing ductwork, as well as integrated with other FGT systems.

Key facts about Redecam's MAS:

- Over 90% effective.

- Removes mercury, furans, dioxins, lead, cadmium, arsenic, chromium, manganese and other metals.
- Dosing function perfected to optimise reagent dispersion in the gas.
- The right PAC pore size, or choosing an impregnated version, ensures lower consumption, safe operation and better integration.
- Sorbent can be injected before the air heater, garnering a faster reaction, further reducing reagent consumption.
- Low maintenance: designed to reduce wear and tear on the system.
- Can be integrated with the One-Step Cleaning Solution, removing all pollutants.

References

1. US Environmental Protection Agency, Six Common Pollutants, Health. Available from: http://www3.epa.gov/airquality/nitrogeNOXides/health.html (October 22, 2015)
2. US Environmental Protection Agency, August 6, 2010. Fact Sheet: Final amendments to national air toxics emission standards and new source performance standards for Portland Cement Manufacturing. Available from: http://www3.epa.gov/airtoxics/pcem/pcem_fs_080910.pdf (October 22, 2015)
3. Ministry of Environmental Protection, The People's Republic of China, January 15, 2014. MEP announces new emission standards for major industries - Efforts to implement the ten major measures against air pollution. Available from: http://english.mep.gov.cn/News_service/news_release/201401/t20140115_266434.htm (October 22, 2015)
4. Ibid.
5. EDWARDS, P. 21 February 2014, 'Global cement emissions standards,' Global Cement Magazine. Available from: http://www.globalcement.com/magazine/articles/845-global-cement-emissions-standards (October 22, 2015)
6. Reuters UK. Research and Markets: Global Industrial DeNOX (SCR and SNCR) Systems & Services Market Forecasts & Opportunities, 2019. Available from: http://uk.reuters.com/article/2014/04/30/research-and-markets-idUKnBw307041a+100+BSW20140430 (October 22, 2015)
7. European Environmental Bureau, July 14, 2011. New Features under the Industrial Emissions Directive. Two page summary followed by a comprehensive analysis. Available from: http://www.eeb.org/?LinkServID=290B7936-ADF0-4AD8-D16350AB49EE7DFC&showMeta=0 (October 22, 2015)
8. EDWARDS.
9. US Environmental Protection Agency, August 6, 2010.
10. Ministry of Environmental Protection (MEP), National Development and Reform Commission (NDRC), and Ministry of Finance, approved by State Council: September 2012, English translation: April 2013. Twelfth Five-Year Plan: on air pollution prevention and control in key regions, Page II. Available from: http://www.epa.gov/ogc/china/air%20pollution.pdf (September 22, 2015)
11. EDWARDS, p. 30.
12. European Cement Research Academy (ECRA), Newsletter 01/2015. Challenging mercury: emission limits and measures - Global abatement strategies to reduce mercury emissions. Available from: http://www.ecra-online.org/uploads/media/ECRA_Newsletter_1-2015.pdf (October 22, 2015)
13. Expert Group on BAT/BEP for Minamata Convention on