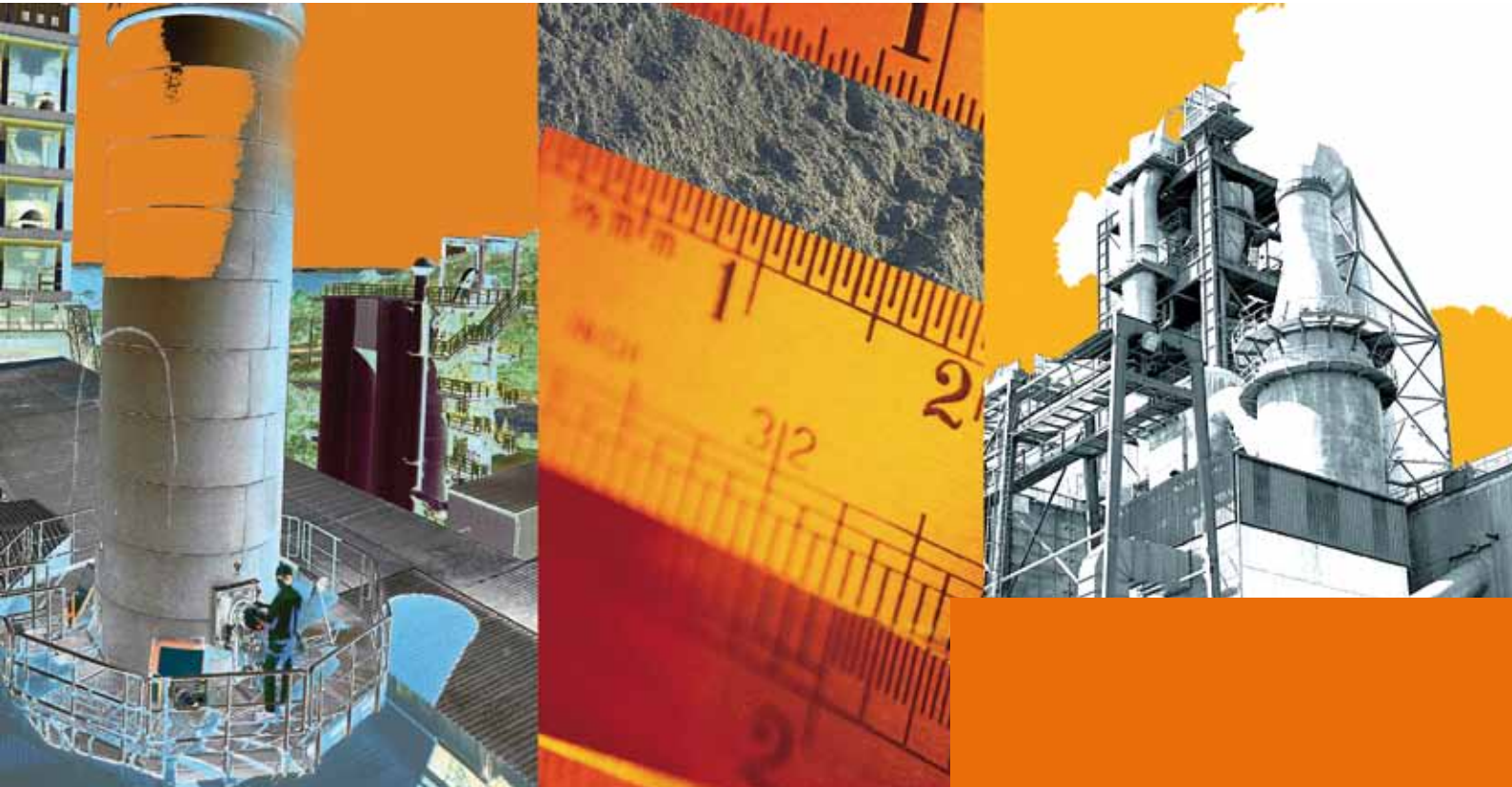


Cement Sustainability Initiative

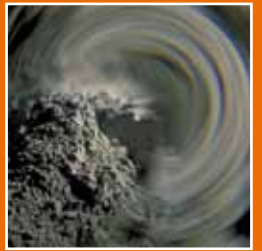


*Guidelines for Emissions
Monitoring and Reporting
in the Cement Industry*

**Emissions Monitoring
and Reporting**

March 2012

Version 2.0



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1 Introduction

1.1 Background

Cement is one of the most widely used man-made substances on the planet. Each year, nearly 450 kg of cement are consumed for each man, woman and child. Making cement is an energy and resource intensive process, with both local and global impacts. Recognizing this, several cement companies initiated the Cement Sustainability Initiative (CSI) in 1999 as a member-sponsored program of the World Business Council for Sustainable Development (WBCSD).

Today, the CSI is a global effort by 24 major cement producers with operations in more than 100 countries who believe there is a strong business case for the pursuit of sustainable development. Collectively these companies account for about one third of the world's cement production and range in size from large multinationals to smaller local producers.

General information on the CSI can be found on the website: www.wbcscement.org

1.2 Emissions monitoring and reporting

One of the issues the CSI has tackled since the publication of its Agenda for Action in 2002 is the management of airborne emissions from cement manufacturing. Emissions measurement, monitoring and reporting contributes to understanding, documenting and improving the industry's environmental performance. Lack of emissions information can lead to local concerns about plant operations.

In 2005, the CSI published its first emissions measurement and reporting protocol to provide a common framework for all CSI members. Subsequently, individual companies set their own emissions targets and started reporting annually on progress toward those targets.

The CSI protocol focuses on the practical task of monitoring and reporting emissions from cement production. While many analytical standards are available under various national and international regimes, these standards are not used systematically in all parts of the world. As a result, emissions may not be properly monitored and environmental regulations may not be available or adequately enforced in some places. This protocol has therefore been developed to meet three main objectives:

- To encourage uniform monitoring and reporting of cement process emissions.
- To provide credible, relevant, and easily understandable information on emissions.
- To provide internal management with a tool for gathering relevant information to plan cement emissions monitoring and reporting.

The protocol covers cement plant main stack emissions. These are the largest single point source, may have a significant impact on the environment, and can be quantified with reasonable effort and accuracy. The methods proposed to quantify emissions are those established by experts in analytical chemistry and with field experience in the cement industry. These methods produce representative results under sometimes inhospitable measurement conditions. Continuous emission monitoring is recommended as the preferred method whenever possible taking into account such factors as accuracy, maintainability of instrumentation, adequate calibration, and cost.

The protocol details the actions that CSI member companies have agreed to take to monitor emissions. Based on these data, individual companies have agreed to set their own emissions targets and to track their progress in emissions reduction using the agreed key performance indicators (KPIs) discussed in Section 5. Each company has agreed to publish their emissions data regularly (on an annual basis), transparently and comprehensibly (but sufficiently aggregated),

and in compliance with applicable anti-trust laws. They have further agreed to monitor reporting frequencies and formats to improve the transparency and understanding of their operations by local communities and regulators.

Version 2 (2012)

This revised Version 2 of the Guidelines for Emissions Monitoring and Reporting in the Cement Industry draws on the experience gained with the application and the evaluation of the first protocol since 2005 by many cement companies worldwide.

It also takes into account the development of the regulatory framework in the years since the first guidelines were published, notably the publication of the Reference Documents on Best Available Technique (BREF) in Europe in June 2010, the Industrial Emissions Directive (IED) in the fall of 2010, and the National Emission Standard for Hazardous Air Pollutants (NESHAP) in the USA in September 2010.

The principle objective for the revision of the guidelines was to adjust them to the technology developments and the evolution of stakeholder expectations in recent years, in order to have a document that can serve as a guide to both member companies and regulators for measurement and reporting of air emissions.



2 Emissions from cement production

2.1 General

Emissions may come from different points in cement production processes, depending on the raw materials and fuels, preparation procedures and kiln systems, and emissions control systems used. The main manufacturing steps, which are also potential emission sources, are:

- Quarrying and preparation of raw material
- Handling of fuels
- Clinker production
- Finish grinding
- Packaging
- Storage
- Blending
- Transport
- Loading of material

The largest volume substances emitted during the production of cement are particulate matter (dust), oxides of nitrogen, sulfur dioxide, carbon dioxide and carbon monoxide. Trace quantities of volatile organic compounds, acid gases, some trace metals, and organic micro pollutants may also be emitted. While cement kilns typically operate at steady conditions (excluding startup and shutdown), naturally occurring changes in raw materials and fuels composition can produce small day-to-day variations in emissions.

2.2 Emission components

2.2.1 Summary of emission components

Cement plants emit a range of pollutants, several of which are now subject to regulation and control. Significant improvements have been made in reducing emissions; nonetheless, cement plants still remain a source of emissions for pollutants. Table 1 indicates the range of emissions of various pollutants as reported in the European BREF document, May 2010.¹

Table 1: Emissions averages and ranges from European cement kilns

Reported emissions from European cement kilns			
Pollutant	Average concentration	Concentration range from/to	Average specific emission
Dust	20.3 mg/Nm ³	0.3/227 mg/Nm ³	46.7 g/t ck
NO _x as NO ₂	785 mg/Nm ³	145/2040 mg/Nm ³	1.805 kg/t ck
SO ₂	219 mg/Nm ³	Up to 4837 mg/Nm ³	0.504 kg/t ck
CO		Up to 2000 mg/Nm ³	
VOC/THC as C	22.8 mg/Nm ³	1/60 mg/Nm ³	52.4 g/t ck
HCl	4.3 mg/Nm ³	0.02/20 mg/Nm ³	9.8 g/t ck
HF	0.3 mg/Nm ³	0.01/1.0 mg/Nm ³	0.7 g/t ck
PCDD/F as ITEQ	0.016 ng/Nm ³	0.000012/0.27 ng/Nm ³	0.037 µg/t ck
Metals			
Hg	0.02 mg/Nm ³	0.0/0.03 mg/Nm ³	0.046 g/t ck
Σ (Cd, Tl)	0.02 mg/Nm ³	0.0/0.68 mg/Nm ³	0.046 g/t ck
Σ (As, Sb, Pb, Cr, Co, Cu, Mn, Ni, V)	0.14 mg/Nm ³	0.0/4.0 mg/Nm ³	0.322 t ck

• Concentrations are reference concentrations, i.e. 273°k, 101.3 kPa, 10% O₂ and dry gases
 • Specific emissions are based on kiln exhaust gas volumes of 2300 m³/ton clinker

Source: BREF on cement, lime and magnesium oxide manufacturing industries, May 2010

2.2.2 Particulate matter/dust

The terms 'dust' or 'particulate matter' include emissions of coarse dust, fine dust, soot, particles and aerosols.

Dust emissions from cement kilns have been reduced dramatically over the last two to three decades due to regular improvements in design and operation, including increased use of modern de-dusting equipment. Nevertheless dust emissions from poorly equipped or poorly operated kilns can be high.

In most countries, the cement industry is not a major source of dust and particulates, though on some sites these particulate emissions may still be of significance. The data on particulate emissions shown in Table 1 from the European BREF are similar to those from Australian and US cement plant inventories (NPI 1999; EPA AP-42 1995).

2.2.3 Oxides of nitrogen (NO_x) and sulfur (SO₂)

NO_x is formed by the reaction of nitrogen in air and fuel with oxygen at the high temperatures reached during the clinker production process. SO_x emissions are predominantly (99%) in the form of sulfur dioxide (SO₂). SO₂ is primarily formed from oxidation of volatile sulfur present in raw materials, but in some specific process configurations it may result from fuel sulfur oxidation.

The cement industry has significantly improved its performance over the last 30 years but it is still a source of NO_x and SO₂ emissions. The data on NO_x and SO₂ emissions shown in Table 1 from the European BREF are again similar to those for Australian and US cement plants (NPI 1999; EPA AP-42 1995).

In some countries, the industry is a relatively small contributor to national emissions of these pollutants. For example, the UK National Atmospheric Emissions Inventory (NAEI 2009) showed that the cement industry contributed about 2.5% of the total NO_x and 1.0% of the total SO₂ emissions in the UK in the year 2008.

2.2.4 Oxides of carbon (CO₂ AND CO)

Cement production is a source of emissions of the greenhouse gas carbon dioxide (CO₂). As much as 6%² of global man-made carbon dioxide emissions originate from cement production.

Approximately 50% of carbon dioxide emissions from cement production originate from the chemical reaction that converts limestone (CaCO₃) to calcium oxide (CaO), the primary precursor to cement. About 40% of the industry's CO₂ emissions come from fossil fuel combustion during cement production. The remaining emissions come from the transport of raw materials (about 5%) and the combustion of fossil fuels required to produce the electricity consumed by cement production (about 5%) (Battelle 2002). According to the CSI's Getting the Numbers Right database (GNR), which covers close to one third of global cement production, the average specific CO₂ emissions amounted to 652 kg/ton cementitious product in 2010.³

Reducing CO₂ emissions is a key focus of the CSI's work. In 2001 the CSI companies agreed on a methodology for calculating and reporting CO₂ emissions, the Cement CO₂ and Energy Protocol. It is aligned with the WBCSD / WRI Greenhouse Gas Protocol and was revised in 2005 and in 2011. To date, all CSI companies follow this protocol to determine and report their CO₂ emissions.⁴

The emission of carbon monoxide (CO) during the clinker production process is caused by incomplete combustion of small quantities of organic constituents present in some raw materials. For most kilns the CO content is well below 2000 mg/Nm³ (BREF 2010).

2.2.5 Volatile Organic Compounds (VOCs)

Cement production is not a significant source of VOCs but small quantities of organic constituents can be released from the natural raw materials during the clinker production process. Under normal circumstances the VOC content of the exhaust gas from cement kilns ranges between 1 and 60mg/Nm³ (BREF 2010). In viewing national inventories of pollutants, major sources of VOC emissions are typically road and air traffic, together with organic solvent use, oil and chemical industry processes, and industrial and residential combustion.

2.2.6 Acid gases

Cement production is a minor source of hydrogen chloride (HCl) and hydrogen fluoride (HF) arising from trace amounts of chlorine and fluorine present in raw materials and fuels.

1 "Reference Document on Best Available Techniques in the Cement, Lime and Magnesium Oxide Manufacturing, May 2010", European Commission. <http://eippcb.jrc.ec.europa.eu>

2 IPCC Special Report on Carbon Dioxide Capture and Storage, UNEP Intergovernmental Panel on Climate Change, 2005 www.ipcc-wg3.de/publications/special-reports/.files-images/SRCCS-WholeReport.pdf, p. 113.

3 See www.wbcsdcement.org/co2data

4 Directly accessible via: www.cement-co2-protocol.org/v3

2.2.7 Trace metals

Trace metals are present in raw materials and fuels, at widely variable but usually very low concentrations⁵. The behavior of the trace metals in a cement kiln depends on their volatility. Non-volatile metals and metal compounds leave the kiln as part of the clinker. Volatile metals condense in the preheater and raw mill system and return to the kiln with the raw meal. This concentrating effect can lead to an increase of emissions, for instance, when the raw mill system is not running or in the event of kiln upsets. Volatile metals which do not condense in the raw mill system leave with the combustion gases in low concentrations.

2.2.8 Organic micro-pollutants

The following substances are sometimes collectively referred to as 'micro pollutants' as the absolute mass of their releases from a given process is normally orders of magnitude lower than the releases of NO_x or other air pollutants:

- Polychlorinated dibenzodioxins and polychlorinated dibenzofurans – collectively known as "dioxins and furans" or "PCDD/PCDFs"
- Polychlorinated biphenyls – usually known as "PCBs"
- Polycyclic aromatic hydrocarbons – known as "PAHs".

Formation of dioxins and furans occurs at relatively low temperatures – most typically in exhaust gases from a variety of combustion processes (including forest fires and domestic cooking) as the gases cool through a temperature range of 450°C to 200°C. To minimize the possibility of dioxin formation it is important that the kiln gases are cooled as quickly as possible through this critical temperature range. Based on detailed analysis of existing data and new samples collected by CSI members, in well-operated, modern cement kilns dioxin emissions are not related to the type of fuels used (SINTEF 2nd edition January 2006).

A number of countries have conducted national dioxin inventories. In some countries, these show that the cement industry is generally a minor contributor to dioxin emissions (less than 3% of the total). Major sources include municipal waste incinerators, residential wood combustion, agricultural burning, and steel mills among others.⁶

⁵ See, for example, typical concentrations as identified by the CSI's work on fuels and materials use: www.wbcsdcement.org

⁶ For example, Canada's 1999 dioxin emissions inventory showed municipal waste incineration as responsible for 58% of total dioxin releases. Emissions from the cement sector accounted for less than 1%: "Dioxins and Furans and Hexachlorobenzene, Inventory of Releases," Environment Canada, January 1999. Can be downloaded from the CEPA website



3 Selection of the main emissions source and pollutants

This protocol aims to ensure that CSI companies focus on monitoring, measuring and reporting of the most important emission sources and pollutants from the cement industry. This section identifies the key sources and pollutants for this protocol.

3.1 Selection of the main emission source

Some regulatory systems designate specific measurement points for specific processes. Based on comparisons of plants with different kiln systems, de-dusting installations and geographical locations, the main stack of the clinker production process has been shown to be the most important source of emissions to air by the cement industry. This is due to the volumetric flows as well as emission concentrations which are comparatively high at this point in the process.

Near-ground fugitive releases of dust originate in most cases from quarrying and preparation of raw materials, handling and storage of fuels, and transport (sometimes worsened by wind action and other natural sources), but not from the combustion process. Fugitive emissions of this sort are difficult to measure and impact mainly on the local environment (and are therefore the responsibility of the local plant management), whereas releases from high stacks may have an impact on air quality over a much larger area.

This protocol therefore considers emissions from the main kiln stack only, but it encourages individual companies to measure on a wider scope of emission releases than those outlined in this reference document.

3.2 Selection of the main pollutants

The following emissions from the main kiln stack have been identified as the main focus for this protocol, and therefore for reporting within the CSI, due to their volume and/or significance:

- Dust / particulate matter
- Oxides of nitrogen (NO_x)
- Sulfur dioxide (SO₂).

3.3 Selection of other pollutants

Other pollutants of concern to stakeholders (including local communities and regulatory authorities) and which should be measured are:

- Trace metals and their compounds such as: Mercury (Hg), Cadmium (Cd), Thallium (Tl), Antimony (Sb), Arsenic (As), Lead (Pb), Chromium (Cr), Cobalt (Co), Copper (Cu), Manganese (Mn), Nickel (Ni) and Vanadium (V).
- Volatile organic compounds (VOCs) or Total Hydrocarbons (THC); they include methane and ethane with other hydrocarbons and are reported as carbon.
- Polychlorinated dibenzodioxins and dibenzofurans (PCDD/PCDFs); they include the 17 congeners of the NATO scheme adopted internationally and are reported as International Toxic Equivalent (I-TEQ)⁷.

This selection is largely in keeping with other important international guidelines, e.g. Reference Documents on Best Available Technique (BREF) and the Industrial Emissions Directive (IED) in Europe, and the National Emission Standard for Hazardous Air Pollutants (NESHAP) in the USA. Others are also considered, such as the US EPA documentation AP-42 and the Australian NPI Guideline.

Other pollutants such as acid gases can be considered as minor and not material considering the trace amounts of Chlorine and Fluor present in raw materials and fuels.

⁷ Refer to Technical Annex, Table A6



4 Emissions monitoring (measurements)

The emissions can be monitored by using either continuous or discontinuous measurements. The measurements will be taken according to the recognized rules of metrology and according to the methods recognized in corresponding national environmental regulations.

The technical annex to this protocol gives insights on various technologies suitable for continuous measurements: “in-situ” and “extractive” measuring devices, “cold” and “hot” extractive devices, and the different physical methods of analyses.

The technical annex gives the standards which are recommended for the measurements – sampling and analyses – of the pollutants and parameters. Those standards are International ISO Standards (see: www.iso.org), US-EPA methods (see: www.epa.gov) and EN standards (see: www.cen.eu). Methods defined by national standards or methods recognized equivalent to the recommended standards may be used as well. Methods used have to be identified.

The technical annex recommends that the selection criteria for continuous emission monitors (CEMs) should include – among others – the right identification of the pollutants to be measured according to the requirements set in the regulations and operating permits and according to the commitments taken in these guidelines; parameters such as oxygen, moisture and the gas flow should also be included. The emission levels and values should be assessed for the various scenarios of operation of the kiln system. The analyzers should be certified by a recognized certification body or suitability demonstrated with performance tests. Attention should be paid to the supplier’s ability to provide local technical support.

The technical annex recommends that contractors or bodies carrying out the discontinuous measurements and the analyses have implemented a quality management system that follows as example the international standards ISO 9001: 2008 and ISO 17025: 2005 “General requirements for the competence of testing and calibration laboratories”. The experience of contractors or bodies should be checked for the components analyzed.

4.1 Recommended frequency of measurements

The frequency of the measurements should be based on the nature of the pollutants released and on the concerns of stakeholders. A company adhering to these guidelines will measure the main pollutants (dust, NO_x and SO₂) continuously with continuous emission monitors (CEMs). Before the CEMs are in operation on a site, these pollutants should be measured at least once a year.

The volatile organic compounds or total hydrocarbons (VOC/THC) should preferably be measured continuously or at least once a year.

Other pollutants should be measured periodically, according to the frequency reported in Table 2. The measurements should be made under conditions which reflect the normal operating conditions of the cement production process.

The measurement made periodically will be renewed within a period of six months following any significant change⁸ in the process: nature of fuels, raw materials, or air pollution control device.

8 Refer to Technical Annex, Section 7

Table 2: Frequency of measurements of covered pollutants

Pollutant	Frequency of measurements...
"dust"	Continuously
"NO _x "	Continuously
"SO ₂ "	Continuously
"VOC/THC"	Continuously or at least once a year
"PCDD/F"	Once every two years
"Hg"	Once every year
"other heavy metals"	Once every two years

The frequency of measurements could be reduced for mercury when the measured emissions are below the threshold set in Table 3. The frequency of measurements would return to the normal frequency as per Table 2 when measurements go above that threshold.

When PCDD/F or mercury is measured continuously, they do not have to also be measured periodically.

Table 3: Threshold for mercury

pollutant	Threshold...	Measurements are...
"Hg"	25 µg/ Nm ³	Once every two years

4.2 Quality assurance

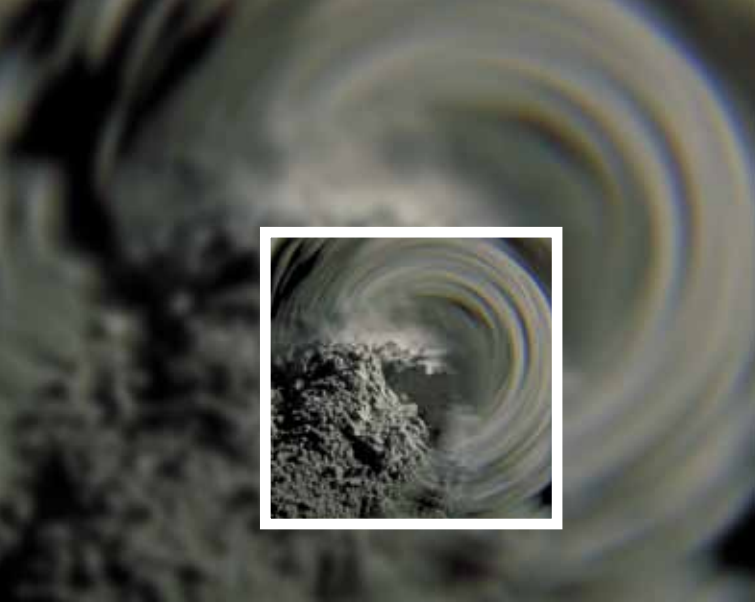
The quality of measurement and reporting relies on the successful implementation of successive working steps: sampling, analysis and reporting. Companies should assign resources and clear responsibilities for the monitoring, validating and recording of emissions. People should be trained for both operational and maintenance checks.

The continuous measurements with CEMs following commissioning need routine checks, proper maintenance and periodical calibration.

The quality assurance process for both continuous and discontinuous measurements should include:

- The technical assessment of data: Data are in usual range for the cement production process, data are coherent.
- The comparison of emissions monitored for the same kiln and pollutant in different months and years.
- A data validation process which should be implemented by the companies.

More indications are given in the Technical Annex.



5 Key Performance Indicators

The CSI companies are aware of the need to track the progress of improvements, and to make this progress clear to all their stakeholders. This protocol therefore includes a number of simple, reliable and representative Key Performance Indicators (KPIs).

KPI 1: Overall coverage rate

This KPI is designed to show the percentage of clinker produced by kilns covered by a monitoring system (continuous or discontinuous measurements) meaning dust, NO_x, SO₂, VOC/THC, heavy metals (Hg, Cd, Tl, Sb, As, Pb, Cr, Co, Cu, Mn, Ni and V), PCDD/F. The full production from a kiln is included in the KPI only when emissions of all pollutants (all 17 listed pollutants) are monitored, otherwise the production contribution from the kiln should be considered zero.

Calculation example for KPI 1:

Company A operates 50 kilns producing 50 million tons of clinker per year. In the reported time frame, all emissions of pollutants (previously identified) were monitored at 35 kilns producing 40 million tons of clinker.

In this case we get: $KPI\ 1 = (40,000,000\ \text{tons} / 50,000,000\ \text{tons}) \times 100 = 80\%$

The KPI 1 of company A is therefore 80%, meaning that 80% of its clinker is produced in kilns covered by monitoring systems which meet this protocol.

KPI 2: Coverage rate continuous measurement

This KPI indicates the percentage of clinker produced by kilns which have installed continuous measurements for dust, NO_x and SO₂. The full production from a kiln is included in the KPI only when all emissions of the pollutants (dust, NO_x and SO₂) are monitored, otherwise the production contribution from the kiln should be considered zero.

KPI 3“X”: Emission data pollutant “X”⁹

This KPI is designed to show the releases of emissions of dust, NO_x, SO₂, VOC/THC, Hg, heavy metals 1 (sum of Cd and Tl), heavy metals 2 (sum of Sb, As, Pb, Cr, Co, Cu, Mn, Ni and V), and PCDD/F (pollutant previously identified) from the kiln to the air. There are separate KPIs for each of these pollutants or group of pollutants as indicated in Table 4. Both specific and absolute values are reported.

Table 4: Definition of KPI 3“X” for each pollutant

Indicator	Comments
KPI 3“dust”	
KPI 3“NO _x ”	Sum of nitrogen monoxide plus nitrogen dioxide expressed as nitrogen dioxide
KPI 3“SO ₂ ”	
KPI 3“VOC/THC”	Total hydrocarbons including methane and ethane expressed as carbon (C)
KPI 3“PCDD/F”	Sum of 17 congeners of NATO scheme expressed as I-TEQ
KPI 3“Hg”	Mercury and its compounds expressed as mercury (Hg)
KPI 3“HM1”	Sum of Cadmium and Thallium and their compounds expressed as cadmium (Cd) and thallium (Tl)
KPI 3“HM2”	Sum of Antimony, Arsenic, Lead, Chromium, Cobalt, Copper, Manganese, Nickel and Vanadium and their compounds expressed as antimony (Sb), arsenic (As), lead (Pb), chromium (Cr), cobalt (Co), copper (Cu), manganese (Mn), nickel (Ni) and vanadium (V)

9 “X” is a generic reference to any of the pollutants

The calculation of emissions on a specific basis (g/ton clinker, mg/ton clinker, ng/ton clinker) must be done using the mass weighted averages of the kilns to ensure accurate data, whereas the absolute values of emissions (t/year, kg/year, mg/year) are calculated by adding the total emissions of each kiln.

Heavy metals (Hg, Cd, Tl, Sb, As, Pb, Cr, Co, Cu, Mn, Ni and V) and PCDD/F do not need to be measured on installations with running factors (operational capacity or time) below 50% in a year. In these circumstances, to avoid any impact on the coverage rates of indicators KPI 1 and KPI 4, the clinker produced from these installations will not be considered for the determination of these indicators.

The absolute values are extrapolated to the total quantity of clinker produced by the company.

Calculation example for specific and absolute dust emissions:

Company A operates 3 kilns:

- Kiln A produces 1 million tons of clinker per year with a specific dust emission of 10 g/ton clinker and an absolute dust emission of 10.0 tons/year,
- Kiln B produces 0.5 million tons of clinker per year with a specific dust emission of 40 g/ton clinker and an absolute dust emission of 20.0 tons/year,
- Kiln C produces 0.4 million tons of clinker per year with a specific dust emission of 100 g/ton clinker and an absolute dust emission of 40.0 tons/year,

$KPI\ 3^{dust} = (10\ g \times 1,000,000\ tons + 40\ g \times 500,000\ tons + 100\ g \times 400,000\ tons) / (1,000,000\ tons + 500,000\ tons + 400,000\ tons) = 36.8\ g/ton\ clinker,$ and

$KPI\ 3^{dust} = 10.0\ tons + 20.0\ tons + 40.0\ tons = 70.0\ tons/year$

If Company A would have operated a kiln D producing 0.2 million tons of clinker per year and no specific dust emission would have been reported, the indicator would have been:

$KPI\ 3^{dust} = 36.8\ g/ton\ clinker,$ and

$KPI\ 3^{dust} = 70.0\ tons \times (1,000,000\ tons + 500,000\ tons + 400,000\ tons) / (1,000,000\ tons + 500,000\ tons + 400,000\ tons) = 77.4\ tons/year$

When mercury has not been measured during one year because it was below the threshold the year before, or other heavy metals or dioxins and furans have not been measured in accordance with the frequency set in these guidelines, the last available specific value measured will be used for reporting; the absolute value being calculated multiplying that specific value by the total mass of clinker produced during the year of reporting.

Calculation example for specific mercury emissions:

A specific mercury emission of 20 mg/ton clinker has been measured in 2009 at the stack of kiln A. In 2010, no measurement has been made, kiln A has produced 1.0 million tons of clinker. Mercury emission reported in 2010 will be:

$KPI\ 3^{Hg} = 20.0\ mg/ton\ clinker,$ and
 $KPI\ 3^{Hg} = 20\ mg \times 1,000,000\ tons = 20.0\ kg/year$

The heavy metals cover the gaseous, the vapor and the condensed forms of the relevant heavy metal emissions as well as their compounds.

KPI 4“X”: coverage rate pollutant “X”

This KPI indicates the percentage of clinker produced by kilns which have monitored pollutant “X”.



6 Reporting

The objective of environmental reporting is to provide the reader with a fair picture of the environmental footprint of the reporting entity. Reporting of emissions therefore needs to meet a number of criteria:

- Data must be consistent, transparent and credible
- Data must be presented in a clear, standard format
- Data must meet quality assurance (QA) requirements (see section 4.2)
- Data must allow emissions to be reported in absolute as well as specific terms
- Reports must provide a flexible tool to suit the needs of different monitoring and reporting purposes

6.1 Which installations are covered?

A company can choose one of the following options to set the organizational boundaries on reporting of emissions data covered by this protocol:

- Equity share approach
- Control approach (operational or financial)
- A combination of both

A company should clearly state in its public reporting which method it applies and the exact scope of what is reported.

For this protocol, the definitions as outlined in the WRI/WBCSD Corporate Greenhouse Gas Reporting and Accounting Standard apply.

The new or acquired entity/facility/installation has to comply with this protocol at the latest the second year following the year the first clinker was produced or the year it was acquired.

The closed or sold entity/facility/installation may be excluded from this protocol for the whole year of their closure or selling.

Nevertheless, the quantities of clinker produced in both circumstances will be considered for the

determination of absolute emissions reported by the company.

Example:

If a facility was acquired in May 2009, it will have to comply with this protocol in 2011, which means reporting the 2011 data in 2012.

6.2 Reporting frequency and periods

The KPI values have to be reported by each company individually on an annual basis. Companies can make their own decisions about which documentation will be used for the reporting (e.g. an environmental or sustainability report, web site, etc.).

Reporting emissions can be based on financial years, rather than calendar years. This can help to reduce reporting costs and causes no problems provided that it is done consistently over time, with no gaps or overlaps. Any changes in the reporting year should be clearly indicated. National regulations and applicable anti-trust laws shall be complied with.

6.3 Reporting emission targets

As agreed in the *CSI Agenda for Action*, each CSI member company will establish, publish and report on their own individual target values for dust, NO_x and SO₂.

6.4 Format for an Emissions Monitoring Report

The KPI will be reported in the format shown in Table 5.

Table 5: KPI reporting form

Name of the company			
Reporting period			
KPI 1 Overall coverage rate		%	
KPI 2 Coverage rate continuous measurement		%	
KPI 3 Emission data & KPI 4 Coverage rate			
Pollutant	Specific emissions	Absolute emissions	Coverage
"dust"	g/ton clinker	ton/year	%
"NO _x "	g/ton clinker	ton/year	%
"SO ₂ "	g/ton clinker	ton/year	%
"VOC/THC"	g/ton clinker	ton/year	%
"PCDD/F"	ng/ton clinker	mg/year	%
"Hg"	mg/ton clinker	kg/year	%
"HM1"	mg/ton clinker	kg/year	%
"HM2"	mg/ton clinker	kg/year	%

6.5 Assurance of emissions data

In order to establish a standard assurance method and increase transparency, reliability and accuracy of reporting of CSI emissions KPIs to stakeholders, these KPIs must be independently assured in accordance with the following requirements:

Table 6: Assurance requirements

Item	Requirement
Assurance Level	Limited assurance at corporate level
Assurer Reputation	The assurer must be a recognized, independent third party assurance practitioner
Scope of Assured Data	CSI KPIs: KPI1: Overall coverage rate KPI2: Coverage rate of continuous emissions monitoring KPI 3 "dust, NO _x , SO ₂ ": Emissions data of dust, NO _x , SO ₂ KPI 4" dust, NO _x , SO ₂ ": Coverage rate pollutant dust, NO _x , SO ₂
Frequency of Assurance	Once every 2 years, assuring data from both years
Coverage of Sites	To be defined by assurer with number of examined business units and sites explicitly stated, and average percentage of pollutants covered in mass reported.
Assurance Standard	Assurer must use ISAE 3000* (or equivalent) and CSI Emissions Guidelines, explicitly citing their use in the assurance letter
Materiality Threshold	5%
Assurance Statement	The assurer must provide to the CSI member an assurance statement summarizing the conclusions about the emissions KPIs and explicitly mention the use of the CSI Emissions Guidelines and the number of sites examined and corresponding % of emissions covered.

* International Standard for Assurance Engagements



7 References

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A1 Introduction

This Technical Annex provides support to the “Guidelines for Emissions Monitoring and Reporting in the Cement Industry”, version 2 (2012), issued by the Cement Sustainability Initiative (CSI). It spells out the requirements for monitoring, maintenance of measurement equipment, reporting and quality assurance during the emissions monitoring and reporting process.

In general, the requirements referenced herein relate to:

- Installation and know-how related to the operation of continuous emission monitoring (CEM) equipment for dust, NO_x, SO₂, VOCs and calibration and maintenance of CEM equipment in regular pre-determined intervals;
- Discontinuous measurements of previous components plus VOCs, PCDD/F and heavy metals (HM), on a regularly defined frequency;
- Competence level of organizations carrying out measurements which must prove their competency; and
- Reporting of emission data in a standardized form allowing companies to communicate emission data internally and externally.



A2 Emissions Measurement – Terminology

Analysis function: The (mathematical) correlation between the response of the instrument and the (apparent) true value, determined by using a standard procedure

Automated Measuring System (AMS): Measuring system permanently installed on site for continuous monitoring of emissions; also called **Continuous Emission Monitor**

Calibration: Determining the variance of response of a measuring device by comparing it against values produced by a reference method. Calibration is a means of establishing or checking the analysis function of measuring equipment in a continuous operation at a plant

Calibration gases: Gases with an accurately defined composition. Calibration gases are prepared by specialist companies

Concentration: The mass of an emitted substance in relation to the volume of the exhaust gas (e.g. in milligrams per cubic meter [mg/m^3])

Data validation: A method for assuring the correct (right) data is used in analysis

Data verification: A method for assuring the data is correct (right)

Emission: Direct or indirect atmospheric pollutant discharge, present in the exhaust gas

Emission Limit Value (ELV): The mass of an emitted substance, expressed as specific parameters (concentration, emission level), that should not be exceeded during one or more periods determined and calculated under standard conditions

Exhaust gas: Gaseous releases to the atmosphere from a stack which may contain pollutants that can be in the form of gases, particles or aerosols

Limit of Detection (LOD): The lowest detectable amount of a substance

Limit of Quantification (LOQ): The smallest concentration of a substance that can be quantified with a prescribed certainty (generally 95 [%]); also called **determination limit**

Mass flow: The mass of an emitted substance per unit of time (e.g. in grams per hour [g/h])

Operating modes: *Compound operation:* flow of kiln exhaust gas partially or completely through a raw mill before being treated in the system dust collector

Direct operation: flow of kiln exhaust gas directly to the system dust collector without passing through a raw mill system (e.g. when the raw mill is not running)

Reference material: Material or substance for which one or more properties are sufficiently homogeneous and well established to be used for the calibration and/or the validation of a measuring system

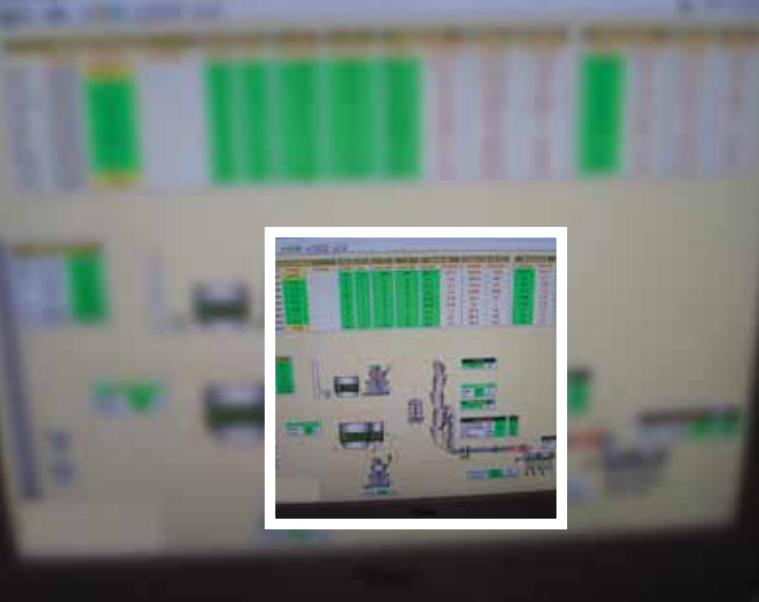
Reference method: A measurement procedure established by a recognized technical organization for determining a measurement variable

Sampling period: Measuring campaign during a sufficient time interval

Sampling location: The position within the exhaust gas channel where sampling is performed

Sampling station: A working platform for performing measurements and where measuring equipment is installed

Standard Reference Method (SRM): Recognized and standardized methodology for carrying out measurements, temporarily installed on site for verification purposes



A3 Continuous emissions monitoring systems (CEMs)

A3.1 Selection criteria for CEMs

The pollutants measured should be identified according to the requirements set in the regulations and operating permits and according to commitments taken in these guidelines and other voluntary agreements taken by the company. In addition to pollutants, other relevant parameters must also be available. These parameters are oxygen, moisture, gas flow, pressure, temperature and clinker output of the kiln system.

For each pollutant and parameter identified, the emission levels and values should be assessed for the various scenarios which could occur during kiln operation: start-up, shut-down, compound or direct mode (gas passing through raw mill or direct to dust collector), and the nature of raw materials and fuel mixes.

The measurement ranges should be set in accordance with permit conditions and expected concentration.

Particular attention should be paid to sampling. Examples of methodologies for sampling can be found in the **international standard ISO 10396:2007** "Stationary sources emissions – Sampling for the automated determination of gas emission concentrations for permanently-installed monitoring systems".

The CEMs should be selected among the proven technologies described within this document.

Table A1: Summary table for dust and gas monitoring

Pollutant	Recommended method of determination
Dust Concentration <20 mg/Nm ³	Scattered light method
Dust Concentration >20 mg/Nm ³	Optical transmission method
NO	NDIR (cold and hot) / FTIR / DOAS-UV
NO ₂	FTIR / NDIR (cold) and converter / Calculation ¹
SO ₂	NDIR (cold and hot) / FTIR / DOAS-UV
VOC	FID (Flame Ionization Detector)

Table A2: Summary table for parameter

Parameter	Recommended method of determination
O ₂	ZRO ₂ method (Zirconium oxide) / Paramagnetic method
Water content	NDIR (hot) / FTIR / Laser method / Fixed value ¹
Volume Flow	Ultrasonic method / Differential pressure principle
Temperature	Pt100-Sensor / In situ analyzer implemented
Absolute Pressure	In situ analyzer integrated / Fixed value ¹
Gas pressure	Separate sensor / Volume flow integrated (differential pressure) / Fixed value ¹

¹ Alternatively, default values based on results of spot measurements or calculated can be used

It is important that suppliers provide local technical support; the best analyzer from the best manufacturer will not be efficient without competent local technical support.

In addition to analyzers, attention must be paid to auxiliary equipment and services which contribute to (or are essential for) analyzers operation and availability of emissions data: shelters/cabins for the analyzers, air conditioning, general lay-out, power and compressed air supply, zero and calibration gases, protection routines, data logging.

The suitability of analyzers should be demonstrated with formal approval – certification by recognized body – or with performance tests according to national requirements.

Equally important is the quality of measurement results which should be reported by the supplier and may be quantified by the measurement uncertainty. An example of quantification of measurement uncertainty can be found in the **international standard ISO 14956:2002** “Evaluation of the suitability of a measurement procedure by comparison with a required measurement uncertainty” and **EN 15267-3:2008** “Certification of automated measuring systems – performance criteria and test procedures for automated measuring systems for monitoring emissions from stationary sources”.

A3.2 Quality assurance for CEMs

Achieving and maintaining the quality of data delivered by CEMs over time will require the development and implementation of specific actions from CEMs commissioning, including routine checks, maintenance and periodical calibrations.

When receiving the measurement cabin, the controls at the plant for **CEMs commissioning** should include equipment testing and instrument-protection routines, leak check, zero and span checks using reference materials. The dust monitor and the CEMs for gaseous pollutants must be calibrated. Calibration is made using manual gravimetric methods for dust – for example the calibration method found in the international standards **ISO 9096** and **ISO 12141** – depending on the concentration of dust, the latter specific for low concentrations in the off-gases. The calibration

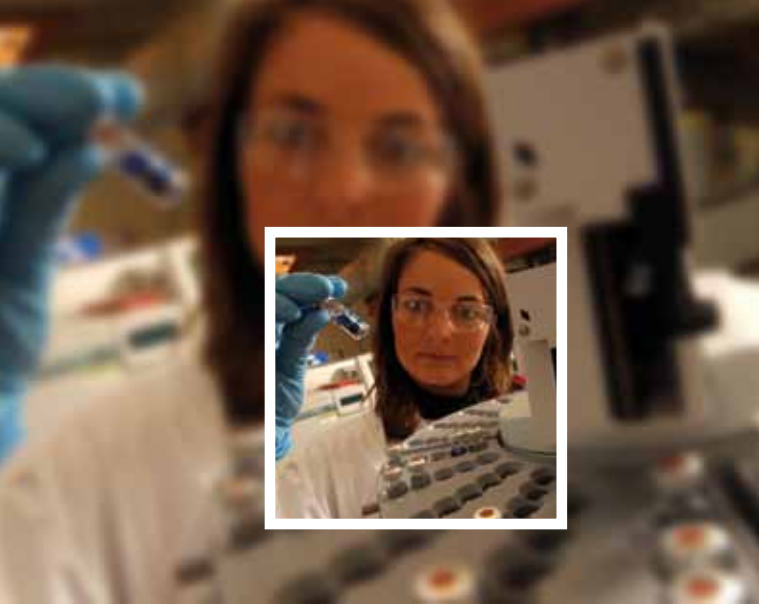
should be made using Standard Reference Methods (SRM) in parallel to the CEMs for gaseous pollutants. In both cases analysis functions must be established. An example of a calibration method can be found in the **international standard ISO 11095:1996** “Linear calibration using reference materials”. The conditions of processes and range (or span) of pollutant concentrations for which the **analysis functions** are established must be precisely assessed. Any significant modification to the conditions such as a major change in plant operation (change in the off-gases abatement system, change or major repair of the CEMs) or a pollutant concentration significantly out of the calibration range will require establishing a new analysis function. **Analysis functions using Standard Reference Methods (SRM) must be re-established at least every five years.** The analysis functions could be determined under different operating conditions if necessary.

Operational routines checks and maintenance must be developed and implemented thoroughly at plant. **Operational routines** must include instrument checks on alarm call, periodical checks of leak, zero and span using reference materials.

Notwithstanding the calibration using SRM, the CEMs drifts in zero and span must be checked using reference materials according to the manufacturer’s recommendations, and adjustments must be made when required.

Maintenance routines must include checks of sampling point (pre-filter), gas treatment system, analyzers and auxiliary devices, and replacement of used parts (spare parts should be available at plant) according to the manufacturer’s recommendations.

The maintenance intervals depend on existing operating parameters such as dust content and nature, gas temperature, gas composition and ambient conditions. Maintenance of CEM equipment shall be carried out according to the recommendations/specifications of the equipment manufacturer and instrumentation should be routinely checked. It is vital that **internal maintenance staff of each plant be trained and qualified** to solve problems that may arise from the daily operation of CEMs. For that reason, it is important to consider the maintenance training for plant personnel when evaluating equipment from different suppliers.



A4 Discontinuous measurements

A4.1 Criteria for selection and evaluation of contractors

Measurements and analysis should be performed by experienced contractors or bodies (testing houses) recognized by the competent authority. When required by national regulation, accreditation and certification of testing houses or acceptance of testing protocols by the competent authority should be verified by the company.

The experience of testing houses should be checked by the company for the components analyzed.

The testing houses should have implemented a quality assurance system. An example of a quality assurance methodology can be found in the **international standards ISO 9001:2008 and ISO 17025: 2005** "General requirements for the competence of testing and calibration laboratories" defining the requirements that testing houses should meet to demonstrate that they operate a quality system, are technically competent and able to generate technically valid results.

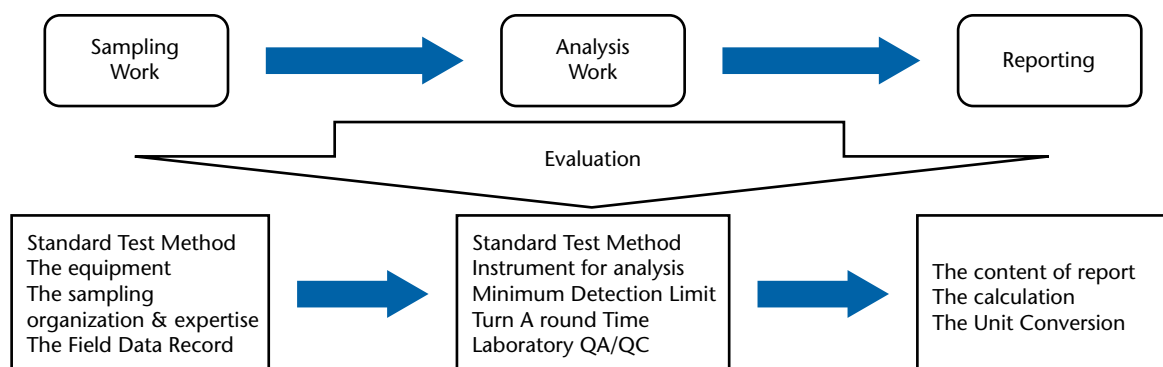
The evaluation should be based on the activities of stack measurement: sampling, analysis and reporting. Each work step contributes to the accuracy of the results.

When plant, business unit and/or technical center request stack sampling services from a testing house, the following should be included in the proposals for a comprehensive assessment and evaluation:

- Site specific method statement and risk assessment as well as safety records;
- Standards and reference methods used, including correct title and revision date;
- Detail of equipments used;
- Qualification and experience of team;
- Quality assurance/quality control procedure;
- Details of laboratory equipment;
- Limits of detection (LOD) for the laboratory equipments used for analysis, of the sampling methods and the samples preparations; and
- The testing house experience in stack emission testing (e.g. references).

The evaluation by the company is done based on document review of the proposal. The assessment applies the technical and quality aspects to meet requirements of standards and reference methods. Figure A1 below illustrates the recommended evaluation.

Figure A1: Recommended evaluation for selection of contractors



A4.2 Standards for measurements: sampling and analyses

The table gathers standards and reference methods available for discontinuous measurements. It indicates the type of sampling and measurement potentially delivering spot data or continuous data (with analyzers) and the scope of the standards and methods which could be sampling only or sampling and analysis.

The plant should provide a proper sampling location in compliance with standards and reference methods. Guidance for establishing proper sampling locations can be found in the **standard EN 15259:2007** "Measurement of stationary source emissions – requirements for the measurement sections and sites and for the measurement objective, plan and report". The standards and reference methods guide the plant on how to determine a sampling location as well as a working platform.

Table A3: Standards and reference methods for sampling (pollutant)

Pollutant	Standard / Reference Method	Spot/Continuous	Sampling/ Analysis
Dust	EN 13284-1:2002	Spot	Sampling and analysis
	US EPA method 5, 5i, 17	Spot	
	ISO 9096:2003	Spot	
	ISO 12141:2002	Spot	
Nitrogen Oxides (NO _x /NO ₂)	EN 14792:2006	Continuous	Sampling and analysis
	US EPA method 7 E	Continuous	
	US EPA method 7 (A to D)	Spot	
	ISO 10849:1996	Continuous	
	ISO 11564:1998	Spot	
Sulfur Oxides (SO _x /SO ₂)	EN 14791:2006	Spot	Sampling and analysis
	US EPA method 6 C	Continuous	
	US EPA 6, 6A, 8	Spot	
	ISO 7935:1992	Continuous	
	ISO 7934:1998	Spot	
	ISO 11632:1998	Spot	
Hg	EN 13211:2001-2005	Spot	Sampling
	EN 14884:2005	Continuous	Sampling and analysis
	US EPA method 29, 101A	Spot	
Heavy Metals	EN 14385:2004	Spot	Sampling and analysis
	US EPA method 29	Spot	
VOC / THC	EN 13649:2002	Spot	Sampling and analysis
	EN 12619:2000	Continuous	
	US EPA method 25A	Continuous	
PCDD/F	EN 1948-1/2/3/4:2006	Spot	Sampling and analysis
	US EPA method 23	Spot	

Table A4: Standards and reference methods for sampling (parameter)

Parameter	Standard / Reference Method	Spot/Continuous	Sampling/ Analysis
GAS VELOCITY, MOISTURE AND OXYGEN			
Flow Rate & Velocity	US EPA 1, 2	Continuous	Measurement
	ISO 10780:1994	Continuous	
Moisture (Water vapor)	EN 14790:2005	Spot	Sampling and analysis
	US EPA 4	Spot	
Oxygen	EN 14789:2006	Spot	Sampling
	US EPA 3, 3B	Spot	
	US EPA 3A	Continuous	Sampling and analysis

It is recommended to use these standards and reference methods. Methods defined by national standards or methods recognized equivalent to the recommended standards and reference methods may be used as well. Equivalent methods could be used after such methods are compared at least once through duplicate testing with the recommended standards and reference methods.

“Measurement of stationary source emissions – requirements for the measurement sections and sites and for the measurement objective, plan and report”.

It shall include the following information:

- An executive summary providing:
 - Reference of the plant where measurement was made
 - Reference to the testing house and laboratories
 - Measurement objective
 - Pollutants and parameters measured
 - Sampling date
 - Measurement uncertainties
 - Measurement methods applied
 - Deviation from the measurement plan and methods
 - Results of the measurements
- Definition of the project by specification of the measurement objective
- Description of the plant and operating conditions
- Identification of measurement points
- Identification of the measurement methods and apparatus according to standards
- Plant operating conditions during the measurements
- Reference on how to access and use the original data for verification purposes
- Measurement results and other relevant data necessary for the interpretation of results
- Calculation procedures
- Presentation of the results
- The reporting requirements of standards shall be observed. A deviation from standards shall be reported and documented, as well as any deviation from the measurement plan

A4.3 Minimum requirements for Limit of Detection

Limit of Detection (LOD) is the minimum number of detectable concentration by the analysis methodology. The LOD value depends on sampling, sample preparation and analytical methods used and thus could differ from one measure or testing house to another. The LOD value should include the whole process, sampling and analysis, and not be limited to the analytical part only. Limit of Detection should be reported by the testing house and should be a determining factor in the choice of a suitable testing house.

Attention should be paid concerning LOD for heavy metals (HM) and dioxins and furans.

Detection limits are reported in Appendix B.

A4.4 Recommendation for report issued by testing house

The report shall provide a description of the measurement objective and the measurement plan, and a comprehensive account of the measurements. It shall provide sufficient details so that the results can be traced back through the calculations to the collected basic data and process operating conditions. A reference for the information reported can be found in the **standard EN 15259:2007**



A5 Data representativeness and validation

Each company must establish its own data validation process.

Each company must assign resources and responsibilities for the monitoring, validating and recording of emissions.

A quality assurance process must be implemented for both continuous and discontinuous measurements which will assess the data coherence. A monitoring error is probable if concentration, specific flow and emission factor are not in the usual range for the cement kiln.

The validation process should compare emissions monitored for the same kiln and pollutant in different months and years. A monitoring error is

probable if differences between emissions cannot be explained by changes in activity level, changes in the nature of fuels and raw materials or process modifications, etc.

The testing house should send a draft report to the company for review. The assigned person should check that the report is consistent with the order given to the testing house and includes the required information set in the order, and that the data complies with the assurance process described here above.

The draft report becomes final once it has been accepted by the company. The report is then recorded and filed.



A6 Data reporting

Worldwide emission reporting should be standardized. To achieve this standardization, it is recommended to install an emission data processing and evaluation system even if it is not an explicit requirement of the authority, or as a minimum, a tool enabling fast and accurate acquisition and reporting of emission information from each kiln.

The acquisition and data management should allow the reporting of the following parameters:

- Concentration of dust, NO_x, SO₂, and in some cases VOCs that are continuously measured, are to be averaged on a hourly, daily, monthly and yearly basis.
- Mass of dust, NO_x, SO₂ and in some cases VOCs that are continuously measured, are to be determined on an hourly, daily, monthly and yearly basis. CSI reporting only includes the yearly mass values with the shorter duration periods integrated to increase the accuracy of the yearly value.
- Data validation in accordance with all legal requirements¹⁰.

In addition, it should satisfy the following requirements:

- Concentration and flow used for the determination of mass be converted to the same reference for the determination of mass.
- Unless otherwise specified by the competent authority, it is recommended that all concentration and flow values be converted to the O₂ reference value (10%), dry gases.

- The integration period of the acquired values should be at a maximum once per hour, every 30 minutes is preferable. The integration period used to calculate the average values should be within the operational period.
- The operational period is defined by the local authority. In the absence of local rule, the operational period is to be defined according to effective operating hours, excluding start-up and shutdown periods.

A – Convention for reporting

Reference Conditions

Temperature and pressure

$$T_{\text{Reference}} = 273 \text{ K}$$

$$P_{\text{Reference}} = 101,3 \text{ kPa (1013 mbar)}$$

Moisture and Oxygen

$$f_{\text{Reference}} = 0\% \text{ H}_2\text{O}$$

$$O_{2\text{Reference}} = 10\% \text{ O}_2$$

Other reference values for concentration of oxygen can be used but in such cases should be explicitly stated when concentration values are used.

¹⁰ It is recommended to monitor the status signal of the continuous emissions monitors (errors, maintenance, etc.) and calculate the availability for each measure.

Conversions

Depending on the measuring method the measured data (C_{measured}) should be calculated according to the conditions established based on ($C_{\text{corrected}}$).

$$C_{\text{corrected}} = C_{\text{measured}} \times \frac{21 - O_{2\text{reference}}}{21 - O_{2\text{measured}}} \times \frac{T_{\text{measured}} + 273}{T_{\text{reference}} + 273} \times \frac{P_{\text{reference}}}{P_{\text{measured}}} \times \frac{100 - f_{\text{reference}}}{100 - f_{\text{measured}}}$$

Concentration ([ppm] to [mg/Nm³])

$$C[\text{mg}/\text{Nm}^3] = \frac{\text{MolarMass}[\text{kg}/\text{kmole}]}{22.4[\text{Nm}^3/\text{kmole}]} \times C[\text{ppm}]$$

Concentration (for reference O₂)

$$C_{O_{2\text{reference}}} = C_{O_{2\text{measured}}} \times \frac{21 - O_{2\text{reference}}}{21 - O_{2\text{measured}}}$$

Volume flow

$$Q_{\text{reference}}[\text{Nm}^3/\text{h}] = Q_{\text{measured}}[\text{m}^3/\text{h}] \times \frac{T_{\text{reference}}[\text{K}]}{T_{\text{measured}}[\text{K}]} \times \frac{P_{\text{measured}}[\text{kPa}]}{P_{\text{reference}}[\text{kPa}]}$$

Volume flow (wet basis to dry basis)

$$Q_{\text{dry}} = Q_{\text{wet}} \times \frac{100 - \%H_2O}{100}$$

Table A5: Inorganic substances in form of gases, vapors or particles

Substances	Remarks
Nitrogen oxides (NO_x) = Nitrogen monoxide (NO) + Nitrogen dioxide (NO ₂) Expressed as NO ₂ : mg NO ₂ /Nm ³ , dry gas, 10% O ₂	a) In cases where analyzers only measure NO [ppm]: $NO_x[\text{mg NO}_2/\text{Nm}^3] = \frac{46}{22.4} \times NO[\text{ppm}]$ Note: the contribution of NO ₂ [≤ 5 % of NO measured] is neglected: b) In cases where NO [ppm] and NO ₂ [ppm] are measured in continuous analyzers: $NO_x[\text{mg NO}_2/\text{Nm}^3] = \frac{46}{22.4} \times (NO[\text{ppm}] + NO_2[\text{ppm}])$
Sulfur oxides (SO_x) = Sulfur dioxide (SO ₂) + Sulfur trioxide (SO ₃) Expressed as SO ₂ : mg SO ₂ /Nm ³ , dry gas, 10% O ₂	Continuous analyzers only measure SO ₂ [ppm]: $SO_2[\text{mg SO}_2/\text{Nm}^3] = \frac{64}{22.4} \times SO_2[\text{ppm}]$ Note: The SO ₃ is insignificant, and in practice only SO ₂ is considered.
Heavy Metals (Hg, Cd, Tl, Sb, Cr, Pb, Cu, Co, Mn, As, Ni, and V). Expressed as mg/Nm ³ , dry gas, 10% O ₂	The heavy metals cover the gaseous, the vapor and the condensed forms of the relevant heavy metal emissions as well as their compounds.

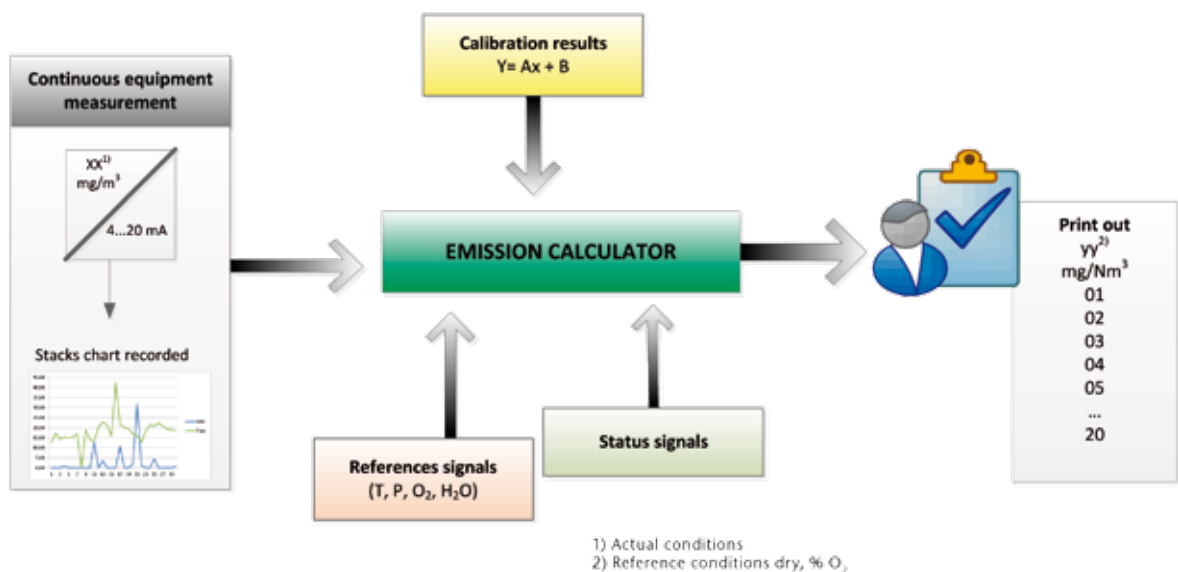
Table A6: Organic substances in form of gases, vapors or particles

Substance	Remarks
Volatile Organic Compounds (VOCs) Expressed as Carbon: mg Carbon/Nm ³ , dry gas, 10% O ₂	VOCs are a large number of different organic compounds, and they are measured as volatile organic carbon (VOC) or total hydrocarbons (THC), they include methane and ethane
Dioxins and furans (PCDD/F) Expressed as ng I-TEQ/Nm ³ , dry gas, 10% O ₂	Where I TEQ is the International Toxic Equivalent to 2,3,7,8 TCDD

It is recommended that the data of the automated measuring system should be processed according to the reference conditions set in the Technical Annex. In any event, the data from the automated

measuring system must be able to be integrated into the annual mass emissions as specified within this document.

Figure A2: Automated measuring system



B – Discontinuous measurements – testing houses

Data from discontinuous measurements delivered by testing houses must be processed to obtain the annual specific and absolute emissions which have to be reported.

Annual data:

The concentration is the average of each measured concentration expressed at reference conditions.

The mass flow may be determined as:

$$\text{Concentration} \times \text{gas flow} \times \text{kiln operating hours}$$

Or:

$$\text{Concentration} \times \text{specific gas flow} \times \text{clinker produced}$$

Where a measurement is lower than the detection limit, the value to be reported by kilns will correspond to one half of the detection limit. In case of two or more measurements, where at least one value is reported with a "<" character (lower than detection limit), the value of the latter will be calculated as one half of the detection limit, and the final average will be calculated accordingly.

In the absence of data in the reporting year due to the absence of measurement in accordance to the frequency of measurement set in the guidelines, the last available specific emission (e.g. concentration multiplied by the specific gas flow) multiplied by the mass produced will be used to report the mass emission of the given pollutant.

Reporting of Annual Emission Data without CEMs and where no spot measurements have been performed during the year:

Where there is no valid measurement, the average company specific emissions shall be applied to the production of the kiln(s) where there is no measurement in accordance with the guidelines version 2.0, section 5.

Determination of specific flow at kiln stack

In the absence of measured gas flow at the kiln stack, the two methods reported below can be used to provide a specific flow: (A) calculation from thermal consumption and (B) default flow factor when thermal consumption is not available.

The specific flows are expressed at 0°C and 1013mbars.

A - Calculation from thermal consumption for conventional fuels:

$$v_{tot} = (0.25 \cdot q + 0.27) \cdot \left(1 + \frac{O_2}{(21 - O_2)} \right)$$

v_{tot} : Specific exhaust gas volume at 0°C, 1013mbar and dry gas state; unit: Nm³/kg clinker,

q: Specific heat consumption of the kiln; unit: MJ/kg clinker,

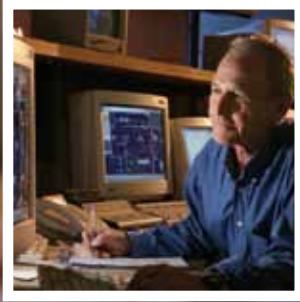
O₂: Oxygen content at measuring point; unit: volume % (dry).

Other formulae may be used as long as company reporting is consistent. In such cases the formula must be available and properly justified.

B - Default factor in Nm³/kg ck at reference conditions depending on the cement process type:

Table A7: Default factors for specific flow at kiln stack per kiln type

Process	Factor (Nm ³ /kg-clinker)
AS Precalciner	2.2
AT Precalciner	2.2
Preheater	2.2
Semi-dry	2.3
Long-dry	2.7
Semi-wet	3.1
Wet	4.1



A7 Significant change

In the guidelines, some pollutants are measured continuously, while it is only possible to measure others on a discontinuous basis.

Depending on the pollutant, the frequency of discontinuous measurement varies from 1 year to 2 years according to criteria that consider the typical emission level of the pollutant, the variability of the emissions, and the potential impact on the environment.

However, when a change in the process system is made that has the potential to change the emission profile of one of these pollutants by the greater of either:

- 20% of the Emission Limit Value, or
- the specific concentration in Table “concentration thresholds” below,

then a discontinuous measurement of the pollutant(s) must be performed to assess the new emission profile of the stack.

Table A8: Concentration thresholds

Pollutant	Concentration ¹
Hg	10µg/m ³
Sum (Cd, Tl)	10µg/m ³
Sum (Sb, As, Pb, Cr, Co, Cu, Mn, Ni, V)	100µg/m ³
PCDD/PCDF as I-TEQ	20pg/m ³

Note:
¹ Concentrations are at reference conditions



A8 Additional information and other references

ISO 10396:2007 – Stationary source emissions – Sampling for the automated determination of gas concentrations

ISO 14956:2002 – Evaluation of the suitability of a measurement procedure by comparison with a required measurement uncertainty

ISO 9096:2003 – Stationary source emissions – Manual determination of mass concentration of particulate matter

ISO 12141:2002 – Stationary source emissions – Determination of mass concentration of particulate matter (dust) at low concentrations – Manual gravimetric method

ISO 11095:1996 – Linear calibration using reference materials

ISO 10849:1996 – Stationary source emissions – Determination of the mass concentration of nitrogen oxides – Performance characteristics of automated measuring systems

ISO 11564:1998 – Stationary source emissions – Determination of the mass concentration of nitrogen oxides – Naphthylethylenediamine photometric method

ISO 7934:1998 – Stationary source emissions – Determination of the mass concentration of sulfur dioxide – Hydrogen peroxide/barium perchlorate/Thorin method

ISO 7935:1992 – Stationary source emissions – Determination of the mass concentration of sulfur dioxide – Performance characteristics of automated measuring

ISO 11632:1998 – Stationary source emissions – Determination of mass concentration of sulfur dioxide – Ion chromatography method

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EN 12619:2000 – Stationary source emissions. Determination of the mass concentration of total gaseous organic carbon at low concentrations in flue gases. Continuous flame ionization detector method

EN 13211:2001-2005 – Stationary source emissions. Manual method of determination of the concentration of total mercury

EN 1948-1,2,3,4:2006 or equivalent – Stationary source emissions. Determination of the mass concentration of PCDDs/PCDFs and dioxin-like PCBs. Sampling of PCDDs/PCDFs

EN 14790:2005 – Stationary source emissions. Determination of the water vapor in ducts

EN 14789:2006 – Stationary source emissions. Determination of volume concentration of oxygen

EN 14181:2004 – Stationary source emissions. Quality assurance of automated measuring systems

US EPA method 5, 5i, 17 – Emissions from stationary sources. Determinations of particulate matters.

US EPA method 6, 6a, 6c – Determination of sulfur dioxide emissions from stationary sources

US EPA method 7a to e – Determination of nitrogen oxide emissions from stationary sources

US EPA method 8 – Determination of sulfuric acid and sulfur dioxide emissions from stationary sources

US EPA method 29 – Determination of metals emissions from stationary sources

US EPA method 101a – Determination of particulate and gaseous mercury emissions from sewage sludge incinerators.

US EPA method 25A – Determination of total gaseous organic concentration using a flame ionization analyzer

US EPA method 23 – Sampling method for polychlorinated dibenzo-p-dioxins and polychlorinated dibenzofuran emissions from stationary sources

US EPA method 1 – Sample and Velocity Traverses for Stationary Sources

US EPA method 2 – Determination of Stack Gas Velocity and Volumetric Flow Rate

US EPA method 3 – Gas Analysis for the Determination of Dry Molecular Weight

US EPA method 3A – Determination of oxygen and carbon dioxide concentrations in emissions from stationary sources (instrumental analyzer procedure)

US EPA method 3B – Gas analysis for the determination of emission rate correction factor or excess air

US EPA method 4 – Determination of Moisture content in stacks gases

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MCERTS is the Environment Agency's Monitoring Certification Scheme. The Environment Agency has established its Monitoring Certification Scheme (MCERTS) to deliver quality environmental measurements. The MCERTS' product certification scheme provides for the certification of products according to Environment Agency performance standards, based on relevant CEN, ISO and national standards.

European Commission – Integrated Pollution Prevention and Control (IPPC) – Reference Document on the General Principles of Monitoring – July 2003.

European Commission – Reference Document on Best Available Techniques in the Cement, Lime and Magnesium Industries – May 2010.

Directive 2010/75/EU of the European Parliament and of the Council of 24 November 2010 on Industrial Emissions (IPPC).

National Emission Standards for Hazardous Air Pollutants Compliance Monitoring (NESHAP).

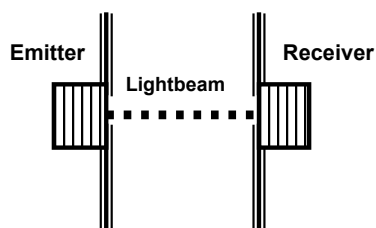


Appendix

AA Continuous Emissions Monitoring Systems: Overview of technology

In-situ measurement is done directly in the stack and no gas is extracted.

Figure A3: Principle of an *in-situ* measuring device



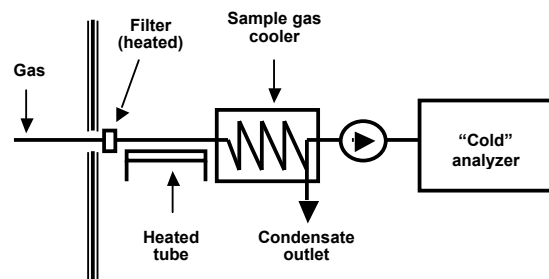
Extractive measuring devices

In extractive measurement, a portion of the gas flow is extracted from the stack and transported to a separate analyzing system. The extracted gas must be cleaned before passing through the analyzers. The extraction can be realized in a “cold” way (sample is cooled down and moisture is condensed) or in a “hot” way (sample is kept warm).

The “cold” extractive measuring device

After extraction, the sample gas stream is cooled down to approximately 4°C. The water vapor condenses and is extracted from the system. The gas is then fed to the analyzer.

Figure A4: Example of a “cold” extractive measuring device

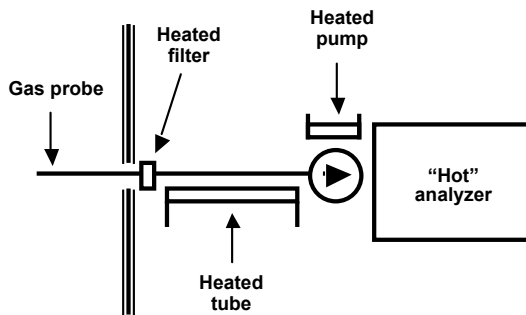


The disadvantages of this device are related to reactions of some of the pollutants with the condensate in the gas cooler. Therefore, compounds like ammonia, sulfur, hydrogen chlorides, etc., are completely or partly “washed out” with the condensate and an accurate measurement is not possible.

The “hot” extractive measuring device

The gas is extracted and kept at a temperature which does not allow condensation or chemical reactions to occur. Depending on the substances measured this temperature must be kept between 140 and 200°C.

Figure A5: Example of a “hot” extractive measuring device



Methods of analysis for dust

Indicative

- **Filter monitor / Combined probe sensor:** The filter monitor uses the triboelectric effect to determine dust loads in flowing gases. The electrical charge which the dust particles experience due to friction is picked up by a probe protruding into the dust channel and converted into a measuring signal by electronics. The measuring signal is proportional to the dust concentration and can be calibrated at a constant gas speed.

Semi-quantitative

- **Optical opacity / Dust concentration monitor:** The device operates using the double-pass method according to the auto-collimation principle. The light beam traverses the measuring distance twice. The attenuation of the light beam by the dust content in the measuring section is measured and evaluated.

Quantitative

- **Dust concentration monitor:** The dust monitor device operates according to the scattering light method. The modulated light from a halogen lamp illuminates the dust particles in the exhaust duct. The scattered light reflected from these particles is measured and assessed.
- **Dust concentration “forward scattering” monitor:** The dust monitor device works according to the principle of forward scattering. The concentrated and modulated light of a laser diode penetrates the measuring volume. The forward-scattered light largely reflected from dust particles is measured and assessed.

- **Dust concentration for wet gases:** A defined partial current is withdrawn from the exhaust gas current and is continuously heated and diluted with clean, heated air directly in the sampling probe. This immediately lowers the relative moisture and aerosols evaporate in the heated probe. The partial current is optically measured in the measuring chamber. The signal is corrected by the measured dilution ratio and is thus a measure of the dust content of the exhaust gas.
- **Extractive beta gauge particulate monitor:** The dust concentration is determined by measuring the absorption of beta rays emitted by a radioactive emitter by particles collected from an exhaust gas flow.

Methods of analysis for inorganic gases

- **DL (Diode Laser):** The measuring principle is based on the specific light absorption of different gas components. If a gas analyzer employs single-line molecular absorption spectroscopy, a diode laser emits a beam of near-infrared light, which is sent through the process gas and detected by a receiver unit. The wavelength of the laser diode output is tuned to a gas specific absorption line. The laser continuously scans over this single absorption line with very high spectral resolution. The result is a fully resolved single molecular line which is analyzed in terms of absorption strengths and line shape. The measurement is free of cross-interferences, since the quasi-monochromatic laser light is absorbed very selectively by only one specific molecular line in the scanned spectral range.
- **IR (Infrared Spectroscopy):** Many gaseous pollutants absorb light energy in one or more regions of the spectrum. Each type of pollutant molecule will absorb light at a characteristic wavelength, and therefore can be distinguished from other pollutant species. An infrared beam is produced and divided into two separate beams. One of the beams passes through the sample, and the other through a reference cell. Both beams are reflected back to the detector, and the two signals are compared. An infrared source is usually used in NDIR, DOAS, and FTIR analyzers.

- **NDIR (Non Dispersive Infrared):** In a NDIR analyzer, infrared light is emitted from a source and transmitted through two gas cells: a reference cell and a sample cell. The reference cell contains a gas (nitrogen or argon) that does not absorb light at the wavelength used in the instrument, and the sample cell contains the sample gas. As the infrared beam passes through the sample cell, pollutant molecules will absorb some of the light, and, as a result, when the light emerges from the end of the sample cell it will have less energy than when it entered. NDIR is used in both extractive and *in-situ* principles of analysis.
- **DOAS (Differential Optical Absorption Spectroscopy):** In this system, a reference wavelength is used instead of a reference cell as described above. A light source is used to emit light at many different wavelengths and transmit it through a cell containing the sample gas. The detector signal at the light wavelength, where no energy is absorbed, is used as a reference measurement for the signal obtained at the wavelength where energy is absorbed. DOAS is used in both extractive and *in-situ* principles of analysis.
- **FTIR (Fourier Transformed Infrared Spectroscopy):** FTIR analyzer of “hot” extraction is a multi-component analyzer and consists of a Michelson interferometer that separates and recombines the infrared light to produce a standard interference (interferogram). The interferogram has the property that every data point (a function of the moving mirror position) which makes up the signal has information about every infrared frequency which comes from the source. A mathematical technique called the Fourier transformation is used to “decode” the individual frequencies.

Methods of Analysis for Organic Pollutants

- **FID (Flame Ionization Detector):** The sample gas is introduced into a hydrogen flame inside the FID. Any hydrocarbons in the sample will produce ions when they are burnt. Ions are detected using a metal collector which is biased with a high DC voltage. The current across this collector is thus proportional to the rate of ionization which in turn depends upon the concentration of HC in the sample gas.

Oxygen and flow measurement

- **Flow measurement (Ultrasonic Measuring Principle):** Two ultrasonic transducers, mounted at a certain angle to the flow axis function alternately as sender and as receiver, i.e., each one sends and receives alternately ultrasonic pulses which are either accelerated or slowed down depending on the direction they travel: *with* (“forward direction” *tf*) or *against* (“reverse direction” *tr*) the gas flow. The resulting difference in transit times is used to determine the mean gas velocity. The cross-sectional area yields the volumetric flow during operation.
- **Zirconia Dioxide Oxygen Analyzer:** Offers exact measurements according to the current sensor measuring principle. This means that a linear sensor signal is achieved over the total measuring range with a fixed physical zero point. A constant measured gas flow passes through the heated solid electrolytical cell. ADC voltage is applied to the cell electrodes at $\geq 650^{\circ}\text{C}$ ($\geq 1,200^{\circ}\text{F}$) to determine the O_2 concentration. The O_2 ion current in the electrolytes is then measured. This is derived from the linear correlation between O_2 concentration and gas quantity passing through the cell per time constant.

AB Limit of Detection – indicative values

Table A9: Indicative values for Limit of Detection

Pollutant	Unit	Limit of Detection ¹⁾
Hg	µg/m ³	3-6
Cd	µg/m ³	2-5
Tl	µg/m ³	4-6
Sb	µg/m ³	5-8
As	µg/m ³	5-8
Pb	µg/m ³	10-20
Cr	µg/m ³	10-15
Cu	µg/m ³	8-12
Co	µg/m ³	10-15
Mn	µg/m ³	5-8
Ni	µg/m ³	6-9
V	µg/m ³	5-8
PCDD/PCDF	pg/m ³	0.1-4 ²⁾

Notes:

¹⁾ Source: Research Institute of the Cement Industry (VDZ 2010), except for PCDD/PCDF.

²⁾ Sum of 17 congeners reported as I-TEQ according to EN 1948 1/2/4:2006

About the World Business Council for Sustainable Development (WBCSD)

The World Business Council for Sustainable Development is a CEO-led organization of forward-thinking companies that galvanizes the global business community to create a sustainable future for business, society and the environment. Together with its members, the council applies its respected thought leadership and effective advocacy to generate constructive solutions and take shared action. Leveraging its strong relationships with stakeholders as the leading advocate for business, the council helps drive debate and policy change in favor of sustainable development solutions.

The WBCSD provides a forum for its 200 member companies – who represent all business sectors, all continents and a combined revenue of more than \$7 trillion – to share best practices on sustainable development issues and to develop innovative tools that change the status quo. The Council also benefits from a network of 60 national and regional business councils and partner organizations, a majority of which are based in developing countries.

www.wbcسد.org

About the Cement Sustainability Initiative (CSI)

The CSI is a global effort by 24 leading cement producers, with operations in more than 100 countries. Collectively, these companies account for around 30% of the world's cement production and range in size from very large multinationals to smaller local producers. All CSI members have integrated sustainable development into their business strategies and operations, as they seek strong financial performance with an equally strong commitment to social and environmental responsibility. The CSI is an initiative of the World Business Council for Sustainable Development (WBCSD).

www.wbcسدcement.org

Disclaimer

This report is released in the name of the WBCSD. It is the result of a collaborative effort by members of the secretariat and executives from member companies participating in the Cement Sustainability Initiative (CSI). Drafts were reviewed among CSI members, so ensuring that the document broadly represents the majority view of this group. This does not mean, however, that every member company agrees with every word.

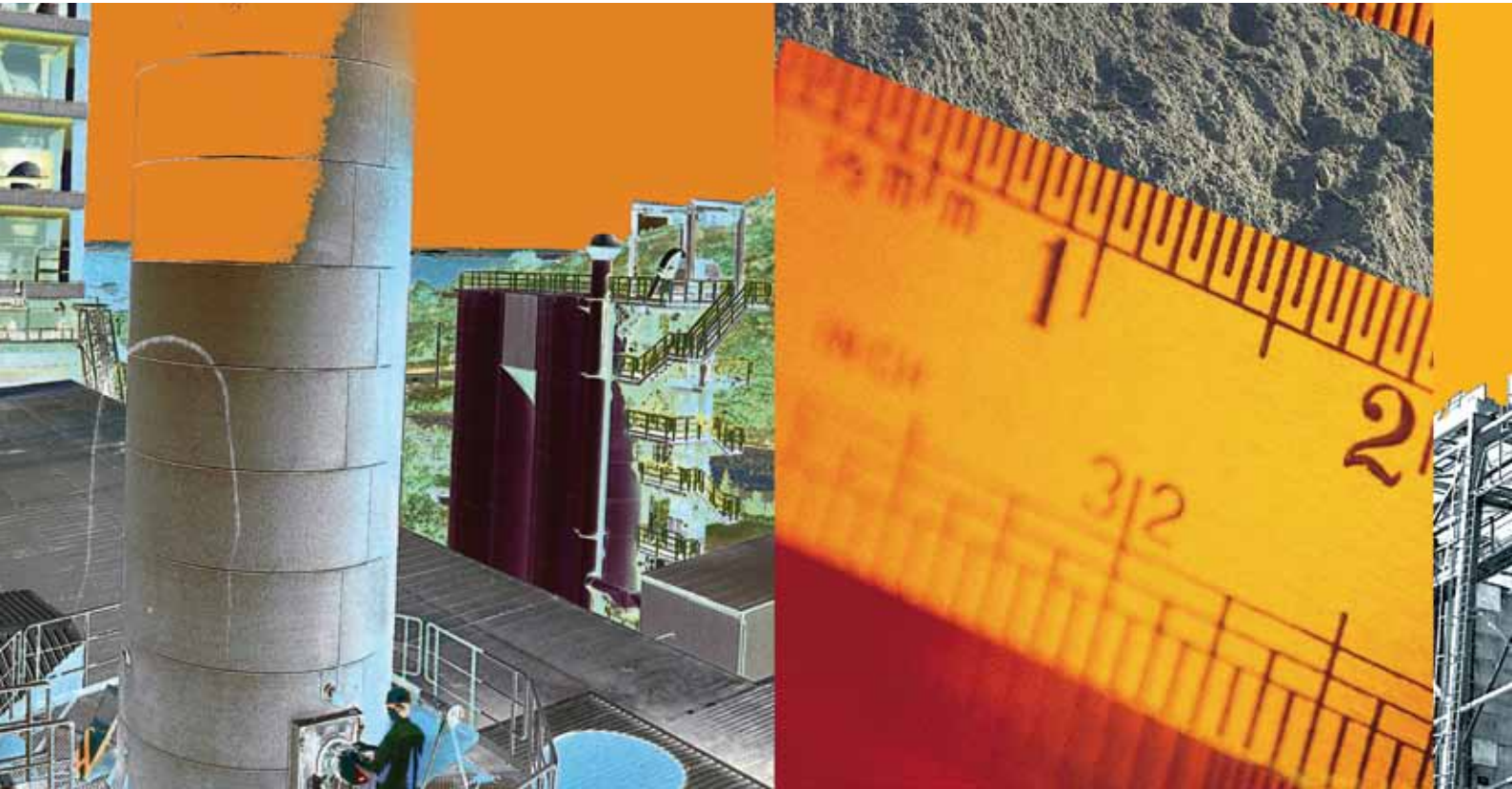
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