MERCURY IN THE CEMENT INDUSTRY

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1. ACRONYMS AND ABBREVIATIONS

ACI	Activated Carbon Injection
AFR	Alternative Fuels and Raw materials, often waste or secondary products from other industries, used to substitute conventional fossil fuels and raw materials.
APCD	Air Pollution Control Device
AGSM	Artisanal Small-scale Gold Mining
BAT	Best Available Technology
BATAEL	Best Available Technology Associated Emission Levels
BF	Bag Filter
BEP	Best Environmental Practice
CEM	Continuous Emission Monitor
CKD	Cement Kiln Dust
CSI	Cement Sustainability Initiative
CVAAS	Cold Vapour Atomic Adsorption Spectroscopy
CVAFS	Cold Vapour Atomic Fluorescence Spectroscopy
ECRA	European Cement Research Academy
ESP	Electrostatic Precipitator
ELV	Emission Limit Value
FF	Fabric Filter
FGD	Flue Gas Desulphurization System
GTZ	Deutsche Gesellschaft für Technische Zusammenarbeit GmbH
IPPC	Integrated Pollution Prevention and Control
LOI	Loss Of Ignition
MWC	Municipal Waste Combustor
PCA	Portland Cement Association
VDZ	Verein Deutscher Zementwerke e.V.
SNCR	Selective Non Catalytic Reduction
US EPA	United States Environmental Protection Agency
WID	Waste Incineration Directive
nm	Nanometre
°C	Degree Celsius
dscm	Dry standard cubic meter
g	Gram
K	(Degree) Kelvin
kJ	Kilojoules (1 kJ = 0.24 kcal)
lb	Pound
Nm^3	Normal cubic meter (101.3 kPa, 273 K)
ppm	Parts per million
t	Tonne (metric) = 1.10231 short tons
$\mu g/m^3$	Micrograms per cubic meter

2. GLOSSARY

BAT AEL — If not otherwise mentioned, emission levels given are expressed on a daily average basis and standard conditions. The following definitions regarding the standard conditions apply for volume flows and concentrations of kiln exhaust gases.

Nm^3/h	volume flow: if not otherwise mentioned, the volume flows refer to 10 vol-% oxygen and standard state
mg/Nm^3	concentration: if not otherwise mentioned, the concentration of gaseous substances or mixtures of substances refer to dry flue-gas at 10 vol-% oxygen and standard statel
standard state	refers to a temperature of 273 K, a pressure of 1013 hPa and dry gas

Compound operation	Kiln exhaust gases, which have a relatively high temperature and low humidity, can be utilised for the drying of raw materials in the raw mill during "**compound operation**", i.e. when the raw mill is in operation.
Direct operation	During "**direct operation**" (raw mill off), the exhaust gases are directly led to the dust collector and the chimney.
Elemental mercury	Mercury present in its elemental state
Kiln inlet/outlet	Where the raw meal enters the kiln system/ where the clinker leaves the kiln system.
Limonite	Limonite is an ore consisting in a mixture of hydrated iron(III) oxide-hydroxide of varying composition.
Oxidised mercury	Mercury in its mercurous or mercuric oxidation states
Particle bound mercury	Mercury associated with particulate matter
Petcoke	**Petroleum coke** (often abbreviated **petcoke**) is a carbonaceous solid derived from oil refinery coker units or other cracking processes

3. EXECUTIVE SUMMARY

During the first half of 2008, CEMBUREAU, the European Cement Association and the WBCSD Cement Sustainability Initiative (CSI) launched a study with the aim of:

- compiling worldwide data on the status of mercury emissions from cement kilns,
- sharing state of the art knowledge about mercury and its derivates behaviour in cement production processes,
- and defining best environmental practices in order to control and minimise mercury emissions from cement kilns through the use of integrated process optimisation (primary measures).

The present report is based on technical and scientific literature, on an exhaustive worldwide inventory of mercury emissions in the cement industry and on the analysis of case studies provided by cement companies which are members of the CSI.

Regulatory framework

Mercury is regulated under national clean air acts and/or waste management standards in many countries. More information on legislation can be found under Chapter 5 of this report.

Mercury inventory

Worldwide cement kiln mercury emissions data were collected through CEMBUREAU and the CSI member companies. The enquiry was launched in spring 2008 and data collection took place from summer 2008 until mid 2009. The enquiry was very general as the main objective was to collect as much data as possible. The questionnaire covered 2005, 2006 and 2007. 1681 emission values were obtained from 62 different countries from all continents, with 62 companies taking part.

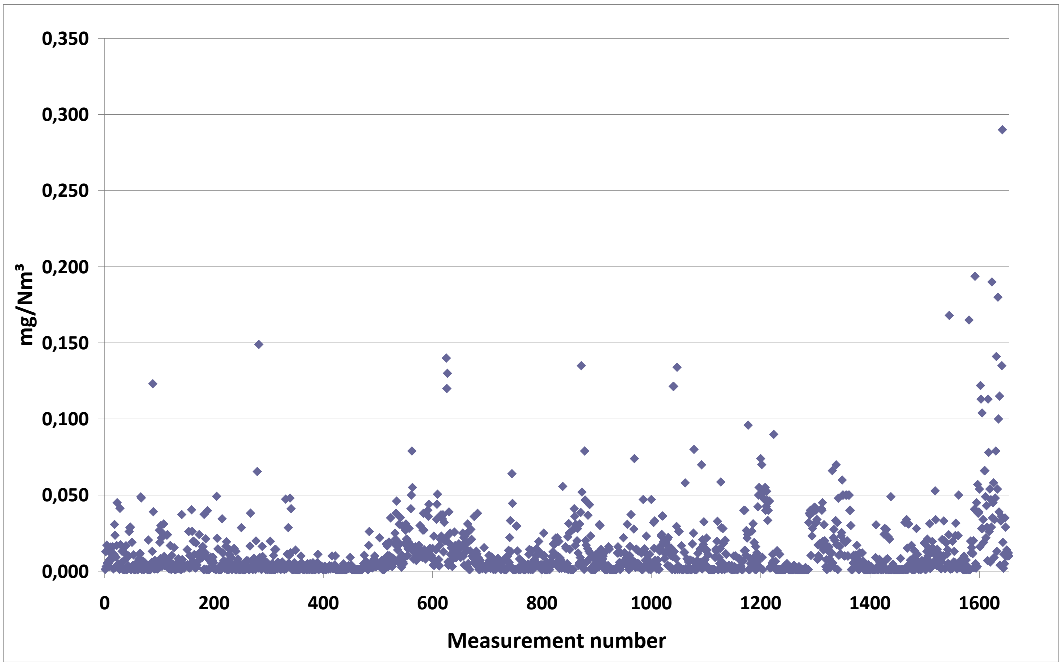

Figure 1: *CEMBUREAU/CSI enquiry: total of 1654 mercury spot measurements.*

Other cement industry mercury emission inventories available were also analysed. On the basis of the different data bases available, the present report proposes an average emission of 0.02 mg/Nm³ for further reference and mercury emission inventories. This corresponds to an emission factor of around 0.035 g/t cement which should be used instead of the factor of 0,1 g/t cement usually found in literature.

Mercury and cement kilns

Mercury enters in the cement manufacturing process as a trace element with the raw materials and the fuels. The mercury content of natural raw materials varies between individual raw material deposits and even within the same deposit. In fuels, the amount of mercury can vary in a similar way, depending on the fuel type and the fuel source. Depending on their origin, alternative raw materials and fuels may have a higher or a lower mercury content than the ordinary materials they replace.

Mass balance tests were conducted on several cement kilns and described in the literature. Moreover, CEMBUREAU and CSI members collected and provided several unpublished case studies. The information and data presented in this report and other studies demonstrate that mercury does not simply volatilise from the fuel and raw materials and directly leave the system through the stack. There are mechanisms and operating conditions that allow cement kilns to capture mercury. There is very low (if any) retention of mercury in the clinker. Mercury and its compounds form an external cycle when the dust, together with the condensed volatile compounds, precipitate on the feedstock in cool areas of the kiln system or when it is separated in dedusting devices and returned to the raw meal and subsequently to the kiln.

In a nutshell, cement kiln systems have a significant inherent ability to control mercury stack emissions. The present report and case studies largely confirm the experience and the key control factors for mercury abatement in cement kiln systems, as referenced in the available literature.

The key control factors and best environmental practices can be summarised as follow:

- ✓ In most cases, the major contributors to total mercury input into the kiln system are the natural raw materials, and not the fuels.
- ✓ Mercury input control is the most important measure for the responsible operation of a kiln. Best environmental practice is to conduct a careful selection and control of all substances entering the kiln in order to avoid too high a mercury input. A dedicated quality assurance system is recommended.
- ✓ Selective mining may be an option in order to control and avoid mercury input peaks into the kiln system.
- ✓ Mercury emissions are typically higher in kiln operations with the raw mill-off (“direct” operation) due to the missing adsorption capacity of the freshly ground particles in the raw mill.
- ✓ Periodic purging (bleeding) of cement kiln dust from the system is an efficient way to control and reduce mercury emissions. Adsorption of mercury is favoured due to the very high dust loadings present in the raw gas streams from preheater-precalciner kilns. This purging process is more efficient in the mill-off mode than in the mill-on mode due

to the higher mercury concentrations in the dust. The efficiency of this measure depends, in part, on the quantity of dust removed from the system, and on the temperature prevailing in the air pollution control device.

- ✓ Other techniques to reduce mercury air emissions are available in other industries such as waste incinerators and coal-fired power stations. Some, such as carbon adsorption, are well proven, whilst others are at laboratory or pilot stage. However, most of the test programs completed in those industries cannot be extrapolated to the cement industry. Therefore, those techniques cannot be considered as best environmental practice in the cement industry.