

**SNAP CODE:** 030311  
040612

**SOURCE ACTIVITY TITLE:** PROCESSES WITH CONTACT  
Cement  
Cement (decarbonizing)

**NOSE CODE:** 104.11.02  
105.11.21

**NFR CODE:** 1 A 2 f  
2 A 1

## 1 ACTIVITIES INCLUDED

This chapter covers emissions released from combustion and technological processes within cement production. Therefore, also non-combustion emissions are mentioned in this chapter where appropriate.

## 2 CONTRIBUTION TO TOTAL EMISSION

The contribution of gaseous emissions released from the production of cement to total emissions in countries of the CORINAIR90 inventory is presented in Table 2.1.

**Table 2.1 Contribution to total emissions of the CORINAIR90 inventory (28 countries)**

Source-activity	SNAP-code	Contribution to total emissions [%]							
		SO <sub>2</sub>	NO <sub>x</sub>	NMVOC	CH <sub>4</sub>	CO	CO <sub>2</sub>	N <sub>2</sub> O	NH <sub>3</sub>
Cement	030311	0.8	2.3	0	0	0.2	2.1	0.3	-

0 = emissions are reported, but the exact value is below the rounding limit (0.1 per cent)

- = no emissions are reported

The emission of dust containing heavy metals is also relevant, particularly in the case when wastes are burnt as fuel. Europe-wide data on dust emissions is not readily available, but the contribution of cement production to the UK's National Atmospheric Emissions Inventory of PM10 is given in Table 2.2. Because of its distribution costs, cement tends to be produced relatively near to its point of use, so other countries might be expected to have comparable levels of cement production and emissions.

**Table 2.2 Contribution of cement production to the total emission of PM10 in the UK**

Compound	Contribution (%)
PM10	1.7

For heavy metal emissions, specific figures for this source activity are available from Baart *et al.* (1995). The average relative contribution from the cement production industry to the total emission of heavy metals has been presented for European countries in Table 2.3.

**Table 2.3 Average relative contribution of the production of cement to the total emission of heavy metals in European countries (Baart et al., 1995)**

Compound	Contribution (%)
Cadmium	1.2
Chromium	1.5
Nickel	1.7
Lead	0.23

In addition to the metals presented in Table 2.3, cement production may be an important source of mercury. It was estimated that on a global scale cement contributes with about 1.0 % to the total emissions of the element emitted from anthropogenic sources (Pacyna and Pacyna, 1996). However, Table 2.4 gives the contribution of cement to total emissions of heavy metals and POPs from the OSPARCOM-HELCOM-UNECE emission inventory, and the estimate for mercury is a 15 % contribution.

**Table 2.4 Contribution to total POP and heavy metal emissions of the OSPARCOM-HELCOM-UNECE emission inventory (up to 39 countries)**

Source-activity	SNAP-code	Contribution to total emissions (including emissions from nature)										
		[%]										
		As	Cr	Cu	Pb	Cd	Hg	Ni	Zn	PCBs	PCDD/Fs	PAH
Cement	040612	0.5	1.2	0	0.1	0.5	15	0.3	0.3	0	0.2	0

### 3 GENERAL

#### 3.1 Description

The “standard” cement is Portland cement, which accounts for about half of the EU/EEA consumption (European IPPC Bureau, 2000). The raw materials for Portland cement clinker are limestone, sand, shale, clay and iron oxide. Other cements are composite cements and blast furnace cement, which substitute blast furnace slag or other materials for a portion of the raw materials. In each case, the processing is largely the same, and the clinker is later combined with gypsum to create the final cement. The main process stages are:

- Handling of raw materials, intermediate products and final product;
- Fuel grinding if solid fuel is used;
- Kiln feed preparation;
- Pyroprocessing in a rotary kiln to form clinker;
- Clinker cooling;
- Milling (grinding and blending with gypsum).

Types of fuels used vary across the industry. Cement kilns are highly energy-intensive and fuel costs have a critical effect on profitability. Historically, some combination of coal, oil, and natural gas was used, but over the last 15 years, most plants have switched to coal. However, in recent years a number of plants have switched to systems that burn a combination of coal and waste fuel. (IPCC, 1995).

### 3.2 Definitions

**Portland cement** a type of hydraulic cement usually made by burning a mixture of limestone and clay in a kiln

**Kiln** a furnace for burning fuel and cement clinker

### 3.3 Techniques

Portland cement can either be produced by dry or wet milling. In the case of wet milling the raw cement clinker is first mixed with water; this mixture is fired into a rotary kiln and finally milled. In the dry process the mixing with water is omitted. The dry process requires less energy than the wet process.

The raw materials are first brought to site; some will normally be conveyed from nearby quarries or open pits. The materials are then mixed, crushed and ground to produce a raw mix (raw meal) of the correct particle size and chemical properties. The raw meal is converted into cement clinker by pyroprocessing in rotary kilns. These consist of a refractory lined cylindrical steel shell slightly inclined to the horizontal and rotating at 1 – 3 rpm. Raw material is fed in at the upper end and gradually moves downward towards the lower end where there is a burner providing counter-current heating.

Most cement kilns now use the dry process, in which raw mill material is fed into the rotary kiln dry. Before passing into the kiln the material may be preheated in a vertically arrayed multi-cyclonic preheater, in which the rising hot gases exiting the kiln contact the downward flowing raw materials. Some dry processes also employ a precalciner stage beneath the preheater, just before the raw material enters the kiln. Preheaters and precalciners often have an alkali bypass between the feed end of the rotary kiln and the preheater to remove undesirable volatile components.

The use of the wet process, where the ground meal is mixed with water and fed into the kiln as a slurry, is now less common. The wet process uses about 40% more energy than the dry process.

The last stage involves cooling the clinker. As the hot clinker comes off the lower end of the kiln it is rapidly cooled by ambient air in a clinker cooler. There are many different designs of cooler, the most common of which is a travelling grate with under-grate fans that blow cool air through the clinker. Some of this air can be used for combustion, but some is vented to atmosphere or used for drying solid fuels and raw materials.

Finally, the cooled clinker is then mixed with gypsum and, for composite cements, other materials such as blast furnace slag, and ground to a fine homogeneous powder to produce the final product, which is then stored in silos prior to bulk transportation or bagging.

### 3.4 Emissions

Dust emissions result from activities such as handling raw materials; on site transportation; firing of clinker; milling; and shipment. The largest emission sources are the three units of kiln operation: the feed system, the fuel firing system, and the clinker cooling and handling system. The most desirable method of disposing of the collected dust is injection into the kiln burning zone and production of clinkers from the dust. If the alkali content of raw materials is too high, however, some of the dust is discarded and leached before returning to the kiln. In many instances, the maximum allowable cement alkali content of 0.6 % (calculated as sodium oxide) restricts the amount of dust that can be recycled.

Nitrogen oxides ( $\text{NO}_x$ ), sulphur dioxide ( $\text{SO}_2$ ), carbon monoxide (CO), and carbon dioxide ( $\text{CO}_2$ ) are the primary emissions in the manufacture of portland cement. Small quantities of volatile organic compounds (NMVOC, methane ( $\text{CH}_4$ )), nitrous oxide ( $\text{N}_2\text{O}$ ), and ammonia ( $\text{NH}_3$ ) also may be emitted (see also Table 8.1). Emissions may also include residual materials from the fuel and raw materials or products of incomplete combustion that are considered to be hazardous. Because some facilities burn waste fuels, particularly spent solvents, in the kiln, these systems also may emit small quantities of additional hazardous organic pollutants (IPCC, 1995).

Oxides of nitrogen are generated during fuel combustion by oxidation of chemically-bound nitrogen in the fuel and by thermal fixation of nitrogen in the combustion air. As flame temperature increases, the amount of thermally generated  $\text{NO}_x$  increases. The amount of  $\text{NO}_x$  generated from fuel increases with the quantity of nitrogen in the fuel. In the cement manufacturing process,  $\text{NO}_x$  is generated in both the burning zone of the kiln and the burning zone of a precalcining vessel. Fuel use affects the quantity and type of  $\text{NO}_x$  generated. There is a marked increase in the amount of oxides of nitrogen (mainly nitric oxide) which is formed at temperatures above 1,400 °C. The formation of nitric oxide is also a function of the excess air (IPCC, 1995; EPA, 1995).

Sulphur dioxide may be generated both from the sulphur compounds in the raw materials and from sulphur in the fuel. Here only emissions from combustion are taken into account originating from the sulphur in the fuel. The sulphur content of both raw materials and fuels varies from plant to plant and with geographic location. Sulphur is normally present in the form of metal sulphide and sulphates. The amount of sulphur present will vary widely according to the nature of the deposits used. During the calcining operation, sulphur dioxide is released.

Compounds of sulphur are common constituents of most fuels and levels of sulphur may be as high as 5 wt%. Sulphides and organic sulphur compounds in the raw materials will normally be oxidised to sulphur dioxide and pass through the burning zone of the kiln with the process gases. For practical purposes sulphur in the kiln exhaust may be assumed to be emitted as sulphur dioxide, although there is usually some sulphur trioxide formed. Where

this sulphur dioxide is formed at temperatures lower than the calcium carbonate calcination, it will be emitted from the kiln and preheater system to a significant extent. Some absorption may take place in the precipitator or raw mill. In most circumstances, only a small fraction of the sulphur dioxide generated within the kiln from the fuel is released to atmosphere, since it is mainly incorporated into the cement clinker by chemical combination. (IPCC, 1995; EPA, 1995).

The CO<sub>2</sub> emissions from portland cement manufacturing are generated by two process steps: As with most high-temperature, energy-intensive industrial processes, combusting fuels to generate process energy releases substantial quantities of CO<sub>2</sub>. Substantial quantities of CO<sub>2</sub> are also generated through calcining of limestone or other calcareous material. This calcining process thermally decomposes CaCO<sub>3</sub> to CaO and CO<sub>2</sub>. The amount of CO<sub>2</sub> released in the calcining process is about 500 kilograms (kg) per Mg of portland cement produced. Total CO<sub>2</sub> emissions from the pyroprocess depend on energy consumption and generally fall in the range of 0.85 to 1.35 Mg of CO<sub>2</sub> per Mg of clinker. Carbon dioxide comprises at least 20 % of the dry combustion gases and is produced from the carbon content of fuels and from calcination of the calcium carbonate (IPCC, 1995; EPA, 1995).

Fuel combustion at portland cement plants can emit a wide range of pollutants in smaller quantities. If the combustion reactions do not reach completion, CO and volatile organic pollutants (VOC) can be emitted. Incomplete combustion also can lead to emissions of specific hazardous organic air pollutants, although these pollutants are generally emitted at substantially lower levels than CO or VOC (IPCC, 1995).

Carbon monoxide is formed by the incomplete combustion of carbonaceous fuels and even with good combustion control small amounts of carbon monoxide will be present in combustion gases. When operating near to stoichiometric conditions in the kiln, there is localised generation of carbon monoxide (HMIP, 1992).

Heavy metal emissions from cement plants depend on their content in fuels and raw materials, industrial technology (e.g. combustion temperature), and emission control measures. During the cement production process at high temperatures many heavy metals present in the fuel and the raw materials evaporate and then condense on the clinker and partly on fine particles in the flue gas. The latter portion of the metals finds its way to the atmosphere after passing through the emission control equipment.

Fluorine compounds in the feed constituents are partly volatilised into gaseous acidic fluorides at the high temperatures in the kiln. However, such acidic compounds are immediately neutralised (in the form of solid calcium fluoride) by the alkaline constituents in both the clinker and the feed. Thus, 88 - 98 % of the fluoride content of the feed materials is trapped in the clinker and the remainder deposits on dust particles and is mainly removed by the dust control devices. Chlorine compounds behave in a similar manner to those of fluorine.

Some kilns do burn hazardous waste as supplemental fuel. Other types of non-hazardous liquid and solid wastes used as supplemental fuels include tyres, waste oil, and wood chips. Dioxins (PCDDs) and furans (PCDFs) were first detected in stack emissions from portland cement kilns in the early 1980s (e.g. EPA, 1994). They were detected at low concentrations and were thought to be caused by the co-firing of liquid hazardous waste with conventional

fossil fuels. Recently more information has become available on the possible formation mechanisms of dioxins in the portland cement kilns. The following mechanisms have been suggested:

- some primary combustion fuels and fuel supplements used to sustain elevated temperatures in the kiln to form clinker may also produce aromatic hydrocarbon compounds that can later become chlorinated ring structures. The oxidation of HCl gas has been shown to provide chlorine available for ring substitution;
- the chlorinated aromatic compounds may act as precursor molecules to the thermalytic formation of CDD/CDFs on the active surface of carbonaceous particles;
- de novo synthesis of CDD/CDFs on the active surface of carbonaceous particles in the presence of a catalytic agent (e.g. metal ions);
- post-kiln temperatures of the combustion gases are often within the range of temperatures that promote the continued formation of CDD/CDFs;
- co-firing of liquid hazardous organic wastes with coal and petroleum coke may lead to an increase in the amount of CDD/CDFs formed in the post-combustion zone.

### 3.5 Controls

Emission reduction is usually obtained by reducing the dust emissions. Electrostatic precipitators (ESPs) and fabric filters (FFs) are most widely used on both kilns and clinker coolers. For electrostatic precipitation dust concentrations of 30 - 40 mg/m<sup>3</sup> can be achieved. For fabric filters a value of 20 to 50 mg/m<sup>3</sup> is common. A few gravel bed filters have also been used to control clinker cooler emissions. Fugitive emission sources are normally captured by a ventilation system and the dust is collected by fabric filters.

A portion of heavy metals in the flue gas will also be removed with particles. However, the most volatile heavy metals are present on very fine particles, often penetrating both ESPs and FFs. It is proposed that further reduction of dust concentrations in the flue gas to 10 mg/m<sup>3</sup> should be achieved in order to obtain reasonable reduction of heavy metals.

Emissions of sulphur dioxide are best reduced by use of low sulphur raw materials. Removal of sulphur dioxide from the exhaust gases is possible using injection of calcium hydroxide into the air stream - after the preheater for minor reductions, or by a separate fluid bed absorber for significant reductions. However, the alkaline nature of the cement provides for direct absorption of SO<sub>2</sub> into the product, thereby mitigating the quantity of SO<sub>2</sub> emissions in the exhaust stream. Depending on the process and the source of the sulphur, SO<sub>2</sub> absorption ranges from about 70 percent to more than 95 percent. However, in systems that have sulphide sulphur (pyrites) in the kiln feed, the sulphur absorption rate may be as low as 70 percent without unique design considerations or changes in raw materials. Fabric filters on cement kilns are also reported to absorb SO<sub>2</sub> (IPCC, 1995; EPA, 1995).

Flue gas desulphurisation equipment also reduces the concentration of gaseous mercury present in the flue gas. This reduction can be as high as 50 %. Further reduction of up to 85 % can be achieved through the application of very expensive measures such as injection of activated carbon or application of activated carbon beds.

Oxides of nitrogen can be reduced by applying the following techniques (EPA, 1995):

- Use of low-NO<sub>x</sub>-burners where practicable, the principle of which is the avoidance of localised hot spots.
- Avoidance of over-burning of the clinker. The temperature in the burning zone can be limited to that necessary to produce a free lime content which gives acceptable clinker quality. Cements kilns can be fitted with on-line oxides of nitrogen sensors which form the basis of an automatic kiln control system. The prevention of over-burning not only gives reduced oxides of nitrogen levels but also provides some worthwhile energy savings.

The formation of carbon dioxide should be minimised by the use of energy efficient systems and techniques (HMIP, 1992).

#### **4 SIMPLER METHODOLOGY**

For the simpler methodology, where limited information is available, a default emission factor can be used together with information on cement production in a given country or region without further specification on the type of industrial technology or the type and efficiency of control equipment. Default emission factors for this purpose are provided in Section 8.1.

#### **5 DETAILED METHODOLOGY**

The detailed methodology to estimate emissions of gaseous pollutants from the cement production is based on measurements or estimations using emission factors. The measurement and estimation approaches described for “Combustion plants as point sources” chapter B111 can also be used for assessing emissions from combustion sources within the cement production.

The detailed methodology to estimate emissions of trace elements from the cement production is similar to the simpler one. However, more information on the type of the process, e.g. wet and dry kilns, as well as on the type of the industrial technology should be made available. This information shall be used to estimate specific emissions for at least a specific industrial technology.

Measurements of the emission rate and chemical composition of fine particles with < 1.0 µm diameter are often carried out at major cement kilns world-wide. The results of these measurements are then used to estimate atmospheric emissions of several trace elements contained as impurities in the raw materials and fuel.

Reference emission factors for comparison with users own data are provided in Section 8.2.

## 6 ACTIVITY STATISTICS

Information on the production of cement is widely available from the UN statistical yearbooks. This information is satisfactory to estimate emissions with the use of the simpler estimation methodology. However, in most cases, no information is available from the statistical yearbooks on the quantities of cement produced by various types of industrial technologies employed in the cement industry. Therefore, the application of the detailed estimation methodology may be complicated unless the statistical data are available directly from a given cement plant.

No information is easily available on the content of impurities in the copper ores from different mines or even mining regions.

## 7 POINT SOURCE CRITERIA

The cement production plants are regarded as point sources if plant specific data are available.

## 8 EMISSION FACTORS, QUALITY CODES AND REFERENCES

### 8.1 Default Emission Factors For Use With Simpler Methodology

Pollutant	Emission factor	Units
Particulate matter		
Total suspended particulate	400	g/tonne cement
PM10	110	g/tonne cement
PM2.5	40	g/tonne cement
Arsenic	0.2	g/tonne cement
Cadmium	0.01	g/tonne cement
Chromium	1	g/tonne cement
Copper	0.4	g/tonne cement
Mercury	0.1	g/tonne cement
Nickel	0.1	g/tonne cement
Lead	0.2	g/tonne cement
Selenium	0.002	g/tonne cement
Zinc	2	g/tonne cement
Dioxins and furans	0.2	µg TEQ/tonne cement
Hexachlorobenzene	11	µg TEQ/tonne cement
Polyaromatic hydrocarbons	3	mg/tonne cement

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Polychlorinated biphenyls	1	µg/tonne cement
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## 8.2 Reference Emission Factors For Use With Detailed Methodology

Table 8.2a contains reference emission factors for the production of cement based on CORINAIR90 data in [g/GJ]. Technique related emission factors, mostly given in other units (e.g. g/Mg product, g/Mg clinker), are listed in footnotes. In the case of using production statistics the specific energy consumption (e.g. GJ/Mg product) has to be taken into account, which is process and country specific. Within CORINAIR90 a value for the specific energy consumption of 13 GJ/Mg product has been reported.

**Table 8.2a Emission factors for the production of cement (fuel related)**

Type of fuel		NAPFUE code	Emission factors						
			SO <sub>2</sub> [g/GJ]	NO <sub>x</sub> [g/GJ]	NM VOC [g/GJ]	CH <sub>4</sub> [g/GJ]	CO [g/GJ]	CO <sub>2</sub> [kg/GJ]	N <sub>2</sub> O [g/GJ]
s coal	hc coking	101	569 <sup>1)</sup> , 85-165 <sup>2)</sup>	701 <sup>1)</sup> , 450-709 <sup>2)</sup>		1 <sup>1)2)</sup>		86 <sup>1)2)</sup>	
s coal	hc steam	102	44-880 <sup>1)</sup> , 35-600 <sup>2)</sup>	150-170 <sup>1)</sup> , 0.4-575 <sup>2)</sup>	15 <sup>1)</sup> , 15-33 <sup>2)</sup>	14.7-15 <sup>1)</sup> , 0.3-15 <sup>2)</sup>	10-110 <sup>1)</sup> , 18-100 <sup>2)</sup>	93-94 <sup>1)</sup> , 78-101 <sup>2)</sup>	12 <sup>1)</sup> , 3-12 <sup>2)</sup>
s coal	hc sub-bituminous	103	134-154 <sup>1)</sup> , 1,260 <sup>2)</sup>	57 <sup>1)</sup> , 820-1,300 <sup>2)</sup>			22 <sup>1)</sup>	99 <sup>1)</sup> , 320-420 <sup>2)</sup>	8 <sup>2)</sup>
s coal	hc brown coal/lignite	105	25 <sup>2)</sup>	575 <sup>2)</sup>	15 <sup>2)</sup>	15 <sup>2)</sup>		100-113 <sup>2)</sup>	3.5 <sup>2)</sup>
s coal	hc briquettes	106	11 <sup>2)</sup>	575 <sup>2)</sup>	15 <sup>2)</sup>	15 <sup>2)</sup>	100-260 <sup>2)</sup>	97-98 <sup>2)</sup>	3.5 <sup>2)</sup>
s coke	hc coke oven	107	25 <sup>2)</sup>	575 <sup>2)</sup>	15 <sup>1)</sup> , 0.5 <sup>2)</sup>	15 <sup>1)</sup> , 0.5 <sup>2)</sup>	110 <sup>1)</sup> , 100 <sup>2)</sup>	108 <sup>1)</sup> , 100-105 <sup>2)</sup>	14 <sup>1)</sup> , 4 <sup>2)</sup>
s coke	petroleum	110	355-511 <sup>1)</sup> , 85-1,200 <sup>2)</sup>	300-568 <sup>1)</sup> , 0.4-575 <sup>2)</sup>	1.5 <sup>1)</sup> , 1.5- 15 <sup>2)</sup>	1.5 <sup>1)</sup> , 1-15 <sup>2)</sup>	10-70 <sup>1)</sup> , 15-100 <sup>2)</sup>	99-102 <sup>1)</sup> , 97-102 <sup>2)</sup>	14 <sup>1)</sup> , 3-14 <sup>2)</sup>
s waste	municipal	115	161 <sup>1)</sup>	200 <sup>1)</sup>	15-40 <sup>1)</sup>	15-40 <sup>1)</sup>	70 <sup>1)</sup>	100-121 <sup>1)</sup>	5-12 <sup>1)</sup>
s waste	industrial	116	135 <sup>2)</sup>	0.4-568 <sup>2)</sup>		0.2 <sup>2)</sup>	1429 <sup>2)</sup>	83 <sup>2)</sup>	4 <sup>2)</sup>
l oil	residual	203	131- 1,030 <sup>1)</sup> , 16-1,079 <sup>2)</sup>	150-220 <sup>1)</sup> , 0.4-575 <sup>2)</sup>	3 <sup>1)</sup> , 3-10 <sup>2)</sup>	1-3 <sup>1)</sup> , 1-5 <sup>2)</sup>	15-20 <sup>1)</sup> , 8-79 <sup>2)</sup>	76-79 <sup>1)2)</sup>	2-15 <sup>1)2)</sup>
l oil	gas	204	4-1,410 <sup>2)</sup>	0.4-575 <sup>2)</sup>	1.5 <sup>1)</sup> , 1.5-2.5 <sup>2)</sup>	1-5 <sup>1)</sup> , 1-8 <sup>2)</sup>	12 <sup>1)</sup> , 12-79 <sup>2)</sup>	74 <sup>1)</sup> , 73- 74 <sup>2)</sup>	12 <sup>1)</sup> , 2-14 <sup>2)</sup>
l gasoline	motor	208			2.5 <sup>1)</sup>	2.5 <sup>1)</sup>	12 <sup>1)</sup>	72 <sup>1)</sup>	12 <sup>1)</sup>
l oil	shale-oil	211						78 <sup>1)</sup>	
g gas	natural	301	0.1-135 <sup>2)</sup>	175 <sup>1)</sup> , 60-560 <sup>2)</sup>	2.5 <sup>1)</sup> , 2.5-18.4 <sup>2)</sup>	2.5 <sup>1)</sup> , 0.4-5 <sup>2)</sup>	20 <sup>1)</sup> , 10-120 <sup>2)</sup>	53-56 <sup>1)</sup> , 55-69 <sup>2)</sup>	3 <sup>1)</sup> , 1-3.7 <sup>2)</sup>
g gas	liquified petroleum gas	303	0.04 <sup>2)</sup>	100 <sup>2)</sup>	2.5 <sup>1)</sup> , 2.1 <sup>2)</sup>	2.5 <sup>1)</sup> , 0.9 <sup>2)</sup>	20 <sup>1)</sup> , 13 <sup>2)</sup>	65 <sup>1)2)</sup>	3 <sup>1)</sup> , 1 <sup>2)</sup>
g gas	coke oven	304	0.6 <sup>2)</sup>	575 <sup>2)</sup>	2.5 <sup>2)</sup>	2.5 <sup>2)</sup>	10 <sup>2)</sup>	44 <sup>2)</sup>	1.5 <sup>2)</sup>
Data quality rating			B	B	D	D	C	C	D

1) CORINAIR90 data, area sources

2) CORINAIR90 data, point sources

Technique related emission factors are listed in Tables 8.2b through 8.2g for sulphur dioxide, nitrogen oxides, non-methane VOCs, CO, methane, and particulate matter. No information exists on the type and efficiency of abatement techniques, but the factors in these tables seem to be valid for emissions from uncontrolled processes.

**Table 8.2b Emission factors for SO<sub>2</sub> from cement production.**

Process type	Abatement type	Abatement efficiency	Fuel type	Unit	Emission factor	Data Quality Code	Country or region
Dry process kiln	N/A	N/A	N/A	kg/tonne	5.1	E	USA
Wet process kiln	N/A	N/A	N/A	kg/tonne product	5.1	E	USA
Cement production	N/A	N/A	N/A	kg/tonne cement	0.2-0.3	E	USA
Clinker production	N/A	N/A	N/A	g/gJ	0.02-50.0	E	USA

**Table 8.2c Emission factors for NO<sub>x</sub> from cement production.**

Process type	Abatement type	Abatement efficiency	Fuel type	Unit	Emission factor	Data Quality Code	Country or region
Dry process kiln	N/A	N/A	N/A	kg/tonne product	1.4-2.1	E	USA
Wet process kiln	N/A	N/A	N/A	kg/tonne product	1.1-1.4	E	USA
Semi-wet process kiln	N/A	N/A	N/A	kg/tonne product	1.8	E	USA
Clinker production	N/A	N/A	N/A	g/GJ	1.2	E	USA
Clinker production (80% NO <sub>x</sub> reduction, 20% energy saving)	N/A	N/A	N/A	kg/tonne clinker	0.6	E	USA
Cement production	N/A	N/A	N/A	g/GJ	130-220	E	USA
Cement production	N/A	N/A	N/A	kg/tonne cement	1.3-1.4	E	USA
Cement/lime industry, kiln	N/A	N/A	Natural gas	kg/GJ	1.1	E	USA
Cement/lime industry, kiln	N/A	N/A	Oil	kg/GJ	0.5	E	USA
Cement/lime industry, kiln	N/A	N/A	Coal	kg/GJ	0.5	E	USA

N/A - Data not available

**Table 8.2d Emission factors for NMVOC from cement production.**

Process type	Abatement type	Abatement efficiency	Fuel type	Unit	Emission factor	Data Quality Code	Country or region
Dry process kiln	N/A	N/A	N/A	g/tonne product	10.0	E	USA
Cement production	N/A	N/A	N/A	kg/tonne cement	50.0	E	USA

N/A - Data not available

**Table 8.2e Emission factors for CO from cement production.**

Process type	Abatement type	Abatement efficiency	Fuel type	Unit	Emission factor	Data Quality Code	Country or region
Cement/lime industry, kiln	N/A	N/A	Natural gas	g/GJ	83.0	E	USA
Cement/lime industry, kiln	N/A	N/A	Oil	g/GJ	79.0	E	USA
Cement/lime industry, kiln	N/A	N/A	Coal	g/GJ	79.0	E	USA

N/A - Data not available

**Table 8.2f Emission factors for CH<sub>4</sub> from cement production.**

Process type	Abatement type	Abatement efficiency	Fuel type	Unit	Emission factor	Data Quality Code	Country or region
Cement/lime industry, kiln	N/A	N/A	Natural gas	g/GJ	1.1	E	USA
Cement/lime industry, kiln	N/A	N/A	Oil	g/GJ	1.0	E	USA
Cement/lime industry, kiln	N/A	N/A	Coal	g/GJ	1.0	E	USA

N/A - Data not available

**Table 8.2g Emission factors for particles from cement production.**

Process type	Abatement type	Abatement efficiency	Fuel type	Unit	Emission factor	Data Quality Code	Country or region
Kilns	“In operation”	N/A	N/A	g/tonne clinker	10 – 400	E	EU (EIPPC, 2000)
Cement production	“In operation”	N/A	N/A	g/tonne clinker	236	E	UK (Passant et al, 2000)
Clinker production	N/A	N/A	N/A	g/tonne product	212.0	E	USA
Cement production	N/A	N/A	N/A	g/tonne product	29.0-46.0	E	USA
Portland cement prod., dry process, fuel preparation	N/A	N/A	N/A	g/tonne product	20.0	E	USA
Portland cement prod., dry process, clinker firing	N/A	N/A	N/A	g/tonne product	100.0	E	USA
Portland cement prod., dry process, cement milling	N/A	N/A	N/A	g/tonne product	100.0	E	USA
Portland cement prod., dry process, cement shipping	N/A	N/A		g/tonne product	30.0	E	USA
Blast furnace cement, raw materials transport	N/A	N/A		g/tonne product	55.0	E	USA
Blast furnace cement, cement drying, milling, shipping	N/A	N/A		g/tonne product	60.0	E	USA

N/A - Data not available

The emission factors for heavy metals are determined by the composition of the raw material and the type of fuels used for firing. An illustration of the range of emission factors to be expected is given in Table 8.2h. This table is derived from the PARCOM-ATMOS Emission Factors Manual (van der Most and Veldt, 1992). Unfortunately, no information is available on the abatement efficiency for these data.

**Table 8.2h Examples of emission factors for heavy metals from cement production in g/Mg cement (van der Most and Veldt, 1992)**

Substance	Coal and oil fired	Proportion of waste oil	Fuel unknown	Fuel unknown	Fuel unknown
Arsenic	-	-	-	0.012	-
Cadmium	-	-	0.04	0.008	< 0.001
Chromium	0.006-0.02	0.02-0.3	-	0.105	-
Lead	0.006	0.012-0.2	1.1	0.216	<0.033
Mercury	-	-	-	0.275	-
Nickel	-	-	-	0.111	-
Selenium	-	-	-	0.002	-
Zinc	-	-	-	0.293	0.003-0.47

- Data not available

Similar results were reported for the UK cement industry (Salway, 1997).

In the CIS countries cement plants operate mostly using the wet process, and in this way 83 % of cement is produced. Some preliminary emission factors suggested for these countries are within the ranges presented in the above tables (EMEP-MS-C-E, 1997). The same can be concluded for the emission factors developed in the Netherlands.

Concentrations of dioxins and furans in the flue gas after passing the control equipment in the cement production are presented in Table 11 after a compilation of data by the Working Group of the Subcommittee Air/Technology of the Federal Government/Federal States Emission Control Committee in Germany (Umweltbundesamt, 1996) and information obtained from Schreiber et al. (1995), EPA (1994), and (Quass, 1997).

## 9 SPECIES PROFILES

An analysis of dust emissions from clinker firing in the Netherlands gave results presented in Table 9.1. The composition is given in mg per tonne cement:

**Table 9.1 Composition of dust from clinker firing**

Substance	Concentration in dust (g/tonne of cement)
Antimony	6
Arsenic	4
Cadmium	6
Chromium	5
Copper	8
Lead	6.5
Mercury	9
Nickel	4
Selenium	3
Tellurium	5
Thallium	3
Uranium	3
Vanadium	5
Zinc	4

EPA (1995) gives size distributions for particulate matter emitted from various cement production processes. These are reproduced in Table 9.2. The profiles for controlled dry process kilns and controlled clinker coolers seem most appropriate for the EU and suggest that particulate matter emissions comprises about 80% PM10.

**Table 9.2 Particle size distributions and size-specific emission factors (EPA 1995)**

Process	Abatement technology	Particle size (µm)	Cumulative mass % less than stated size
Kilns, wet process	Uncontrolled	2.5	7
		5	20
		10	24
		15	35
		20	57
		total	100
Kilns, wet process	ESP	2.5	64
		5	83
		10	58
		15	91
		20	98
		total	100
Kilns, dry process	Uncontrolled	2.5	18
		10	42
		15	44
		total	100
Kilns, dry process	Fabric filter	2.5	45
		5	77
		10	84
		15	89
		20	100
		total	100
Clinker coolers	Uncontrolled	2.5	0.54
		5	1.5
		10	8.6
		15	21
		20	34
		total	100
Clinker coolers	Gravel bed filter	2.5	40
		5	64
		10	76
		15	84
		20	89
		total	100

In general, no reliable information exists at present on physical and chemical species of trace elements emitted during the cement production. It can be assumed that the majority of trace elements volatilised from the raw material and fuel enter the atmosphere on fine particles. Very general information collected by Pacyna (1987) appears to indicate that elemental forms, oxides and sulphates are the major chemical forms of atmospheric trace elements from the cement production.

## **10 UNCERTAINTY ESTIMATES**

It is rather difficult to assess current uncertainties of emission estimates for pollutants emitted during the cement production. The uncertainties of sulphur dioxide emission estimates can be assessed in a similar way as the uncertainties of the estimates for the fossil fuel combustion (see chapter B111).

Recently it was concluded that up to 50% of uncertainties can be assigned to the emission estimates of most of the trace elements emitted from major point sources in Europe (Pacyna, 1994). Similar uncertainty can be assigned for emission estimates of these compounds from the cement production.

## **11 WEAKEST ASPECTS/PRIORITY AREAS FOR IMPROVEMENT IN CURRENT METHODOLOGY**

Knowledge of abatement techniques, dust removal efficiencies and operating techniques is limited; measurement data of composition of dust is poor.

The fuel specific emission factors provided in Table 8.1 are related to point sources and area sources without specification. CORINAIR90 data can only be used in order to give a range of emission factors with respect to point and area sources. Further work should be invested to develop emission factors, which include technical or fuel dependent explanations concerning emission factor ranges. Emission factors also need to be generated, which specifically relate to different levels of abatement on different types of plant.

## **12 SPATIAL DISAGGREGATION CRITERIA FOR AREA SOURCES**

Cement production plants should be considered as point sources if plant specific data are available. Otherwise national emissions should be disaggregated on the basis of plant capacity, employment or population statistics.

## **13 TEMPORAL DISAGGREGATION CRITERIA**

Cement production can be considered as a continuous process.

## **14 ADDITIONAL COMMENTS**

No additional comments.

## **15 SUPPLEMENTARY DOCUMENTS**

Emission inventory in The Netherlands, 1992. Emission to air and water

Personal information and experience during emission inventories 1975 - 1995

Emission factors to be used for the building industry, TNO report 89/091

Environmental Protection Agency, Compilation of Air Pollutant Emission Factors AP 42  
PARCOM-ATMOS Emission Factors Manual

## **16 VERIFICATION PROCESSES**

Verification of the emissions can be done for metal emissions by calculating the emissions using the factors from the PARCOM ATMOS manual and comparing the results with a mean profile.

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## 18 BIBLIOGRAPHY

For a detailed bibliography the primary literature mentioned in AP 42 or the PARCOM-ATMOS Manual can be used.

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