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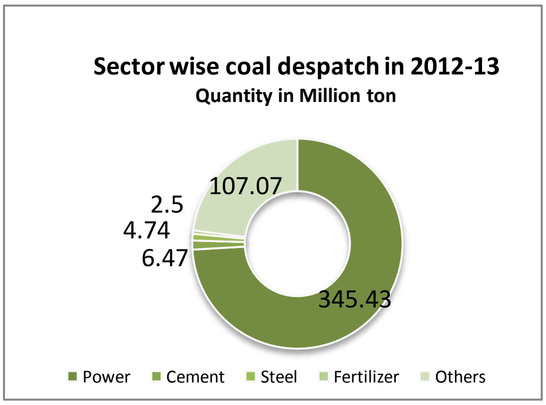
Chapter-01

INTRODUCTION

1.1 Mineral plays an important role in the economic development of the country as a basic raw material to promote the growth. India produces 86 types of various minerals out of which 04 are fuel minerals, 10 metallic, and 46 non-metallic and 23 minor minerals. India has immense natural resources and is ranked among top 10 globally for deposits in iron ore at 206 million tons, coal 491 million tons and bauxite 23084 thousand tons, which constitute 10 %, 7.7 % and 10.8% respectively of the world's resources. Coal provides around 30% of global primary energy needs, generates 41% of the world's electricity and is used in the production of 70% of the world's steel.

1.2 As per data published in Coal India Directors Reports, sector wise coal consumption during financial year 2012-13 was as Power (345 million ton), Cement (6.47 million ton), Steel (4.74 million ton), Fertilizer (2.5 million ton) and Others (107 million ton). In India maximum coal consumption is in power sector i.e. 74% and 23% in other unorganized sector. As per consumption quantity cement sector comes on third level whereas ferrous and non-ferrous metal on fourth level.



1.3 In general coal composition depends on its origin however range of variation of different parameters may be summarized as below:-

S. No.	Proximate analysis parameter	Values	
		From	To
01	Moisture	2.4 %	13.15%
02	Volatile matter	23.27%	33.96%
03	Ash	8.84%	52.00 %
04	Fixed carbon	22.6%	53.16 %
05	Mercury	0.01 ppm	0.10 ppm
06	Arsenic	1.4 ppm	71 ppm
07	Selenium	1.0 ppm	3.0ppm

Mercury is a global threat to human and environment health. Mercury is naturally occurring element and is found throughout the world. There are thus many natural sources of mercury, creating background environment levels that have been present since long.

Mercury is contained in many minerals including cinnabar, an ore mined to produce mercury. Much of the present day demand for mercury is met by supply from mercury recovered from industrial sources and stockpiles rather than mercury mining. Mercury is also present as an impurity in many other economically valuable minerals, in particular the non-ferrous metals and fossil fuels, coal in particular.

1.4 Human activity especially mining and the burning of coal have increased the mobilization of mercury into the environment, raising the concentration in the atmosphere, soils, fresh water and oceans. The majority of these human emissions and releases of mercury have occurred since 1800, associated with the industrial revolution based on coal burning, base metal ore smelting, and gold rushes in various parts of the world. To some extent the same drivers of mercury and releases are continuing with fossil fuel based energy generation powering industrial economic growth in Asia and South America, which in turn helps drive high demand for metals including gold, spurring Artisanal and Small Scale Gold Mining (ASGM) around the world.

In preparing inventories of mercury emissions and releases, it is important to distinguish various categories of sources. Three main types of emissions and releases can be distinguished, each of which may briefly be introduced as below in qualitative term with particular emphasis on anthropogenic sources.

Natural source- Mercury is an extremely rare element of the Earth’s crust with an average abundance by mass of only 0.08 ppm (parts per million). The richest mercury ores contain up to 2.5% mercury by mass and the leanest concentrated deposits are at least 0.1% mercury (UNEP, 2002). Mercury in the earth crust can be emitted and released in several ways to air, water and land i.e. natural weathering of mercury-containing rocks.

Re-emission and re-mobilization of mercury constitute major category of sources presently comprising about 60% of mercury emission to air. Mercury previously deposited from air on to soils, surface waters and vegetation from past emission can be emitted back to the air. Re-emission is a result of natural process that converts inorganic and organic forms of mercury to elemental mercury, which is volatile and therefore readily returns to air. Mercury deposited on the plant surfaces can be re-emitted during forest fires or bio-mass burning. Mercury may be deposited and re-emitted many times as it cycles through the environment.

Anthropogenic sources of mercury emissions account for about 30% of the total mercury entering the atmosphere each year. The main industrial sources of atmospheric mercury are coal burning, mining, industrial activities that process ores to produce various metals or process other raw materials to produce cement. In these activities mercury is emitted because it is present as an impurity in fuels and raw materials. In these cases mercury emissions and releases are sometimes referred to as ‘by product’ or unintentional emissions or releases.

Coal burning and to a lesser extent the use of fossil fuels, is one of the most significant anthropogenic source of mercury emissions to the atmosphere. Coal does not contain high concentration of mercury, but the combination of the large volume of coal burned and the fact that a significant portion of the mercury present in coal is emitted to the atmosphere yield large overall emissions from this sector. The mercury content of coal varies widely introducing a high degree of uncertainty in estimating mercury emission from coal burning.

Mining, smelting and production of iron and non-ferrous metals are also a large source of global mercury emissions to air, and also very important sector with regard to releases to water. Oil refining emits and releases mercury, as oil deposits are known to contain mercury, generally at low concentration. Mercury is removed from most petroleum products and natural gas prior to combustion and therefore combustion related emissions are low. Most of the mercury in crude oil is associated with solid waste that is disposed of in landfills.

Artisanal and small scale gold mining (ASGM) is a major source for emissions and releases of mercury worldwide, In ASGM miners use mercury to create an amalgam separating gold from other materials. They then have to separate the mercury from gold.

Cement production, which typically involves the burning of fossil fuels to heat the material required to make cement, is another major anthropogenic source of mercury emissions. Both the raw material and the fuel may contain mercury and lead to emissions. The quantity of mercury evolved varies greatly with the raw materials. In some countries including India cement kilns are burning increasing quantity of alternative fuels, including wastes that may contain mercury. This may add to the emissions from cement kilns.

Chapter-02

THE PROJECT

2.1 PERCEPTUAL FACTS FOR PROJECT

Concern about mercury emissions and their control has increased over the past several years in India. Mercury and most of its chemical compounds are volatile. It's different forms, whether elemental or oxidized to various compounds, affects the human health. The major health effects of mercury exposure are

- For fetuses, infants and children, the primary health effect of **methylmercury** is impaired neurological development. Methylmercury exposure in the womb through mother's consumption of fish containing methylmercury can adversely affect a baby's growing brain and nervous system. Impacts on cognitive thinking, memory, attention, language and visual spatial skills have been seen in children exposed to methylmercury in the womb. In addition to the subtle impairments, symptoms of methylmercury poisoning may include; impairment of the peripheral vision; disturbances in sensations; lack of coordination of movements; impairment of speech, hearing, walking; and muscle weakness.

- **Elemental (metallic) mercury** primarily causes health effects when it is breathed as a vapor where it can be absorbed through the lungs. These exposures can occur when elemental mercury is spilled or products that contain elemental mercury break and expose mercury to the air, particularly in warm or poorly-ventilated spaces. Symptoms of mercury effect include tremors; emotional changes; insomnia; neuromuscular changes; headaches; disturbances in sensations; changes in nerve responses. At higher exposures there may be kidney effects, respiratory failure and death.

- High exposures to inorganic mercury may result in damage to the gastrointestinal tract, the nervous systems and kidneys. **Both inorganic and organic mercury** compounds are absorbed through the gastrointestinal tract and affect other system via this route. However organic mercury compounds are more readily absorbed via ingestion than inorganic mercury compounds. Symptoms of high exposure to inorganic mercury include: skin rashes and dermatitis; mood swing; memory loss; mental disturbances; and muscle weakness.

- No human data indicate that exposure to any form of mercury causes cancer, but the human data currently available are very limited. Mercuric chloride has caused increases in several types of tumors in rats and mice and methylmercury has caused kidney tumor in male mice. These health effects are observed at extremely high doses, above levels that produced other effects.

As per Global Mercury Assessment 2013 (Source, Emissions, Releases and Environment Transport) three major sources of mercury release have been identified i.e. Natural source, Re-emission & remobilization and Anthropogenic source. Current anthropogenic sources are responsible for about 30% of annual emissions of mercury to air. Another 10% comes from natural geological sources and the rest (60%) is from ‘re-emission’ of previously released mercury that has built up over decades and centuries in surface soils and ocean.

The inventory confirms the role of artisanal and small scale gold mining (ASGM) and coal burning as the largest components of anthropogenic emissions, **followed by the production of ferrous and non-ferrous metals and cement production.** A preliminary calculation of anthropogenic emission in 2005 indicates that emissions from fossil fuel combustion, metal and cement production increased between year 2005-2010, but continue to decline in other sectors such as chlor-alkali industry.

2.2 PROJECT PROFILE

Portland cement manufacturing is a coal based energy-intensive process that grinds and heats a mixture of raw materials such as limestone, clay, sand and iron ore in a rotary kiln. That product, called clinker, is cooled, ground and then mixed with a small amount of gypsum to produce cement. A variety of pollutants are emitted from the burning of fuels and heating of raw materials. Emissions occur from grinding, cooling and materials-handling steps in the manufacturing process which may also include Mercury.

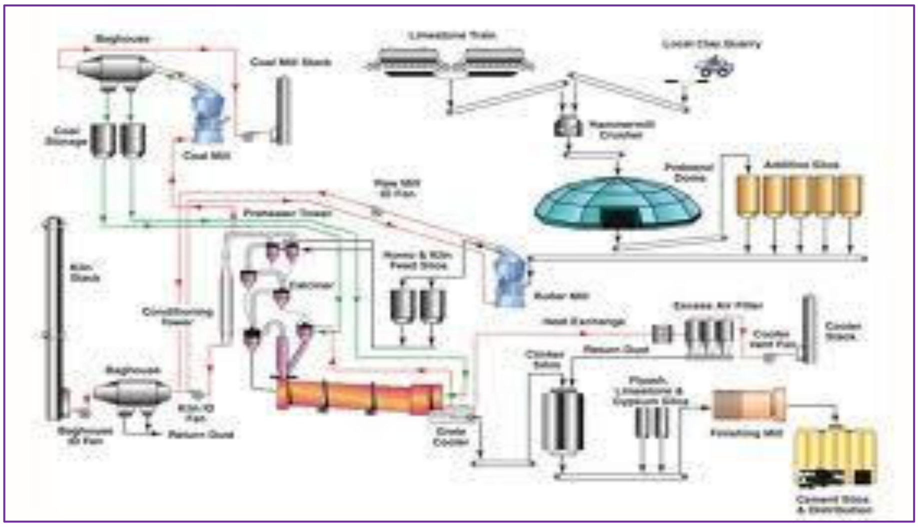
Mercury emitted from cement production may originate from coal and other fuels used and raw material such as limestone and other additives. Mercury concentrations are highly variable in fuels and raw materials and significant emission reductions can be achieved by switching to lower mercury fuels and raw materials.

In order to identify the source of mercury emission from cement industry this study has been taken up with following major objectives-

- To update database on qualitative emission in cement industry.
- To identify the source of mercury emission and its pathway in cement production.
- To identify mercury bearing raw materials if any.
- To evaluate impact of mercury emission in nearby water bodies.

2.3 CEMENT PRODUCTION PROCESS

Portland cement clinker is produced from a mixture of raw materials, the main elements of which are calcium, silica, Aluminium, and iron. The prepared raw material ("kiln feed") is fed into the kiln system where it is subjected to a thermal treatment process consisting of drying/preheating, calcination (e.g. release of CO2 from limestone), and sintering (or "clinkerisation", e.g. formation of clinker minerals at temperatures of up to 1450 °C).



The resulting product, "clinker", is cooled to 100-200°C with air and is transported for intermediate storage. Portland cement is produced by grinding clinker with a percentage of gypsum (or anhydrite) in a cement mill. Blended cements contain other additional constituents.

2.3.1 RAW MATERIALS

Natural ("primary") raw materials such as limestone/chalk, marl, and clay/shale are extracted from quarries which, in most cases, are located close to the cement plant. After extraction, these raw materials are crushed at the quarry site and transported to the cement plant for intermediate storage, homogenization and further preparation.

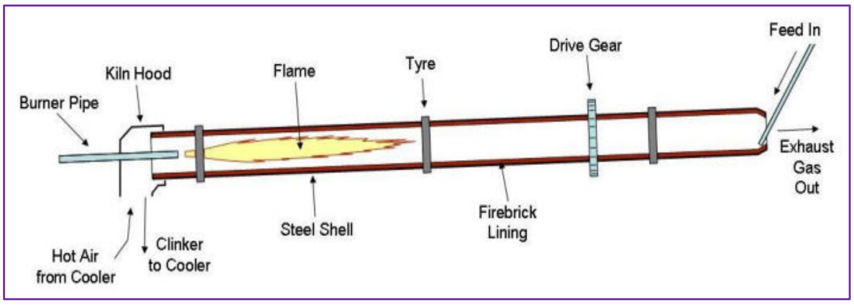
"Corrective" materials such as bauxite, iron ore or sand may be required to maintain the chemical composition of the raw mix to the requirements of the process and product specifications. The quantities of these corrective materials are usually low compared to the huge mass flow of the main raw materials.

Depending on availability and chemical composition, both main and corrective raw mix components may also originate from industrial sources ("alternative" raw materials). Examples include coal fly ash from power stations, steel slag, foundry sand, lime sludge and many others.

After intermediate storage and pre-homogenization, the raw materials are dried and grind together in defined and well-controlled proportions in a raw mill to produce a raw meal for the dry (and semi-dry) process. In the wet (and semi-wet) process, the raw materials are slurred and grinded with the addition of sufficient water to produce raw slurry.

2.3.2 KILN PROCESSING

The kiln systems commonly applied are rotary kilns with or without so-called "suspension



preheaters" (and, in more advanced systems, "precalciners"), depending on the main process design selected.

In all processes the kiln feed is first dried, then calcined by dissociation of carbon dioxide (CO_2) from the $CaCO_3$ in the feed material, and finally sintered to clinker at temperatures ranging between 1400 and 1450 ºC. During this process the feed loses approximately one third of its original dry mass. The hot clinker is cooled to 100-200ºC with air in a clinker cooler. The heated air is used as secondary combustion air in the kiln.

The rotary kiln itself is an inclined steel tube with a length to diameter ratio of between 10 and 40. The slight inclination (2.5 to 4.5%), together with the slow rotation (0.5–4.5 revolutions per minute), allows for a material transport which is sufficiently long in order to achieve the thermal conversion processes required.

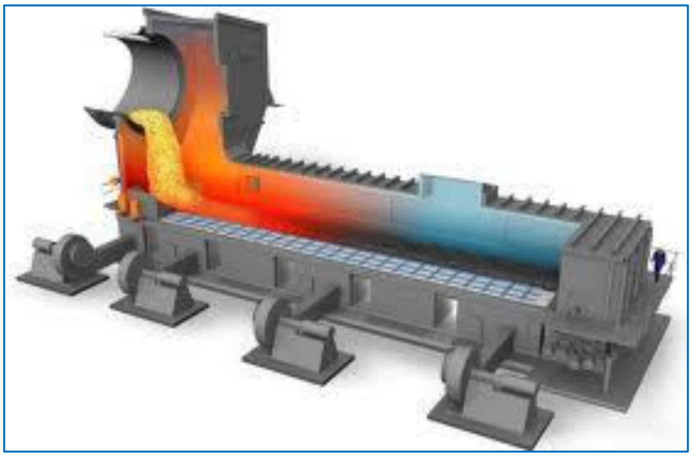
Exhaust heat from the kiln system is utilized to dry the raw materials, solid fuels or mineral additions in the mills. Exhaust gases are dedusted using either electrostatic precipitators or bag filter systems before being released into the atmosphere.

The clinker formation process can be divided into 4 steps:

- Drying and preheating (20–900°C): release of free and chemically bound water;
- Calcination (600–1050°C): release of CO_2: initial reactions with formation of clinker minerals and intermediate phases;
- Sintering or clinkerisation (1050–1450°C): formation of calcium silicates and liquid phase;
- Kiln internal cooling (1350–1200°C): crystallization of calcium aluminate and calcium ferrite.

Minor mineral constituents in the cement clinker include unbound calcium oxide (“free lime”) and magnesium oxide, as well as alkali sulphates. Additional chemical elements present in the raw materials, such as manganese, phosphorus, titanium or heavy metals, are mainly incorporated into the mineral structure of the major clinker phases.

The clinker properties (and thus, of the cement produced) are mainly determined by its mineral composition and its structure. Some elements in the raw materials, such as the alkalis, sulfur and chlorides are volatilized at the high temperatures of the kiln system resulting in a permanent internal cycle of vaporization and condensation (“circulating elements”). A large part of these elements will remain in the kiln system and will finally leave the kiln with the clinker. A small part will be carried out with the kiln exhaust gases and will be mainly precipitated with the particulates in the dedusting system.



If there is a high surplus of volatile elements, the installation of a preheater “bypass” may become necessary where part of the dust laden exhaust gases of the rotary kiln are extracted from the system. Both filter dust and bypass dust can be partially or totally used in the cement manufacturing process.

Historically, the development of the clinker manufacturing process was characterized by the change from “wet” to “dry” systems, with the intermediate steps of the “semi-wet” and “semi-dry” process routes. The first rotary kilns – introduced in around 1895 – were long wet kilns.

The four different basic processes can be briefly defined as follows:

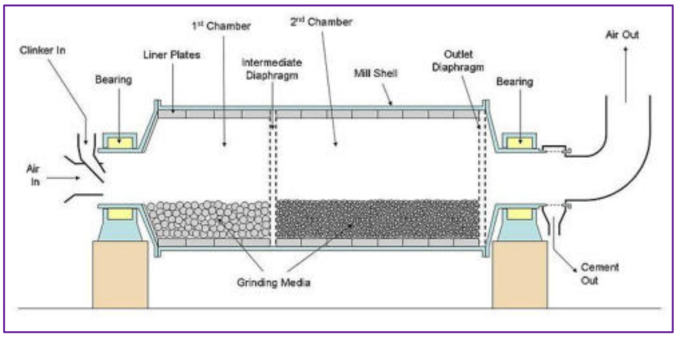
- ✓ **Dry process**: Dry raw meal is fed into a cyclone preheater or precalciner kiln or, in some cases, into a long dry kiln with an internal chain preheater. Most of the plant in central zone is based on this process only due to high energy efficiency. Most of the plants have 06 stage pre-heater system and some plants have installed waste heat recovery system also to produce 7 to 20 MW of electricity.
- ✓ **Semi-dry process**: Dry raw meal is pelletized with water and fed into a travelling grate preheater prior to the rotary kiln or, in some cases, to a long kiln equipped with internal cross preheaters.
- ✓ **Semi-wet process**: Raw slurry is first dewatered in filter presses. The resulting filter cake is either extruded into pellets and fed into a travelling grate preheater or fed directly into a filter cake drier for (dry) raw meal production prior to a preheater/precalciner kiln.

- ✓ **Wet process**: The raw slurry is fed either directly into a long rotary kiln equipped with an internal drying/preheating system (conventional wet process) or into a slurry drier prior to a preheater/ precalciner kiln now this process has phased out due to high energy requirement. In central zone only one plant is based on this process and main raw material is carbide sludge.

The main fossil fuels ("primary" fuels) used in the cement industry are coal, petcoke, and to a lesser extent heavy fuel oil. "Alternative" fuels such as tyres, waste oil, plastics, RDF, hazardous sludge and solvents are increasingly used today. The chemical components of the ash of solid fuels combine with the raw materials and are fully incorporated into the clinker produced. Thus, the chemical composition of the ash has to be considered in the raw mix design.

2.3.3 GRINDING

Portland cement is produced by grinding clinker with natural or industrial gypsum or anhydrite (calcium sulphate), which acts as a set regulator, and major other constituents such as slag and fly ashes. Metal concentration in fly ash and slag play a very important role in final product. The fly ash used may contain mercury (<0.002-0.8 mg/kg according to Renzoni et al, 2010) but it is difficult to assess how much of mercury enters the environment through this pathway.



2.3.4 KILN EXHAUST GASES

In all kiln systems, the exhaust gases are finally passed through an air pollution control device for separation of the dust before being released into the atmosphere via stacks. Today, two types of dust separators are commonly used in the cement industry, namely electrostatic precipitators and bag filters.

Electrostatic precipitators use electrostatic forces to separate the dust from the exhaust gas. By means of discharge electrodes, the dust particles are negatively charged and can be separated onto corresponding collecting electrodes. The particles are then discharged from the collecting electrodes to dust hoppers by electrode rapping.

Bag filters make use of a fabric filter system, the "bags" which separate the dust particles from the exhaust gas. The dust particles are captured on the bag surface while the gas passes through the bag tissue.

In the dry process, the kiln exhaust gases have a relatively high temperature and low humidity. Therefore, they 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. During "direct operation" (with the raw mill off), the hot exhaust gases have to be cooled down to a temperature suitable for the dust collector by means of water injection before the filter. The dust collected in the filter devices can be fed back into the process, by reintroducing it into the raw material preparation system (dry process).

MONITORING

3.1 METHDOLOGY

Physical Chemistry of Mercury	
Chemical Symbol	Hg (Hydrargyrum)
Atomic Weight	200.61
Atomic Number	80
Valency	1-2
Density	13.456
Boiling Point	356.9 ^{0}C
Solidity	-39 ^{0}C

Mercury can be found as a native metal (rarely) or in cinnabar and other possible host minerals. Cinnabar (HgS) is the most common ore. Natural sources of mercury include volcanoes, evaporation from soil and water surfaces, degradation of minerals and forest fires. Mercury can exist in three different oxidation states: metallic-Hg(0) or Hg0, mercurous-Hg(I) or Hg+, mercuric-Hg(II) or Hg2+. Mercurous and mercuric mercury form numerous inorganic and organic chemical compounds, but Hg+ mercury is rarely stable under ordinary environmental conditions.

Metallic mercury (or elemental mercury) is a heavy, silvery-white liquid metal at typical ambient temperatures and pressures, which vaporizes under such conditions. It is rarely found in nature as a pure liquid metal but rather within compounds and inorganic salts. The melting point of mercury is -38.9°C, and the boiling point is 357°C.

Inorganic mercuric compounds (or mercury salts) includes mercuric sulphide (HgS), mercuric oxide (HgO), mercuric chloride ($HgCl_2$), mercury sulphates ($HgSO_4$, Hg_2SO_4) and mercury silicates ($HgSiO_3$, $Hg_6Si_2O_7$, etc.). Organic mercury compounds are the compounds formed when mercury combines with organic molecules. They are of type R_2Hg and RHgX, where X represents atoms or groups such as chlorine, bromine, iodine, cyanide, and hydroxyl, and R represents a simple alkyl group, such as methyl (CH_3-). Depending on their properties, these compounds will be primarily soluble in organic liquids or in water. Two of the organic compounds are methyl mercury halide, CH_3Hg_X, and dimethyl mercury, (CH_3)2Hg, the most important chemical form of mercury with respect to environmental impact.

A major fraction of the mercury input could probably be released at a temperature of less than 500ºC. At this temperature, most of the mercury should be in the form of oxidized mercury (Hg2+).

The present study report is based on review of technical and scientific literature, inventory of mercury emissions monitoring in the cement industry and on the data provided by cement companies which are located in Central Zone. In this regard a format has been prepared by the Zonal Office and distributed to the cement industry of the zone for feedback information. The questioner was very general and mainly contains information related to raw material characteristics, production, fuel used, emission data etc.

The format was forwarded to concern unit in July 2012 and data collection took place from October 2012. On the basis of compiled data monitoring has been carried out in the selected cement plants and samples of raw material, water and emissions has been collected to assess the probable source and routs of Hg and how Hg entering and exit from cement manufacturing process.

This study was proposed to assess the emission of mercury in cement industries. In Central Zone 35 cement plants are operational and using various type of raw material and fuel i.e. coal, (imported & pet cock), RDF, Hazardous waste and plastic. Solid samples of coal, raw meal and clinker were also collected to know the source of mercury in emission.

The samples were prepared in the laboratory and analyzed on AAS (GBC Avanta) using HG 3000 method i.e. cold vapour by hydride generator. The vapour generation method increases the sensitivity of the AAS technique for mercury. The sodium boro hydride method involves reacting the analyte element in an acidified solution with sodium boro hydride to form gaseous hydrides and atomic mercury vapour. In this process vapour is passes into a closed flow through quartz cell and analyzed in usual way on defined wavelength on 253.7 nm.

Multiple dilutions in between 10 – 100 µg/l were used for calibration of instrument to ensure detection of minimum concentration. Certified standard reference materials (SRM) were used for preparation of calibration solution for optimization and validation of method.

All solid samples were preserved properly in field and taken in the laboratory. Processing of solid samples was done by using 0.2 gram of each solid sample. The samples were digested in BOD bottle with 5ml aqua regia solution (3 part of Concentrated HCL and 1 part concentrated HNO_3) by heating at 95^0C for 2 minutes. After cooling, 50 ml distilled water and 15 ml acidified $KMNO_4$ was mixed thoroughly and again heated at 95^0C for half an hour. After cooling 6 ml hydroxylamine hydrochloride solution was added to reduce the excess permanganate. Samples were analyzed by using AAS with cold vapour technique after filtration with what man filter paper.

3.2 MONITORING PLAN

The monitoring has been performed in 21 cement industries (08 in Madhya Pradesh, 04 in Chhattisgarh and 09 in Rajasthan.) of Central Zone for assessment of mercury in source emissions. Water samples were also collected from nearby surface water bodies to find out the possibility of accumulation of Hg in water if any. Samples of raw materials and product were also collected to establish the source of mercury in process leading to environment.

Sample was collected in acidified $KMNO_4$ (10%H2SO4) from emission sources by using glass lined tube @ 2 LPM upto the maximum 100 liter gas.

3.3 FIELD OBSERVATIONS

The monitoring was conducted in 21 cement plants and major observations during monitoring was as under-

1. It was observed that indigenous coal is being used in majority of cement plants. The breakup of industries based on nature of coal used may be taken as Indigenous coal (11), imported coal (03) and pet coke (07).

2. In most the industries maximum coal was found stored openly and Hg parameter was not included in coal analysis report.

3. Most of the industries were found storing rain water in to limestone mining pit and quantity of water stored was more than yearly requirement.

4. Most of the industries have installed bag houses on raw mill kiln stack and ESP in clinker cooler stack.

5. Co-incineration facility was found installed in 08 cement plants out of 21 monitored.

6. The temperature variation in raw mill kiln stack was found between 80^{o}C to 141^{o}C and in clinker cooler stack 105^{o}C to 241^{o}C.

7. All cement plants monitored were found operational on dry process.

8. Only solid streams (fresh feed and coal/pet coke) were analyzed for their mercury content.

Chapter-04

DATA ANALYSIS

4.1 DATA PRESENTATION

All samples collected from monitoring of 21 cement industries were analyzed in CPCB laboratory and analysis results were compiled. The same is presented in the following table.

Case number	Location	APCD	Fuel Used	PM in mg/Nm3	Hg Mg/NM^3	Hg concentration (mg/kg) in solid sample	
01	Kiln	BGH	Coal & Pet Coke	108	0.030	Raw Mix	0.017
	Cooler	ESP		128	0.036	Coal	0.007
						Pet Coke	0.021
						Clinker	BDL
02	Kiln no.	BGH	Coal & Pet Coke	123	0.041	Raw Mix	0.124
	Cooler	ESP		113	0.153	Clinker	0.743
03	Kiln	BGH	Coal & Pet Coke	87	0.002	Raw Mix	BDL
	Cooler	ESP		91	0.003	Coal	BDL
						Pet Coke	0.014
						Clinker	BDL
04	Kiln	BGH	Pet Coke	22	0.050	Raw Mix	15.443
	Cooler	ESP		36	0.300	Pet Coke	8.306
						Clinker	2.305
05	Kiln	BGH	Coal	37	0.020	Raw Mix	BDL
	Cooler	ESP		28	0.050	Coal	3.047
						Clinker	0.012
06	Kiln 01	BGH	Imported Coal & Pet Coke	117	0.003	Raw Mix	BDL
	Cooler 2	ESP		92	0.056	Imported Coal	0.112
						Pet Coke	0.017
						Clinker	0.023
07	Kiln	BGH	Pet Coke	47	0.609	--	--
	Cooler	ESP		51	12.563	--	--
08	Raw mill kiln	BGH	Coal	39	0.008	--	--
09	Raw mill kiln	BGH	Coal	51	0.087	Coal	0.025
	Cooler stack	ESP		22	--		
10	Raw mill stack	BGH	Pet Coke	86	0.001	Raw Mix	0.011
	Cooler stack	ESP		102	2.382	Pet Coke	BDL
						Clinker	BDL
11	Raw mill stack	BGH	Imported Coal & Pet Coke	31	0.005	Raw Mix	0.056
	Cooler stack	ESP		42	1.387	Imported Coal	10.422
						Pet Coke	0.119
						Clinker	8.971
12	Raw mill	BGH	Coal	56	0.031	Raw Mix	0.053
	Cooler	ESP		48	0.224	Coal	BDL
						Clinker	BDL
13	Raw mill	---	Coal	91	0.003	Raw Mix	BDL
	Cooler stack	ESP		103	0.962	Coal	1.165
						Clinker	0.070
14	Raw mill-02	BGH	Coal	39	0.001	---	---
	Cooler	ESP		--	--	---	---
15	Raw mill	BGH	Pet Coke	59	0.003	Raw Mix	BDL
	Cooler stack	ESP		63	1.388	Pet Coke	0.114
						Clinker	0.015

16	Raw mill Stack	BGH	Coal & Imported Coal	71	0.501	Raw Mix	BDL
						Coal	1.387
						Imported Coal	20.40
						Clinker	8.38
17	Raw mill	BGH	Coal	61	0.532	Raw Mix	0.111
	Cooler	ESP		69	0.690	Coal	BDL
						Clinker	BDL
18	Raw mill	BGH	Coal	118	0.001	Raw Mix	BDL
	Cooler stack	ESP		72	0.790	Coal	0.158
						Clinker	BDL
19	Raw mill-1 stack	BGH	Coal	82	0.023		
	Cooler	ESP		76	0.009		
20	Raw mill stack	ESP	Coal	41	0.020	Raw Mix	0.030
	Cooler	ESP		35	0.240	Coal	0.649
						Clinker	0.049
21	Raw mill	BGH	Coal	183	0.030	Raw Mix	BDL
	Cooler	ESP		152	0.519	Coal	0.941
						Clinker	0.195

BGH- Bag house, ESP= electrostatic precipitator, BDL= 0.002 µg/l

4.2 DATA INTERPRETATION

The data obtained from analysis of samples indicate that

- Mercury concentration in emission from raw mill Kiln varies from 0.001 to 0.790 mg /NM^3 whereas in clinker cooler it varies from 0.003 to 12.5 mg /NM^3. It indicates that emission of mercury from the process may be mainly from clinker cooler stack.
- In order to locate source of mercury in cement process, solid samples of various constituents were also collected. The results obtained indicate that mercury concentration in coal varies from0.007 to 3.047 mg/kg.
- Mercury concentration in imported coal was found varying from 0.112 mg/kg to 20.40 mg/kg.
- Mercury concentration in pet coke was found varying from 0.014 mg/kg to 8.306 mg/kg.
- Mercury concentration in raw mix was found varying from 0.017 mg/kg to 15.44 mg/kg.
- Mercury concentration in clinker was found varying from 0.012 mg/kg to 8.971 mg/kg. The very high concentration of mercury in clinker was found only in two cases where mercury concentration in imported coal was observed between 10.422 – 20.40 mg/kg. The data indicates that mercury concentration in clinker is always with respect to mercury content in the raw mix or fuel like imported coal, indigenous coal or pet coke.

4.3 OUTCOME OF THE PROJECT

The study undertaken was at primary stage just to find out qualitative presence of mercury in cement process. The mode and method of the study was formulated based on the technical information available in the literature and requirement of further modification and improvement in method cannot be ruled out. The results obtained after monitoring of 21 industries indicate the qualitative presence of mercury in the emission of cement plant. The probable main source of the mercury may be the fuel used in process i.e. , imported coal, indigenous coal and pet coke.

4.3 RECOMMENDATIONS

Based on the field experience and trend of data obtained it is recommended that the study shall be continued with more comprehensive vision and specific case study. In order to derive contribution of mercury from various raw materials and its pathway further validation of monitoring may be continued keeping the following points-

1. Monitoring of source emission on raw mill off and on condition.
2. Monitoring of oxygen for applying oxygen correction factor.
3. Collection of solid samples from GCT, Cooler ESP dust and kiln accretion.

In addition to above cement industries may install suitable instrument for monitoring and analysis of mercury in their raw material as well as in emission. The data generated shall be useful in formulation of emission standards in future.

Chapter-05

WAY FORWARD

5.1 FURTHER SCOPE OF STUDY

The information and data presented in this report and other studies presented in reference demonstrate that mercury does not simply volatilize from the fuel and raw materials to directly leave the system through the stack. High dedusting system can be achieved with electrostatic precipitator and bag filter. The reduction of dust emissions is very important in terms of reducing heavy metals. Fractions of many metals leave the kiln with the emitted dust particles. Nevertheless, contrary to common opinion, the upgrading of dedusting equipment may not provide an effective solution to the capture of mercury since it is mainly emitted in vapour form from the cement kiln stack. Literature PCA (PCA, 1992) reveals that the fraction of mercury present in the particle bound form is only 0.07%.

Data generated from the study indicates qualitative presence of mercury in the raw material and emission of cement industries but insufficient to prepare mercury mass balance. In order to prepare complete inventory of mercury in cement process monitoring in following areas are required.

1. Mercury emission monitoring in Kiln+ raw mill and clinker cooler stack at raw mill on condition and raw mill off condition.
2. Mercury estimation in solid samples from GCT, Cooler ESP dust and kiln accretion.
3. Mercury estimation in solid samples of all raw materials, clinker, fly ash and cement.

The present study may be useful to initiate further studies for formulation of standards, industries for considering control option and research scholars for its impacts on environment and habitation.

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5.3 PHOTOGRAPHS OF MONITORING

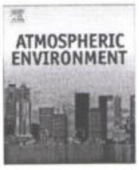
5.4 LITERATURE

Atmospheric Environment 62 (2012) 265–271

Contents lists available at SciVerse ScienceDirect

Atmospheric Environment

journal homepage: www.elsevier.com/locate/atmosenv



Estimation of total annual mercury emissions from cement manufacturing facilities in Korea

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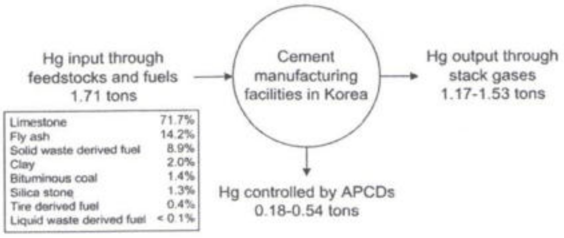
HIGHLIGHTS

- ► Mercury concentrations of stack gases from cement kiln were measured.
- ► Feedstocks and fuels used in cement kiln were analyzed for their mercury contents.
- ► Majority of mercury input were released to the atmosphere without being controlled.
- ► Total annual mercury emissions from cement manufacturing facilities were estimated.
- ► Cement manufacturing facilities are one of major sources of mercury emissions.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 17 June 2012
Received in revised form
13 August 2012
Accepted 15 August 2012

Keywords:
Mercury
Cement manufacturing facility
Cement kiln
Combustion flue gas
Ontario Hydro Method
Continuous emission monitor

ABSTRACT

This study examined mercury (Hg) emissions from cement manufacturing facilities in Korea. Hg concentrations in stack gases from a kiln at the largest cement manufacturing facility (CMF) in Korea were measured using three different methods: a wet-chemical method and on-line measurements with two different types of conversion systems ($SnCl_2$ and thermal) attached in front of each analyzer. The Hg concentrations of the feedstocks and fuels were then analyzed to determine the total amount of Hg input into CMFs and how much each material contributed to the Hg input. The total annual Hg input into all CMFs in Korea was estimated to be 1.71 tons, while the total annual Hg emissions estimated from the stack-gas measurement was 1.17–1.53 tons, indicating that 68–89% of total Hg input is released into the atmosphere. Therefore, more stringent regulation and effective control technologies should be applied to the CMFs to reduce Hg emissions.

1. Introduction

Thanks to extensive efforts by the Governing Council of the United Nations Environment Programme (UNEP), a legally binding international mercury (Hg) treaty is in progress and is expected to be signed in 2013 in Minamata City, Japan. Upon implementation, all participating countries are expected to report their domestic total Hg emissions to the UNEP regularly. Although the creation of provisions regarding atmospheric Hg emissions is still in progress, it is important to identify the major sources of Hg emissions in the domestic sphere.

Coal-fired utility boilers are currently considered to be the largest anthropogenic source of atmospheric Hg both in Korea (NIER, 2008; Pudasainee et al., 2009; Kim et al., 2010) and worldwide (Pacyna et al., 2006; Wilson et al., 2006; Nelson, 2007; Glodek

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http://dx.doi.org/10.1016/j.atmosenv.2012.08.035

and Pacyna, 2009; Pacyna et al., 2010). Numerous studies have been conducted on the analysis and control of Hg emissions from coal-fired power plants (Senior et al., 2000; Jeon et al., 2008; UNEP, 2008a and 2008b; Sundseth et al., 2010). However, little attention has been paid to Hg emissions from cement manufacturing facilities (CMFs). In fact, CMFs are the fourth largest source of global anthropogenic Hg emissions, after coal-fired utility boilers, artisanal gold mines, and nonferrous metal production facilities. Only recently have efforts begun to reduce the release of Hg from CMFs.

In 2010, the US Environmental Protection Agency (EPA) proposed a regulation that would require a 94% reduction in the current Hg emission rate at CMFs in the US. This rule stated that existing CMFs would be limited to a 30-day rolling average of 55 pounds of Hg per million metric tons of clinker produced, while newly constructed facilities (constructed after May 6, 2009) would be limited to 21 pounds of Hg per million metric tons of clinker (Federal Register, 2011). Since the early 2000s, the European Union (EU) has also placed a similarly strict Hg regulation on cement producers, limiting emissions to 44–132 pounds per million metric tons of clinker (Neundorfer, 2010). Many other countries limit Hg emissions based on the Hg concentration in stack gases from kilns (Renzoni et al., 2010). Canada limits Hg emissions to stack concentrations of 0.15 mg m^{-3} for cement kilns using wastes as fuel (CCME, 1998; Smith, 2006).

In Korea, the current Hg emission regulation for CMFs is set at an effluent concentration of 0.1 mg m^{-3}. Due to the fact that the current regulation concerns stack gas Hg concentration rather than the total amount of Hg emitted from the facility, CMFs are still the third-largest anthropogenic source of atmospheric Hg in Korea after coal-fired power plants and petroleum refining facilities. Efforts must be made to reduce Hg emissions from CMFs because Korea is the seventh largest cement-producing country in the world.

The accurate and continuous monitoring of Hg emissions from CMFs are essential to the successful implementation of aggressive new domestic regulations, as well as adherence to the upcoming international Hg treaty in 2013.

There are four major types of cement manufacturing processes: long-wet, long-dry, preheater, and precalciner. For long-wet process, feedstock slurry enters the kiln where drying, calcining and sintering all takes place inside the kiln. Long-dry process is same as long-wet process except the dry feedstocks are entered into the kiln. Cement manufacturing processes have been improved over time and for efficient energy use, long-wet and long-dry processes are gradually being shut down and replaced by preheater/precalciner facilities. A typical cement manufacturing process is divided into three fundamental stages: (1) preparation of feedstocks, (2) production of clinker, and (3) production of cement. The feedstock preparation step includes the quarrying, crushing, and milling of raw materials, most of which are composed of limestone. Once feedstocks are milled, they are homogenized in a silo and held until they are needed in the next stage. Most chemical reactions, including the desorption of Hg, occur in the cement kiln, which is heated to approximately 1450 °C (Mlakar et al., 2010; Sikkema et al., 2011; Zheng et al., 2012). Once clinker is produced from the feedstock inside the kiln, clinker nodules are then milled and mixed with other materials to produce cement.

In this study, Hg concentrations in stack gas from a cement kiln were first measured using the following procedures: (1) the Ontario Hydro Method (OHM; ASTM International, 2002) and (2) direct measurement using a cold vapor atomic absorption spectrometer (CVAAS) Hg analyzer in conjunction with a Hg^{2+} to Hg^0 conversion system. Next, feedstocks and fuels were analyzed to examine their Hg content and individual contribution to the total Hg input to the cement kiln. Finally, the total annual Hg emissions from CMFs located in Korea were estimated using field-measurement data and statistical data provided by the Korea Cement Association (KCA).

2. Materials and methods

2.1. Hg analysis of stack gas

Hg analysis of stack gas was conducted at the largest cement factory in Korea, which has an annual cement production of 7.2 million tons. There are seven cement kilns at this site, and the analysis was conducted at the largest of these kilns, which uses a preheater process and has a clinker manufacturing capacity of 290 ton h^{-1}. Fig. 1 shows the basic layout of the preheater cement manufacturing process. Once feedstocks enter the raw mill, a fine powder called raw meal is created and stored in homogenizing silos until the powder is introduced into the preheater. In a preheater tower, the raw meal is intermixed and preheated with the exhaust gases from the kiln for efficient energy use. The exhaust gases from the preheater then go to the raw mill, where incoming feedstocks are dried. Finally, the exhaust gasses are passed through an air pollution control device (APCD) and released into the atmosphere through the stack. The dust collected in the APCD is recycled back to the homogenizing silo and used as a component in the feedstocks. After the feedstocks are passed through the preheater, they undergo chemical reactions that produce clinker in the kiln, where the temperature reaches approximately 1450 °C. Once clinker is produced from the feedstock inside the kiln, clinker nodules are then milled and mixed with other materials to produce cement.

Hg measurements were conducted at such a stack. APCDs at this facility are consisted of a bag filter, electrostatic precipitator (ESP), and selective non-catalytic reduction (SNCR) system. Hg concentrations in the stack gas were measured using both CVAAS analysis of a stack gas sample collected by OHM and on-line Hg measurements with two different types of conversion systems ($SnCl_2$ and thermal) attached in front of each Hg analyzer.

During the OHM sampling procedures, stack gas was passed through eight impingers in series placed in an ice bath. Each impinger contained a different solution for absorbing different Hg species. First, three impingers containing KCl solution collected Hg^{2+}. Hg^0 was collected using H_2O_2–HNO_3 and $KMnO_4$–H_2SO_4 solutions contained in the fourth and the following three impingers, respectively. The last impinger contained silica gel, which removed moisture from the gas stream prior to the gas entering the dry-gas pump. After the collection of stack gas

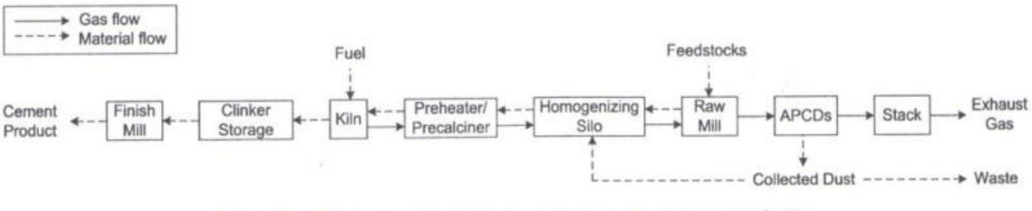

Fig. 1. Schematic diagram of a preheater/precalciner cement manufacturing facility.

samples, the Hg in the absorbing solutions was recovered using acids. Finally, the sample-containing solution was diluted and analyzed further using a CVAAS-type Hg analyzer (RA-915$^+$, Lumex Ltd., St. Petersburg, Russia).

Two identical Hg analyzers (VM-3000, Mercury Instruments, Karlsfeld, Germany) were used for the on-line Hg measurement. VM-3000 is a CVAAS-type Hg analyzer with a measuring sensitivity of 0.1 μg m^{-3}. While different chemical forms of Hg—elemental (Hg^0), oxidized (Hg^{2+}) and particulate (Hg^P)—are found in flue gas, the CVAAS-type Hg analyzer is capable of measuring only Hg^0. Therefore, it is necessary to convert Hg^{2+} to Hg^0 prior to the on-line measurement. Currently, the conversion of Hg^{2+} to Hg^0 utilizing either a $SnCl_2$ solution or a thermal conversion system is most frequently used in conjunction with a continuous Hg emission monitor (Hg CEM) (Laudal et al., 2004; US EPA, 2007a). A Hg CEM can provide continuous monitoring of Hg with significantly less time delay, labor, and cost than the conventional wet chemistry-based methods. For the $SnCl_2$ conversion system, a fresh solution was prepared daily by dissolving 10 g of $SnCl_2$ in a mixed solution of 100 mL deionized (DI) water and 1.8 mL concentrated H_2SO_4. As for the thermal conversion system, neither chemical nor mechanical parts required regular replacement. This system heated the sample gas stream to above 800 °C, at which all Hg compounds are reduced to Hg^0. Calibrations were performed regularly for all the Hg analyzers used in this study.

2.2. *Hg analysis of feedstocks and fuels*

Samples of feedstocks and fuels used at the measuring site were collected over a 4-week period, including limestone, clay, fly ash, silica stone, bituminous coal, and solid waste derived fuel. Data on the additional types of feedstocks and fuels used, such as residual fuel oil, petroleum coke, refined oil, regenerated oil, waste oil, tire-derived fuel, waste rubber, and refuse plastic fuel (RPF), were provided by KCA. Ten samples of each material were collected and analyzed for their Hg content. The US EPA Method 7471B (Park et al., 2006; US EPA, 2007b) was used for solid samples, while the BrCl extraction method was used for oil samples.

In preparing solid samples, a collected sample was pulverized into fine powder and sieved with a mesh size of 45 μm. 0.5 g of the sample was then placed in a vial, to which a mixture of 5 mL DI water and 5 mL aqua regia was added. This solution was heated for 2 min at 95 °C and a mixture of 50 mL DI water and 15 mL $KMnO_4$ solution was added. Once the purple color of the sample solution remained for more than 15 min, the sample was heated again for another 30 min at 95 °C. Then, a $(NH_2OH)_2 \cdot H_2SO_4$ solution was added to reduce excess permanganate. Finally, the Hg concentration of each sample was measured three times using an RA-915$^+$ Hg analyzer.

The BrCl extraction method was used for oil samples because previous studies have shown that the BrCl extraction method is more accurate than the acid extraction method for analyzing total Hg from petroleum products (Wilhelm et al., 2006; Won et al., 2007). A 5-mL aliquot of oil sample was mixed with 12 mL of BrCl solution. After 30 min of vigorous shaking of the mixed solution, a clear separation of two phases was observed. The aqueous phase was then taken for analysis with an RA-915$^+$ Hg analyzer.

The Hg inputs into the cement kiln at the test site (over a 4-week period) and all CMFs in Korea (2010) were estimated based on the Hg content of each material. The input amounts of each material, which are also necessary for the estimation of Hg input, were provided by the KCA (2011a,b) and the company operating the CMF at which the measurements were conducted.

2.3. *Estimation of Hg emissions from cement manufacturing facilities in Korea*

The estimation of the total annual Hg emissions from all CMFs in Korea was conducted based on the Hg concentrations measured in stack gases. Additional data necessary for the estimation of Hg emissions were also provided by KCA and the company operating the CMF at the test site. The clinker production rate of the corresponding kiln was provided by the cement company, whereas the flow rate of the stack gas was measured by a telemonitoring system (TMS) installed in the stack. The total annual production rate of clinker in Korea was provided by the KCA (2011a,b). There are 51 individual cement kilns in 13 CMFs in Korea, with a total annual production of approximately 48 million tons of cement and 45 million tons of clinker.

3. Results and discussion

3.1. *Hg concentration in stack gas from a cement kiln*

During the 4-week measurement period, a total of fourteen measurements were performed using the OHM. The Hg concentrations in stack gases fell within the range of 0.89–17.89 μg m^{-3} with significant fluctuations (Fig. 2). The average Hg concentration in stack gas from the cement kiln was 10.14 μg m^{-3}. The average Hg^{2+} concentration was 1.52 μg m^{-3} while the average Hg^0 concentration was 8.62 μg m^{-3}. As for Hg^P, negligible amount of Hg^P was detected for all fourteen OHM analyses. The fluctuation in Hg concentrations may have been caused by fluctuations in the Hg contents of the input materials (feedstocks and fuels) and the operating conditions of the APCDs, among other factors. The condition of the raw mill is another important factor determining Hg emissions from cement kilns. Modern CMFs have inline raw mills that use exhaust gases from the preheater/precalciner to dry the raw meal. Typical raw mills are operated for 80–90% of the kiln operating time (DEQ, 2007). When the raw mill is shut off, the exhaust gases are routed directly to the main filter. Significant fluctuations in Hg emissions have been observed due to this practice, with higher Hg emissions occurring when the raw mill is off (Schreiber and Yonley Associates, 2007; Schreiber and Kellett, 2009). Hg present in the exhaust gas from the kiln and preheater is condensed and adsorbed on the dust and raw mix particles in the raw grinding mill. This condensation and adsorption of Hg result in lower Hg emissions through the stack when the kiln gas is used for drying in the raw mill. Although Hg concentrations varied from

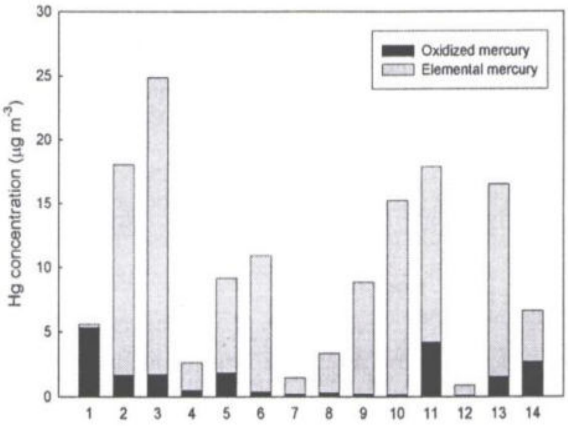

Fig. 2. Hg concentrations in stack gases at cement kiln measured by the Ontario Hydro Method.

measurement to measurement, the results indicated that most of the Hg was in the elemental form. A negligible amount of Hg^p was found in all measurements conducted.

Figs. 3 and 4 show the Hg concentrations measured by the on-line Hg analyzers with $SnCl_2$ solution and the thermal conversion system attached in front, respectively. Because only a negligible amount of Hg^p had been detected by the OHM, the on-line Hg measurement was carried out only for gaseous Hg (Hg^0 and Hg^{2+}). Furthermore, the Hg concentrations were monitored continuously except for the period of daily calibration and maintenance, which took about 3 h. Thus, the averaging time was about 21 h for each data point. As in the OHM analysis, fluctuations in Hg concentration were observed with both on-line analyzers. The average Hg concentrations measured using the $SnCl_2$ and thermal conversion systems were 13.3 and 12.9 $\mu g\ m^{-3}$, respectively. The results were in agreement with each other, with only a 3% difference. However, slightly larger differences in measurements between the OHM and the on-line Hg measurements with two different conversion systems were observed. This difference was probably due to the inherent disadvantages of the OHM: (1) an analysis throughout the entire procedure (which is time-consuming and complicated) using the OHM provides only one data point, and (2) quality control of the OHM is extremely difficult because the procedure heavily relies on human skills and is prone to human error. Increasing the number of analyses would be one way to minimize the deviations caused by these disadvantages. Considering the operating cost, time, and expert knowledge necessary to run the OHM properly, using a Hg CEM would be a more reasonable option.

The flow rate of the stack gas was measured using a TMS installed at the stack, and the 4-week average flow rate was 741,500 $m^3\ h^{-1}$. Using this value, the hourly Hg emission rates were calculated to be 9.86, 9.57, and 7.52 $g\ h^{-1}$ using the measurement data obtained by using the on-line Hg analyzer with a $SnCl_2$ conversion system, the on-line Hg analyzer with a thermal conversion system, and the OHM, respectively. It should be noted that the estimation of annual Hg emissions based solely on the hourly Hg emission rate is inaccurate because cement kilns typically do not operate at full capacity throughout the year. For example, business is usually slow for the construction industry in Korea during the winter, and consequently, the cement production rate and cement kiln operation time are reduced as well. Therefore, more comprehensive and accurate data are necessary to estimate the total annual Hg emissions from the entire CMFs in Korea.

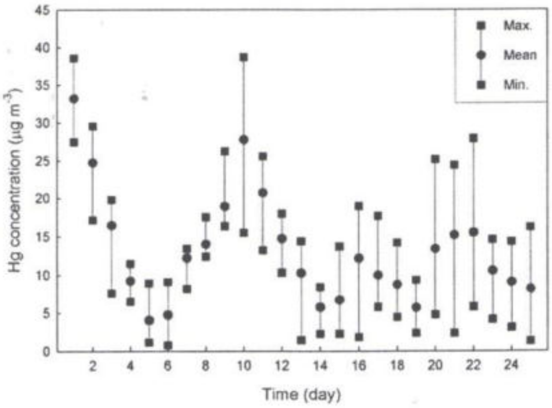

Fig. 3. Hg concentrations in stack gases at cement kiln measured by on-line Hg analyzer with $SnCl_2$ conversion system attached in front.

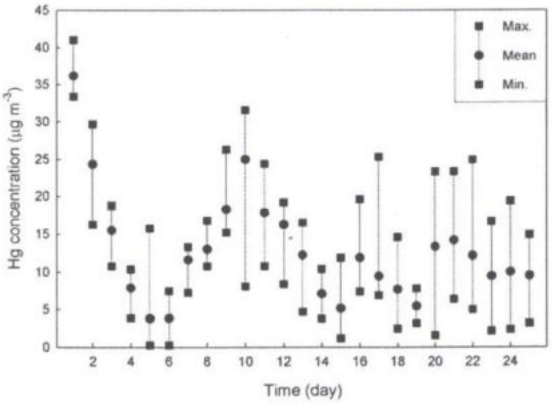

Fig. 4. Hg concentrations in stack gases at cement kiln measured by on-line Hg analyzer with thermal conversion system attached in front.

3.2. *Hg contents of feedstocks and fuels*

In most cases, limestone is the most abundant material in a cement kiln, making up approximately 85% of the total feedstock. Several studies (Johansen and Hawkins, 2003; Hills and Stevenson, 2006; US EPA, 2009) have suggested a correlation between Hg content in limestone and Hg concentration in stack gases from cement kilns. A 97% linear correlation was observed when the Hg content of limestone was abnormally high (over 500 ppb). However, after eliminating the data obtained from limestone with unusually high Hg content, the linear correlation between the Hg content of limestone and the Hg concentration in stack gas was reduced to 14%. This difference suggests that the Hg emissions from a cement kiln should not be estimated solely based on the Hg contents of feedstocks.

The Hg contents of feedstocks and fuels used in the kiln at the test site (limestone, clay, fly ash, silica stone, bituminous coal, and solid waste derived fuel) were analyzed to examine their relative contributions to the total Hg input to the cement kiln. For the calculation of Hg input estimates, only those used in the production of clinker (not cement) were considered because most Hg desorption occurs during the clinker production rather than the subsequent cement production. Ten samples were collected and analyzed for each of the feedstocks and fuels during the 4-week period (Fig. 5). It can be seen in Fig. 5 that the Hg contents of the individual constituents of feedstocks and fuels significantly differ from each other, which explains the fluctuation in Hg emission measurements observed in the previous section because the homogeneity of feedstocks and fuels is very difficult and almost impossible to maintain continuously. The inhomogeneity of feedstocks and fuels indicates the inhomogeneity of the Hg introduced into the cement kiln. The highest average Hg content (221 $ng\ g^{-1}$) was obtained from solid waste derived fuel with a range of 100–570 $ng\ g^{-1}$. The Hg contents of fly ash, limestone, silica stone, clay, and bituminous coal were in the range of 30–390, 4.9–79.1, 3.4–21.6, 5.6–12.8, and 4.0–7.7 $ng\ g^{-1}$, respectively. All average Hg content values are listed in Table 1.

The Hg contents of materials (liquid waste derived fuel, and tire derived fuel) that are used in other CMFs were then analyzed to examine their relative contributions to the total annual Hg input to all CMFs in Korea. The corresponding kiln uses liquid waste derived fuel only when the kiln is shut down for maintenance and the burner needs to be reignited. During the 4-week test period, liquid waste derived fuel was not used in the corresponding kiln.

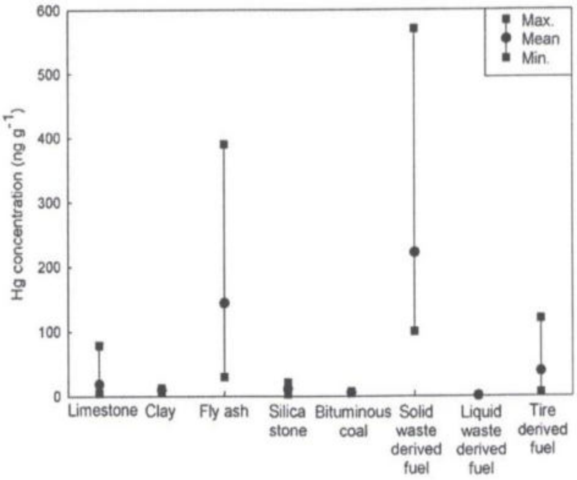

Fig. 5. Hg concentrations of feedstocks and fuels measured by a CVAAS analyzer.

For the analysis of liquid waste derived fuel and tire derived fuel, ten samples of each material were collected and analyzed for their Hg content, and the results are also shown in Fig. 5. The liquid waste derived fuel showed the average Hg content of 0.6 ng g^{-1} with a range of 0.2–1.0 ng g^{-1}. The Hg content of tire derived fuel was 6.1–120.1 ng g^{-1}, with average value of 39.2 ng g^{-1}.

The quantities of feedstocks and fuels introduced into the cement kiln during the 4-week period were 342,796 and 25,593 tons, respectively, and the annual consumption of feedstocks and fuels by all cement kilns in Korea was 71,373,800 and 5,594,112 tons, respectively. As shown in Table 1, the fractions of individual material to the total material input (feedstocks and fuels) were similar in the corresponding kiln and in all cement kilns in Korea, with limestone making up more than 80% of the total material. Bituminous coal was the main source of fuel for all CMFs, including the kiln studied here, with a small percentage of alternative fuels used with the intention of recycling wastes.

Using the analyzed Hg content and the input amount of each material, the Hg input amount and its contribution to the total Hg input was calculated for both the kiln studied here and all CMFs in Korea. These results are shown in Table 1. During the 4-week study period at the test site, the Hg input and the relative contribution of limestone were 5.71 kg and 63.2%, respectively. As for fly ash, solid waste derived fuel, clay, bituminous coal, and silica stone, their inputs and contributions were 2.03 (22.5%), 0.85 (9.4%), 0.26 (2.9%), 0.15 (1.7%), and 0.03 kg (0.3%), respectively. The total amount of Hg input during the 4-week period was 9.03 kg. For all CMFs, the annual contribution by each of the feedstocks and fuels to the total Hg input was not considerably different from the contribution of these materials at the kiln being studied. Limestone was the largest Hg input, at 1228.46 kg (71.7%). As for fly ash, solid waste derived fuel, clay, bituminous coal, silica stone, tire derived fuel, and liquid waste derived fuel, their contributions were 243.03 (14.2%), 152.62 (8.9%), 34.26 (2.0%), 24.79 (1.4%), 22.53 (1.3%), 6.50 (0.4%), and 0.40 kg (less than 0.1%), respectively. The total amount of Hg input in 2010 was 1.71 tons. These results indicate that limestone is the material most heavily responsible for the Hg emissions from CMFs, being the largest single material input into the kiln. It is important to note here that fly ash, with a relatively small material input of 2.03% and 2.19% in the test kiln and all CMFs, respectively, was a surprisingly large contributor to the Hg input because of its high Hg content.

3.3. *Estimates of total annual Hg emissions from cement manufacturing facilities in Korea*

Before estimating the total annual Hg emissions from CMFs in Korea, the amount of Hg released to the atmosphere per ton of clinker produced was calculated by dividing the amount of Hg emitted with the amount of clinker produced during the 4-week study period, and came to 195,000 tons. The amount of Hg emitted was calculated to be 26–34 mg per ton of clinker produced. To compare these numbers with the US EPA regulation on CMFs, the units are converted to pounds per million metric tons, which results in 57–75 pounds of Hg per million metric tons of clinker produced. Considering the fact that the new US EPA rule places the limit at 55 pounds of Hg per million metric tons of clinker produced for existing CMFs, more effort is needed to reduce Hg emissions from CMFs in Korea.

The total Hg emission from the cement kiln during the 4-week study period was calculated by multiplying 672 h (4 weeks) by the hourly Hg emission rate. During the 4-week period, 6.63 kg of Hg was released into the atmosphere based on the measurements made using the $SnCl_2$ conversion system. The thermal conversion system and the OHM gave 6.43 and 5.05 kg, respectively. By comparing these values with the estimated amount of Hg input, it is clear that 56–73% of the total Hg input was released into the atmosphere through the stack.

After finding the amount of Hg released to the atmosphere per ton of clinker produced, the total annual Hg emission from CMFs in Korea was calculated by a simple multiplication with the annual clinker production. The annual clinker production in Korea for the year 2010 was 44,835,095 tons, so annual Hg emissions of 1.17–1.53 tons were thus calculated. Previous research by National Institute of Environmental Research (Korea) has shown that

Table 1
Analyzed Hg concentrations, material and Hg input amount, and Hg contribution of each material.

Input type	Material type	Hg conc. (ng g^{-1})[a]	Measuring CMF[b]				Entire CMFs in Korea[c]			
			Input amount (ton)	Fraction to total input (%)	Hg input (kg)	% Hg contribution	Input amount (ton)	Fraction to total input (%)	Hg input (kg)	% Hg contribution
Feedstock	Limestone	19.1	299,849	80.85	5.71	63.2	64,317,195	83.56	1228.46	71.7
	Clay	10.1	25,593	6.90	0.26	2.9	3,392,429	4.41	34.26	2.0
	Fly ash	144.0	14,077	3.80	2.03	22.5	1,687,698	2.19	243.03	14.2
	Silica stone	11.4	3065	0.83	0.03	0.3	1,976,478	2.57	22.53	1.3
Fuel	Bituminous coal	6.1	24,442	6.60	0.15	1.7	4,063,182	5.28	24.79	1.4
	Solid waste derived	221.0	3837	1.03	0.85	9.4	690,598	0.90	152.62	8.9
	Liquid waste derived	0.6					674,739	0.88	0.40	<0.1
	Tire derived	39.2					165,593	0.21	6.50	0.4

[a] Averaged value.
[b] Based on the 4-week test period.
[c] For entire cement manufacturing facilities in Korea during 2010 provided by the Korea Cement Association.

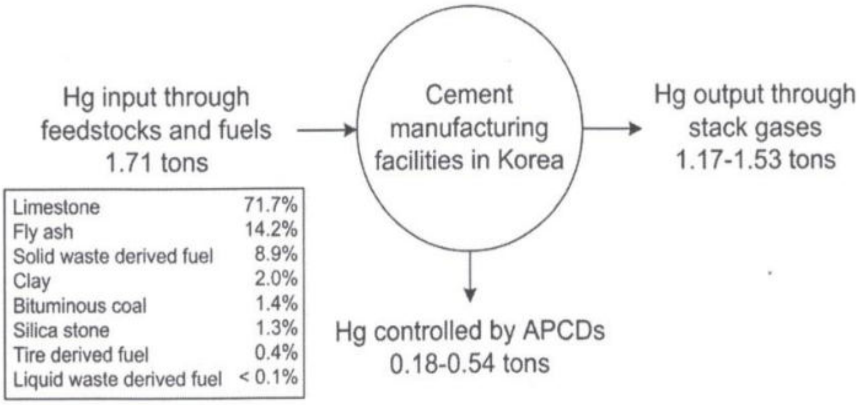

Fig. 6. Graphical representation of total annual Hg emissions estimated for the entire cement manufacturing facilities in Korea.

12.81 tons of Hg is emitted annually from anthropogenic sources in Korea (NIER, 2008). Based on this study, the estimated amount of 1.17–1.53 tons of Hg per year from CMFs corresponds to 9–12% of total Hg emissions in Korea, making it one of the major anthropogenic sources of Hg emissions. Furthermore, comparing the Hg input amount of 1.71 tons with the emissions suggests that the majority of Hg input, namely 68–89%, is released into the atmosphere without being captured or controlled by APCDs. Since clinker, the only material output from a cement kiln, can be assumed free of mercury (Schreiber et al., 2005; US EPA, 2009), the results suggest that 0.18–0.54 tons of Hg is captured by APCDs. Fig. 6 is the graphical representation of Hg transport through all CMFs in Korea based on the estimated values. These results signify that more rigorous Hg emission regulation and control must be applied to CMFs in Korea.

Because all 51 cement kilns at 13 manufacturing plants in Korea use similar processes (preheater/precalciner) and the experiment was conducted at the largest cement plant in the country, the 4-week Hg measurements conducted at this cement kiln can be considered to be representative of all the cement kilns in Korea. However, more research must be conducted to fully understand the fate of Hg in cement kilns and further improve current analysis and control techniques.

4. Conclusions

It is estimated that 1.17–1.53 tons of Hg are emitted annually from CMFs in Korea. Although further studies are necessary to fully understand the fate of Hg in a cement kiln, there is no doubt that the CMFs are one of the major sources of anthropogenic Hg emissions in Korea. The estimated annual Hg input of 1.71 tons also indicates that the majority of Hg input is released into the atmosphere without being captured or controlled by APCDs. These results suggest that more stringent Hg emission regulations in Korea must be implemented. Furthermore, The US EPA has recently implemented a new Hg regulation that will drastically reduce Hg emissions from CMFs. Limiting Hg emissions based on the amount of clinker produced is a better solution than limiting Hg emissions based on the Hg concentrations. Diluting the stack gas using a blower may lower the Hg concentration without any effort being put into the control of gaseous Hg emission. Thus, other countries including Korea need to implement Hg emission regulation based on the amount of Hg released rather than Hg concentrations. In addition, stringent Hg regulations on CMFs in the US alone, or in a few additional countries as well, may not be sufficient in reducing Hg emissions worldwide, especially from cement manufacturers. Instead of producing cement in compliance with the new stringent Hg regulations, one may be able to import cement from countries with less stringent or no Hg regulations at all, which will eventually increase global Hg emissions. This situation necessitates a joint international effort to reduce Hg emissions. Furthermore, the Republic of Korea, which is the 7th largest cement-producing country in the world, must take an active part in the global effort to reduce Hg emissions from CMFs.

Acknowledgment

This work was supported by the National Research Foundation of Korea (NRF) grant funded by the Korea government (MEST) (No. 2009-0079977).

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9. KILN INPUT: FUELS AND RAW MATERIALS IN CEMENT PRODUCTION

Mercury enters the cement manufacturing process as a trace element in the raw materials and the fuels.

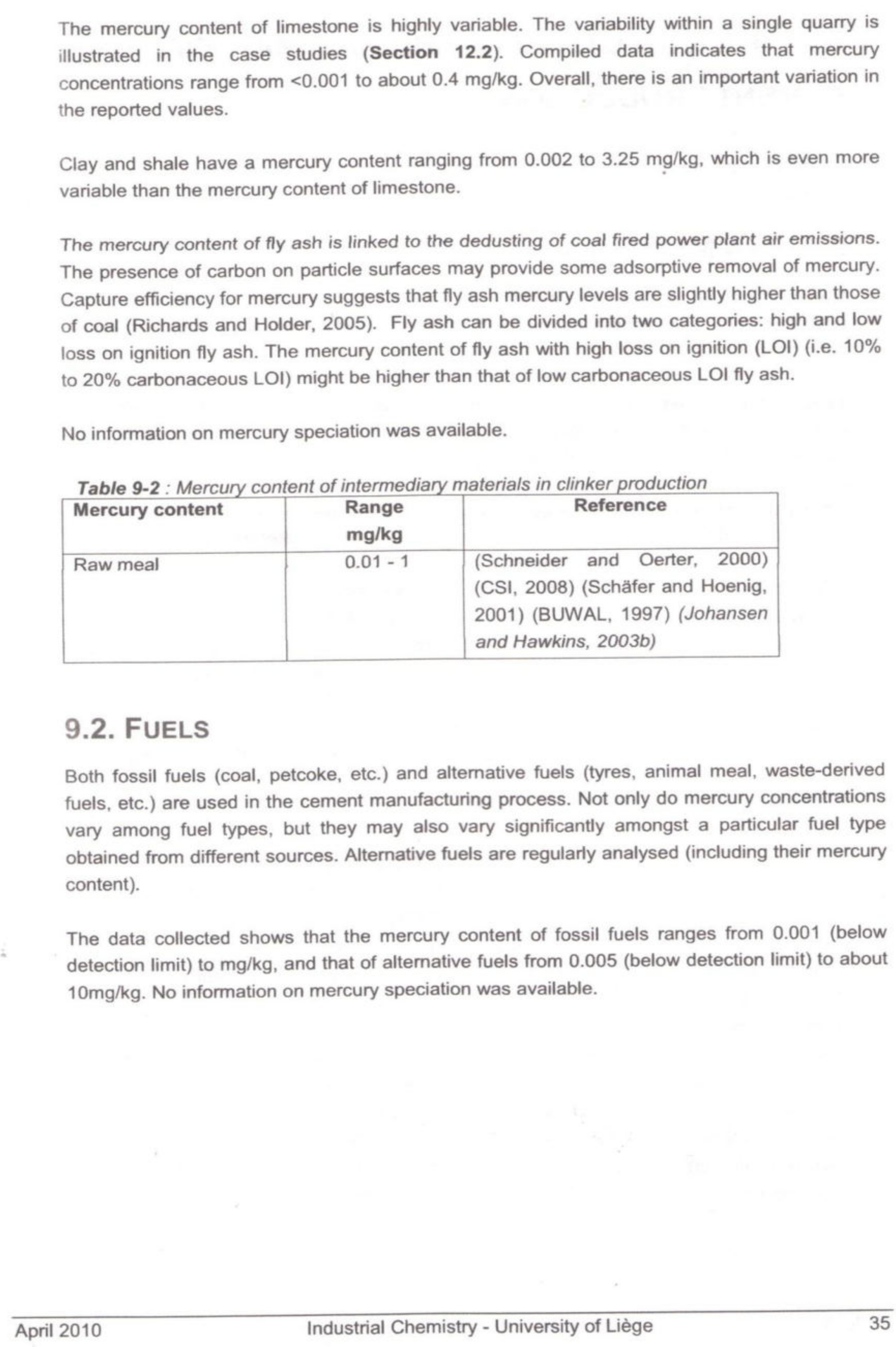
9.1. RAW MATERIALS

Mercury concentrations can vary significantly from one raw material to another and even within a single quarry. Limestone and clay are the main kiln feed constituents with fly ash capable of substituting up to 20% of these raw materials.

Table 9-1 (compiled using different sources) shows the mercury content of different raw materials extracted from quarries as well as other raw materials which are usually used in cement manufacturing, such as fly ash or other alternative materials.

Table 9-1 : Mercury content of materials used for cement production

Mercury content	**Range mg/kg**	**Reference**
Limestone, lime marl, chalk	<0.005 - 0.40	(Schneider and Oerter, 2000); (Sprung, 1985); (BUWAL, 1997); (Johansen and Hawkins, 2003b); (VDZ, 2008b) (CSI, 2008) (Cement_Company_A, 2008) (Hills and Stevenson, 2006)
Clay	0.002 - 0.45	(Schneider and Oerter, 2000) (CSI, 2008) (Hills and Stevenson, 2006) (Sprung, 1985) (Cement_Company_J, 2007)
Sand	< 0.005 – 0.55	(Cement_Company_A, 2008) (Hills and Stevenson, 2006)
Fly ash	< 0.002 – 0.8	(VDZ, 2008b) Adriano in (Johansen and Hawkins, 2003b) (Hills and Stevenson, 2006)
Iron ore	0.001 – 0.68	(Cement_Company_A, 2008)
Blast furnace slag	< 0.005 – 0.2	(Cement_Company_A, 2008)
Pouzzolana	< 0.01 – 0.1	(VDZ, 2008b)
Burned oil shale	0.05 – 0.3	(VDZ, 2008b)
Shale	0.002 – 3.25	(Hills and Stevenson, 2006) (Johansen and Hawkins, 2003b)
$CaSO_4$	< 0.005 – 0,02	(VDZ, 2008b)
Gypsum (natural)	< 0.005 – 0.08	(VDZ, 2008b)
Gypsum (artificial)	0.03 – 1.3	(VDZ, 2008b)
Aggregates	< 0.01 – 0.1	(VDZ, 2008b)



The mercury content of limestone is highly variable. The variability within a single quarry is illustrated in the case studies (**Section 12.2**). Compiled data indicates that mercury concentrations range from <0.001 to about 0.4 mg/kg. Overall, there is an important variation in the reported values.

Clay and shale have a mercury content ranging from 0.002 to 3.25 mg/kg, which is even more variable than the mercury content of limestone.

The mercury content of fly ash is linked to the dedusting of coal fired power plant air emissions. The presence of carbon on particle surfaces may provide some adsorptive removal of mercury. Capture efficiency for mercury suggests that fly ash mercury levels are slightly higher than those of coal (Richards and Holder, 2005). Fly ash can be divided into two categories: high and low loss on ignition fly ash. The mercury content of fly ash with high loss on ignition (LOI) (i.e. 10% to 20% carbonaceous LOI) might be higher than that of low carbonaceous LOI fly ash.

No information on mercury speciation was available.

***Table 9-2** : Mercury content of intermediary materials in clinker production*

Mercury content	**Range mg/kg**	**Reference**
Raw meal	0.01 - 1	(Schneider and Oerter, 2000) (CSI, 2008) (Schäfer and Hoenig, 2001) (BUWAL, 1997) *(Johansen and Hawkins, 2003b)*

9.2. FUELS

Both fossil fuels (coal, petcoke, etc.) and alternative fuels (tyres, animal meal, waste-derived fuels, etc.) are used in the cement manufacturing process. Not only do mercury concentrations vary among fuel types, but they may also vary significantly amongst a particular fuel type obtained from different sources. Alternative fuels are regularly analysed (including their mercury content).

The data collected shows that the mercury content of fossil fuels ranges from 0.001 (below detection limit) to mg/kg, and that of alternative fuels from 0.005 (below detection limit) to about 10mg/kg. No information on mercury speciation was available.

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Figure 12-6 presents the results of extensive research (VDZ, 2001b) into the mercury content of cement performed on more than 400 spot samples taken in 2001 for the quality surveillance of standard German cements. The average is 0.00006 mg Hg/g of cement.

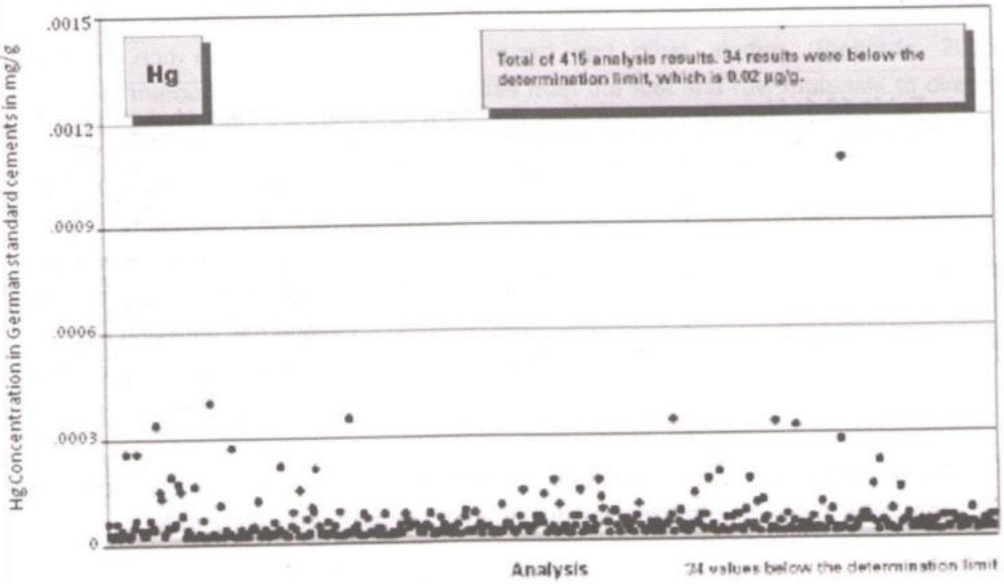


Figure 12-6: Mercury concentration in German standard cements; the determination limit was marked as a grey area to facilitate assessment (VDZ, 2001b).

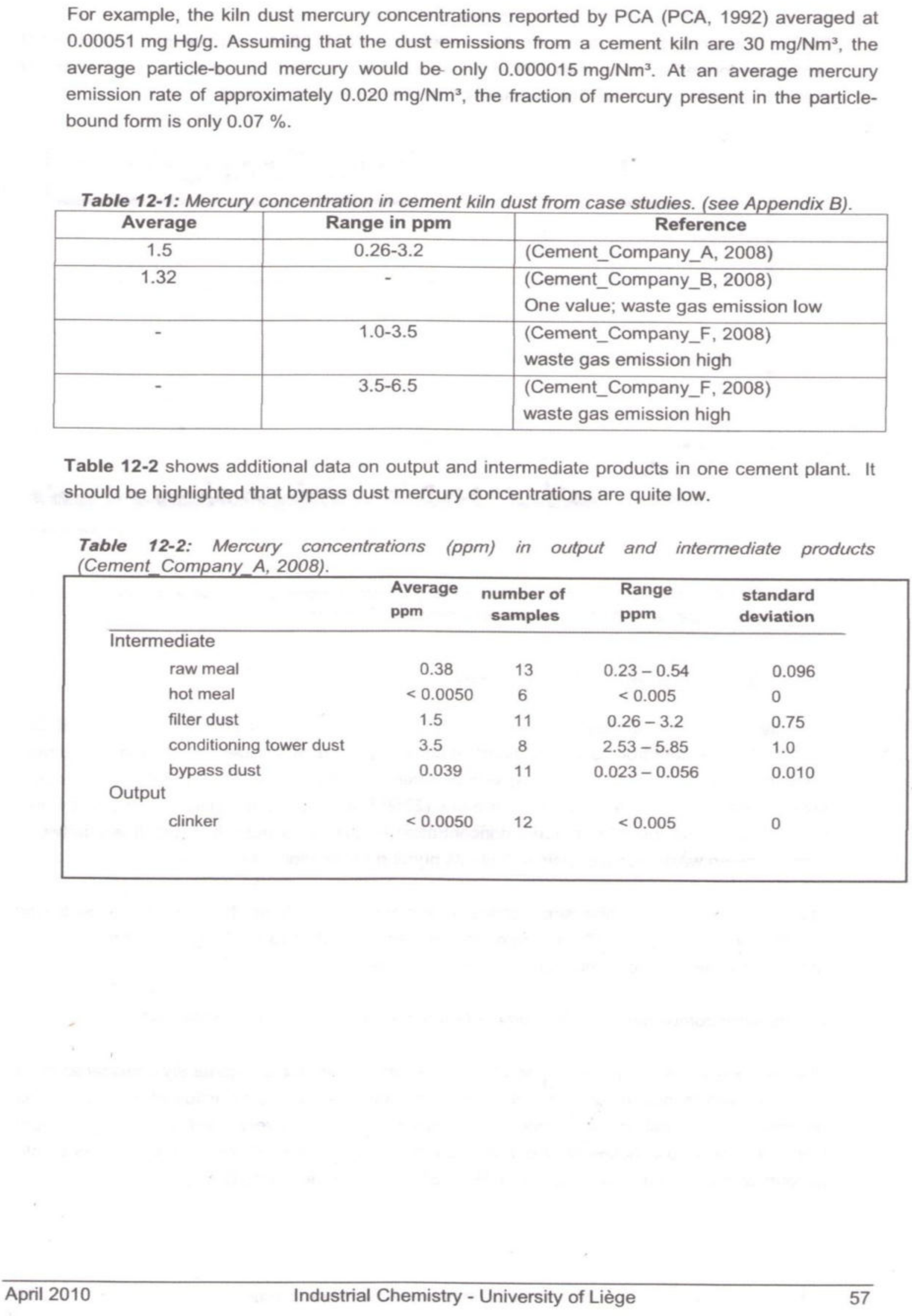
12.3.3. *Cement Kiln Dust*

A study on cement kiln dust constituents (including mercury) was conducted in 1992 (PCA, 1992). The raw data from US and Canadian cement plant dust samples resulted in an average mercury content of 0.00051 mg Hg/g with a maximum value of 0.0255 mg Hg/g. The mercury content was below the detection limit in many (27/95) of the samples analysed. The study also demonstrated that the total mercury concentration in dust does not differ statistically between plants burning waste-derived fuels and plants burning conventional fuels only.

In a study reported by Johansen (Johansen and Hawkins, 2003a), the mercury concentration ranged from 0.00013 to 0.001 mg Hg/g with an average of 0.0003 mg Hg/g. Half of the samples presented a mercury concentration below the detection limit.

CSI member companies provided some information which is shown in **Table 12-1**.

The concentrations of particle-bound mercury in cement kiln gas are generally considered to be very low - this is independent from the probable removal of a major fraction of the mercury as an adsorbed material on the surface of cement kiln dust. This is very significant as the mercury stack emissions are not very dependent on the effectiveness of the dedusting (taking into account that a normal dedusting device like ESP or FF is implemented).



For example, the kiln dust mercury concentrations reported by PCA (PCA, 1992) averaged at 0.00051 mg Hg/g. Assuming that the dust emissions from a cement kiln are 30 mg/Nm³, the average particle-bound mercury would be only 0.000015 mg/Nm³. At an average mercury emission rate of approximately 0.020 mg/Nm³, the fraction of mercury present in the particle-bound form is only 0.07 %.

***Table 12-1:** Mercury concentration in cement kiln dust from case studies. (see Appendix B).*

Average	Range in ppm	Reference
1.5	0.26-3.2	(Cement_Company_A, 2008)
1.32	-	(Cement_Company_B, 2008) One value; waste gas emission low
-	1.0-3.5	(Cement_Company_F, 2008) waste gas emission high
-	3.5-6.5	(Cement_Company_F, 2008) waste gas emission high

Table 12-2 shows additional data on output and intermediate products in one cement plant. It should be highlighted that bypass dust mercury concentrations are quite low.

***Table 12-2:** Mercury concentrations (ppm) in output and intermediate products (Cement_Company_A, 2008).*

	Average ppm	number of samples	Range ppm	standard deviation
Intermediate				
raw meal	0.38	13	0.23 – 0.54	0.096
hot meal	< 0.0050	6	< 0.005	0
filter dust	1.5	11	0.26 – 3.2	0.75
conditioning tower dust	3.5	8	2.53 – 5.85	1.0
bypass dust	0.039	11	0.023 – 0.056	0.010
Output				
clinker	< 0.0050	12	< 0.005	0

13. MEASURES FOR MINIMISATION AND CONTROL OF MERCURY EMISSIONS

The information and data presented in this report and other studies (Richards, 2005) demonstrate that mercury does not simply volatilise from the fuel and raw materials to directly leave the system through the stack. There are mechanisms and operating conditions that allow cement kilns to capture mercury in some form. Cement kiln systems have a significant inherent ability to control mercury stack emissions.

The present report and the case studies largely confirm the experience and the key control factors for mercury abatement in cement kiln systems, as referenced in the available literature.

- ✓ In most cases, the major contribution to the total mercury input into the kiln system is the natural raw materials, and not the fuels.
- ✓ Control of mercury input is the most common reduction measure.
- ✓ Selective mining can be an option in order to control and reduce the mercury input 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.
- ✓ To avoid accumulation of mercury in the kiln system, the primary measures to reduce mercury emissions are:
    - o Extraction of the filter dust ("bleeding") during direct kiln operation (i.e. when the dust has a high mercury concentration)
    - o Reduction of the temperature in the gas cleaning device.
- ✓ Secondary measures, such as the injection of activated carbon, may further contribute to the reduction of mercury emissions, but will impose technical solutions if the filter dust is recycled back into the kiln or into the cement mill.

In this context it has to be noted that the cement industry's conversion of existing wet kiln and long dry kilns to advanced preheater-precalciner kilns has resulted in a significant industry-wide reduction in mercury emissions. The conversion to preheater-precalciner kilns provides significant energy recovery improvements and thereby reduces the quantity of fossil fuel needed and the specific amount of exhaust flue gas.

In terms of controls, periodic measurements of mercury emissions ensure that the emission levels remain low or that modifications to kiln operation or raw material variations do not have an effect on the mercury emissions.

Continuous monitoring of mercury emissions cannot yet be considered as an available technology for the cement industry such as, for example, the continuous monitoring of dust or NO_x. However, in the event of significant mercury emissions, continuous measurement can provide precious support towards understanding the parameters which influence mercury emissions and to finding solutions in order to improve the situation.

Very low levels of global mercury emissions have been reported. Though most of values are lower than 0.03 mg/Nm³, values higher than 0.05 mg/Nm³ may require further investigation.

High dedusting efficiencies can be achieved with electrostatic precipitators and bag filters. The reduction of dust emissions is very important in terms of reducing heavy metal emissions. Fractions of many metals leave the kiln with the emitted dust particles. Nevertheless, contrary to common opinion, the upgrading of dedusting equipment does not provide an effective solution to the capture of mercury since it is mainly emitted in vapour form from the cement kiln stack.

In principle, the following methods are available to reduce mercury emissions:

- Input control,
- Process integrated measures.

Other techniques are described in order to reduce mercury air emissions, mainly for waste incinerators and coal-fired boilers.

13.1. BEST ENVIRONMENTAL PRACTICE

13.1.1. Input control

As explained, mercury enters the kiln system as a trace element naturally present in raw materials and, to a lesser extent, in fuels. **Best environmental practice** is to carry out a careful selection and control of all substances entering the kiln in order to reduce mercury input.

13.1.1.1. Raw materials

A. RAW MATERIALS FROM QUARRIES

As shown in chapter 9.1, mercury concentrations in raw materials (limestone, marl or clay) vary significantly from quarry to quarry. There are even cases where mercury concentrations vary significantly within a single deposit, thereby sometimes requiring selective mining.

In those cases, after exploration and analyses of the quarry, it is possible to define specific parts of the quarry with higher mercury concentrations and to continue exploitation in zones where the concentration is lower (selective mining) (see case study n°4 (Cement_Company_C, 2008)). It has to be highlighted that such a procedure is complex to manage and cannot always be carried out (case studies n°5 and 6 (Cement_Company_D, 2008; Cement_Company_E, 2008).

If mercury is present in all quarry layers, other options have to be considered.

B. OTHERS RAW MATERIALS AND WASTE MATERIALS

"Corrective" materials such as bauxite, iron ore or sand may be required to adapt the chemical composition of the raw mix to the requirements of the process and product specifications. To a limited extent, alternative raw materials are used to substitute natural raw materials and correctives.

Introduction

Background and mandate

Global inventories for mercury emissions to air from human sources have been produced at approximately 5-year intervals since 1990 by scientific groups. UNEP produced its first Global Mercury Assessment in 2002. In 2007, the Governing Council of UNEP through its decision 24/3 requested the Executive Director of UNEP:

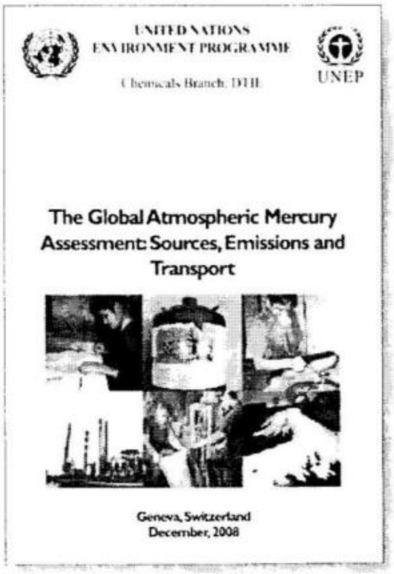
to prepare a report, drawing on, among other things, ongoing work in other forums, addressing:

(a) Best available data on mercury atmospheric emissions and trends including where possible an analysis by country, region and sector, including a consideration of factors driving such trends and applicable regulatory mechanisms;

(b) Current results from modelling on a global scale and from other information sources on the contribution of regional emissions to deposition which may result in adverse effects and the potential benefits from reducing such emissions, taking into account the efforts of the Fate and Transport partnership established under the United Nations Environment Programme mercury programme.

The results of this request were presented as a summary report entitled "The Global Atmospheric Mercury Assessment: Sources, Emissions and Transport", released in December 2008, and an accompanying "Technical Background Report to the Global Atmospheric Mercury Assessment".

The technical background report, which formed the basis for statements made in the summary report and was prepared in cooperation with the Arctic Monitoring and Assessment Programme (AMAP) Secretariat, included an updated inventory of anthropogenic emissions of mercury to the atmosphere. The inventory was based on national emissions data for the year 2005 submitted by governments, as well as estimates prepared for countries that did not provide data, and was coordinated with work related to mercury under the UN Economic Commission for Europe Convention on Long-range Transboundary Air Pollution (LRTAP). The report also drew on the work of the UNEP Global Mercury Partnership, in particular the Mercury Air Transport and Fate Research partnership area.



UNITED NATIONS
ENVIRONMENT PROGRAMME

Chemicals Branch, DTIE

UNEP

The Global Atmospheric Mercury Assessment: Sources, Emissions and Transport

Geneva, Switzerland
December, 2008

UNEP's 2008 Global Atmospheric Mercury Assessment Report.

In 2009, the Governing Council of UNEP, through its Decision 25/5, paragraph 36, requested the Executive Director of UNEP:

... in consultation with Governments, to update the 2008 report entitled Global Atmospheric Mercury Assessment: Sources, Emissions and Transport for consideration by the Governing Council/Global Ministerial Environment Forum at its twenty-seventh session.

This updated Global Mercury Assessment 2013 and its accompanying and updated Technical Background Report are the response to that Governing Council request.

Developing the 2013 Report

As in 2008, the *Technical Background Report for the Global Mercury Assessment 2013* forms the basis for the statements made in the Summary

Report and is fully referenced according to standard scientific practice. As such, it is the single reference for the Summary Report. It has again been prepared in co-operation with the Arctic Monitoring and Assessment Programme (AMAP) and uses national data and information submitted by several governments. Contributions have also been incorporated from the UNEP Global Mercury Partnership, in particular its partnership areas on mercury control from coal combustion, reducing mercury in artisanal and small-scale gold mining (ASGM), and mercury air transport and fate; AMAP mercury expert group; UN Economic Commission for Europe (UN ECE) Long-range Transboundary Air Pollution (LRTAP) Convention groups; industry; and non-governmental organizations. Each section was prepared by a team of experts and then reviewed to ensure its scientific accuracy. The evaluation of information of mercury released into the aquatic environment benefits from contributions from the Group of Experts on Scientific Aspects of Marine Environmental Protection (GESAMP).

Scope and coverage

This update to the Global Mercury Assessment provides the most recent information available for the worldwide emissions, releases, and transport of mercury in atmospheric and aquatic environments. To the extent possible, the information comes from the published scientific literature, supplemented where necessary by other sources. Since the Global Mercury Assessment is intended as a basis for decision making, emphasis is given to anthropogenic emissions (mercury going into the atmosphere) and releases (mercury going into water and land), that is, those associated with human activities.

The Technical Background Report includes a detailed inventory of global mercury emissions to air based on data for 2010. "Inventory" in this context means a compilation of the estimated emissions and releases from various sectors and sources. While it attempts to catalogue all major sources of mercury emissions worldwide, it should not be regarded as complete and exhaustive.

In addition, for the first time, this Global Mercury Assessment includes an evaluation of information of mercury released into the aquatic environment and its associated pathways and fate. The information available for this evaluation is less complete than that for emissions to air and is based on data from recent years. The inclusion of this new element of the Global Mercury Assessment is as a response to the requests from many governments in the Intergovernmental Negotiating Committee (INC) for more information on releases to land and water. The aquatic environment is the main route of exposure to humans and wildlife, because it is in water that inorganic mercury is transformed into highly toxic methylmercury.

The Technical Background Report includes chapters on:

- *Global Emissions of Mercury to the Atmosphere*, describing sources, anthropogenic emissions, and trends in emissions;
- *Atmospheric Pathways, Transport and Fate*, examining pathways, levels and trends in air and deposition, and modelling of pathways and deposition;
- *Global Releases of Mercury to Aquatic Environments*, containing global estimates of releases to water; and
- *Aquatic Pathways, Transport and Fate*, examining mercury pathways in aquatic systems that result in important routes of human exposure.

Technical Background Report chapters were prepared by teams of experts and then reviewed to ensure their scientific validity. This Summary Report is based on the content of the Technical Background Report and has been reviewed by the authors of the Technical Background Report. It was also circulated for national review.

This Summary Report provides, in Chapter 2, an overview of natural and anthropogenic sources of mercury, outlining the main sectors involved. The global inventory of anthropogenic emissions to air is presented in Chapter 3, and Chapter 4 describes trends in mercury emissions to the atmosphere. What happens after mercury is released to the atmosphere is covered in Chapter 5 on atmospheric chemistry, monitoring, and deposition, and Chapter 6 on atmospheric concentrations and deposition. Chapter 7 provides a first attempt to estimate global releases to water, followed in Chapter 8 by a discussion of aquatic pathways, transformations, and fate. A review of gaps in knowledge is given in Chapter 9. Chapter 10 summarizes key findings.

What's new in the Global Mercury Assessment 2013

Global mercury emissions inventories continue to improve as new data and better data become available concerning some sources. The method for compiling the inventory of anthropogenic emissions to the atmosphere has also been revised and improved. Differences in air pollution control technologies and differences in the mercury content of raw materials and fuels in different countries and regions have been factored into emissions calculations to better reflect actual conditions in each country.

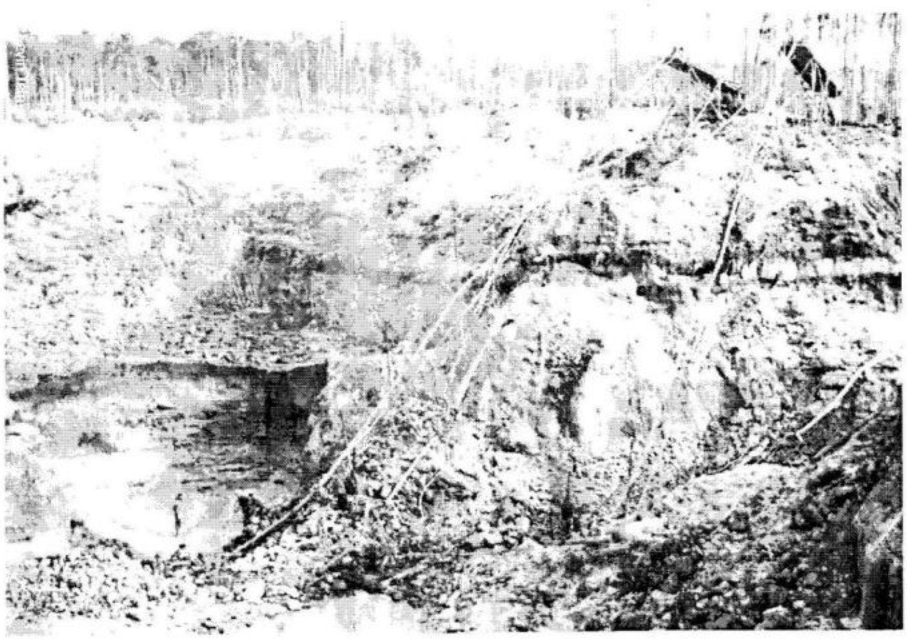
In the Global Mercury Assessment 2013, a new updated inventory, based on data from 2010, is presented in which some new sources (including emissions from combustion of natural gas and primary aluminium production and emissions associated with oil refining) have been quantified for the first time. A more detailed analysis has also been made of some of the major mercury emission sectors, including the break-down of emissions from coal burning in power plants, industrial and other uses. In addition, new information acquired through the UNEP Global Mercury Partnership area on Reducing Mercury in Artisanal and Small-scale Gold Mining, in particular from the Artisanal Gold Council, has resulted in a significant re-evaluation of emissions from the ASGM sector.

New observational data and new modelling results provide fresh insight into atmospheric mercury transport and fate.

One of the objectives of the updated assessment has been to provide transparent documentation and comprehensive compilations of the data that form the basis for all of the estimates presented. This approach will allow a more consistent and replicable method for compiling the global mercury emission inventory, so that valid comparisons can be made in the future. In addition, a wider range of experts from around the world have been involved in preparing the Technical Background Report on which this summary is based.

The inclusion of an assessment of releases of mercury to the aquatic environment and its subsequent pathways and fate is a further significant development as these topics were not addressed in the 2008 UNEP Global Atmospheric Mercury Assessment. The aquatic environment is critical for three reasons:

- Hundreds of tonnes of mercury is released directly into water, so an inventory limited to mercury emissions to air provides an incomplete assessment of anthropogenic impacts on the mercury cycle.
- Mercury in aquatic environments can be transformed into methylmercury, which is far more toxic to humans and animals and can enter and biomagnify in food webs more readily than other forms of mercury.
- Much human exposure to mercury is through the consumption of fish and other marine foods, making aquatic pathways the critical link to human health.



A large open artisanal and small-scale gold mining pit.

Sources of mercury emissions to air and releases to water

Mercury is a naturally occurring element and is found throughout the world. There are thus many natural sources of mercury, creating background environmental levels that have been present since long before humans appeared.

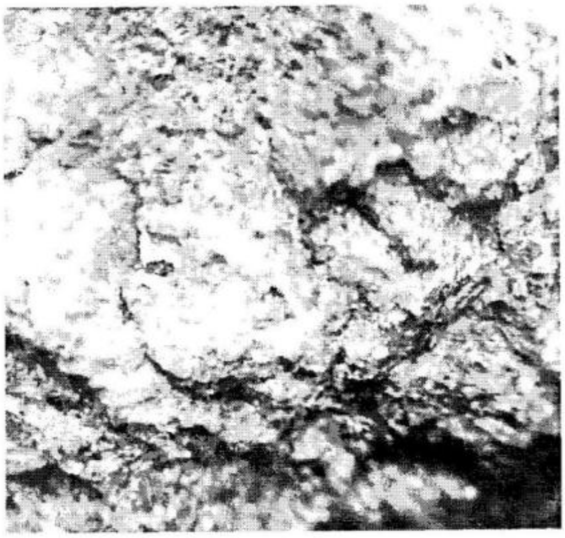
Mercury is contained in many minerals, including cinnabar, an ore mined to produce mercury. Much of the present day demand for mercury is met by supply from mercury recovered from industrial sources and stockpiles rather than from mercury mining. Mercury is also present as an impurity in many other economically valuable minerals, in particular the non-ferrous metals, and in fossil fuels, coal in particular.

Human activity, especially mining and the burning of coal, has increased the mobilization of mercury into the environment, raising the amounts in the atmosphere, soils, fresh waters, and oceans. The majority of these human emissions and releases of mercury have occurred since 1800, associated with the industrial revolution based on coal burning, base-metal ore smelting, and gold rushes in various parts of the world. To some extent the same drivers of mercury emissions and releases are continuing with fossil-fuel-based energy generation powering industrial and economic growth in Asia and South America, which in turn helps drive high demand for metals including gold, spurring artisanal and small-scale gold mining (ASGM) around the world.

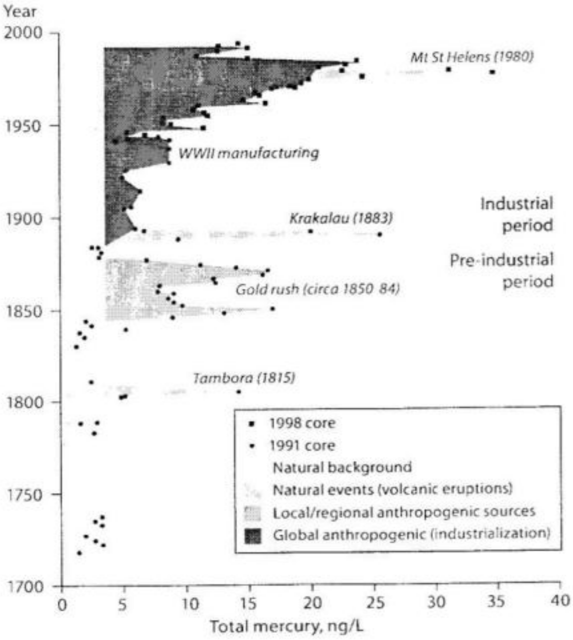
In preparing inventories of mercury emissions and releases, it is important to distinguish various categories of sources. Three main types of emissions and releases can be distinguished, each of which is briefly introduced here in qualitative terms, with particular emphasis on anthropogenic sources.

Natural sources of mercury emissions and releases

Mercury in the earth's crust can be emitted and released in several ways to air, water, and land. Natural weathering of mercury-containing rocks



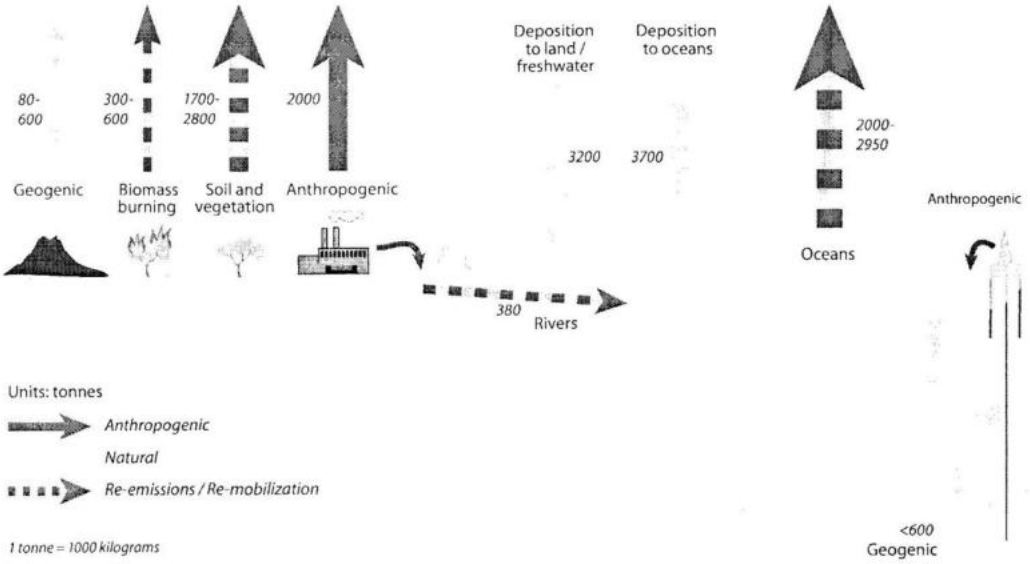
Cinnabar: the principal ore of mercury.



Ice core record of deposition from Wyoming, USA. The elevated levels associated with the 1850-84 US gold rush probably reflect local/regional sources rather than a global signature. Increasing environmental levels of mercury associated with industrialization, however, are found in environmental archives like this ice core around the globe.

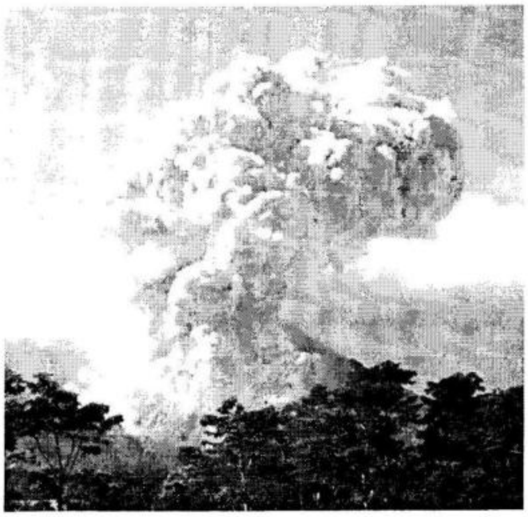
Global mercury cycling

Mercury is released to the environment from natural sources and processes and as a result of human activities. Once it has entered the environment, mercury cycles between air, land, and water until it is eventually removed from the system through burial in deep ocean sediments or lake sediments and through entrapment in stable mineral compounds. Methylmercury, the most toxic and bioaccumulative form of mercury, which presents the greatest health risk to humans and wildlife, is mainly formed in aquatic environments through natural microbial processes.



Global mercury budgets, based on models, illustrate the main environmental compartments and pathways that are of importance in the global mercury cycle, and the ways in which natural and anthropogenic releases to air land and water move between these compartments. Emissions to air arise from natural sources and anthropogenic sources, as well as re-emissions of mercury previously deposited from air onto soils, surface waters, and vegetation.

is continuous and ubiquitous, allowing mercury to escape to air and to be washed into lakes and rivers. Volcanoes emit and release mercury when they erupt. Geothermal activity can also take mercury from underground and emit it to the atmosphere and release it to the deep oceans. Some recent models of the flow of mercury through the environment suggest that natural sources account for about 10% of the estimated 5500-8900 tonnes of mercury currently being emitted and re-emitted to the atmosphere from all sources.



Anthropogenic sources of mercury emissions and releases

Anthropogenic sources of mercury emissions account for about 30% of the total amount of mercury entering the atmosphere each year.

As found in previous global mercury assessments, the main industrial sources of atmospheric mercury are coal burning, mining, industrial activities that process ores to produce various metals or process other raw materials to produce cement. In these activities, mercury is emitted because it is present as an impurity in fuels and raw materials. In these cases, mercury emissions and releases are sometimes referred to as 'by-product' or 'unintentional' emissions or releases. A second category of sources includes sectors where mercury is used intentionally. Artisanal and small-scale gold mining (ASGM) is the largest of these, in which mercury emissions and releases result from the intentional use of mercury to extract gold from rocks, soils, and sediments. Other intentional-use release sectors include waste from consumer products (including metal recycling), the chlor-alkali industry, and the production of vinyl-chloride monomer.

Coal burning, and to a lesser extent the use of other fossil fuels, is one of the most significant anthropogenic source of mercury emissions to the atmosphere. Coal does not contain high concentrations of mercury, but the combination of the large volume of coal burned and the fact that a significant portion of the mercury present in coal is emitted to the atmosphere yield large overall emissions from this sector. The mercury content of coal varies widely, introducing a high degree of uncertainty in estimating mercury emissions from coal burning. Data on mercury content is now available from many countries, including major emitters of mercury.

Mining, smelting, and production of iron and non-ferrous metals are also a large source of global mercury emissions to air, and also a very important sector with regard to releases to water. In the mining and processing of metals, most of the mercury is captured and either stockpiled or sold for use in various products, creating anthropogenic sources associated with intentional use, discussed below. Nonetheless, the volume of ores and metals involved result in large total emissions and releases. The relatively small volume of primary mercury production makes mercury mining a far smaller source today than it has been in the past.

Cement production, which typically involves the burning of fossil fuels to heat the materials required to make cement, is another major anthropogenic source of mercury emissions. Both the raw materials and the fuel may contain mercury and lead to emissions. The amount of mercury involved varies greatly with the mercury content of these fuels and especially with the raw materials. In some countries, cement kilns are burning increasing amounts of alternative fuels, including wastes that may contain mercury. This may add to the emissions from cement kilns.

Oil refining emits and releases mercury, as oil deposits are known to contain mercury, generally at low concentrations. Mercury is removed from most petroleum products and natural gas prior to combustion, and therefore combustion-related emissions are low. Most of the mercury in crude oil is associated with solid waste that is disposed of in landfills. However, emissions and releases during refining of crude oil do occur and these have been quantified for the first time in the 2010 inventory. The inventory does not quantify other emissions and releases during oil and gas extraction and transport or from flaring.

Unintentional mercury emissions from these sectors can be reduced by the application of pollution control measures at power plants and industrial plants. Some of the mercury captured is refined and enters the commercial supply chain; however, large amounts of mercury captured in materials such as fly ash and oil refinery waste need to be disposed of. Some of the resulting wastes are themselves used as raw materials, for example in construction materials, but large amounts are disposed of in landfills, which can thus become a potential source of mercury emissions and releases.

Among intentional-use sectors, **Artisanal and small-scale gold mining** is a major source for emissions and releases of mercury worldwide. In ASGM, miners use mercury to create an amalgam separating gold from other materials. They then have to separate the mercury from the gold. Calculating emissions from this sector presents a particular challenge because it is typically widely dispersed and often unregulated and may be illegal. Uncertainties regarding release estimates from the ASGM sector are therefore high. Furthermore, the miners are typically poor and perhaps have little awareness of the hazards of mercury, and pollution control devices may be hard to obtain.

Wastes from consumer products containing mercury can end up in landfills or incinerators.

Mercury is still used in a wide range of products, including batteries, paints, switches, electrical and electronic devices, thermometers, blood-pressure gauges, fluorescent and energy-saving lamps, pesticides, fungicides, medicines, and cosmetics. Once used, many of the products and the mercury they contain enter waste streams. While mercury in landfills may slowly become re-mobilized to the environment, waste that is incinerated can be a major source of atmospheric mercury, especially from uncontrolled incineration. Incinerators with state-of-the-art controls have low emissions.

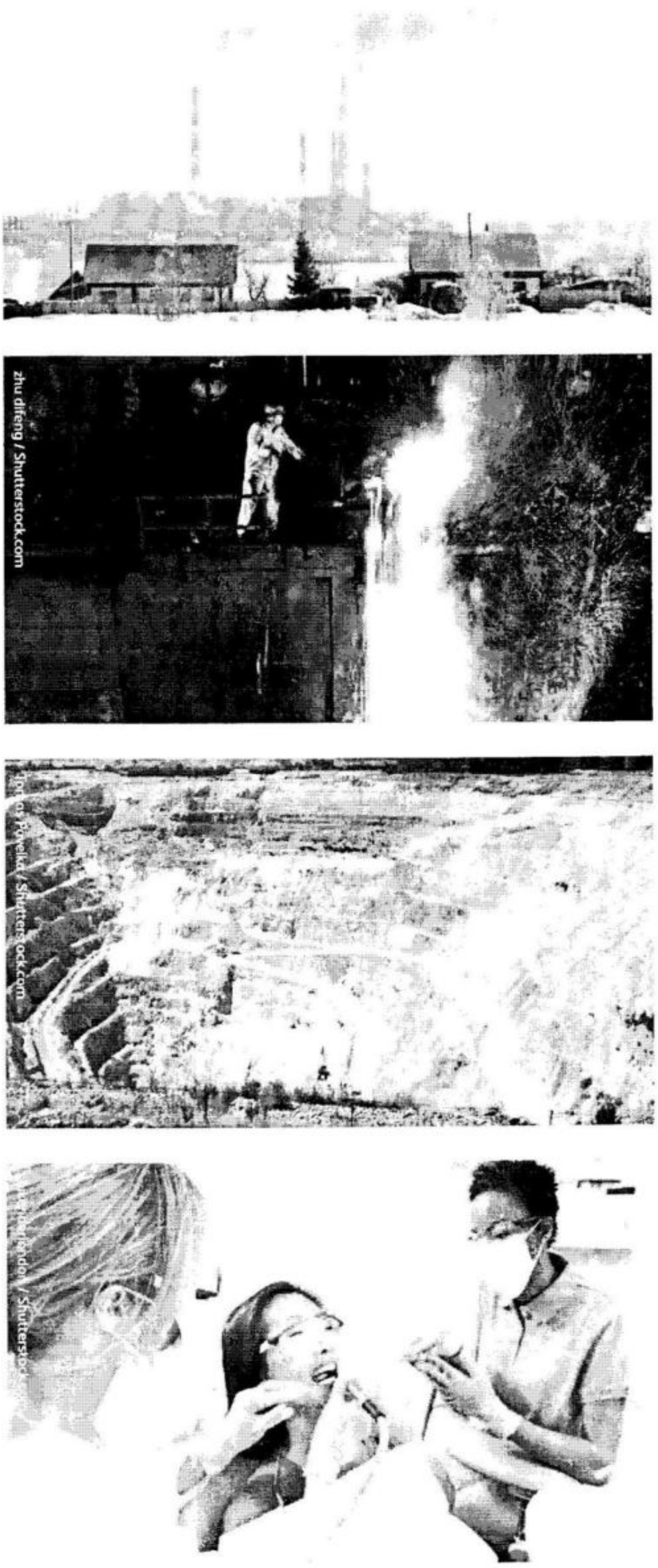
Another use of mercury is in **dental amalgam** for filling teeth. When bodies are cremated, mercury in fillings can be emitted. Mercury can also be emitted and released during production and preparation of fillings and from the disposal or removed fillings. In addition, mercury from removed fillings can be recycled or go into solid waste and wastewater.

The amount of mercury released in the recycling of scrap metals, for example in secondary steel and non-ferrous metal production, is generally assumed to be much lower than that released during primary metal production, which is why the present global inventory only addresses primary metal production. However, lower emissions from recycling may not be the case in all countries. Much of the scrap steel in some countries comes from automobiles that may still have devices that contain mercury, and which may not be removed prior to recycling of the steel. These devices are largely being phased out so mercury emissions from scrap steel may be expected to decrease. However, large differences exist between countries in the way they treat their mercury-containing wastes, including scrap metals that are recycled in secondary metal production.

Mercury is also used in a number of industrial processes. A major industrial use is in the **chlor-alkali industry** where mercury-cell technology may be used in the production of chlorine and caustic soda.

Mercury is also used as a catalyst in the production of **vinyl chloride monomer** (VCM) from acetylene, mainly in China.

Mercury releases to aquatic systems as a result of current human activities arise from many of the same uses or the presence of mercury in various products and processes that emit mercury to the air. As with emissions to the atmosphere, aquatic releases come from two main sources. First, mercury is released with water effluent from the sites where mercury is used. Second, mercury can leach into water from disposal sites that have mercury in the waste.



Anthropogenic sources of mercury from industry and intentional use.

Re-emission and re-mobilization of mercury

Re-emissions constitute the third category of sources, presently comprising about 60% of mercury emissions to air. Mercury previously deposited from air onto soils, surface waters, and vegetation from past emissions can be emitted back to the air. Re-emission is a result of natural processes that convert inorganic and organic forms of mercury to elemental mercury, which is volatile and therefore readily returns to the air. Mercury deposited to plant surfaces can be re-emitted during forest fires or biomass burning. Mercury may be deposited and re-emitted many times as it cycles through the environment.

It is important that re-emitted mercury should not be considered a natural source. It may originally have come from natural or anthropogenic sources, but by the time it is re-emitted, it is difficult or impossible to identify its specific origin. Nonetheless, human activity has increased the environmental burden of mercury, resulting in higher levels of re-emission. This is compounded by changes in land use practices as well as increasing temperatures due to climate change.

In the aquatic environment, re-mobilization of mercury occurs when mercury deposited on and accumulated in soils or sediments is re-mobilized by, for example, rain or floods that cause the mercury to enter or re-enter the aquatic system. Resuspension of aquatic sediments due to wave action or storm events is an additional way for mercury to re-enter the aquatic ecosystems.

Estimating re-emission and re-mobilization rates is difficult. It is often done using modelling approaches. These models are based on data on atmospheric levels and other observations as well as current understanding of chemical transformations and other processes that determine how mercury moves between air, land, and water. The models aim to balance the amount of mercury in circulation at any given time while remaining consistent with observational data. Temperature is a key factor. With lower temperatures, re-emission rates are generally lower.

Re-emission is also a major factor in determining the length of time needed for anthropogenic emission reductions to be reflected in decreasing environmental levels of mercury. Mercury emitted in one year may be deposited to and retained in soils and waters for some time before being re-emitted or re-mobilized in subsequent years. This cycle can be repeated, keeping levels in air and water elevated even after anthropogenic sources have been lowered. Conversely, continuing to add to the global pool will leave an ever-longer legacy of anthropogenic mercury contamination worldwide. It is thus imperative that international efforts to reduce mercury emissions continue and are strengthened as soon as possible.

Forest fires re-emit mercury deposited to vegetation.

5.5 INFORMATIONS PROVIDED BY THE INDUSTRIES

M/s Jamul Cement Works (ACC Limited)
Durg, Bhilai Chhattisgarh

1.0	Production details	
1.1	Products manufactured	Portland Slag Cement
1.2	Capacity in TPD / TPA	15.8 LTPA
1.3	Bye-Product (If Any)	Nil
2.0	Raw material & fuel consumption / tonne of clinker production	

S. No.	Name of the raw materials & fuels	Quantity in MT / MT of clinker production
1.	Limestone (Raw material)	1.45
2.	Coal (Fuel)	0.201

3.0	Quality detail of raw material and coal

S.No.	Name of raw material/fuel etc.	Hg Concentration mg/kg
1.	Limestone	<5.0
2.	Coal	<5.0

4.0	Details of fuel quality

S. No.	Fuel	Average ash content	Average sulphur content	Average nitrogen content	Average calorific value (Kcal/Kg)
1.	Coal	36	0.36	0.91	3984.57

5.0	Energy requirement	
5.1	Electrical energy in kwh/ tonne of cement	92.14
5.2	Thermal energy in kcal/kg of clinker	836.74
6.0	Details of hazardous waste co-processing	

S.No	Name of Hazardous waste material used	Quantity MT / day	Hg Concentration mg/kg
NIL			

7.0	Air Pollution Control		
7.1	Name of the pollution control devices installed	Bag Houses & ESP	
7.2	Mercury concentration found in emission	Stack Name	Hg Conc. ($\mu g/m^3$)
		Kiln -1	2.1
		Kiln -2	3.0
		Kiln -3	1.0

M/s Aditya Cement Works & Aditya Cement Works-II (Aditya Birla)Ultra Tech Cement Ltd. Adityapuram, Chittorgarh

1.0	Production details	
1.1	Products manufactured	Grey Cement
1.2	Capacity in TPD / TPA	8 MTPA
1.3	Bye-Product (If Any)	Nil
2.0	Raw material & fuel consumption / tonne of clinker production	

S. No.	Name of the raw materials & fuels	Quantity in MT / MT of clinker production
1	Limestone (Raw material)	1.38
2	Laterite (Raw material)	0.073
3	Redocher (Raw material)	0.025
4	Pet Coke (Fuel)	0.079
5	Coal (Fuel)	0.043

3.0	Quality detail of raw material and coal(Attach chemical analysis report including Hg)

S.No.	Name of raw material/fuel etc.	Hg Concentration mg/kg
1.	Limestone (Raw material)	NA (Not Available)
2.	Latrite (Raw material)	NA (Not Available)
3.	Red Ochre (Raw material)	NA (Not Available)
4.	Gypsum	NA (Not Available)
5.	Fly Ash	NA (Not Available)
6.	Pet Coke (Fuel)	1.2-1.3
7.	Imported Coal (Fuel)	<0.10

4.0	Details of fuel quality

S. No.	Fuel	Average ash content	Average sulphur content	Average nitrogen content	Average calorific value (Kcal/Kg)
1.	Imported Coal	15	0.7	1.86	6400
2.	Pet Coke	0.6	6.5	0.99	8200

5.0	Energy requirement	
5.1	Electrical energy in kwh/ tonne of cement	Unit-I: 74.54 Unit-II: 81.76
5.2	Thermal energy in kcal/kg of clinker	Unit-I: 697.50 Unit-II: 698.06
6.0	Details of hazardous waste co-processing	

S.No	Name of Hazardous waste material used	Quantity MT / day	Hg Concentration mg/kg
1.	Paint Sludge	2.71	<0.1
2.	ETP Sludge	44.71	0.86
3.	Phosphate Sludge	7.63	<0.1

7.0	Air Pollution Control	
7.1	Name of the pollution control devices installed	Bag Houses
7.2	Mercury concentration found in emission	ND (Not Detecteable) *Detection Limit 1.0μg/Nm^{3}

M/s Ambuja Cements Ltd. Rabriyawas, Pali, Rajasthan

1.0	Production details	
1.1	Products manufactured	Cement
1.2	Capacity in TPD / TPA	3.6 MTPA
1.3	Bye-Product (If Any)	Nil
2.0	Raw material & fuel consumption / tonne of clinker production	

S. No.	Name of the raw materials & fuels	Quantity in MT / MT of clinker production
1.	Limestone	1.49
2.	Iron dust	0.00096
3.	China Clay	0.00292
4.	Red Ochre	0.00028
5.	Silica Sand	0.00925
6.	Iron Ore	0.01594
7.	Indian Coal	0.6349
8.	Lignite	0.00120
9.	Imported Coal	0.4924
10.	Pet Coke	0.02364

3.0	Quality detail of raw material and coal(Attach chemical analysis report including Hg)

S.No.	Name of raw material/fuel etc.	Hg Concentration Mg/kg
1.	Gypsum	<0.5
2.	Fly Ash	
3.	Bed Ash	
4.	Coal (Domestic)	
5.	Pet Coke	
6.	Clinker	
7.	Cement	

4.0	Details of fuel quality

S. No.	Fuel	Average ash content	Average sulphur content	Average nitrogen content	Average calorific value (Kcal/Kg)
1.	Indian Coal	26	0.9	1	6000
2.	Imported Coal	16	0.8	0.8	6200
3.	Pet Coke	3	7	-	8400
4.	Lignite	35	1	1.1	3800

5.0	Energy requirement	
5.1	Electrical energy in kwh/ tonne of cement	80.31
5.2	Thermal energy in kcal/kg of clinker	760.885
6.0	Details of hazardous waste co-processing	

S.No.	Name of Hazardous waste material used	Quantity MT / day	Hg Concentration mg/kg
1.	Paint Sludge	1.23	-

7.0	Air Pollution Control	
7.1	Name of the pollution control devices installed	Details provided
7.2	Mercury concentration found in emission	ND (Detection Limit: 1.0µg/m^3)

M/s Bhilai Jaypee Cement Ltd.
Babupur, Raghuraj Nagar,
Satna, MP

1.0	Production details	
1.1	Products manufactured	Clinker : 1.09 MTPA
1.2	Capacity in TPD / TPA	3300
1.3	Bye-Product (If Any)	Nil
2.0	Raw material & fuel consumption / tonne of clinker production	

S. No.	Name of the raw materials & fuels	Quantity in MT / MT of clinker production
1.	Limestone	1.46
2.	Laterite/ Iron Ore	0.044
3.	Coal	0.13

3.0 Quality detail of raw material and coal (Attach chemical analysis report including Hg)

S. No.	Name of raw material/fuel etc.	Hg Concentration (% by mass)
1.	Limestone	NA (Not Analysed)
2.	Laterite	
3.	Iron Ore	
4.	Bauxite	
5.	Coal	

4.0 Details of fuel quality

S. No.	Fuel	Average ash content	Average sulphur content	Average nitrogen content	Average calorific value (Kcal/Kg)
1.	Coal	20-25	<1	Not Monitored	5400-6000

5.0	Energy requirement	
5.1	Electrical energy in kwh/ tonne of cement	<63
5.2	Thermal energy in kcal/kg of clinker	700
6.0	Details of hazardous waste co-processing	

S. No.	Name of Hazardous waste material used	Quantity MT / day	Hg Concentration mg/kg
NIL			

7.0	Air Pollution Control	
7.1	Name of the pollution control devices installed	ESP/ Bag House/ Bag Filter
7.2	Mercury concentration found in emission	Not Monitored

M/s Binani Cement Ltd.
Binanigram, Sirohi, Rajasthan

1.0	Production details	
1.1	Products manufactured	Cement (OPC & PPC)
1.2	Capacity in TPD / TPA	4.85 LTPA
1.3	Bye-Product (If Any)	Nil
2.0	Raw material & fuel consumption / tonne of clinker production	

S. No.	Name of the raw materials & fuels	Quantity in MT / MT of clinker production
1.	Silica Sand	0.00142
2.	Lime Stone	1.51008
3.	Gypsum	0.06562
4.	Fly Ash	0.05702
5.	Pet Coke	0.03142
6.	SA Coal	0.12400
7.	Red Ochre	0.00058

3.0 Quality detail of raw material and coal (Attach chemical analysis report including Hg)

S. No.	Name of raw material/fuel etc.	Hg Concentration mg/kg
1.	Silica Sand	<0.1
2.	Lime Stone	0.12
3.	Gypsum	<0.1
4.	Fly Ash	0.16
5.	Pet Coke	0.13
6.	SA Coal	0.18
7.	Red Ochre	<0.1

4.0 Details of fuel quality

S. No.	Fuel	Average ash content	Average sulphur content	Average nitrogen content	Average calorific value (Kcal/Kg)
1.	SA Coal	15	0.8	-	6450
2.	Pet Coke	0.8	4.0	-	8200

5.0	Energy requirement	
5.1	Electrical energy in kwh/ tonne of cement	78.61
5.2	Thermal energy in kcal/kg of clinker	685

6.0 Details of hazardous waste co-processing

S. No.	Name of Hazardous waste material used	Quantity MT / day	Hg Concentration mg/kg
No Hazardous waste is used as Raw Material			

7.0	Air Pollution Control	
7.1	Name of the pollution control devices installed	Bag House (for Kiln & Raw mill-1) Bag House (for Kiln & Raw mill-2)
7.2	Mercury concentration found in emission	1. 0.16 mg/nm^3 2. 0.15 mg/nm^3

M/s Birla White (Aditya Birla),
Ultra Tech Cement Ltd.
Kharia Khangar, Jodhpur

1.0	Production details	
1.1	Products manufactured	White Cement
1.2	Capacity in TPD / TPA	560000 TPA
1.3	Bye-Product (If Any)	Nil
2.0	Raw material & fuel consumption / tonne of clinker production	

S. No.	Name of the raw materials & fuels	Quantity in MT / MT of clinker production
1	*Limestone*	*1.3062*
2	China Clay	0.2562
3	Feldspar	0.0062
4	Gypsum	0.0392
5	Furnace oil	0.0043
6	Pet Coke	0.1198

3.0	Quality detail of raw material and

S.No.	Name of raw material/fuel etc.	Hg Concentration mg/kg
1.	Limestone	Not Done
2.	China Clay	
3.	Feldspar	
4.	Gypsum	
5.	Furnace oil	Nil
6.	Pet Coke	Nil

4.0	Details of fuel quality

S. No.	Fuel	Average ash content	Average sulphur content	Average nitrogen content	Average calorific value (Kcal/Kg)
1.	Furnace Oil	<0.5	1-3	0.1-0.15	9400-9500
2.	Pet Coke	<1	4-6	1.5-2	7800-8050

5.0	Energy requirement	
5.1	Electrical energy in kwh/ tonne of cement	Line -I: 121.53 Line-II: 109.23
5.2	Thermal energy in kcal/kg of clinker	Line -I: 1161 Line -II: 1052
6.0	Details of hazardous waste co-processing	

S.No	Name of Hazardous waste material used	Quantity MT / day	Hg Concentration mg/kg
Nil			

7.0	Air Pollution Control	
7.1	Name of the pollution control devices installed	Details provided
7.2	Mercury concentration found in emission	Not Done

M/s Century Cement, Baikunth
Raipur, Chhattisgarh

1.0	Production details	
1.1	Products manufactured	Portland Clinker
1.2	Capacity in TPD / TPA	Cement: 21 LTPA
1.3	Bye-Product (If Any)	Nil
2.0	Raw material & fuel consumption / tonne of clinker production	

S. No.	Name of the raw materials & fuels	Quantity in MT / MT of clinker production
1.	Limestone	1.46
2.	Coal	0.19

3.0	Quality detail of raw material and coal

S.No.	Name of raw material/fuel etc.	Hg Concentration mg/kg
1.	Limestone	ND
2.	Coal	

4.0	Details of fuel quality

S. No.	Fuel	Average ash content	Average sulphur content	Average nitrogen content	Average calorific value (Kcal/Kg)
1.	Coal	24	0.6	1.0	5200

5.0	Energy requirement	
5.1	Electrical energy in kwh/ tonne of cement	95
5.2	Thermal energy in kcal/kg of clinker	815
6.0	Details of hazardous waste co-processing	

S.No	Name of Hazardous waste material used	Quantity MT / day	Hg Concentration mg/kg
NIL			

7.0	Air Pollution Control	
7.1	Name of the pollution control devices installed	Reverse Air Bag House
7.3	Mercury concentration found in emission (if monitored)	Not Monitored

M/s New Chittor Cement Works
Madhav Nagar, handeria
Chittorgarh, Rajasthan

1.0	Production details	
1.1	Products manufactured	Cement
1.2	Capacity in TPD / TPA	1.2 MTPA
1.3	Bye-Product (If Any)	Nil
2.0	Raw material & fuel consumption / tonne of clinker production	

S. No.	Name of the raw materials & fuels	Quantity in MT / MT of clinker production
1.	Redochre (Hard)	0.0377
2.	Redochre (Soft)	0.0192
3.	Coal	-
4.	Limestone	1.4331
5.	Pet coke	-
6.	Imported Coal	0.1425

3.0	Quality detail of raw material and coal

S.No.	Name of raw material/fuel etc.	Hg Concentration mg/kg
Data Not Available		

4.0	Details of fuel quality

S. No.	**Fuel**	**Average ash content**	**Average sulphur content**	**Average nitrogen content**	**Average calorific value (Kcal/Kg)**
1.	Indian Coal	38.20	1.06	-	4000
2.	Imported Coal	18.09	0.65	-	5823
3.	Pet coke	-	-	-	-

5.0	Energy requirement	
5.1	Electrical energy in kwh/ tonne of cement	Plant under Stabilization
5.2	Thermal energy in kcal/kg of clinker	
6.0	Details of hazardous waste co-processing	

S.No	Name of Hazardous waste material used	Quantity MT / day	Hg Concentration mg/kg
NIL			

7.0	Air Pollution Control	
7.1	Name of the pollution control devices installed	Bag House : Kiln ESP : Cooler
7.2	Mercury concentration found in emission	Not Measured

M/s Hirmi Cement Works
(A unit of Ultratech Cement Ltd.)
Hirmi, Baloda – Bazar
Chhattisgarh

1.0	Production details	
1.1	Products manufactured	Cement (PPC, OPC)
1.2	Capacity in TPD / TPA	2.75 MTPA
1.3	Bye-Product (If Any)	Nil
2.0	Raw material & fuel consumption / tonne of clinker production	

S. No.	Name of the raw materials & fuels	Quantity in MT / MT of clinker production
1.	Limestone	1.49
2.	Coal	0.135
3.	Flue Dust	0.005

3.0	Quality detail of raw material and coal

S.No.	Name of raw material/fuel etc.	Hg Concentration mg/kg
1.	Limestone	Data Not Available
2.	Bituminous Coal	

4.0	Details of fuel quality

S. No.	Fuel	Average ash content	Average sulphur content	Average nitrogen content	Average calorific value (Kcal/Kg)
1.	Coal	18-35	0.41	1.22	5300

5.0	Energy requirement	
5.1	Electrical energy in kwh/ tonne of cement	78-79
5.2	Thermal energy in kcal/kg of clinker	64-65
6.0	Details of hazardous waste co-processing	

S.No	Name of Hazardous waste material used	Quantity MT / day	Hg Concentration mg/kg
	NIL		

7.0	Air Pollution Control	
7.1	Name of the pollution control devices installed	Provided
7.2	Mercury concentration found in emission	Data Not Available

M/s J. K. Cement Works
(A unit of J. K. Cement Ltd.)
Gotan, Nagaur Rajasthan

1.0	Production details	
1.1	Products manufactured	Grey Cement (OPC)
1.2	Capacity in TPD / TPA	0.471900 MTPA
1.3	Bye-Product (If Any)	Nil
2.0	Raw material & fuel consumption / tonne of clinker production	

S. No.	Name of the raw materials & fuels	Quantity in MT / MT of clinker production
1.	Limestone	1.31
2.	Clay	0.135
3.	Laterite	0.06
4.	Raw Petcoke	0.656

3.0	Quality detail of raw material and coal

S.No.	Name of raw material/fuel etc.	Hg Concentration (% by mass)
1.	Limestone	NM (Not Measured)
2.	Clay	
3.	Laterite	
4.	Raw Petcoke	

4.0	Details of fuel quality

S. No.	Fuel	Average ash content	Average sulphur content	Average nitrogen content	Average calorific value (Kcal/Kg)
1.	Raw Pet Coke	0.92	6-7.5	1-1.5	8180

5.0	Energy requirement	
5.1	Electrical energy in kwh/ tonne of cement	67.35
5.2	Thermal energy in kcal/kg of clinker	850
6.0	Details of hazardous waste co-processing	

S.No.	Name of Hazardous waste material used	Quantity MT / day	Hg Concentration mg/kg
NIL			

7.0	Air Pollution Control	
7.1	Name of the pollution control devices installed	ESP & Bag Filter
7.3	Mercury concentration found in emission	Not Monitored

M/s J. K. Cement Works, Mangrol
Chittorgarh, Rajasthan

1.0	Production details	
1.1	Products manufactured	Cement (OPC, PPC)
1.2	Capacity in TPD / TPA	2100 TPD
1.3	Bye-Product (If Any)	Nil
2.0	Raw material & fuel consumption / tonne of clinker production	

S. No.	Name of the raw materials & fuels	Quantity in MT / MT of clinker production
1.	Limestone	1.394
2.	Laterite	0.086
3.	Coal	0.1215

3.0	Quality detail of raw material and coal

S.No.	Name of raw material/fuel etc.	Hg Concentration (% by mass)
1.	Limestone	DNA (Data Not Available)
2.	Laterite	
3.	Coal	
4.	Gypsum	
5.	Fly Ash	

4.0	Details of fuel quality

S. No.	Fuel	Average ash content	Average sulphur content	Average nitrogen content	Average calorific value (Kcal/Kg)
1.	Coal	25-35	0.6-1.0	-	4000-5500
2.	Pet Coke	1-2	5-6.5	-	7900-8150

5.0	Energy requirement	
5.1	Electrical energy in kwh/ tonne of cement	82.38
5.2	Thermal energy in kcal/kg of clinker	771.1
6.0	Details of hazardous waste co-processing	

S. No.	Name of Hazardous waste material used	Quantity MT / day	Hg Concentration mg/kg
NIL			

7.0	Air Pollution Control	
7.1	Name of the pollution control devices installed	ESP, Bag Filter & Dust Cyclone
7.2	Mercury concentration found in emission	Not Monitored

M/s J. K. Lakshmi Cement Ltd.
Jaykaypuram, Pindwara
Sirohi, Rajasthan

1.0	Production details	
1.1	Products manufactured	Cement (OPC, PPC)
1.2	Capacity in TPD / TPA	12,500 TPD/ 40,00,000 TPA
1.3	Bye-Product (If Any)	Nil
2.0	Raw material & fuel consumption / tonne of clinker production	

S. No.	Name of the raw materials & fuels	Quantity in MT / MT of clinker production
1.	Cement Grade Limestone	55-58 LT/ TPA
2.	Red Ochre	36,000 MTPA
3.	Petroleum Coke	4,00,000 MTPA
4.	South African Coal	40,000 MTPA
5.	Gypsum (Mineral)	3,00,000 MTPA
6.	Fly Ash	5,00,000 MTPA

3.0	Quality detail of raw material and coal

S.No.	Name of raw material/fuel etc.	Hg Concentration (% by mass)
1.	Cement Grade Limestone	NA (Not Analyzed)
2.	Red Ochre	
3.	Petroleum Coke	
4.	South African Coal	
5.	Gypsum (Mineral)	
6.	Fly Ash	

4.0	Details of fuel quality

S. No.	Fuel	Average ash content	Average sulphur content	Average nitrogen content	Average calorific value (Kcal/Kg)
1.	South African Coal	16 – 18	0.5- 0.6	0.5- 0.6	6000-6100 (G.C.V)
2.	Pet Coke	2-3	5.5-5.7	0.8-1.0	8200-8300 (G.C.V)

5.0	Energy requirement	
5.1	Electrical energy in kwh/ tonne of cement	79 (Excluding Crusher)
5.2	Thermal energy in kcal/kg of clinker	738
6.0	Details of hazardous waste co-processing	

S.No.	Name of Hazardous waste material used	Quantity MT / day	Hg Concentration mg/kg
NIL			

7.0	Air Pollution Control	
7.1	Name of the pollution control devices installed	ESP, Reverse Air Bag House & Hybrid Bag Filter
7.2	Mercury concentration found in emission	Not Monitored

M/s Jaypee Bela Plant
Jaypeepuram, Rewa, MP

1.0	Production details	
1.1	Products manufactured	Cement
1.2	Capacity in TPD / TPA	2.5 MTPA
1.3	Bye-Product (If Any)	Nil
2.0	Raw material & fuel consumption / tonne of clinker production	

S. No.	Name of the raw materials & fuels	Quantity in MT / MT of clinker production
1	Limestone	1.46
2	Laterite	0.030
3	Iron Ore	0.009
4	HG Laterite	0.0047
5	Indigenous Coal	0.1311
6	Imported Coal	0.0135
7	Pet Coke	0.0020

3.0	Quality detail of raw material and coal

S. No.	Name of raw material/fuel etc.	Hg Concentration (% by mass)
1.	Limestone	NA (Not Available)
2.	Laterite	
3.	Iron Ore	
4.	HG Laterite	
5.	Indigenous Coal	
6.	Imported Coal	
7.	Pet Coke	

4.0	Details of fuel quality

S. No.	**Fuel**	**Average ash content**	**Average sulphur content**	**Average nitrogen content**	**Average calorific value (Kcal/Kg)**
1.	Indigenous Coal	23-39	<0.8	0.6-1	3600-5500
2.	Imported Coal	15-17	0.5-0.7	1.5-1.7	6300-6500
3.	Pet Coke	0.8-3	4-7	-	7990-8300

5.0	Energy requirement	
5.1	Electrical energy in kwh/ tonne of cement	89.6
5.2	Thermal energy in kcal/kg of clinker	691
6.0	Details of hazardous waste co-processing	

S.No.	Name of Hazardous waste material used	Quantity MT / day	Hg Concentration mg/kg
NA			

7.0	Air Pollution Control	
7.1	Name of the pollution control devices installed	ESP, Bag House, Bag Filter & Precip Filter
7.2	Mercury concentration found in emission	Not Monitored

M/S Jaypee Rewa Plant
Jaypee Nagar, Rewa, MP

1.0	Production details	
1.1	Products manufactured	Cement
1.2	Capacity in TPD / TPA	3.5 MTPA
1.3	Bye-Product (If Any)	Nil
2.0	Raw material & fuel consumption / tonne of clinker production	

S. No.	Name of the raw materials & fuels	Quantity in MT / MT of clinker production
1.	Limestone	1.45
2.	Laterite	0.0023
3.	Iron Ore	0.019
4.	HG Laterite	0.015
5.	Indigenous Coal	0.112
6.	Imported Coal	0.0281
7.	Pet Coke	0.0064

3.0	Quality detail of raw material and coal

S.No.	Name of raw material/fuel etc.	Hg Concentration (% by mass)
1.	Limestone	NA (Not Available)
2.	Laterite	
3.	Iron Ore	
4.	HG Laterite	
5.	Indigenous Coal	
6.	Imported Coal	
7.	Pet Coke	

4.0	Details of fuel quality

S. No.	Fuel	Average ash content	Average sulphur content	Average nitrogen content	Average calorific value (Kcal/Kg)
1.	Indigenous Coal	23-37	<0.8	0.621	4050-5600
2.	Imported Coal	14-15	0.5-0.7	1.5-1.7	6546
3.	Pet Coke	1-3	3-7	-	7800-8200

5.0	Energy requirement	
5.1	Electrical energy in kwh/ tonne of cement	92.5
5.2	Thermal energy in kcal/kg of clinker	691
6.0	Details of hazardous waste co-processing	

S. No.	Name of Hazardous waste material used	Quantity MT / day	Hg Concentration mg/kg
1.	Polythene Waste	1.5	NA

7.0	Air Pollution Control	
7.1	Name of the pollution control devices installed	ESP, Bag House, Bag Filter & Precip Filter
7.2	Mercury concentration found in emission	Not Monitored

M/s Jaypee Sidhi Cement Plant
Jaypee Vihar, PO- Bharatpur
Naikin, Sidhi, MP

1.0	Production details	
1.1	Products manufactured	Clinker/ Cement
1.2	Capacity in TPD / TPA	2.0 MTPA Cement, 1.5 MTPA Clinker
1.3	Bye-Product (If Any)	Nil
2.0	Raw material & fuel consumption / tonne of clinker production	

S. No.	**Name of the raw materials & fuels**	**Quantity in MT / MT of clinker production**
1.	Limestone	1.4444
2.	Laterite	0.0395
3.	Iron Ore	0.0140
4.	Bauxite	0.0022
5.	Coal	0.1402

3.0	Quality detail of raw material and coal

S. No.	Name of raw material/fuel etc.	Hg Concentration (% by mass)
1.	Limestone	NA (Not Available)
2.	Laterite	
3.	Iron Ore	
4.	Bauxite	
5.	Coal	

4.0	Details of fuel quality

S. No.	Fuel	Average ash content	Average sulphur content	Average nitrogen content	Average calorific value (Kcal/Kg)
1.	Coal	28.32	Not Monitored	Not Monitored	5045

5.0	Energy requirement	
5.1	Electrical energy in kwh/ tonne of cement	86.28
5.2	Thermal energy in kcal/kg of clinker	707.12
6.0	Details of hazardous waste co-processing	

S. No.	Name of Hazardous waste material used	Quantity MT / day	Hg Concentration mg/kg
NIL			

7.0	Air Pollution Control	
7.1	Name of the pollution control devices installed	ESP/ Bag House
7.2	Mercury concentration found in emission	Not Monitored

M/s KJS Cement Ltd.,
Rajnagar, Maihar, MP

1.0	Production details	
1.1	Products manufactured	Cement
1.2	Capacity in TPD / TPA	2.25 MTPA
1.3	Bye-Product (If Any)	Nil
2.0	Raw material & fuel consumption / tonne of clinker production	

S. No.	Name of the raw materials & fuels	Quantity in MT / MT of clinker production
1.	Lime stone	1.520
2.	Latrite	0.040
3.	Iron Ore	0.012
4.	Coal	0.188
5.	Gypsum	0.0482
6.	Fly Ash	0.2000

3.0	Quality detail of raw material and coal

S.No.	Name of raw material/fuel etc.	Hg Concentration mg/kg
1.	Lime stone	Not analyzed
2.	Latrite	
3.	Iron Ore	
4.	Coal	
5.	Gypsum	
6.	Fly Ash	

4.0	Details of fuel quality

S. No.	Fuel	Average ash content	Average sulphur content	Average nitrogen content	Average calorific value (Kcal/Kg)
1.	Coal	34.88	0.78	1.86	4216

5.0	Energy requirement	
5.1	Electrical energy in kwh/ tonne of cement	86.95
5.2	Thermal energy in kcal/kg of clinker	710
6.0	Details of hazardous waste co-processing	

S.No.	Name of Hazardous waste material used	Quantity MT / day	Hg Concentration mg/kg
No Hazardous waste is used as Raw Material			

7.0	Air Pollution Control	
7.1	Name of the pollution control devices installed	Bag Filter & ESP
7.2	Mercury concentration found in emission	Nil

M/s Kotputli Cement Works
(A unit of Ultratech Cement Ltd.)
Mohanpura, Kotputli
Jaipur, Rajasthan

1.0	Production details	
1.1	Products manufactured	Cement & Clinker
1.2	Capacity in TPD / TPA	Cement: 4.0 MTPA Clinker: 4.0 MTPA
1.3	Bye-Product (If Any)	Nil

2.0	Raw material & fuel consumption / tonne of clinker production

S. No.	Name of the raw materials & fuels	Quantity in MT / MT of clinker production
1.	Limestone	1.3985
2.	Red Ochre	0.0723
3.	Laterite	0.0421
4.	Bituminous Coal	0.0945
5.	Pet coke	0.0144

3.0	Quality detail of raw material and coal

S.No.	Name of raw material/fuel etc.	Hg Concentration mg/kg
1.	Limestone	Not Measured
2.	Red Ochre	
3.	Laterite	
4.	Bituminous Coal	
5.	Pet coke	

4.0	Details of fuel quality

S. No.	Fuel	Average ash content	Average sulphur content	Average nitrogen content	Average calorific value (Kcal/Kg)
1.	Bituminous Coal	16.3	0.65	1.63	6400
2.	Pet coke	1.1	6.5	1.22	8270

5.0	Energy requirement	
5.1	Electrical energy in kwh/ tonne of cement	79.85
5.2	Thermal energy in kcal/kg of clinker	697.16

6.0	Details of hazardous waste co-processing

S.No	Name of Hazardous waste material used	Quantity MT / day	Hg Concentration mg/kg
NIL			

7.0	Air Pollution Control		
7.1	Name of the pollution control devices installed	Stack	Control Device
		Raw Mill/ Kiln	Bag House
		Coal Mill	Bag House
		Clinker Cooler	Bag House
		Cement Mill	ESP
		Boiler 1&2	ESP
		D.G. Set -1	Acoustic Enclosure Stack
		D.G. Set -2	Acoustic Enclosure Stack
7.2	Mercury concentration found in emission	Not Monitored	

M/s Sonadih Cement Plant
(A unit of lafarge India Pvt. Ltd.)
Raseda, Balodabazar- Bhatapara
Chhattisgarh

1.0	Production details	
1.1	Products manufactured	Clinker - Cement
1.2	Capacity in TPD / TPA	0.55 MTPA, 1800 TPD: Cement (PPC) 3.5 MTPA (1.5+2.0): Clinker Line-1: 4500 TPD, Line-2: 5000 TPD
1.3	Bye-Product (If Any)	Nil
2.0	Raw material & fuel consumption / tonne of clinker production	

S. No.	Name of the raw materials & fuels	Quantity in MT / MT of clinker production
1.	Limestone	1.44
2.	River Sand	0.05
3.	Iron Ore	0.01
4.	Coal	0.16

3.0	Quality detail of raw material and coal

S.No.	Name of raw material/fuel etc.	Hg Concentration (% by mass)
1.	Limestone	NA (Not Available)
2.	River sand	
3.	Iron Ore	
4.	Coal	

4.0	Details of fuel quality

S. No.	Fuel	Average ash content	Average sulphur content	Average nitrogen content	Average calorific value (Kcal/Kg)
1.	Indigenous Coal	30 - 32	1.3	2.3	4400
2.	Imported Coal	18	0.5	-	6200
3.	Pet Coke	1.0	6.5	-	7100
4.	AF	-	<1.5	-	4000

5.0	Energy requirement	
5.1	Electrical energy in kwh/ tonne of cement	72-74
5.2	Thermal energy in kcal/kg of clinker	730-755
6.0	Details of hazardous waste co-processing	

S.No.	Name of Hazardous waste material used	Quantity MT / day	Hg Concentration mg/kg
1.	TDI tat waste	20-25	<0.1
2.	Waste mix solid	17	BDL
3.	Waste mix liquid	72	BDL

7.0	Air Pollution Control		
7.1	Name of the pollution control devices installed	Bag House/ Hybrid Filter	
7.2	Mercury concentration found in emission	Material Used	Hg Conc. (mg/kg)
		Raw Meal	1.8
		Clinker	3.3
		Coal	0.2

M/s Maihar Cement
Sarlanagar
Maihar, Satna

1.0	Production details	
1.1	Products manufactured	Cement (PPC, OPC)
1.2	Capacity in TPD / TPA	5 MTPA
1.3	Bye-Product (If Any)	Nil
2.0	Raw material & fuel consumption / tonne of clinker production	

S. No.	Name of the raw materials & fuels	Quantity in MT / MT of clinker production	
		Unit I	Unit II
1.	Limestone	1.453	1.450
2.	Laterite/ Iron Ore tailing	0.030	0.030
3.	Coal	0.171	0.137

3.0	Quality detail of raw material and coal

S.No.	Name of raw material/fuel etc.	Hg Concentration mg/kg
1.	Limestone	ND
2.	Laterite	
3.	Coal	

4.0	Details of fuel quality

S. No.	Fuel	Average ash content		Average sulphur content		Average nitrogen content		Average calorific value (Kcal/Kg)	
		Unit I	Unit II	Unit I	Unit II	Unit I	Unit II	Unit I	Unit II
1.	Coal	24.8	22.4	0.7	0.7	1.2	1.2	5012	5688

5.0	Energy requirement		
5.1	Electrical energy in kwh/ tonne of cement	Unit I	Unit II
		82	67.48
5.2	Thermal energy in kcal/kg of clinker	800	695
6.0	Details of hazardous waste co-processing		

S.No	Name of Hazardous waste material used	Quantity MT / day	Hg Concentration mg/kg
NIL			

7.0	Air Pollution Control	
7.1	Name of the pollution control devices installed	Hybrid Filter, Reverse Air Bag House, ESP, Bag Filter
7.2	Mercury concentration found in emission	Not Monitored

M/s Manglam Cement Ltd.
Morak, Rajasthan

1.0	Production details	
1.1	Products manufactured	Cement
1.2	Capacity in TPD / TPA	10.99 MTPA
1.3	Bye-Product (If Any)	Nil
2.0	Raw material & fuel consumption / tonne of clinker production	

S. No.	Name of the raw materials & fuels	Quantity in MT / MT of clinker production
1.	Morak Limestone	1.27
2.	High Grade Limestone	0.14
3.	Additives (Redochre/BD)	0.07
4.	Pet Coke/ Coal	0.13

3.0	Quality detail of raw material and coal (Attach chemical analysis report including Hg)

S.No.	Name of raw material/fuel etc.	Hg Concentration (% by mass)
1.	Morak Limestone	0.002
2.	High Grade Limestone	ND
3.	Red Ochre	0.006
4.	Pet Coke/ Coal	ND
5.	Coal	ND
6.	Fly Ash	ND
7.	Chemical Gypsum	ND
8.	Mineral Gypsum	0.003
9.	Latrite	0.008

4.0	Details of fuel quality

S. No.	Fuel	Average ash content	Average sulphur content	Average nitrogen content	Average calorific value (Kcal/Kg)
1.	Pet Coke	0.40	4.47	0.59	8200

5.0	Energy requirement	
5.1	Electrical energy in kwh/ tonne of cement	95.0
5.2	Thermal energy in kcal/kg of clinker	860
6.0	Details of hazardous waste co-processing	

S.No	Name of Hazardous waste material used	Quantity MT / day	Hg Concentration mg/kg
No Hazardous waste is used as Raw Material			

7.0	Air Pollution Control	
7.1	Name of the pollution control devices installed	Provided
7.2	Mercury concentration found in emission	Nil

M/s Neer Shree Cement
(Unit of Manglam Cement Ltd.)
Ramganjmandi, Kota, Rajasthan

1.0	Production details	
1.1	Products manufactured	Cement
1.2	Capacity in TPD / TPA	4000 TPD/ 1.32 MTPA
1.3	Bye-Product (If Any)	Nil
2.0	Raw material & fuel consumption / tonne of clinker production	

S. No.	Name of the raw materials & fuels	Quantity in MT / MT of clinker production
1.	Morak Limestone	1.23
2.	High Grade Limestone	0.17
3.	Additives (Redochre/BD)	0.08
4.	Pet Coke/ Coal	0.12

3.0	Quality detail of raw material and coal

S.No.	Name of raw material/fuel etc.	Hg Concentration (% by mass)
1.	Morak Limestone	0.002
2.	High Grade Limestone	ND
3.	Red Ochre	0.006
4.	Pet Coke/ Coal	ND
5.	Coal	ND
6.	Fly Ash	ND
7.	Chemical Gypsum	ND
8.	Mineral Gypsum	0.003
9.	Latrite	0.008

4.0	Details of fuel quality

S. No.	Fuel	Average ash content	Average sulphur content	Average nitrogen content	Average calorific value (Kcal/Kg)
	Pet Coke	0.40	4.47	0.59	8200

5.0	Energy requirement	
5.1	Electrical energy in kwh/ tonne of cement	73.0
5.2	Thermal energy in kcal/kg of clinker	760
6.0	Details of hazardous waste co-processing	

S.No.	Name of Hazardous waste material used	Quantity MT / day	Hg Concentration mg/kg
No Hazardous waste is used as Raw Material			

7.0	Air Pollution Control	
7.1	Name of the pollution control devices installed	Provided
7.2	Mercury concentration found in emission	Nil

M/s Rawan Cement Works (A unit of Ultratech Cement Ltd.) Grasim Vihar, Balodabazar-Bhatapara Chhattisgarh

1.0	Production details	
1.1	Products manufactured	Cement & Clinker
1.2	Capacity in TPD / TPA	Cement: 3.3 MTPA, Clinker: 2.07 MTPA
1.3	Bye-Product (If Any)	Nil
2.0	Raw material & fuel consumption / tonne of clinker production	

S. No.	Name of the raw materials & fuels	Quantity in MT / MT of clinker production
1.	Limestone	1.49
2.	Coal	0.1577

3.0	Quality detail of raw material and coal

S.No.	Name of raw material/fuel etc.	Hg Concentration mg/kg
1.	Limestone	Not Measured
2.	Coal	

4.0	Details of fuel quality

S. No.	Fuel	Average ash content	Average sulphur content	Average nitrogen content	Average calorific value (Kcal/Kg)
1.	Coal	30.76	0.60	0-7	4653

5.0	Energy requirement	
5.1	Electrical energy in kwh/ tonne of cement	72.029
5.2	Thermal energy in kcal/kg of clinker	701
6.0	Details of hazardous waste co-processing	

S. No	Name of Hazardous waste material used	Quantity MT / day	Hg Concentration mg/kg
NIL			

7.0	Air Pollution Control	
7.1	Name of the pollution control devices installed	Bag Filters/ ESP
7.2	Mercury concentration found in emission	Not Monitored

M/s Satna Cement Works
Birla Corporation Ltd.
Satna, MP

1.0	Production details	
1.1	Products manufactured	Cement
1.2	Capacity in TPD / TPA	2.25 MTPA
1.3	Bye-Product (If Any)	Nil
2.0	Raw material & fuel consumption / tonne of clinker production	

S. No.	Name of the raw materials & fuels	Quantity in MT / MT of clinker production
1.	Limestone	1.5019
2.	Iron Ore	0.0481
3.	Coal	0.1520
4.	Gypsum	0.0661 (Per ton of Cement)
6.	Fly Ash	0.265 (Per ton of Cement)

3.0	Quality detail of raw material and coal

S.No.	Name of raw material/fuel etc.	Hg Concentration mg/kg
1.	Lime stone	21.50 ppb
3.	Iron Ore	BDL
4.	Coal	4.60 ppb
5.	Gypsum	4.30 ppb

4.0	Details of fuel quality

S. No.	Fuel	Average ash content	Average sulphur content	Average nitrogen content	Average calorific value (Kcal/Kg)
1.	Coal	28.71%	0.8%	1.81%	5259 NCV

5.0	Energy requirement	
5.1	Electrical energy in kwh/ tonne of cement	90.0
52	Thermal energy in kcal/kg of clinker	799 NCV
6.0	Details of hazardous waste co-processing	

S.No.	Name of Hazardous waste material used	Quantity MT / day	Hg Concentration mg/kg
No Hazardous waste is used as Raw Material			

7.0	Air Pollution Control	
7.1	Name of the pollution control devices installed	Provided
7.2	Mercury concentration found in emission	Nil

M/sVikram Cement Works (Aditya Birla)
Ultra Tech Cement Ltd.
Khor, Neemuch, MP

1.0	Production details	
1.1	Products manufactured	Cement
1.2	Capacity in TPD / TPA	4000000 TPA
1.3	Bye-Product (If Any)	Nil
2.0	Raw material & fuel consumption / tonne of clinker production	

S. No.	Name of the raw materials & fuels	Quantity in MT / MT of clinker production
1.	Limestone (Raw material)	1.3762
2.	Latrite (Raw material)	0.0391
3.	Red Ochre (Raw material)	0.0571
4.	Bauxite (Raw material)	0.0054
5.	Pet Coke (Fuel)	0.0754
6.	Coal (Fuel)	0.0125

3.0	Quality detail of raw material and coal

S.No.	Name of raw material/fuel etc.	Hg Concentration mg/kg
1.	Limestone (Raw material)	1.9
2.	Latrite (Raw material)	
3.	Red Ochre (Raw material)	
4.	Bauxite (Raw material)	
5.	Pet Coke (Fuel)	0.13
6.	Coal (Fuel)	0.10

4.0	Details of fuel quality

S. No.	Fuel	Average ash content	Average sulphur content	Average nitrogen content	Average calorific value (Kcal/Kg)
1.	Imported Coal	26-28	0.40-0.90	1-2.4	6050-6250
2.	Pet Coke	0.20-0.50	6-7	1-1.5	7880-7950

5.0	Energy requirement	
5.1	Electrical energy in kwh/ tonne of cement	69.87
5.2	Thermal energy in kcal/kg of clinker	690
6.0	Details of hazardous waste co-processing	

S. No	Name of Hazardous waste material used	Quantity MT / day	Hg Concentration mg/kg
1.	Paint Sludge	48	NA
2.	Opium Marc	48-72	1.2

7.0	Air Pollution Control	
7.1	Name of the pollution control devices installed	ESPs, Bag Houses and Bag filters
7.2	Mercury concentration found in emission	Provided

M/s Wonder Cement Ltd.
Nimbahera, Chittorgarh,
Rajasthan

1.0	Production details	
1.1	Products manufactured	Cement
1.2	Capacity in TPD / TPA	2.5 MTPA
1.3	Bye-Product (If Any)	Nil
2.0	Raw material & fuel consumption / tonne of clinker production	

S. No.	Name of the raw materials & fuels	Quantity in MT / MT of clinker production
1.	Limestone	1.41
2.	Red Ochre	0.076
3.	Laterite	0.046
4.	Pet Coke	0.088

3.0	Quality detail of raw material and coal

S.No.	Name of raw material/fuel etc.	Hg Concentration (% by mass)
1.	Raw mix	2.2
2.	Pet Coke	1.2
3.	Clinker	2.6

4.0	Details of fuel quality

S. No.	Fuel	Average ash content	Average sulphur content	Average nitrogen content	Average calorific value (Kcal/Kg)
1.	Pet Coke	0.3	6.5	0.8	8100

5.0	Energy requirement	
5.1	Electrical energy in kwh/ tonne of cement	-
5.2	Thermal energy in kcal/kg of clinker	-
6.0	Details of hazardous waste co-processing	

S.No.	Name of Hazardous waste material used	Quantity MT / day	Hg Concentration mg/kg
Nil			

7.0	Air Pollution Control	
7.1	Name of the pollution control devices installed	Bag House, Bag Filter, ESP
7.2	Mercury concentration found in emission	ND