Mercury Emissions and Health Hazards

TREC-STEP

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CONTENT

0. Executive Summary

Mercury is widely considered to be among the highest priority environmental pollutants of concern on the global scale. Mercury is a natural part of the earth's crust. Like all elements, the same amount of mercury has existed on the planet since the Earth was formed. But the release of Mercury into the environment has increased since the beginning of the industrial age.

Mercury enters the environment as a result of the normal breakdown of minerals in rocks and soil, from exposure to wind and water,and from volcanic activity. When released to the air, mercury is transported and deposited globally and eventually falls back to Earth in rain, snow or as dry particles and settles on or is washed into water. Mercury is also released by anthropogenic processes, primarily fossil fuel combustion for power generation.

During combustion, mercury in coal is volatilized and converted to elemental mercury vapor in the high temperature regions of coal-fired boilers. As the flue gas is cooled, a series of complex reactions begin to convert elemental mercury to ionic mercury compounds and/or Hg compounds that are in a solid-phase at flue gas cleaning temperatures or Hg that is adsorbed onto the surface of other particles.

There are two broad approaches to mercury control in coal based power plants : (1) Activated Carbon Injection (ACI), where variety of activated carbon is injected down stream of the ESP, (2) multi-pollutant control, in which Hg capture is enhanced in existing/new sulphur di-oxide and nitrogen-oxide and PM control devices, combustion modification, such as coal re-burning technology which increases the carbon in fly ash and yield enhanced mercury capture in PM control devices and use of Selective Catalytic Reduction (SCR) for nitrogen oxide control which also enhances oxidation of elemental mercury in flue gas and results in increased mercury removal in wet FGD.

Mercury's ability to alloy with most metals, liquidity at room temperature, ease of vaporising and freezing and electrical conductivity make mercury a very important and popular industrial metal. Mercury finds it's use primarily in the caustic soda-chlorine production, manufacturing of thermometers and other industrial instruments, electrical apparatus and formulation of various compounds. Artisanal gold mining is a lifeline for many developing communities, but the use of mercury in processing the gold ore poses a toxic threat.

Mercury contamination of the world's oceans is the most blatant disregard for human health because of its unique ability to bio-accumulate/bio-magnify in a significant portion of the world's food stocks, fish, etc. Minute quantities of mercury are sufficient to pollute entire ecosystems. Studies reveal that 1/70th (Ref 2 page 6) of a teaspoon of mercury can contaminate a 20 acre lake to the extent that fish are unsafe to eat.

Little is known about the processes involved in the exchange of mercury between the air and the sea or the land and the air, or about the reactions of mercury with oxygen in the air. This paper helps for a better understanding of these processes which could lead to new ways of reducing mercury's impact on the environment and human health.

1. Mercury Emission – Introduction

Mercury is a chemical element with the symbol Hg and atomic number 80. It is also known as quick silver. Mercury is the only metal that is liquid at Standard condition for Temperature and Pressure with a freezing point −38.83 °C and boiling point of 356.73 °C.

Mercury is a naturally occurring element and is found throughout the world. There are many natural sources of mercury, creating background environmental levels that have been present since long before humans appeared. Like all elements, the same amount of mercury has existed on the planet since the Earth was formed. However, the amount of mercury mobilized and released into the environment has increased since the beginning of the industrial age.

Mercury is released to the environment from natural sources and processes and as a result of human activities.Natural weathering of mercury-containing rocks 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. Once it has entered the environment, mercury cycles between air, land, and water until it is eventually removed from the system. Mercury contamination of the world's oceans is the most blatant disregard for human health because of its unique ability to bio-accumulate/bio-magnify in a significant portion of the world's food stocks, fish, etc. Methyl mercury, the most toxic and bioaccumulative form of mercury is mainly formed in aquatic environments through natural microbial processes.

Mercury's ability to alloy with most metals, liquidity at room temperature, ease of vaporising and freezing and electrical conductivity make mercury a very important and popular industrial metal. Mercury is used in (1) Artisanal and small scale gold mining (ASGM) to extract gold from rocks, soils, and sediments, (2) the chlor-alkali industry, and the production of vinyl-chloride monomer, (3)Mining, smelting, and production of iron and non-ferrous metals, (4) Cement production, (5)Oilrefining, (6)dentalamalgam, (7)Healthcareequiments, (8)medical incinerators and (9) municipal waste incinerators.

Human activity, especially mining and the burning of coal, has increased the mobilization of mercury into the environment. The majority of these human emissions and releases of mercury have occurred since 1800(Ref 1-Page 4), associated with the industrial revolution based on coal burning, base-metal ore smelting, and gold mining. Coal burning is one of the most significant anthropogenic sources of mercury emissions to the atmosphere.

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-emissions' of previously released mercury that has built up over decades and centuries in surface soils and oceans. Although the original source of this remitted mercury cannot be determined with certainty, the fact that anthropogenic emissions have been larger than natural emissions since the start of the industrial age about 200 years ago implies that most re-emitted mercury was originally from anthropogenic sources. Reducing current anthropogenic sources is therefore vital to reduce the amount of mercury that is cycling in the environment (Ref 1-page 5).

The use of mercury in industrial processes is a concern. The manufacture of chlorine in chlor-alkali plants represents one such process. The loss of mercury is 100 per cent in the production of caustic soda. Developed countries have stopped using the mercury cell process in the chlor-alkali industries.

On an average, India consumes 15 Tonnes of mercury annually to produce clinical and laboratory thermometers as well as blood pressure monitors (sphygmomanometers). Mercury, which exists as contaminants in medical waste ,vaporises at high temperature in medical waste incinerators and emitted through stacks causing concern to the environment.

The consequences of mercury exposure are still not fully understood. Precise medical understanding of what mercury does to our body and how is lacking. In addition to deposits derived from air pollution and contaminated food, dental amalgam contributes to more harmful levels of accumulated mercury in the body. Widespread dispersal of mercury in the environment has become a major concern in recent years. Mercury is highly toxic and can affect a number of organs, including the kidney. Mercury is a global threat to human and environmental health and is widely considered to be among the highest priority environmental pollutants of concern on the global scale.

This report brings out the details about the sources of mercury release to the environment, to the land and water and it's harmful effect to the human health and environment, Mercury emissions from anthropogenic sources, Road Maps of Environment Protection Agency, awareness program by UNEP, Initiatives of World Health Organisation on mercury emission and mercury emission control technologies.

2. Global emission of mercury to the atmosphere

Global emissions inventory

The global emissions inventory for year 2010 estimates that 1960 tonnes of mercury was emitted to the atmosphere as a direct result of human activity (Ref 1- page 9).

Emission from combustion of fossil fuel - Coal

The updated inventory of emissions to air confirms coal burning as a continuing major source of emissions, responsible for 475 tonnes of mercury emissions to air annually, compared with around 10 tonnes from combustion of other fossil fuels. According to the new inventory, more than 85% of these emissions are from coal burning in power generation and industrial uses. In the earlier reports, emissions from domestic and residential coal burning were highlighted as a possible larger contribution. Better information on coal consumption for domestic and residential uses indicates that these activities are a smaller contribution to total emissions from coal burning than previously thought (Ref 1 – page 9).

Emissions from various sectors, in tonnes per year with the range of the estimate, and as a percentage of total anthropogenic emissions

Sector	Emission (range), tonnes	Nearest %
Fossil fuel burning		
Coal burning (all uses)	474 (304 - 678)	24
Oil and natural gas burning	9.9 (4.5 – 16.3)	1
Mining, smelting, & production of metals		
Primary production of ferrous metals	45.5 (20.5 – 241)	2
Primary production of nonferrous metals (Al, Cu, Pb, Zn)	193 (82 – 660)	10
Large-scale gold production	97.3 (0.7 – 247)	5
Mine production of mercury	11.7 (6.9 – 17.8)	<1
Cement production	173 (65.5 - 646)	9
Oil refining	16 (7.3 - 26.4)	1
Contaminated sites	82.5 (70 - 95)	4
Intentional Uses		
Artisanal and small-scale gold mining	727 (410 – 1040)	37
Chlor-alkali industry	28.4 (10.2 – 54.7)	1
Consumer product waste	95.6 (23.7 – 330)	5
Cremation (dental amalgam)	3.6 (0.9 - 11.9)	<1
Grand Total 1960 Tonnes	**(1010 – 4070)**	100

Ref 1 : Global Mercury Assessment 2013 - UNEP
www.unep.org/PDF/PressReleases/REPORT_Layout11.pdf Page No. 9

The global emissions inventory for 2010 (Ref 1-page 9) estimates that 1960 tonnes of mercury were emitted to the atmosphere as a direct result of human activity.

Worldwide emission of Mercury to the Air

Region	Emission(range), tonnes	%
Australia, New Zealand & Oceania	22.3 (5.4 - 52.7)	1.1
Central America and the Caribbean	47.2 (19.7 - 97.4)	2.4
CIS & other European countries	115 (42.6 - 289)	5.9
East and Southeast Asia	777 (395 - 1690)	39.7
European Union (EU27)	87.5 (44.5 - 226)	4.5
Middle Eastern States	37.0 (16.1 - 106)	1.9
North Africa	13.6 (4.8 - 41.2)	0.7
North America	60.7 (34.3 - 139)	3.1
South America	245 (128 - 465)	12.5
South Asia	154 (78.2 - 358)	7.9
Sub-Saharan Africa	316 (168 - 514)	16.1
Undefined (global total for emissions from contaminated sites)	82.5 (70.0 - 95.0)	v4.2
Grand Total 1960	**(1010 – 4070)**	**100**

Ref 1 : Global Mercury Assessment 2013 - UNEP www.unep.org/PDF/PressReleases/REPORT_Layout11.pdf Page No. 11

Re-emission and re-mobilization of mercury

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 air. Mercury deposited to plant surfaces are re-emitted during forest fires or biomass burning. Mercury may be deposited and re-emitted many times as it cycles through the environment. 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. Re-suspension of aquatic sediments due to wave action or storm events is an additional way for mercury to re-enter the aquatic ecosystems.

As per UNEP Global Mercury Assessment 2013 report, anthropogenic releases of mercury to water is 1000 tonnes at a minimum. Point sources are industrial sites such as power plants or factories and they release an estimated 185 tonnes (Ref 1-Page 9) of mercury per year. Contaminated sites, including old mines, landfills, and waste disposal locations, release 8-33 tonnes per year (Ref 1-page 24). Artisanal and small-scale gold mining was evaluated separately, with total releases to water and land totalling more than 800 tonnes per year (Ref 1-Page 25). Deforestation mobilizes another 260 tonnes (Ref 1-Pqge 25) of mercury into rivers and lakes. Other sources remain to be quantified, and so these estimates comprise only a partial total. Thus, anthropogenic releases of mercury to waters are likely to be at least 1000 tonnes per year.

Mercury concentrations in the oceans and in marine animals have risen due to anthropogenic emissions. Anthropogenic emissions and releases have doubled the amount of mercury in the top 100 meters of the world’s oceans in the last 100 years. Concentrations in deeper waters have increased by only 10-25%, because of the slow transfer of mercury from surface waters into the deep oceans. In some species of Arctic marine animals, mercury content has increased by 12 times on average since the pre-industrial period. This increase implies that, on average, over 90% of the mercury in these marine animals today comes from anthropogenic sources. The timing of the initial stage of the increase, which started in the mid-19th century and accelerated in the early 20th century before the rise of Asian industrialization, indicates emissions from Europe, Russia and North America were probably responsible. Studies from the South China Sea suggest a similar pattern occurring there more recently, likely as a result of Asian industrialization (Ref 1).

3. Mercury Emission from Thermal Power Stations in India

Mercury in the atmosphere is in three primary forms. Gaseous elemental mercury is the most common in anthropogenic and natural emissions to the atmosphere. Gaseous oxidized mercury and mercury bound to particulates are less common. Elemental mercury stays in the atmosphere long enough for it to be transported around the world, whereas oxidized and particulate mercury are more readily captured in existing pollution control systems. As a result, most mercury in the air is in the gaseous elemental phase. Although gaseous oxidized mercury is very important in mercury cycling between air and other environmental compartments, the process of oxidation in the air is not fully understood with reactions and resulting compounds yet to be verified in observations.

Thermal Power Plants: India is the fourth-largest producer of coal in the world. Seventy per cent of India's coal production is used for power generation.

As per CEA Mar 2013, installed capacity of Coal based Thermal Power Stations (All India) is 130220 MW (Ref 4-Page 2).

Emissions from Coal Burning: Coal burning, is one of the most significant anthropogenic sources of mercury emissions to the atmosphere. The updated inventory of emissions to air confirms coal burning as a continuing major source of emissions, responsible for around 475 tonnes of mercury emissions globally to air annually, compared with around 10 tonnes from combustion of other fossil fuels. According to the new inventory, more than 85% of these emissions are from coal burning in power generation and industrial uses. In the previous assessment, emissions from domestic and residential coal burning were highlighted as a possible larger contribution. Better information on coal consumption for domestic and residential uses indicates that these activities are a smaller contribution to total emissions from coal burning than previously thought (Ref 1-page 9).

Coal consumption in TPPs in India has increased from 273 Mt to 417 Mt (Ref 4-Page 2) in which contribution of imported coal was 7 to 8 Mt only from year 2006 to 2008 respectively (Ref CE-2008).

Run-of-mine coals typically have high ash content, high moisture content, low sulphur content, and low calorific values (between 2500–5000 kcal/kg). The low calorific value implies more coal usage to generate the same amount of electricity. Indian coal, however, has lower sulphur content in comparison to other coals, although it has relatively high amounts of toxic trace elements, especially mercury.

As per Mercury in India-Usage and Release Report 2008, the total mercury pollution potential from coal in India is estimated to be 77.91 tonnes per annum, considering average concentration of mercury in coal as 0.272 ppm. About 59.29 tonnes per annum mercury is mobilised from coal-fired thermal power plants alone. Thus, mercury being persistent in the environment, its presence in the air in this amount could enter into the body through the oral route and prove a great threat to people, especially those living in the vicinity of these thermal power plants (Ref 3-Page 32).

Around 75 thermal power plants in India produce 65-75 million tonnes of fly ash. Mercury is concentrated as 0.1 ppm as a trace element in the fly ash. The influence of leached trace elements on ground water quality is an area of major concern (Ref 3-Page 32).

Total Installed generating capacity remains at 130220 MW. All India coal consumption in the year 2008-09 was 355 MT, 2009-10 - 367 MT, 2010-11 - 387 MT and 2011-12 - 417.56 MT (Ref 4-Page 2).

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.

Mercury (Hg) concentration in bituminous and other coal types across the world.

Country	Hg in Bituminous coal(mg/Kg)	Hg in coal (mg/Kg)
Australia	0.026-0.40	0.01-1.0
Germany	0.70-1.40	-
Japan	0.027-0.11	0.045
New Zealand	0.020-0.56	-
Poland	0.050-0.07	-
England	0.20-0.70	-
USA	0.01-1.80	0.17
South America	-	0.20-0.96
The former Soviet Union	0.074-0.18	0.02-0.9
China	-	0.15-0.303
Europe	-	0.01-1.5
Korea		0.012-0.048

Ref 5 : Source: Emission Estimate of Passport-Free Heavy Metal Mercury from ...
toxicslink.org/.../Mercury_Emission_inventory_TPP_NON_FERROUS_I...Page 14

Mercury (Hg) concentration in Indian coal across India

Locations	Hg in coal (µg/g)
GHTTP, Lehra, Mohab-att	0.26
Anpara, UP	0.26
North Chennai	0.33
NLC-TPS II	0.18
Chandrapura STPS	0.325
Kolghat TPS	0.61
Talchar TPS	0.33
Gandhinagar TPS	0.42

Ref 5 : Emission Estimate of Passport-Free Heavy Metal Mercury from ...
toxicslink.org/.../Mercury_Emission_inventory_TPP_NON_FERROUS_I...Page 15

Species- specific Emission profiles of Hg from TPPs in India

Hg-in coal released into the exhaust gas as elemental-Hg at the high temperature. Part of elemental Hg formed get oxidized to mercuric form in presence of SO2, fly-ash etc. Physicochemical properties of Hg depend upon its state. Elemental mercury is insoluble whereas mercuric is soluble in water. Because of the soluble nature of mercuric-form it has a tendency to get associated or adhered to the particles in the flue-gas as well. The residence time of Hg in the elemental state varies between 0.5 to 2 years whereas in the Hg+2 and Hg-particulate much less (few days to weeks). So, elemental Hg has contribution in the global circulation whereas other forms predominate in the regional one by atmospheric deposition.

Species-specific emission of Hg (ton) based upon estimated-mean value from TPPs in India.

Species of Hg	2006	2007	2008
Hg0 (gas)	47.4	51.2	55.8
Hg+2	37.9	40.9	44.6
Hg (particulate)	9.5	10.2	11.2

Ref 5 : Source: Emission Estimate of Passport-Free Heavy Metal Mercury from ...
toxicslink.org/.../Mercury_Emission_inventory_TPP_NON_FERROUS_I...Page 18

Projection for Coal consumption for year 2008-2020 from Indian TPPs

Total consumption of coal in the power sector is expected to be around 1000 MT by 2020 Coal use for electricity generation in India is projected to grow by 1.9 percent per year .

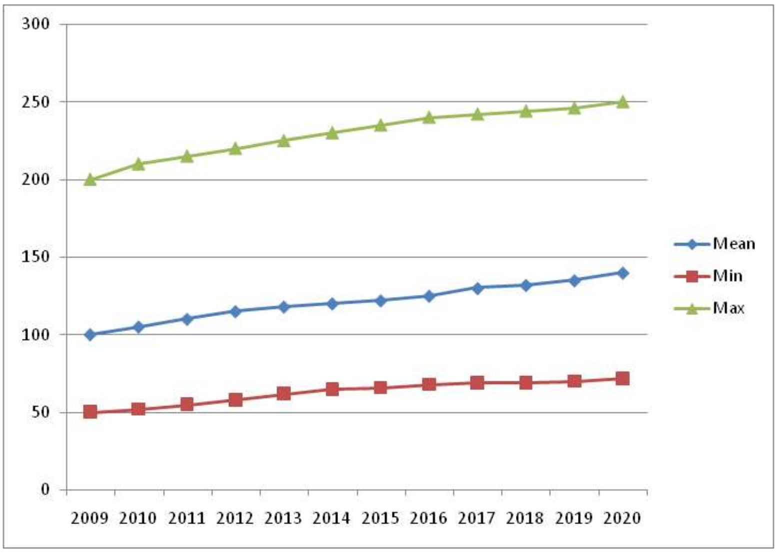
Year	Rate of increment in annual consumption (%)	Increase in annual coal consumption Projected (1000 ton)	Total projected coal consumption (1000 ton)
2009	1.9	6219	333539
2010	1.9	6337	339876
2011	1.9	6458	346334
2012	1.9	6580	352914
2013	1.9	6705	359620
2014	1.9	6833	366453
2015	1.9	6963	373415
2016	1.9	7095	380510
2017	1.9	7230	387740
2018	1.9	7367	395107
2019	1.9	7507	402614
2020	1.9	7650	410264

Ref:5: Emission Estimate of Passport-Free Heavy Metal Mercury from Indian Thermal Power Plants and Non-Ferrous Smelters
http://toxicslink.org/docs/Mercury_Emission_inventory_TPP_NON_FERROUS_INDISTRY.pdf

Projected Hg-emission from the coal based TPPs in India (2009-2020)

Using lowest and highest possible emission factor for Hg-emitted from TPPs is between 68 Tons to 250 Tons (Ref 5-Page 20) as shown below. Apart from emission factor of coal there are certainly other factors like the actual growth rate in the coal consumption and use of typical air pollution control devices in future that can change the projected estimate.

Emission projection of Hg-from coal based TPPs in India (2009-2020):



Ref 5 : Emission Estimate of Passport-Free Heavy Metal Mercury from ...
toxicslink.org/.../Mercury_Emission_inventory_TPP_NON_FERROUS_I...Page 20

4. Mercury Emission control Technologies for Coal-fired Electric Utility Boilers

Control-technology options for reducing Hg-releases may be divided into the following three categories,(1) Pre-treatment measures; (2) Combustion modifications; and (3) Flue gas cleaning or end-of-pipe controls.

Pre-treatment measures: This typically includes Coal Beneficiations. Coal beneficiation is a generic term used for washing of coal and is done to lower the ash by 8 to 12% and increase the Gross Calorific Value (GCV), Kcal/ Kg.

Combustion modifications: These modifications may be used to reduce mercury concentrations in the flue gas, or they may be used to change the characteristics of the flue gas stream so that mercury is more easily captured in downstream flue gas cleaning equipment. The modifications may include using technologies such as fluidized bed combustor, mass burn/waterwall combustor, low- (Oxides of Nitrogen) NOx burner, etc.,

Flue gas treatment, or end-of-pipe controls: These are currently deployed for control of SO2, NOx, particulate matter (PM) and hence also trace metals like Hg. SO2 control technologies include a variety of wet and dry scrubbers; NOx may be controlled by selective catalytic or selective non-catalytic reduction; and PM might be controlled by fabric filters (FFs) or electrostatic precipitators (ESPs). Additional Hg-control can be achieved by injection of a sorbent (Activated carbon- and/or calcium based) prior to the flue gas treatment system.

During combustion, the mercury (Hg) in coal is volatilized and converted to elemental mercury (Hg0) vapor in the high temperature regions of coal-fired boilers. As the flue gas is cooled, a series of complex reactions begin to convert Hg0 to ionic mercury (Hg2+) compounds and/or Hg compounds (Hgp) that are in a solid-phase at flue gas cleaning temperatures or Hg that is adsorbed onto the surface of other particles.

The majority of gaseous mercury in sub-bituminous- and lignite-fired boilers is elemental Mercury Hg0. Control of mercury emissions from coal-fired boilers is currently achieved via existing controls used to remove particulate matter (PM), sulphur dioxide (SO2), and nitrogen oxides (NOx). This includes capture of Hgp in PM control equipment and soluble Hg 2+ compounds in wet flue gas de-sulphurization (FGD) systems. Use of selective catalytic reduction (SCR) NOx control enhances oxidation of Hg0 in flue gas and results in increased mercury removal in wet FGD.

Table 1. Average mercury capture by existing post-combustion control configurations used for PC-fired boilers

Post - Combustion Control Strategy	Post - Combustion Emission Control Device Configuration	Average Mercury Capture by Control Configuration		
		Coal Burned in Pulverized - coal - fired Boiler Unit		
		Bituminous Coal	Subbituminous Coal	Lignite
PM Control Only	CS-ESP	36%	3%	0%
	HS-ESP	9%	6%	not tested
	FF	90%	72%	not tested
	PS	not tested	9%	not tested
PM Control and Spray Dryer Adsorber	SDA+CS-ESP	not tested	35%	not tested
	SDA+FF	98%	24%	0%
	SDA+FF+SCR	98%	not tested	not tested
PM Control and Wet FGD System	PS+FGD	12%	0%	33%
	CS-ESP+FGD	75%	29%	44%
	HS-ESP+FGD	49%	29%	not tested
	FF+FGD	98%	not tested	not tested

Ref 6: Control of Mercury Emissions from Coal-fired Electric Utility Boilers
www.epa.gov/ttnatw01/utility/hgwhitepaperfinal.pdf Page 2

CS-ESP = cold-side electrostatic precipitator (a) Estimated capture across both control devices
HS-ESP = hot-side electrostatic precipitator
FF = fabric filter
PS = particle scrubber
SDA = spray dryer absorber system

As seen in Table 1, in general, the amount of Hg captured by a given control technology is greater for bituminous coal than for either sub-bituminous coal or lignite. For example, the average capture of Hg in plants equipped with a CS-ESP is 36 percent for bituminous coal, 3 percent for sub-bituminous coal, and 0 percent for lignite.

There are two broad approaches to mercury control: (1) activated carbon injection (ACI), and (2) multi pollutant control, in which Hg capture is enhanced in existing/new SO2, NOx, and PM control devices.

State-of-the-art of Controlling Mercury Emissions by Activated Carbon Injection:

ACI has the potential to achieve moderate to high levels of Hg control. The performance of an activated carbon is related to its physical and chemical characteristics. Generally, the physical properties of interest are surface area, pore size distribution, and particle size distribution. The capacity for Hg capture generally increases with increasing surface area and pore volume. The ability of Hg and other sorbates to penetrate into the interior of a particle is related to pore size distribution. The pores of the carbon sorbent must be large enough to provide free access to internal surface area by Hg0 and Hg2+ while avoiding excessive blockage by previously adsorbed reactants. As particle sizes decrease, access to the internal surface area of the particle increases along with potential adsorption rates.

Carbon sorbent capacity is dependent on temperature, the concentration of Hg in the flue gas, the flue gas composition, and other factors. In general, the capacity for adsorbing Hg2+ will be different than that for Hg0. The selection of a carbon for a given application would take into consideration the total concentration of Hg, the relative amounts of Hg° and Hg2+, the flue gas composition, and the method of capture [electrostatic precipitator (ESP), FF, or dry FGD scrubber].

Improvement of Abatement of Mercury Emissions via Oxidation with Bromine Compounds:

Mercury is released when coal is burned and takes three forms in the flue gas: elemental, oxidized, and particulate. Oxidized and particulate mercury can be controlled by abatement equipment designed for other pollutants such as ESP or FGD units. Elemental mercury is gaseous at combustion temperatures and is difficult to capture.

Calcium bromide (CaBr2) is one of the chemical additives that has been developed as a mercury-specific control technology. CaBr2 is effective in reducing total mercury emissions by oxidizing elemental mercury that is then captured by the abatement equipment.

The baseline data indicates the percentage of mercury removed by the APC configuration without any mercury specific control technology. With the addition of calcium bromide the percentage of mercury removed increases with each abatement configuration. The increased removal of mercury indicates that calcium bromide effectively oxidizes previously uncaptured elemental mercury, which is then collected by the APC devices.

Mercury Removal with the Addition of Calcium Bromide

	% Mercury Removed					
Equipment	FF	CS-ESP	CS-ESP/FGD	HS-ESP/FGD	SCR CS-ESP	SRC/SDA/FF
Baseline	19	28	28	44	60	20
CaBr2	>55	60	86	>80	90*	85

*Fly ash passed concrete use test

Ref 7 : CALCIUM BROMIDE TECHNOLOGY FOR MERCURY EMISSIONS ...
www.greatlakes.com/.../GreatLakes/.../GeoBrom%20White%20Paper.pdf .. .. .. Page 4

- FF (fabric filter bag house)
- CS-ESP (cold-side electrostatic precipitator)
- CS-ESP / FGD (cold-side electrostatic precipitator / flue gas desulfurization unit)
- HS-ESP / FGD (hot-side electrostatic precipitator / flue gas desulfurization unit)
- SCR / CS-ESP (selective catalytic reduction / cold-side electrostatic precipitator)
- SCR / SDA / FF (selective catalytic reduction / spray dryer absorber / fabric filter)

Table below shows a number of abatement configurations where calcium bromide has been used in combination with activated carbon. The data indicate that the addition of calcium bromide improves the effectiveness of activated carbon in removing mercury.

Mercury Removal with Activate Carbon & Calcium Bromide

	% Mercury Removed					
Equipment	FF	CS-ESP	SDA/CS-ESP	SDA/FF	SCR/FGD/CS-ESP	SCR/SDA/FF
Baseline	19	28	18	20	15	20
AC Only	58	73				48
CABr2/AC	>90	88	>80	86	90	>90

Ref 7 : CALCIUM BROMIDE TECHNOLOGY FOR MERCURY EMISSIONS ... www.greatlakes.com/.../GreatLakes/.../GeoBrom%20White%20Paper. pdf Page5

1. FF (fabric filter bag house)
2. CS-ESP (cold-side electrostatic precipitator)
3. SDA / CS-ESP (spray dryer absorber / cold-side electrostatic precipitator)
4. SDA / FF (spray dryer absorber / fabric filter bag house)
5. SCR / FGD (selective catalytic reduction / flue gas desulfurization unit)
6. SCR / SDA / FF (selective catalytic reduction / spray dryer absorber / fabric filter bag house)

Multi pollutant Removal in Wet FGD: More than 20% (Ref 6-Page 7) of coal-fired utility boiler capacity uses wet FGD systems to control SO2 emissions. In such systems, a PM control device is installed upstream of the wet FGD scrubber. Wet FGD systems remove gaseous SO2 from flue gas by absorption. For SO2 absorption, gaseous SO2 is contacted with a caustic slurry, typically water and limestone or water and lime.

The capture of Hg in units equipped with wet FGD scrubbers is dependent on the relative amount of Hg2+ in the inlet flue gas and on the PM control technology used. Study reveals that average Hg capture ranged from 29 % (Ref 6-Page 7) for one PC-fired ESP plus FGD unit burning sub-bituminous coal to 98 percent in a PC-fired FF plus FGD unit burning bituminous coal. The high Hg capture in the FF plus FGD unit was attributed to increased oxidization and capture of Hg in the FF followed by capture of any remaining Hg2+ in the wet scrubber.

Multi pollutant Removal in Dry Scrubbers: Spray dryer absorber (SDA) systems are used to control SO2 emissions. An SDA system operates by the same principle as a wet FGD system using a lime scrubbing agent, except that the flue gas is mixed with a fine mist of lime slurry instead of a bulk liquid (as in wet scrubbing). The SO2 is absorbed in the slurry and reacts with the hydrated lime reagent to form solid calcium sulfite and calcium sulfate. Hg2+ may also be absorbed. Sorbent particles containing SO2 and Hg are captured in the downstream PM control device (either an ESP or FF). If the PM control device is a FF, there is the potential for additional capture of gaseous Hg0 as the flue gas passes through the bag filter cake composed of fly ash and dried slurry particles.

Studies reveal that units equipped with SDA scrubbers (SDA/ESP or SDA/FF systems) exhibited average Hg captures ranging from 98 % for units burning bituminous coals to 24 % for units burning sub-bituminous coal (Ref 6-Page 8).

Multi-pollutant Removal Via SCR and Wet FGD: The speciation of mercury is known to have a significant impact on the ability of air pollution control equipment to capture it. In particular, the oxidized form of mercury, mercuric chloride (HgCl2), is highly water-soluble and is, therefore, easier to capture in wet FGD systems than Hg0 which is not water-soluble. SCR catalysts can act to oxidize a significant portion of the Hg0, thereby enhancing the capture of mercury in downstream wet FGD.

Oxidation of elemental mercury by SCR catalyst may be affected by the following:

- The space velocity of the catalyst;
- The temperature of the reaction;
- The concentration of ammonia;
- The age of the catalyst; and
- The concentration of chlorine in the gas stream.

Current practices in controlling Hg-emissions

The Ministry of Environment and Forest (MoEF) insists on making space provision for Flue Gas Desulphurization (FGD) in the design of thermal power units of 500MW and above capacity to facilitate their retrofitting at a later stage in case the need for such plant is established. In sensitive areas the installation of FGD Plant may be insisted upon even for stations with smaller capacity.

Electrostatic Precipitators

Electrostatic Precipitators have been provided to control the emission of particulate matter with appropriate stack height for adequate dispersion of gaseous pollutants. For wider dispersal of SO2, stack height of different capacity units have been stipulated. For units less than 500 MW the stack height has been stipulated as 220 meters whereas 500 MW units it is 275 meters.

Levels of Mercury Controls at Existing Plants around the Globe

Information from a number of countries confirms the variety of options available to achieve substantial reductions in mercury emissions. Mercury control is Achieved significantly with Activated Carbon Injection system.

New Hampshire, USA : The Bridgeport Harbor Station in New Hampshire, USA operates a 403 MW sub-bituminous coal fired conventional boiler built in the 1960s. It is equipped with a cold side Electrostatic precipitator without flue gas conditioning; a pulse jet fabric filter and activated carbon injection were added. The mercury capture rate was observed to be greater than 90 percent.

Michigan, USA : The Presque Isle Station in Michigan operates a mix of fuels in its conventional boilers. Several boilers use a mix of bituminous coal and petroleum coke, and are equipped with cold side ESPs; these achieve a 60 to 66 percent mercury removal rate. Other boilers at this plant (No. 7-9, 270 MW) burn Powder River Basin sub-bituminous coal and are equipped with hot side ESPs but achieve virtually no mercury reduction at all without specialized mercury controls. These units were equipped with a TOXECONTM carbon injection and fabric filter system that achieves a roughly 90 percent mercury removal rate. The TOXECONTM bag house was installed after the hot-side ESPs. The system performs best with a brominated carbon (DARCO® Hg-LH at 0.5-3lb/MMacf) .

Texas, USA: The Monticello station in Texas burns lignite and sub-bituminous coal in several conventional boilers and has a cold side ESP and a wet FGD on one of the major boilers (#3, 593 MW). Baseline mercury removal rates were roughly 36 percent. The use of halogen additives including calcium chloride and calcium bromide reduced mercury by up to 92% ($CaBr_2$ having been the most effective at very high injection rates of 332 ppmw). Catalysts were also tested on this unit downstream of the ESP, producing mercury reductions of up to 87 percent. **The Palladium catalyst was the most successful.**

New Jersey, USA: The Logan Generating Plant in New Jersey operates a 242 MW bituminous fired conventional boiler, which is equipped with a bag house, spray dryer and SCR (all installed in 1994). It achieves a 97 percent mercury reduction without any specialized mercury controls.

Russia : The Kashirskaya Power Plant outside of Moscow has three 300 MW coal boilers with ESPs and wet ash removal. Mercury removal rates of 74% have been measured. **Mercury Control Possible with Wet Scrubbers**

Slovenia: One of the major thermal power plants, which supplies one third of the power in Slovenia, reports a mercury capture rate approaching 90% with wet FGD. The high mercury removal rates for the five lignite firedboilers outfitted with ESPs is attributed to oxygen in the scrubber that oxidizes the mercury.

China: Numerous studies have documented mercury removal rates from existing air pollution controls on power plants in China. Removal efficiencies vary greatly: ESPs removed from 4.6% to 98.6% (Average, 22%);17 Wet FGDs removed 7.3% to 75%; FFs removed 2% to 85%; SCR/ESP/WFGD removed 73% to 93%. The most common scenario, ESPs plus FGD, removes 70% of mercury on average, but FFs and SCR should improve mercury removal; they are expected to be widely installed from 2010 to 2020. Large ranges in mercury removal efficiencies among existing air pollution controls suggest that halogen additives or other chemical treatments may be useful in boosting mercury removal rates. **NOx Controls Can Enhance Mercury Removal**

South Korea: Thermal power plants in Korea report mercury control of 68 percent to 91 percent from some plants with certain high efficiency air pollution controls including SCR, CS-ESP, and wet FGD. One bituminous fuelled plant (500 MW) with just ESP and wet FGD, however, reports a 95 percent mercury removal rate.

Massachusetts, USA: The Salem Harbor Station in Massachusetts operates several bituminous fuelled conventional boilers equipped with ESP and Selective noncatalytic reduction achieving a roughly 90 percent mercury reduction without any specialized mercury controls.

Netherlands : Fairly high mercury removal rates are reported for certain combinations of existing air pollution controls on coal fired power plants: around 50% for ESPs alone; around 75% for ESPs with wet scrubbers; and up to 90 percent for SCR with ESPs and wet scrubbers.

It should be noted that simply having multi-pollutant air pollution control devices in place does not ensure mercury control. For example, the Wygen station in Wyoming has two boilers burning sub-bituminous fuel (91 and 96 MW) equipped with pulse fabric filters, spray dryers and SCR. Mercury removal rates are very low: 5 to 33%. (*Ref 8 : NRDC: Evaluating Mercury Control Technologies for Coal Power ... www.nrdc.org/international/.../mercury-controls-coal-power-plants-FS.pdf)*

5. Mercury in industrial Usage

The largest consumer of mercury is the chlor-alkali industry, which manufactures caustic soda and chlorine as a by-product using electrolytic process with mercury electrodes.

The second-largest consumption of mercury is for the production of Instruments, electrical apparatus, mercury vapour lamps, electrical switches, fluorescent lamps, thermometres, barometers, etc.

Mercury is used in the health care sector for blood pressure monitoring instruments, dental amalgams and also used in laboratory chemicals.

Mercury finds application in metallurgy and mirror coating and as a coolant and neutron absorber in nuclear power plants as well.

Chlor-alkali Industry: The caustic soda industry had always been plagued by the problem of high-energy consumption and mercury pollution. Caustic soda and chlorine are two basic chemicals being used in various products. The usage pattern of caustic soda is depicted in the table below.

Caustic Soda Usage Pattern ('000 tonnes)			
End Use	1990	1995	2000
Paper/paper board	160	235	300
Miscellaneous	113	133	160
Soaps and detergents	110	115	130
Chemicals	90	105	120
Aluminium	86	110	110
Exports	15	35	93
Rayon grade wood pulp/viscose yarn/VSF	89	89	89
Cotton textiles	77	77	77
Fertilisers	40	50	72
Dyes and intermediates	35	42	50
Pharmaceuticals	31	34	38
Petrochemicals	13	22	35
Demineralisation	16	20	26
Power	16	20	26
Oil drilling	8	10	12
Vegetable oils	8	9	10
Rayon tyre cord	9	9	9
Mineral and metals	4	5	6
Total	**920**	**1120**	**1363**

Ref : 3 MERCURY IN INDIA - Toxics Link
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Increased requirement of caustic soda and chlorine is due to increase in the production of paper, aluminium, soaps and detergents, chemicals and other miscellaneous items.

There are two processes currently used by the chlor-alkali industry, the mercury cell and the more modern membrane cell.

Releases from Chlor-alkali Industry : There is an immediate environmental impact from the use of mercury in the mercury cell process. Although mercury does not take part in the reaction, it is always lost to the environment during the process, often as a contaminant in brine sludge. The quantity of mercury that is consumed in the production of one tonne of caustic soda is nearly the same as the amount lost in the same production process.

Recent update By UNEP - Global Mercury Assessment 2013 Sources, Emissions, Releases and Environmental Transport says that the mercury release from Chlore –Alkali industries ranges from 10.2T to 54.7T (Ref 1). Mercury-cell technology is becoming less common in the chlor-alkali industry as other, more cost effective processes are adopted. No new plants are being constructed, though many older plants remain to be converted. Old chlor-alkali plants and other decommissioned industrial sites may constitute contaminated sites that continue to release mercury to the environment for many years and emissions from contaminated sites are now part of the inventory.

Mercury in Health Set-ups:

Mercury is widely used in the health care sector. Source of Mercury in Hospitals are:

1. Thermometers and thermostats
2. Blood pressure monitors (sphygmomanometers)
3. Dilators and batteries
4. Dental amalgams
5. Laboratory chemicals like zenkers solution and histological fixatives

Hospitals and clinics, big or small, are the largest consumers of these instruments.

Usage of Mercury Instrument Manufacturing Industry: Mercury is used in many medical and industrial instruments for measurement and control functions. These instruments include all types of thermometers such as clinical, laboratory and meteorological ones, as well as blood pressure monitors (sphygmomanometers) and barometers.

Thermometer Industry: The thermometer industry in India is essentially a small sector industry with a capacity of 40,000 to 50,000 (Ref 3-page 21) pieces per month.

A clinical thermometer contains approximately 0.61 grams of mercury. Thus with an annual capacity of 5 million clinical thermometers, about 3.1 tonnes of mercury are required annually for their manufacture (Ref 3-Page 22).

Clinical Thermometer Manufacturers	
Company	**(Production pieces per month approx)**
Unitech Thermometers(Delhi)	40,000-50,000
Hanimax Thermometers(Delhi)	50,000-60,000
Hindustan Thermometers(Delhi)	50,000-60,000
Wilkho Thermometers(Delhi)	30,000-35,000
MCP(Medical Products) (Delhi)	40,000-45,000
Locally made (unorganised sector) (Delhi)	25,000-30,000
Hick Thermometers(Aligarh)	60,000-70,000
Maharana Thermometers(Sonepat)	50,000-55,000
Locally made (unorganised sector) (Ambala)	50,000-60,000
Total	**395,000-465,000**

Ref 3 : MERCURY IN INDIA - Toxics Link
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Laboratory Thermometers: Laboratory thermometers are bigger in size than clinical thermometers and are used in various laboratories of educational and research institutions for research purposes. The laboratory thermometer industry is based in Delhi, Ambala, and a few other places in India.

Approximately, about 300,000 laboratory thermometers are manufactured annually in India. A laboratory thermometer contains approximately 3 gm of mercury. Thus, about 900 kg of mercury is consumed to produce 300,000 laboratory thermometers in one year (Ref 3-Page22).

Blood Pressure Monitors (Sphygmomanometers): Blood pressure monitors, one of the important instruments used in the health care sector, are found in all hospitals and clinics. Mercury is used in sphygmo-manometers because its high density occupies less volume. A blood pressure monitor contains approximately 60 gm (Ref 3-Page22) of mercury. Thus about 12,000 (Ref 3-Page22) kg of mercury is consumed to produce 200,000 blood pressure monitoring instruments annually.

Dental amalgams: Mercury is used in dentistry, primarily in amalgam fillings for teeth. The cavity is drilled and filled with amalgams. Dental amalgams are typically 40-50 (Ref 3-Page29) per cent elemental mercury by weight. In dental amalgams, mercury is mixed with copper, gold and silver to form an amalgam. Dental amalgams represent a significant source of overall mercury exposure and are probably the population's major source of elemental mercury vapour

Barometers: Barometers are one of the important instruments used in meteorological departments, and can also be found in weather stations and educational and research institutions. Generally all the barometers manufactured are of one standard size and contain approximately 5 kg of mercury. On an average, around 25 pieces a year are manufactured in India, generally on the basis of orders given by various institutions. Thus, about 125 kg of mercury is annually required in the manufacturing of barometers (Ref 3-Page23) .

Releases from Instrument Manufacturing Industry: India produces approximately 10 to 12 (Ref 3-Page24) million instruments a year including clinical and laboratory thermometers as well as blood pressure monitors (sphygmomanometers), consuming about 15 (Ref 3-Page24) tonnes of mercury annually.

Name	Unit (in kg)	Used/unit
Clinical thermometers	3,100	0.61 gm
Laboratory Thermom-eters	900	3.00 gm
Blood pressure moni-tors (Sphygmomanom-eters)	12000	60 gm
Barometers	125	5 Kg
Total	**16,125**	

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Electrical Apparatus Manufacturing Industry: Mercury is one of the best electrical conductors among metals and is used in many areas of electrical apparatus manufacturing.

Electric Switches: The electric switch is an important house hold item; it's presence is necessary in every building and house, where electricity is available. Mercury switches are used in thermostats and some alarm type clocks. Mercury switches are also used in automobiles, thus playing an important part in the automobile industry.

Electric lamps containing mercury include fluorescent, mercury vapour, metal halide and high-pressure sodium vapour lamps. The main mercury-containing electric lamps manufactured in India are:

Fluorescent lamps: Fluorescent lamps contains approximately 15 to 250mg (Ref 3-Page26) of elemental mercury (both tubes and bulbs) in the form of mercury vapour, put inside the glass tube.

Production of Fluorescent Lamps	
Years	**Numbers in Million**
1980-81	2.36
1985-86	3.55
1990-91	5.07
1993-94	6.36
1994-95	7.71
1995-96	9.77
1996-97	11.36
1997-98	14.5
1998-99	13.23
1999-2000	12.49

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Mercury and metal halide lamps consist of an inner quartz arc tube enclosed in an outer envelope of heat resistant glass. The quartz arc tube contains a small amount of mercury ranging from20 mg in a 75-watt lamp to 250 mg in a 1000-watt lamp (Ref 3-Page27) .

Battery Production: Generally the battery is made up of an anode (positive electrode), a cathode (negative electrode) and an electrolyte. Different materials are used to make the anodes and cathodes, such as zinc, mercury oxide and silver oxide, lead acid, carbon and nickel and cadmium.

Mercuric oxide batteries fall into two categories: button cell and larger sizes. Most mercuric batteries sold for personal use are button cells. Mercuric oxide batteries are widely used for applications including medical, industrial and military applications and other non-household devices.

Fungicide Industry: Fungicides are based on the broadly toxic elements; copper, mercury and sulphur were among the earliest agrochemicals. Though synthetic systemic compounds have largely superseded them, mercury-based compounds are still an integral part of the pesticide industry.

Thus, 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.

The major contributors of adding mercury to the environment via air emissions are, Coal fired thermal power plants, Medical waste incinerators and Municipal waste incinerators.

Municipal Solid Waste Disposal: Municipal solid waste is generally disposed off in three ways in India (i.e.) Landfill dumping, Open dumping and Open burning. Municipal solid waste consists primarily of household garbage and other commercial, institutional and industrial solid wastes. Mercury batteries are a known source of mercury in municipal solid waste.

Even though the amount of mercury present in municipal solid waste is small in proportion, it is enough to cause environmental and health concerns to large population.

Medical Waste Disposal: Mercury is found in many health care instruments. Medical waste incinerators are one of the largest sources of mercury pollution in the environment. It is estimated that up to 50 times (Ref 3-Page34) more mercury is present in hospital waste than in general municipal waste, and the amount of mercury emitted by medical waste incinerators represents more than 60 times the emissions' level from pathological waste incinerators.

6. Methyl mercury contamination and its impact on Health

Industrial emissions of mercury into the atmosphere have contaminated the fish in many of the freshwater sources within the industrialized countries, as well as the world's oceans. The poisoning of the human race has been ongoing at an ever-increasing rate to reveal itself as neurological problems in children born to mothers who eat fish and shellfish. For this reason, mercury contamination has become the first global pollutant requiring a swift and focused approach to overcome this issue.

The myriad of chemicals that find their way into the world's oceans go into a vast and complicated web of nature, we call the food chain. Every living thing on earth that eats fish or shellfish has elevated levels of chemicals and metals in their bodies associated with the industrialized world.

Minute quantities of mercury are sufficient to pollute entire ecosystems. For example, it is a fact that 1/70th(Ref 2-Page 6) of a teaspoon of mercury can contaminate a 20 acre lake to the point that fish are unsafe to eat.

Mercury enters the atmosphere as a vapor that escapes with smoke stack flue gases when coal is burned in power generating plants. Mercury is emitted in three chemical states: in the elemental form, as oxidized mercury, and absorbed to particulates. Each of the mercury species has a different fate in the atmosphere. Elemental mercury vapor can be transported over very long distances, even globally, with air masses. The atmospheric residence time of elemental mercury is in the range of months to approximately one year. Therefore, emissions of mercury on any continent of the world can contribute to deposition on all other continents. Particle-bound mercury has a much shorter atmospheric lifetime than elemental mercury vapor and deposit by wet or dry deposition within roughly a few days, or within 500 miles of the source.

Gaseous elemental mercury in the atmosphere falls naturally on to land as it mixes with air-borne particulates or is washed by rain and snow from the air. A portion of it enters the aquatic systems directly and the remaining becomes bound to the soil until rain and irrigation waters wash it into adjacent water bodies. Mercury is converted by bacteria and algae in water and in sediments to methyl mercury, this process is often referred to as the methylation of inorganic mercury.

Fish feed on algae and other organisms absorb methyl mercury in two ways, directly from water as it passes over their gills. As larger fish eat smaller ones, methyl mercury concentrations increase in bigger fish, a process known as bioaccumulation. Humans, birds and other wildlife that eat fish are exposed to methylmercury in this way.

7. World Health Organisation - Mercury in Health Care

Mercury may be fatal if inhaled and harmful if absorbed through the skin. Around 80% of the inhaled mercury vapour is absorbed in the blood through the lungs. It may cause harmful effects to the nervous, digestive, respiratory, immune systems and to the kidneys, besides causing lung damage. Adverse health effects from mercury exposure can be: tremors, impaired vision and hearing, paralysis, insomnia, emotional instability, developmental deficits during fetal development, and attention deficit and developmental delays during childhood.

Contribution from the health-care sector and Regulation: Health-care facilities are one of the main sources of mercury release into the atmosphere because of emissions from the incineration of medical waste. Emissions from incinerators were the fourth-largest source of mercury emission to the atmosphere. Health-care facilities may also have been responsible for as much as 5% of all mercury releases in waste water.

Dental amalgam is the most commonly used dental filling material. It is a mixture of mercury and a metal alloy. The normal composition is 45-55% (Ref 9-Page1) mercury; approximately 30% (Ref 9-page1) silver and other metals such as copper, tin and zinc. World Health Organization confirmed that mercury contained in dental amalgam is the greatest source of mercury vapour in non-industrialized settings, exposing the concerned population to mercury levels significantly exceeding those set for food and for air. Mercury from dental amalgam is discharged to the sewer, atmosphere or land, with the clinical waste stream.

Mercury releases from the health sector in general are substantial. Some countries have restricted the use of mercury thermometers or have banned them without prescription. A variety of associations have adopted resolutions encouraging physicians and hospitals to reduce and eliminate their use of mercury containing equipment.

Recent update by UNEP - Global Mercury Assessment 2013 Sources, Emissions, Releases and Environmental Transport says that the Global emissions from use of mercury in dental amalgam resulting from cremation of human remains are estimated at 3.6 (0.9 – 11.9) tonnes in 2010. Approximately 340 tonnes of mercury is used per year in dentistry, of which about 70-100 tonnes (i.e. 20-30%) likely enters the solid waste stream (Ref 1-Page10).

Occupational health hazard: The most common potential mode of occupational exposure to mercury is via inhalation of metallic liquid mercury vapours. If not cleaned up properly, spills of even small amounts of elemental mercury, such as from breakage of thermometers, can contaminate indoor air above recommended limits and lead to serious health consequences. Since mercury vapour is odourless and colourless, people can breathe mercury vapour and not know it. For liquid metallic mercury, inhalation is the route of exposure that poses the greatest health risk

Studies demonstrate that mercury containing health-care equipment will invariably break. Small spills of elemental mercury on a smooth, non-porous surface can be safely and easily cleaned up with proper techniques. However, beads of mercury can settle into cracks or cling to porous materials like carpet, fabric, or wood, making the mercury extremely difficult to remove. Spilled mercury can also be tracked on footwear. Inadequate cleaning and disposal may expose already compromised patients and health-care staff to potentially dangerous exposures.

Alternatives: The research findings suggest that many non-mercury alternatives are available to address the full range of functions required by consumer products. For health care, these include blood pressure devices, gastrointestinal devices, thermometers, barometers, and in other studies include the use of mercury fixatives used in labs. Both mercury and aneroid sphygmomanometers have been in use for about 100 years, and when working properly, either gives accurate results.

Of all the mercury instruments used in health care, the largest amount of mercury is used in mercury sphygmo-manometers (80 to 100g/unit) (Ref 9-page2), and their widespread use, collectively make them one of the largest mercury reservoirs in the health-care setting. By choosing a mercury-free alternative a health-care institution can make a tremendous impact in reducing the potential for mercury exposure to patients, staff and the environment. Aneroid sphygmomanometers provide accurate pressure measurements when a proper maintenance protocol is followed. It is important to recognize that no matter what type of blood pressure measurement device is used both aneroid and mercury sphygmomanometers must be checked regularly in order to avoid errors in blood pressure measurement and consequently the diagnosis and treatment of hypertension.

International Conventions: The UNEP Governing Council concluded that there is sufficient evidence of significant global adverse impacts from mercury to warrant further international action to reduce the risks to humans and wildlife from the release of mercury to the environment. The UNEP Governing Council decided that national, regional and global actions should be initiated as soon as possible and urged all countries to adopt goals and take actions, as appropriate, to identify populations at risk and to reduce human-generated releases.

Strategy: To understand better the problem of mercury in health-care sector, it is recommended that countries conduct assessments of current mercury usage and waste management programs. WHO proposes to work in collaboration with countries through the following strategic steps.

Short-term: Develop mercury clean up and waste handling and storage procedures. Until countries in transition and developing countries have access to mercury free alternatives it is imperative that safe handling procedures be instituted which minimize and eliminate patient, occupational, and community exposures. Proper procedures should include spill cleanup response, educational programs, protective gear, appropriate waste storage containment, staff training, and engineered storage facilities. Countries that have access to affordable alternatives should develop and implement plans to reduce the use of mercury equipment and replace them with mercury-free alternatives. Before final replacement has taken place, and to ensure that new devices conform with recommended validation protocols, health-care facilities will need to keep mercury as the "gold" standard to ensure proper calibration of mercury sphygmomanometers.

Medium-term: Increase efforts to reduce the number of unnecessary use of mercury equipment. Hospitals should inventory their use of mercury. This inventory should be categorized into immediately replaceable and gradually replaceable. Replaced devices should be taken back by the manufacturer or taken back by the alternative equipment provider. Progressively discourage the import and sale of mercury containing health-care devices and mercury use in health-care settings, also using global multi lateral environmental agreements to this end. Provide support to countries to make sure that the recovered mercury equipment is not pushed back in the supply chain.

Long-term: Support a ban for use of mercury containing devices and effectively promote the use of mercury free alternatives. Support countries in developing a national guidance manual for sound management of health-care mercury waste. Support countries in the development and implementation of a national plan, policies and legislation on mercury health-care waste. Promote the principles of environmentally sound management of health-care waste containing mercury, as set out in the UN Base Convention on the Control of Trans-boundary Movements of Hazardous Wastes and their Disposal. Support the allocation of human and financial resources to ensure procurement of mercury free alternatives and a sound management of health-care waste containing mercury.

8. EPA Road Map

It is a global concern that the methyl mercury is a potent form of mercury to which humans are primarily exposed. Humans are exposed to methyl mercury mainly by consuming fish that contain methyl mercury. Concentrations of methyl mercury in fish are generally in the order of a million times the methyl mercury concentration in water. In addition to mercury deposition, key factors affecting methyl mercury production and accumulation in fish include the amount and forms of sulphur and carbon species present in a given water body. Thus, two adjoining water bodies receiving the same deposition can have significantly different fish mercury concentrations.

While the primary pathway of human exposure to mercury is through eating fish containing methyl mercury, individuals may also become exposed to harmful levels of elemental mercury vapour found indoors in work places and in homes. When exposed to air, elemental mercury vaporizes and can be inhaled.

Fish Consumption Advice: Fish and shellfish are an important part of a healthy diet, since they contain high quality protein and other essential nutrients, are low in saturated fat and contain omega-3 fatty acids.

Mercury concentrations in fish vary widely. While local freshwater fish also contain methyl mercury, the majority of fish species consumed are ocean species and the methyl mercury concentrations in these species are primarily influenced by the global mercury pool.

Reducing Exposure by Addressing Mercury Releases and Uses Internationally: The Long-term goal of International advisory boards is to reduce risks associated with mercury and also take action to identify exposed populations, minimize exposures through outreach efforts, and appropriately reduce anthropogenic releases.

Six Areas of proposed focus for Mercury emission reduction are:

1. Addressing mercury releases to the environment
2. Addressing mercury uses in products and processes
3. Managing commodity-grade mercury supplies
4. Communicating risks to the public
5. Addressing international mercury sources
6. Conducting mercury research and monitoring

I. Addressing Mercury Releases

Air: In the last 15 years, EPA has focused most of its mercury reduction efforts in air. The Agency now has Clean Air Act (CAA) standards in place limiting mercury air releases from most major known industrial sources.

Water: EPA will further characterize mercury discharges to water and will issue guidance on implementation of its methyl mercury water quality criterion.

Land: As per Global Mercury Assessment 2013, Emissions, Releases and Environmental Transport under UNEP, activities in Artisanal and Small scale Gold Mining (ASGM) are increasing due to rise in gold price. Due to increased activities the emissions rate is also increased from this sector . As per 2010 inventory, the emission rate from this sector is 727 tonnes per year (Ref 1-Page 10). Out of total emission from this sector, 30% (Ref 1-Page 11) is placed in the surface impounds, 70% (Ref 1-Page 11) is placed directly on the land in waste piles and very less quantity goes to land fill. EPA is placing a higher priority on efforts to understand the risks associated with mercury releases to land from mining.

II. Addressing Mercury Uses in Products and Processes:

EPA's long-term goal is to reduce risks associated with mercury. EPA will take action to identify exposed populations, minimize exposures through outreach efforts, and appropriately reduce anthropogenic releases.

III. Managing Commodity-Grade Mercury Supplies:

Elemental mercury is used in many products and processes, and is sold as a commodity on the global market.
EPA expects that there will be an excess supply of elemental commodity-grade mercury on the global market in the near future. As a result, there will be an increasing need for safe storage of excess mercury supplies.

IV. Communicating to the Public about Mercury Exposure Risks:
The Agency will provide consumers with reliable risk information about mercury exposure so that they can make informed choices about the fish they eat and the products they use.

V. International Mercury Sources:

EPA will build collaborative partnerships with industries and environmental groups to bring technical expertise and assistance to address the global mercury problem.

9. UNEP's Awareness programs on mercury emission

The major points covered under UNEP's awareness programs are:

1. National threat Vs local concern
2. Main contributors to mercury emissions in India
3. Mercury free alternatives
4. Mercury laws
5. Technologies and practices
6. Strategies to reduce mercury exposures

The iron and steel industry, the single largest source of huge quantities of particulates was reported to contain as high as 56 ppm Hg in dust fall out and 40-72 ppm in surface soils(Ref 11-Page 8).

The fallout of elemental mercury over the soil-horizon in the vicinity of a steel plant was reported to be in the range of 60.36 to 836.18 g/km2/month (Ref 11-Page 8).

High concentration of the gaseous mercury present in the ambient air closer to the chloroalkali industries may lead to long-range transport of mercury.

The concentration of mercury in blood and hair of human population has been reported to be as high as 100µg/dl and 8µg/g respectively at industrial site compared to 5 µg/dl. and 1 µg/g, respectively in unexposed population. (Ref 11-Page 8)
Based on the studies of occupationally exposed Indian adult population several fold higher concentration of mercury in blood (5 µg/dl and hair 0.15 – 8.4 µg/g) was observed compared to control population(Ref 11-Page 8) .
The concentration of mercury in fish and other sea food consumed in certain coastal areas is reported in range of 0.03-10.82 µg/g compared to the permissible limit of 0.5 µg/g(Ref 11-Page 8)

There is a potential risk to human health and environment due to the entry of mercury in food chain. The fruits and vegetables contain several folds higher concentration mercury in certain industrial area against prescribed standards.

Anthropogenic releases to the aquatic environment

Global assessment

The 2013 Report presents the first attempt at compiling a global inventory of mercury releases to aquatic environments. Releases directly into the aquatic environment present a completely different chemistry, set of pathways, and fate to those released to air. Unlike mercury releases to air, which are predominantly in the form of gaseous elemental mercury, releases to water are predominantly inorganic mercury and to a lesser extent liquid elemental mercury. Global releases from point sources were estimated to be 185 tonnes per year. Total releases to aquatic environments from contaminated sites are estimated to be 8.3-33.5 tonnes per year (Ref 1-Page 24).

Global Threat versus National Concern: It is estimated that 30–70% of Mercury deposition comes from long-range environmental transport of mercury emissions from other countries causing increase of concentration in water,specially in fishes.

Risk due to mercury release by the Indian caustic-chlorine sector:

Although local conditions may affect mercury exposure in certain populations, most people are also exposed to elemental mercury vapours due to occupational activities.

Recent update By UNEP - Global Mercury Assessment 2013 Sources, Emissions, Releases and Environmental Transport says that the mercury release from Chlore –Alkali industries ranges from 10.2T to 54.7T. Mercury-cell technology is becoming less common in the chlor-alkali industry as other, more cost effective processes are adopted.

Mercury Free Alternatives: Majority of products that use mercury purposefully have acceptable alternatives. The following list of alternatives that are currently available for use in health care facilities.

Health Sector

Alternatives for Mercury-containing Thermometers: Electronic (digital), Infrared, Chemical Strip, Glass filled with gallium, indium or tin

Alternatives for Mercury-containing Sphygmomanometers: Aneroid, Electronic

Alternatives for Mercury-containing Gastrointestinal Tubes: Bougie tubes (tungsten), Cantor Tubes (tungsten), Miller Abbott tubes (tungsten), Feeding tubes (tungsten)

Dental Amalgam: Metal ceramic crown,glass synthetic polymer,gold alloy,etc. these alternatives are however available but they are beyond the reach of common people.

Electrical Applications: A Number of alternatives are available to these products such as electronic thermostats, float control, temperature sensitive switches.

Switch	Quantity of mercury	Available
Tilt Switch		
Thermostats	3000-6000mg	Electronic type and snap switch
Float Control(septic tank and sump pumps	2000mg	Magnetic dry reed switch, optic sensor or mechanical switch
Freezer Light	2000mg	Mechanical Switch
Washing Machine	2000mg	Mechanical Switch
Silent Switches(light switches prior to 1991	2600mg	Mechanical Switch
Thermo-Electrical Applications		
Flame Sensor (used for both electrical or mechanical output)	2,500mg	Hot surface ignition system for devices or products that have electrical connections

Ref 11: MERCURY POLLUTION IN INDIA - UNEP Chemicals
www.chem.unep.ch/MERCURY/2003-gov-sub/India-submission.pdf .. .. Page 29

Automobile Sector: Mercury use in automobiles and alternatives-

Products Known to Contain Mercury	Quantity of Mercury (if known)	Known/Possible Use	Available Alternative
Airbag sensors	Not confirmed		mercury-free versions,
Anti-lock braking systems (ABS)	~ 3,000 mg ,		
Headlamps	0.5 - 1 mg	used in high intensity discharge (HID) lamps	standard halogen or tungsten filament for car headlights
Radios		rechargeable batteries for radios;	mercury-free versions
Remote transmitters		mercury oxide batteries	mercury-free versions (zinc air)
Light switches	1,000 mg		electro-mechanical switches

Ref 11 : MERCURY POLLUTION IN INDIA - UNEP Chemicals
www.chem.unep.ch/MERCURY/2003-gov-sub/India-submission.pdf .. .. Page 29

Mercury – Containing Chemicals: Chemical reagents used with regularity in a wide range of laboratory testing are likely sources of mercury contaminations. After concerns shown by several environmental organizations, these mercury reagents are substituted with other chemical alternatives.

Mercury Containing Chemicals and Alternatives

Chemical	Alternatives
Mercury (II) Oxide	Copper Catalyst
Mercury Chloride	None Identified
Mercury (II) Chloride	(i)Magnesium Chloride/Sulphuric Acid or Zinc. (ii)Freeze drying
Mercury Nitrate (For corrosion of copper alloys) for antifungal use.	Ammonia/Copper Sulphate. Mycin
Mercury Iodide	Phenate method
Sulfuric Acid (Commercial grade mercury as impurity)	Sulfuric acid from a cleaner source.
Zenker's solution	Zinc Formalin
Mercury (II) Sulphate	Silver Nitrate / Potassium / Chromium (III Sulphate)

Ref 11 : MERCURY POLLUTION IN INDIA - UNEP Chemicals
www.chem.unep.ch/MERCURY/2003-gov-sub/India-submission.pdf .. .. Page 30

Technologies and Practices and Their Effectiveness Including the Use of Suitable Substitutes: The mercury cell chloro-alkali plant is reported to discharge mercury in waste water. The pollution can be substantially reduced either by the use of some other metal electrodes and electrolytic cell,or by the effective treatment of the effluents from these polluting industries.

DIFFERENT TYPES OF ELECTROLYTIC CELLS: The diaphragm cells are well known substitutes of the mercury cells. The use of titanium substrate insoluble anodes (TSIA) is reported by central Electrochemical Research Institute, Karaikudi, India.

Other Methods: Various other methods for the removal of mercury are reported. These included precipitation of mercury by a more reactive metal, such as Al, Fe, Cu, Zn etc., and also as mercuric sulphide using sulphide reagents. Granulated slag of a steel plant is also effective in removing the mercuric ions as mercuric sulphide because of the presence of sulphide in the slag matter. The Hg (II) can be reduced to elemental mercury by electrochemical means in the presence of reactive metals. One gram of the slag was found to remove about 70 mg of the mercuric ions in a 7 days period using electrochemical method.

Strategies to Reduce Mercury Exposure to Humans & Environment

• Awareness programmes for general public on potential adverse effects of mercury.

• Restrict release and sale of Indian herbal medicine containing mercury for human consumption without toxicological data / profile.

• Stringent legislation to reduce industrial mercury emission to safeguard humans and environment.

• To establish task force to coordinate and implement the mercury action plan on the long-range trans-boundary air pollution and to resolve some of the uncertainties involving various mercury issues.

• Steps to reduce the international demand and supply of mercury and its derivatives.

- Development of low cost and safe technology to absorb and release of mercury from industrial effluents.

- Regular monitoring of mercury levels in drinking water resources.

- To collect information on environmental burden of mercury with time.

- Identification of vulnerable human populations who may be at risk of mercury poisoning based on their blood and hair values (Increasing risk: 20 – 100 ppb in blood, 6-30 ppm in hair. At risk > 100 ppb in blood and > 30 ppm in hair) as reported by Canadian studies Ref (11-Page 38).

- Establish regional poison information / control centres in the country to provide round the clock information on the signs, symptoms and antidote for mercury poisoning.

- Nutritional supplementation of Vitamin 'E', selenium and omega3 fatty acids, and Garlic (a source of selenium, a common item in India, used in preparation of fish in India) in the amelioration of mercury toxicity.

10. Summary

Sources and Fate of Mercury in the Environment: Like all elements, the same amount of mercury has existed on the planet since the Earth was formed. However, the amount of mercury mobilized and released into the environment has increased since the beginning of the industrial age.

Mercury continues to be used in many commercial and household products. Controlling the deliberate use or release of mercury can be difficult because mercury tends to be used in small quantities but is dispersed across many different kinds of products. In many cases, mercury is concealed inside products or is an additive. People using products with mercury are generally unaware of the fact that there is mercury in the product. Hence making control of mercury releases at disposal is very difficult.

Even though mercury is often thought of as a substance used in "old" technology, mercury applications can be found in notebook computers, modern telephones, new lighting technologies and anti-lock brakes in cars. Mercury-cell chlor-alkali plants, used to manufacture chlorine, are one of the largest deliberate uses of mercury today.

Mercury emissions are transported through the air and eventually deposit to water and land, where humans and wildlife are exposed. Most of the mercury entering the environment is the result of air emissions. Mercury also can directly contaminate land and water as a result of the release of industrial wastewater/disposal of waste.Mercury enters waters, directly and through air deposition, bio accumulates in fish and animal tissue in its most toxic form, methyl mercury. Mercury deposition can occur very close to the source.

Health Effects and Exposure: Exposure to mercury occurs primarily through eating contaminated fish. People who regularly and frequently eat contaminated fish, are the most likely to be at risk from mercury exposure. Ingested methyl mercury is almost completely absorbed into the blood and distributed to all tissues (including the brain). It also readily passes through the placenta to the fetus and fetal brain. The developing fetus is considered the most sensitive to the effects of mercury. Therefore, women of child bearing age are the population of greatest concern.

Recent Actions to Reduce Mercury Pollution: EPA and UNEP have taken a number of actions to reduce mercury emissions that significantly contributes to mercury pollution. Once fully implemented, these actions will reduce mercury emissions caused by human activities substantially. EPA also provides technical assistance to state and local governments to develop mercury pre-treatment programs at sewage treatment plants and other industrial sectors.

Planned Actions to Reduce Mercury Pollution: Regulations and action plans to limit mercury emissions from utility boilers are under way. Although mercury pollution has received much attention, many concerning aspects of this mysterious toxic element are still not fully understood. The development of cost-effective and clean technologies for removing mercury from gaseous and liquid streams is needed.

WHO works in collaboration with countries through the strategic short term, medium term and long term steps in understanding better the problem of mercury in health-care sector through assessments of current mercury usage and waste management programs. The EU Mercury Strategy also recognises the need for global action to reduce mercury in the environment which includes actions to help other countries reduce their mercury use.

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Abbreviations	
EPA	Environment Protection Agency
UNEP	United Nations Environment Program
CS-ESP	Cold-side electrostatic precipitator
HS-ESP	Hot-side electrostatic precipitator
FF	Fabric filter
PS	Particle scrubber
SDA	Spray dryer absorber system
CS-ESP / FGD	Cold-side electrostatic precipitator / flue gas desulfurization unit
HS-ESP / FGD	Hot-side electrostatic precipitator / flue gas desulfurization unit
SCR / CS-ESP	Selective catalytic reduction / cold-side electrostatic precipitator
SCR / SDA / FF	Selective catalytic reduction / spray dryer absorber / fabric filter
SDA / CS-ESP	Sray dryer absorber / cold-side electrostatic precipitator
SDA / FF	Spray dryer absorber / fabric filter bag house
SCR / FGD	Selective catalytic reduction / flue gas desulfurization unit
SCR / SDA / FF	Selective catalytic reduction / spray dryer absorber / fabric filter
PM	Particulate Matter
MPC	Multi Pollutant Control

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