Mercury emissions control from coal fired thermal power plants in India: Critical review & suggested Policy measures

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Absract : Mercury is an invisible hazardous pollutant, whose effects are visible after a long time. Its symptoms are similar to common diseases as such it becomes very difficult to identify its ill effects. Coal fired thermal power plants are increasing faster than ever to meet overall developmental & ever increasing energy needs of the country. During the process of coal combustion, in coal fired thermal power plants, the mercury contained as trace elements in coal is released. The ill effects of mercury not being on visible side has not received due consideration in our country, though worldwide, stringent standards have been prescribed and efforts are being made to reduce the emission of mercury from CFTPP. This paper reviews the current situation and trends in mercury legislation and imminent need for action to be taken in India. While comparing the measures taken in different countries, the paper suggests the policy measures to be adopted In India to curb the menace of the mercury pollution.

Key words : Mercury, Coal, Thermal power plants, health, emission standards, fish consumption

Mercury emissions: There are two sources from which mercy is emitted in the Environment.

(i) Natural : Like mercury emitted through volcanic eruptions
(ii) Human Generated activities i.e. anthropogenic emissions.

Anthropogenic emission again can be of two kinds:

(a) Intentional : Like mercury used in production of caustic soada from Chlor Alkali plants,etc
(b) Unintentional

The release of mercury in to the environment through industrial processes & products is generally intentional, while mobilization of mercury through impurities in fossil fuels- particularly coal and to a lesser extent gas & oil is mostly unintentional.

It is the anthropogenic emissions of mercury that is cause of great concern. In anthropogenic emissions, the contribution of intentional release of mercury is being reduced due to strict policy initiatives taken by the nations, the thrust needed in present scenario is on unintentional release of mercury especially coal fired thermal power plants, which are being built to meet the electricity demand at a much faster rate than ever in India as well as in China. The China has taken a number of policy initiatives and regulations for control of mercury from coal fired thermal power plants, but India is lacking far behind in this and immediate & effective policy & regulation need to be brought in India.

Unintentional Mercury Releases: The mercury content in Indian Coal ranges between 0.01 ppm to 1.1 ppm. A typical power plant emits 90 % of its mercury in to Air and 10% to land. The main reason for such high rate of emissions is that mercury boils at low temperatures.

Assuming the average mercury content in coal found in India to be 0.272 ppm as per CPCB and considering the total coal consumption in the country as 589.87 Million MT in 2010-11, the mercury release works out to about 160.44 MT out of which about 113.42 MT comes from thermal power plants alone considering coal consumption of 417 Million MT for electricity generation in 2010-11. The above release has been worked out considering no mercury capture from APCD. The mercury emission will reduce to the extent of capture of mercury in APCD. The contribution of coal fired thermal power plant for mercury emissions works out to 70.7 % of total emission from coal combustion. The figures of mercury release is very difficult to quantify due to wide variation in mercury content of coal of different seams for the same mine and from different mines also. The concentrations of mercury within the same mining field might vary by one order of magnitude or more.

Further, when mercury moves from Air to water and land ,it generally is in an oxidized gaseous or particle form, whereas when it is re-emitted to air it has been converted back to gaseous elemental mercury, theses complicated mechanisms make final calculation a challenging task.

There are four major groups of parameters affecting emission of mercury to the atmosphere:

- Contamination of raw materials by mercury,
- Physico-chemical properties of mercury affecting its behavior during the industrial processes
- The technology of industrial processes, and
- The type and efficiency of control equipment.

Global mobility of Mercury: The problem of mercury emissions assumes menacing proportion once we consider the fact that mercury is highly mobile and travels far and wide. It represents a grave danger even for populations that have no major mercury polluting sources.

In a study conducted by Center for Science & Environment (CSE), the testing of soil within & outside the mercury cell plant ,it was found that the amount of mercury in the soil within the premises of chlor- Alkali plant, a major mercury consumer plant, was consistently less than that more than a kilometer away.

This leads to conclusion that mercury is not likely to be found next to the place where it is used. Instead it will evaporate and travel far & wide & get deposited elsewhere. Mercury is an invisible pollutant and threatens public health far away from the place of actual use.

Mercury is therefore, too dangerous a substance to be allowed to move freely in the country. Therefore, it needs to be looked in an entirely different perspective than the one with which we view general industrial pollution. For instance regulating mercury in waste water is not of much use, we need to monitor the total mercury consumed in the process.

According to Canadian Global Emissions Interpretation Center (CGEIC),which has published data on the spatial distribution of mercury emissions in Air, India is one of the world's mercury hotspots, with mercury being released to the air uniformly at the rate of 0.1-0.5 Mt/year, with coastal areas having an even higher emission rate ranging between 0.2 Mt/year.

According to Canadian Global Emissions Interpretation Center (CGEIC), anthropogenic emissions of mercury is estimated to have increased in India by 27% in last decade. Clearly mercury is a major problem and action needs to be taken now.

Health Hazard of Mercury: Exposure to mercury even in small amounts is a great danger to humans & wild life. When mercury enters the body it acts as a small neurotoxin, which means it harms our brain & nervous system. Mercury exposure is especially harmful to pregnant women, women who are likely to be pregnant & small children, but all adults are at risk for serious medical problems. Most mercury pollution is produced by coal fired thermal power plants and other industrial processes. The most common ways we are exposed to mercury is by eating contaminated fish.

Emission standards for mercury reduction from CFTPP:

China:

On July 18, 2011, China adopted the air pollutant emission standards for coal-fired power plants, effective starting January 1, 2012. In addition to mercury, the new standards regulate emissions of particulate matter, sulfur dioxide, and nitrogen oxides. About 73 percent of China's electricity comes from thermal power plants that consume 1.6 billion tons of coal annually.

By the end of 2010, the country's total electricity generation capacity reached 962 million kilowatts (kW), the second highest in the world. The total mercury emission from power plants in China was estimated to be 123.3 tonnes in 2007. Today, coal power plants alone contribute almost 20 percent of mercury emissions in China. Fortunately, increasing use of scrubbers has led to decreasing mercury emissions over time.

The emission limits for mercury and mercury compounds were set at 0.03 milligrams per cubic meter (mg/m3) for both new and existing coal-fired power plants beginning on January 1, 2015. Stack testing is also suggested.

Table 1. : Emission limits for coal-fired boilers in China, from 2011 (for particulates, SO_2 and NO_x) and 2015 (for mercury) (ZHB, 2011)

Pollutant	Conditions	Limit
Soot	All units	30 mg/m3
	Plants in key regions‡	20 mg/m3
SO_2	New boiler	100 mg/m3
		200 mg/m3*
	Existing boiler	200 mg/m3
		400 mg/m3*
	Plants in key regions‡	50 mg/m3
NO_x (as NO_2)	All units	100 mg/m3
		400 mg/m3†
	Plants in key regions‡	0.01 mg/m3
Hg and compounds	All units	0.03 mg/m3

* Applies in Guangxi Zhuang Autonomous Region, Chongqing Municipality, Sichuan Province and Guizhou Province

† W-type thermal power generation boilers, furnace chamber flame boilers, circulating fluidised bed boilers and boilers in operation before 31 December 2003

‡ Plants in 'key regions' are defined as those situated where development is concentrated and environmental capacity is low (such as existing weak environmental capacity, vulnerable ecological environment and major air pollution problems, as defined by the MEP)

United States : On December 21, 2011, the U.S. Environmental Protection Agency (EPA) issued final mercury and other emission standards for power plants. Table 1 summarizes these standards. All power plants with 25 megawatts or more of capacity will have to meet the new standards within four years.

In addition to mercury, this rule regulates emissions of particulate matter, sulfur dioxide, nitrogen oxides, acid gases including hydrogen chloride and hydrogen fluoride, and other heavy metals including arsenic, cadmium, chromium, lead, and nickel. Power plants are responsible for 50 percent of mercury emissions in the United States, for which coal-fired units contribute 99 percent of emissions. Roughly 40 percent of coal-fired plants currently lack advanced pollution control equipment. Expected mercury emissions reductions in 2016 will be 20.0 tons from the power sector (a 70 percent reduction relative to the status quo).

Table 2 : Emission Limit values for combustion Plants:

Plant Size	Emission Limit for SO2 (mg/cum)		Emission Limit for NOx (mg/cum)	
	Pre-2013 Plants	Post-2013 Plants	Pre-2013 Plants	Post-2013 Plants
50-100 MW	400	400	300	300
100-300 MW	250	200	200	200
> 300 MW	200	150	200	150

Mercury and Air Toxics Standards (MATS). Signed on 1th Dec 2011, The standards apply to: Metals (including mercury, arsenic, chromium and nickel and others); acid gases (including HCl and HF). The MATS is based on emission standards (similar to the EU ELV approach) set to achieve emission reductions that are at least as great as the emission reductions achieved by the average of the top 12% best controlled sources for the relevant source categories. The emission limits for existing plants are based on coal input rates and plant power output rates and are in British Imperial units which makes it difficult to compare these emission limits with the ELVs listed under the IED in the EU. The emission limits for new plants are also listed below and these are based on outputs. Again the difference in units makes it difficult to compare with other standards. However, it has been estimated that the emission limit of 1.2 lb/TBtu is equivalent to around 1.7 µg/m3, making it by far the most stringent national emission limit anywhere in the world at the moment. Individual states within the US, however, may set even more stringent standards if they wish.

In order to clarify the standard for existing plants, it can be simplified

Table 3 : Hg reduction requirements under the MATs (Hendricks, 2011):

Coal	Typical Hg content, kg/GWh	Required Hg reduction, %
Bituminous	15.5–31	88–94
Sub bituminous	7.75–23.25	76–92
Lignite	31–77.5	80–92

These values are based on mercury concentrations in US coals. As mentioned earlier, mercury concentrations in coals vary greatly, as do concentrations of other species such as ash and chlorine which will also affect mercury emissions.

Comparison of US and Chinese standards:

The Chinese mercury standard for coal-fired power plant emissions is twice as high as the weak end of the range of the U.S. standards for coal plants, which are measured in units of power output to encourage energy efficiency. Converting the U.S. standards to mg/m3 requires the heating value of the coal to be factored in; thus, the following are examples of how two different power plants may compare to the Chinese standard (0.03 mg/m3):

1) U.S. standard, as it applies to a Bituminous coal plant: 0.0017 mg/m3 (0.013 lb/GWh)
2) U.S. standard, as it applies to a Lignite coal plant: 0.0153 mg/m3 (up to 0.12 lb/GWh)

The biggest reason for the difference is that lignite—or "low rank"—coal plants in the United States have a much less stringent standard. The Chinese standard is similar to an old German standard for mercury emissions from waste combustion. A recent report by the China Council for International Cooperation on Environment and Development (CCICED recommended that China tighten its mercury standard to 0.005 mg/m3 by 2015, and 0.003 mg/m3 by 2020. If this recommendation was followed, according to the CCICED, China mercury emissions would be

reduced from 2007 levels by an additional 10 percent by 2015, and an additional 30 percent by 2020, even with a 10 percent annual growth of coal consumption within this sector.

European Union: There is no specific mercury legislation in EU & the emission limit value (ELV) for coal fired power plants (CFPPs) of 30 microgram Hg/m3 i.e. 0.03 mg/cum set in countries like China & Germany can be met by plants with little or no abatement technology in place, and that plants fitted with ESP or bag house, FGD & SCR could easily meet a target limit of 0.003 mg/cum.

Germany : The emission limit value (ELV) for coal fired power plants (CFPPs) of 30 microgram Hg/m3 i.e. 0.03 mg/cum. Continuous emission monitoring for mercury are also required. Since, al plants have GFD & SCR fitted, mercury is also captured efficiently & as yet no mercury specific control technology has been required at any plant firing coal alone. (Thorwarth, 2011).

Canada :A new coal-fired EPG unit will achieve a capture of mercury from coal burned no less than specified below or an average annual mercury emission rate no greater than specified below:

Table 4 : Mercury capture & emission rate for different coal type

Coal type	**Percent capture in coal burned* (%)**	**Emission rate* (kg/TWh)**
Bituminous coal	85	3
Sub Bituminous coal	75	8
Lignite	75	125
Blends	85	3

- These rates are based on best available technologies economically achievable.

Japan : Environmental legislation in Japan is set on a private individual company/plant basis and it is therefore not possible to summarise the requirements that apply. There is a very high priority based on social responsibility and most companies wish to enhance their public credibility by not exceeding any requirements set. Most, if not all, coal-fired units in Japan already have FGD and deNOx systems in place and many plants pride themselves in fitting the most up to date systems (Sloss, 2003). By 2000 over 90% of plants had wet scrubber systems installed and less than 3% had no flue gas treatment for sulphur. It is likely that these few remaining plants have been retrofitted since then. Over 75% of plants have both low NOx burners and SCR systems installed and the remainder had one or the other (Ito and others, 2006).

Australia : Although **Australia** has a National Pollutants Inventory (NPI) for the quantification of emissions, there are no binding national emission standards for SO2 or NOx. The guidelines issued by the National Health and Medical Research Council are very general and are set at levels which can be met relatively easily. Australian coals are generally low in sulphur and therefore SO2 emissions are not regarded as a high priority for control and there are, to date, no FGD or similar controls on any Australian coal-fired plants. Although NOx limits have
been specified in some states, it is thought that these are relatively lenient and have not required the installation of any NOx control technologies (Sloss, 2003). This means that the co-benefit mercury removal rate in Australia is likely to be relatively low, compared to North America, developed Asia and the EU. However, in the review by Morrison and Nelson (2004) of future strategies for energy in Australia towards 2050, most of the strategies considered related to the reduction of mercury and CO2 emissions through the use of brown coal in IGCC (integrated gasification combined cycle) with and without CCS (carbon capture and storage). Australia's future energy strategies appear more concerned with greenhouse gas reductions and energy efficiency with SO2 and NOx emissions taking much lower priority. It can therefore be assumed that there will be limited co-benefit reductions in mercury emissions, based on current legislation.

South Africa : In March 2010, the South African Government established updated requirements for sulphur emission control. The limits are 3500 mg/m3 for SO2 from existing coal-fired power plants and 500 mg/m3 for new plants (>50MW). The emission limits for NOx are 1100 mg/m3 and 750 mg/m3 for existing and new plants respectively (GG, 2010) . There is also a move towards requiring the installation of FGD on all large coal-fired units in the country. However, the financial constraints and, perhaps more importantly, the limited availability of water in the country, will make the installation of FGD within the required time period a significant challenge. But, once FGD or equivalent sulphur control is required, some level of co-benefit mercury control can be expected.

Russia : Russian coals have relatively low mercury concentrations, the lack of FGD and SCR systems mean that there is little or no co-benefit mercury reduction.

Mercury abatement Technologies:

Mercury exists in three forms in coal fired thermal power plants flue gas:

(i) Elemental (Hg O)
(ii) Oxidized Hg (2+)
(iii) Particle bound (Hg(P)

Hg(2+) & Hg (P) are relatively easy to remove from flue gas using typical air pollution control devices such as electrostatic precipitator (ESP) & wet- Flue gas Desulphuriser (FGD). Increasing the emission of Hg(2+) allows for high Hg emission reduction because Hg(2+) or Hg(2+) derived species such as Hgcl2 can be removed in downstream equipment such as ESP and Wet FGD systems. Hg(O) is difficult to capture, since it is insoluble in water.

Mercury emissions are mainly impacted by following factors in a coal fired thermal power plant (CFTPP):

1. Coal consumption & coal composition
2. Type of environmental control equipment installed on the unit
3. Boiler operating conditions
4. Fly ash characteristics

1.1 Washing of Coal: Improving energy efficiency is an important way to control coal fired power plants generating atmospheric mercury. Among them, coal washing is one of the main methods, with traditional coal mercury removal efficiencies to the extent of20 to 30 %.The advantages of coal beneficiation are many folds and the cost incurred in washing of coal is more than compensated considering overall benefits including health & preventing potential health related issues**.** Some of the benefits are:

- Coal washing reduces ash content and improves heat value of coal
- It removes other pollutants such as particulate, sulphur & hazardous air pollutants.
- It improves combustion efficiency.
- Fly ash transportation & disposal costs are reduced along with the less requirement of land for ash pond construction for its storage.
- Plant maintenance is reduced which improves the availability of plant.

As per study done by CSE, the % reduction in SO2 emissions due to coal washing at the Rihand Power Plant, near Singrauli was observed as 25%. In the United States the average mercury content of coal is 0.18mg/kg and it has been observed that washing of coal reduces approximately 20 % of mercury.

Considering the overall benefits of coal washing, it should become an integral part of all major coal projects. At present in India as per directives of MoEF coal washing has been made mandatory for power plants located beyond 1000 km from the pithead so as to have ash content of coal less than 34 %. The washing of coal is also mandatory for power plants located in ecologically sensitive zones.

To improve the situation, the installed capacity of washeries has been increased in the last one decade. The installed capacity of washery in 2009-10 was 126 MTY, and has increased to 131 MTY in 2010-11. As on 31.3.2011, a total of 52 washeries, both PSU & Private were operating in the country. In 2010-11, the installed capacity for coking & non coking coal was 29.69 MTY & 101.55 MTY respectively. Contribution of private washeries, like thermal power plants is also increasing has reached to 20 % in 2010-11.In 2010-11, about 22% coal consumed is washed in India.

1.2 Change in Technology for reduction of Coal Consumption: Most of the CFTPP are based on Sub critical technology in India, while Super critical & Ultra super critical power plants are being built recently and their number is increasing in new up coming power plants. The Supercritical & Ultra supercritical power plants are more efficient as compared to sub critical power plants.

Gains in efficiency are reflected directly in the environmental benefits ,i.e. savings in coal consumption that means lower amount of $CO2$, NOx and $SO2$ emissions per KWh of power generated using efficient supercritical plants. The best thermodynamically achievable gross efficiency in India has been calculated as :

- Sub critical Plant : 38.1 %
- Super critical plant : 41.10 %
- Ultra super critical Plant : 44.4 %

Table 5 : The capacity wise efficiency for sub critical power plants are as below :

Capacity	**Gross efficiency**	**Net efficiency**
500 MW	35.67 %	33.25 %
200/210/250 MW (Siemens Technology)	34.98 %	31.96 %
200/210 MW (Russian Technology)	34.62 %	31.66 %
100-200 MW	27.55 %	24.22 %
< 100 MW	25.79 %	22.8 %

Source : Ananth P Chikkatur & Ambuj D Sagar 2007, Cleaner power in India : Towards a clean coal technology roadmap. Harvard Unviersity.

Thus the options for future coal fired units in India are Super critical & Ultra supercritical units.

2, Environmental pollution control options :

2.1.(i)Sulphur dioxide (SO2): Indian coal in general has low sulphur content. The typical SO2 emissions from coal based power plants are estimated to be 1250 mg/m3.Therefore, CPCB has not yet fixed any emission standards for SO2, but has suggested the monitoring of SO2 emissions from the stack height. It has prescribed stack height for various capacities of power generation namely 275 m for 500 MW and above, 220 m for 200 MW to 500 MW and for units less than 200 MW, the stack height is governed by the formula H = 14(Q)0.8 metres, where H is the stack height and Q is the emission rate in kg/hr.

The WB has prescribed emission standard of 2000 mg/m3 for SO2. It also states that the maximum permissible emission level would be 0.2 tonne per day (tpd) per MW upto 500 MW and 0.1 tpd per MW for each additional MW over 500 MW but not more than 500 tpd for any plant. Emission standards for SO2 are prescribed to be 960, 400, 1200-2100 mg/m3 for USA, EU and China respectively.

2.1.(ii).Control measures for Sulfur di oxide : In general, as proposed in WB guidelines, for low sulphur (<1%S) and high calorific value fuels, specific control may not be required. Coal cleaning (when feasible), sorbent injection or fluidized bed combustion may be adequate for medium sulphur fuels (1-3 per cent S). FGD may be considered for high sulphur fuels (>3 per cent S). The choice depends on factors like cost, operating characteristics, and quality of coal.

2.2 (i). Oxides of nitrogen : India does not have any NOX emission limits for coal based thermal power generation. The typical emission level from a boiler is about 650 ppm. But over the last few years, burners with emission of less than 400 ppm have been introduced. World Bank emission standards for NOx is 750 mg/m3 (365ppm).

2.2 (ii). Control measures for reduction of NOx : Two types of control systems namely low NOX burner (LNB) and off stoichiometric combustion based on combustion modification are generally used. Tangentially fired boiler generates less NOX than the front wall fired boilers. High amount of exhaust air is used to control temperature thus reducing NOX emission. Reduction of NOX using LNB ranges between 30-50 per cent. In off stoichiometric combustion, oxygen content in the furnace is regulated to reduce the fuel NOX and some of the thermal NOX reduction is possible up to 30 per cent. Further reductions can be achieved only by treating the flue gas to reduce NOX to N2. These reduction strategies could be based on selective non-catalytic reduction (SNCR) or on selective catalytic reduction (SCR). The combustion modification and the reduction technologies together can achieve up to 95 per cent reduction in NOX emissions. Combustion modifications, such as LNB is the most cost effective interventions but can reduce emissions only up to 60 per cent. They also have low operation & maintenance costs. On the other hand, both the capital and O & M costs for SCR are very high, and variable costs for SCR can represent up to 50 per cent of the total levelized cost. The air to fuel ratio is reported to be 1:5 to 1:8 in India. The WB recommended control options are low NOX burners with or without other combustion modifications, reburning, water/steam injection and selective catalytic or non-catalytic reduction.

2.3(i). Particulate matter : In India, the CPCB has prescribed emission standards for particulate matter, which should not exceed 150 mg/m3 for power generation units of capacity of 210 MW and above and

350 mg/m3 for units less than 210 MW. These standards are based on Indian coal characteristics, meteorological conditions, existing flue gas concentration level, and best available control technology. The existing emission standard for particulate matter for WB and European Union is 50 mg/m3. Alternatively, WB guidelines propose that particulate removal efficiency should be designed for 99.9 per cent if 50 mg/m3 is not achievable and operated at least at 99.5 per cent efficiency

2.3 (ii). Control measures for reduction of Particulate matter :

There are two globally acceptable technologies for control of particulate matter (PM), namely electrostatic precipitators (ESP) and bag filters using fabric filter which can offer over 99.8 per cent reduction in particulate emission. The basic criteria for selection of a control system is the desired level of control needed. The choice of technology depends on resistivity of the ash, which depends on fly ash composition and sulphur content of the coal, and operational factors. The commercially proven indigenous ESP's are being used in all the coal based thermal power plants in India. For Indian coal, with an ash content of 35-45 per cent, the ESP efficiency is 99.7 per cent and more is required for meeting the standard of150 mg/m3. The ESP's are particularly efficient in removing all types of particles with diameter larger than 0.01 micro meter, including those bearing mercury after condensation within exhaust gases.

While thermal power plants in India commonly use ESP, which is less expensive to install and operate, bag filters are the most efficient, particularly while dealing with smaller particulate and are insensitive to ash resistivity, inlet particulate concentration and changes in the flue gas flow rate. However, flue gas with acid or alkaline presence reduce bag house life, and hygroscopic material and tarry components in the ash can lead to bag house filter plugging.

The choice of advanced control technology is governed by the coal quality (particularly its high ash and silica content and low sulphur content) and operating practices. The more robust design and operational characteristics of ESPs, along with their lower O & M costs (as compared to bag house filters) suggests that they are the preferred particulate control technology to meet emission standards more than or equal to 100 mg/m3, since there is a relatively small cost difference between ESPs and bag house filters upto this emission limit.

For high resistivity coal, ESPs are the most cost-effective option for emission limits higher than 120 mg/m3. Pulsejet bag house filters are more economical for lower emission limits, but have high O & M costs. However, to achieve emission limits of 50 mg/m3or less, both the levelized and the capital costs of ESPs are at least 20 per cent more than that of pulsejet bag houses. However, lack of experience in bag house operation and maintenance in India suggests that a long learning process may be inevitable if the adoption of this technology is required to meet future standards.

2.4. Mercury abatement as co-benefit of reduction of NOx, SO2 and dust : For a coal fired power plant the APCD (air pollution control device) normally consists of several abatement techniques. In most cases an ESP is used as a first step in reduction of dust emissions. More and more installations also apply a fabric filter to further reduce emissions of dust. Most installations in the EU and part of the installations in the USA and Canada reduce emissions of SO_2 by applying flue gas desulphurization (FGD) based on wet or semi-dry scrubbers with lime stone slurry. In many modern power plants also selective catalytic reduction (SCR) is used to reduce emissions of NOx.

The Hg(P) fraction is typically removed by a particulate control device such as an electrostatic precipitator (ESP) or fabric filter (FF). The Hg(2+) portion is water-soluble and therefore a relatively high percentage can be captured by the wet flue gas desulphurization (FGD) systems. The Hg(0) fraction is generally not captured by existing APCD. However, when an SCR is applied this will promote oxidation of Hg(0) to Hg (2+) and enhance Hg capture in a downstream FGD .

This means that in many current coal fired power plants emissions of mercury are already abated by the existing APCD. The efficiency of the reduction of mercury can be very high, depending on the installation and quality of the coal. Reported levels of emissions from CFTPP in plants in EU & USA equipped with an ESP and FGD show that mercury concentrations in the stack gases are below 0.005 mg/cum.

3. Boiler operating Conditions : Various technologies within the same industry may generate different amounts of atmospheric emissions of mercury. It can be generalized for conventional thermal power plants that the plant design, particularly the burner configuration has an impact on the emission quantities. Wet bottom boilers produce the highest emissions among the coal-fired utility boilers, as they need to operate at the temperature above the ash -melting temperature (Pacyna, 1989).

The load of the burner affects the emissions of trace elements including mercury in such a way that for low load and full load the emissions are the largest (Bakkum and Veldt, 1986).For a 50 % load the emission rates can be lower by a factor of two.

Non-conventional methods of combustion, such as fluidized bed combustion (FBC) were found to generate comparable or slightly lower emissions of mercury and other trace elements than the conventional power plants (Carpenter, 1979; Abel et al., 1981).

4.Fly Ash Characteristics : : The unburned carbons in fly ash can capture varying amounts of Hg depending upon the temperature and composition of the flue gas at the air pollution control device, with Hg capture increasing with a decrease in temperature; the amount of carbon in the fly ash, with Hg capture increasing with an increase in carbon; and the form of the carbon and the consequent surface area of the carbon, with Hg capture increasing with an increase in surface area. The latter is influenced by the rank of the feed coal, with carbons derived from the combustion of low-rank coals having a greater surface area than carbons from bituminous- and anthracite-rank coals.

The same properties that may favor Hg capture (high carbon content, high surface area, and fine particle size distribution) are those that lead to problems in ash utilization.

There are, however, issues of boiler design, coal selection, and optimization with respect to a variety of emissions requirements that result in an unburned carbon content of around a percent to a few percent by mass in the fly ash from a typical power station. The economic and design considerations that lead to this incomplete combustion generally outweigh the incentives to reduce unburned carbon below a few percent. A few percent carbon in ash can result even at very high levels of fuel burnout; for example, 99.5% burnout of a 10% ash coal would result in roughly 4% unburned carbon in the ash.

Mercury control specific technologies : There are two broad approaches to mercury control:

(i) activated carbon injection (ACI), and

(ii) multipollutant control, in which Hg capture is enhanced in existing/new SO2, NOx, and PM control devices.

(i) 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. ACI may be used either in conjunction with existing control technologies and/or with additional control such as the addition of an FF. There are three alternative ACI configurations. Standard Powdered Activated Carbon(SPAC),Modified powdered activated carbon (MPAC), or SPAC in combination of a fabric filter.

The MPAC option exploits the discovery that by converting elemental mercury to oxidized mercury, halogens like (chlorine, bromine, iodine) can make activated carbon more effective in capturing mercury at the high temperatures found in Thermal power plants. In the MPAC, a small amount of bromine is chemically bonded to the powdered carbon, which is then injected in to the flue gas stream either upstream of both the particulate control device (ESP or fabric filter) and the air preheater (APH), between the APH and the particulate control device, or downstream of both the pre-existing APH and particle control devices but ahead of dedicated pulse jet filter.

(ii) Multi pollutant control for Mercury Control by Enhancing the Capability of Existing/New SO2/NOx Controls : . Multi pollutant technologies are defined as technologies that, if installed, would themselves be capable of removing SO2, PM, NOX, and mercury rather than relying on optimization of air pollution control equipment operation for maximization of co-benefit mercury removal. Several multi pollutant technologies are capable of simultaneously removing mercury in addition to removing SO2, PM, and NOX from flue gas. These technologies are at varying levels of development and commercial availability

A significant fraction of existing boiler capacity already has wet or dry scrubbers for SO2 control and /or SCR for NOx control. As such, multi pollutant control approaches capable of providing SO2/NOx/Hg reductions are of great interest.

Type and efficiency of control equipment:

The type and efficiency of control equipment is the major parameter affecting the amount of trace elements released to the atmosphere. Unlike other trace elements, mercury enters the atmosphere from various industrial processes in a gas form. Halogens, mercuric chloride and selenium dioxide, are removed with SO2 absorption. Large variations of mercury removal are found, probably due to differences in the behavior of specific mercury compounds. Formation of particles of chloride and sulfate salts is considered to be an important removal mechanism for mercury in the FGD process. This would be promoted by high Chlorine content in the coal and for mercury sulfate, by low temperatures combined with the catalytic effect of activated carbon.

Two major types of FGD systems can be distinguished: wet and dry FGDs.

Due to relatively low temperatures found in wet scrubber systems allow many of the more volatile trace elements to condense from the vapor phase and thus to be removed from the flue gases. In general, removal efficiency for mercury ranges from 30 to 50%

The overall removal of mercury in various spray dry systems varies from about 35 to 85%. The highest removal efficiencies are achieved from spray dry systems fitted with downstream fabric filters.

Low NOx Technologies :

Low NOx technologies are also likely to reduce mercury emission in the exhaust gases due to the lower operating temperatures. However, low NOx technologies are far less used compared to the FGD systems.

Thus, among the technologies being considered for mercury reduction in Coal fired Thermal Power Plants (CFTPP), the combination of Selective Catalytic Reduction (SCR) & a wet scrubber is available for removal of Hg(o). The SCR catalyst oxidized mercury is subsequently absorbed by the scrubber system.

Oxidation catalysts fall in to one of the three groups:

(i) SCR Catalyst
(ii) Carbon based catalyst
(iii) Metal & metal oxides

SCR has been a well developed and commercialized technology for controlling emissions of NOx from Power Plants. The co-benefit of increased Hg(2+) through the SCR catalyst is very important to the overall control of mercury emission from coal fired thermal power plant.

When coal fired power plants meet the emission limit values for NOx, SO2 and PM , the emissions of mercury will be reduced to concentration levels that are far below 0.03 mg/ m3. Expected emission levels for most power plants are in the range of 0.03mg/ m3. The proposed ELV for the revised Heavy Metals Protocol can be met by most installations without taking additional measures. This means that an ELV of 0.03mg/ m3 for mercury emissions from power plants in practice will not result in a reduction of mercury emissions from coal fired power plants.

BAT to reduce mercury emissions is the application of SCR, in combination with FGD. If an SCR is not applied BAT for the reduction of mercury is based on sorbent injection, which can reduce emission concentrations by 90%. In this way an emission limit value of of 0.003mg/ m3 for coal fired power plants can be reached.

POST-CONTROL ISSUES : Depending on the configuration of the existing air pollution control equipment for mercury capture, mercury may be transferred from gas phase (flue gas) to solid phase (e.g., fly ash, synthetic gypsum) or into a liquid or solid/liquid phase (e.g., wet FGD sludge, fixated FGD sludge). These different media are residues from coal-fired power plant operation and are generated in various processes. Fly ash is the product of coal combustion and is collected by the ESP or FF. Gypsum is the byproduct of LSFO. In LSFO, nearly all of the byproduct is calcium sulfate dihydrate ($CaSO_4 \bullet H_2O$), also called synthetic gypsum. The resulting synthetic gypsum can be disposed in a landfill, used for wallboard production, or as feedstock in making cement and concrete. Wet FGD sludge is collected from natural or inhibited oxidation wet FGD. In an inhibited oxidation system, nearly all of the byproduct is calcium sulfite hemi hydrate ($CaSO_3 \bullet ½H_2O$). In a natural oxidation system, the byproduct is a mixture of $CaSO_3 \bullet ½H_2O$ and $CaSO_4 \bullet H_2O$. FGD sludge is typically blended with fly ash and lime prior to land disposal. Collectively, these materials are often called coal combustion residues (CCR). Because of the increased content of mercury in the CCRs as the result of mercury capture, there is a concern about the potential for mercury release (mercury leaching) and cross media transfers of mercury and other constituents of potential concern (COPC) resulting from land disposal or use of CCRs.

The potential mercury release route for CCRs that is of most concern is leaching to groundwater because it could negatively affect drinking water quality. Also of concern is the release of mercury to surface waters and potential for its bioaccumulation.

Global action for mercury emission reduction : At present, there is no international treaty which requires specific mercury control at coal-fired utilities. However, this is likely to change shortly with the introduction of the UNEP Convention named " Minamata Convention ". In February 2009, the Governing Council of the United Nations Environment Programme (UNEP) agreed on Decision 23/9 defining the need to develop a global legally binding instrument on mercury. In 25 th session of UNEP council, countries agreed to set up an Inter Governmental Negotiation Commission (INC), to develop a legally binding instrument of mercury. On 19th January 2013, INC adopted the " Minamata Convention " aiming at of the global scope & reduction of mercury emissions. The point of view of this convention is that coal fired power plant is one of largest sources of mercury pollution, and all countries should control all kinds of large scale atmospheric mercury emissions from coal fired power plants.

Recommendations:

(i) Both technology development and strong policy actions are indispensable for reducing mercury emissions from coal fired thermal power plants.

(ii) Regional impact assessment and carrying capacity study to assess how many coal based power plants, coal mining & other industries the area can sustain depending on the assimilative capacity of the environment. This assessment must give primacy to mercury pollution.

(iii) Regulation of sulphur di oxide & NOx by installing FGD & SCR will not only significantly reduce the emissions of conventional pollutants but also benefit the mercury emission from coal fired power plants and hence should be done immediately as new power plants are coming up at a faster rate than ever in the country.

(iv) MoEF, CPCB & SPCB should issue fish consumption recommendations from time to time.

(v) Local as well as imported fish should be tested for mercury levels

(vi) We need to raise public awareness so that vulnerable groups have the opportunity to reduce their methyl mercury intake.

(vii) Phasing out small units (below 200 MW) and the application of supercritical & ultra supercritical coal fired power plants to improve energy efficiency and ultimately reducing atmospheric mercury emissions.

(viii) In clean coal technology, reduction of non-GHG pollutant emissions (SO2, NOx, PM) is indispensable and deployment of best available flue gas treatment technologies should be intensively promoted.

(ix) USC for new installation and retrofit should be largely deployed and R&D of higher efficiency plants (A-USC, IGCC) be intensively promoted.

(x) Policies enacted to lead to closing of old existing plants and as replacement bigger capacity plants with USC technology be adopted.

(xi) Govt. has to come up with laws to monitor and control, release of mercury impurities during coal combustion, during limestone calcinations for cement, pulp & paper etc.

(xii) Economic instruments such as a carrot & stick measures are needed to make this switch over feasible.

(xiii) The policy of locating new power plants along coastal areas needs to be revisited in view of the fact that mercury levels in coastal areas have been found more as compared to other places.

(xiv) The catastrophic effect the mercury can pose on human health should be mentioned and given due consideration in EIA of new thermal power plants, who are seeking Environmental clearance from MoEF. In Public hearings, the local people must be informed about the likely mercury emissions of Power plants and its consequent health hazard along with the measures being proposed for mitigation of the ill health effects.

(xv) Comprehensive and sustained effort to monitor, document and analyze, coal plant mercury emissions must be initiated.

(xvi) Immediately launch a full-scale environmental audit of all existing coal plants in the country including all areas located in primary and regional impact zones of operating coal plants. Alongside this, immediately implement a full-scale health audit of all coal plant communities.

(xvii) Like China, we should also devise different emission norms for different regions depending on the general air pollution level in the region. We should have very strict norms for critically polluted regions.

Conclusion : There is abundant evidence that mercury and its compounds are highly toxic to humans, Research & monitoring over the years have provided ample justification for the need to taking measures to reduce mercury emissions from CFTPP. In US, EU & China recently, mercury emission reductions has been achieved due to measures taken to tackle emissions of other pollutants. Even without mercury specific legislation for coal combustion plants, these reductions are expected to continue due to co-benefits of Sox, NOx & particulate matter reduction technology.

Mercury specific legislation has been passed in Canada, US & China. However, In India, an increase in mercury emission from coal combustion is expected due to the high energy demand & lack of legislation & control of mercury pollution.

India is the 2nd largest emitter of mercury from coal fired thermal power plants. Mercury reduction as a co-benefit offered by Sox & NOX control units as obtained in other countries is not available In India as for Sox reduction, only stack height criteria is prescribed by regulation and for NOX no specific emission limit from CFTPP & meeting the ambient air quality norms is enough as per present regulation . The ESP provided in most of the thermal power plants in India is also not very effective to offer co benefit of reduction of mercury due to fly ash characteristics.

Thus, the need of the hour is not only to regulate SOX & NOX as compared to limits followed globally but also strive to monitor mercury emissions regularly &provide ELV for mercury & provide control equipments, wherever needed.

Further, at **present** the entire attention is placed on removal of mercury for its dispersal in Air, water & soil and for this different technologies are being used worldwide. This is the first part of the problem; the real issue will be how to dispose of the mercury so collected through different removal technologies. Its safe disposal is the real issue, which also needs to be considered. The widespread use of fly ash generated during coal combustion also contains traces of mercury and the ill effects that may create through different products in which they are used need to be assessed carefully.

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