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Threat to Environment: Mercury in Thermal power Plants

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ABSTRACT

Thermal power plant (TPP) emissions have added new dimensions to the nature. These are the second largest source of mercury emission in India. The demand of coal for thermal power stations will increase year after year being the largest source of power generation. Coal contains mercury as a natural component along with other elements in trace amounts (0.04- 0.7 mg/kg). In the process of combustion mercury is not used but gets released and is further accumulated and persists in the environment, through air it could enter bodies through the nasal route and prove a great threat to people, especially those living in the vicinity of these thermal power plants. Once Hg reaches to the environment it never breaks down and cycles through land, air and water. Exposure of Hg may cause permanent damage to the central nervous system (CNS), damage vital organs such as lungs and kidneys. Mercury has been the focus of regulatory activity because of its documented toxic and carcinogenic effects, as well as its persistent prevalence in the environment, being volatile and readily mobilized. Thus it becomes necessary to regulate its concentration before releasing into the atmosphere. The control of mercury emissions is an important issue facing the coal-fired power industry. Technologies to measure and control mercury emissions from coal-fired power plants are relatively new when compared to technologies to measure and control SO2 and NOx emissions that have been commercially available for at least two decades. Some mercury is collected naturally in ESP's and bag houses, and for units with SCR's and wet FGD's, or in wet scrubbers. Senso-removal paptodes developed by Amlathe and co workers can be effectively utilized to trap the mercury from TPP released smoke. The present paper emphasizes the same.

Keywords:— *Thermal Power Plants, Mercury, Removal, Paptode*

I. INTRODUCTION

The environment includes the biotic and abiotic surrounding of an organism or population, includes the factors influencing their survival, development and evolution.[1] Environmental pollution is the biggest menace to the human race on this planet. There are

various types of pollution such as water, soil, land, noise, and air pollution. Air pollution is most devasting. Among the major sources of air pollution are power and heat generation, the burning of solid wastes, industrial processes, and, especially, transportation. The six major types of air pollutants are carbon monoxide, hydrocarbons, nitrogen oxides, mercury oxide, particulates, sulphur dioxide, and photochemical oxidants.[2] "A growing concern in India is the release of various toxic trace elements such as mercury (Hg), arsenic (As), lead (Pb), cadmium (Cd), etc., from power plants through the disposal and dispersal of coal ash. Among the various toxic elements mercury emissions from coal based TPP are of particular concern, mercury emitted in flue gases or in fly ash/bottom ash that is disposed off in ash ponds enters the hydrological system, wherein the mercury can be methylated. Then this methyl mercury can then enter the human food chain, mainly through consumption of fish (Shah *et al*., 2008). Thus this food chain exposure pathway to mercury at high levels can harm the brain, heart, kidneys, lungs, and immune system of people of all ages. "Mercury can be emitted in three different forms: elemental (HgO), oxidized (Hg^{2+}) and particle bound (HgP). Upon combustion, coal fly ash tends to have a higher concentration of mercury, and estimates indicate that Indian coal ash has an average mercury concentration of 0.53 mg/kg, based on measurements from a few selected power plants. [3]

Coal fired thermal power plants (TPPs) are the second largest source of mercury emission in India. Almost 73% of energy is obtained from TPP which uses about 220 millions tonnes coal/year. Coal contains mercury (Hg) naturally and its combustion in the boilers to generate electricity causes release of mercury in to the environment. A typical 100 mw TPP can emit over 10kg of mercury in a single year. Once Hg reaches to the environment it never breaks down and persists in the environment, cycling through land, air and water. Mercury (Hg) is a naturally occurring, highly volatile heavy metal. It is found in trace quantities throughout the environment rocks, soils and the oceans. Being an element, mercury never breaks down but persists in the environment, cycling through land, air and water. Mercury can exist in the environment in elemental, organic or inorganic forms. According to the International Chemical Safety Council of United Nations, an organic form of mercury (methyl mercury) is one of the six most serious pollution threats to the earth. While most of the mercury released into the environment by human activity is in either elemental or inorganic form, biological processes convert inorganic mercury into highly dangerous forms of organic mercury, such as methyl mercury. This form is the most harmful to people and wildlife because of its ability to take part in biochemical reactions and accumulate in the food chain.[4]

II. Health Hazards Due to Mercury

Mercury is a potent neurotoxin. Even at extremely low levels of exposure, it can cause permanent damage to the human central nervous system. The addition of even 0.9 g of mercury is enough to contaminate a 25-acre lake. At higher levels, mercury can damage vital organs such as lungs and kidneys. The nervous system is very sensitive to all forms of mercury. Methyl mercury and metallic mercury vapours are more harmful than other forms, because more mercury in these forms reaches the brain. Exposure to high levels of metallic, inorganic, or organic mercury can permanently damage the brain, kidneys, and developing fetus. Effects on brain functioning may result in irritability, shyness, tremors, changes in vision or hearing, and memory problems. Short term exposure to high levels of metallic mercury vapours may cause effects including lung damage, nausea, vomiting, diarrhea, increases in blood pressure or heart rate, skin rashes, and eye irritation. Mercuric

chloride has caused increases in several types of tumors in rats and mice, and methyl mercury has caused kidney tumors in male mice. The Environmental Protection Agency (USEPA) has determined that mercuric chloride and methyl mercury is possible human carcinogens Health hazards of mercury to young children- Very young children are more sensitive to mercury than adults. Mercury in the mother's body passes to the fetus and may accumulate there. It can also pass to a nursing infant through breast milk. However, the benefits of breast feeding may be greater than the possible adverse effects of mercury in breast milk. Mercury's harmful effects that may be passed from the mother to the fetus include brain damage, mental retardation, in-coordination, blindness, seizures, and inability to speak. Children poisoned by mercury may develop problems of their nervous and digestive systems, and kidney damage. Besides affecting human beings, it also increases morbidity and mortality among fish, wild animals and birds, causing ecological imbalance and economical loss. Methylmercury can be more harmful to bird embryos when selenium, another potentially toxic element, is present in the diet. Hunter-Russellsyndrome and Minamata disease also occurs In several areas of the United States, concentrations of mercury in fish and wildlife are high enough to be a risk to wildlife.[3],[5],[6].

III. Environmental Exposure of Mercury Due To Coal Based TPPs

Mercury distribution in the environment has been a focus of scientific attention because of the potential health risks posed by mercury exposure. India is one among the world's most active mercury industrial centres. Coal fired thermal power plants are the second largest source of mercury emission in India. Mercury is released into the air by burning fossil fuels (coal) in thermal power plants. In the process of combustion mercury is not used but gets released and is further accumulated, as mercury remains persistent in the environment A typical 100 megawatt thermal power plant can emit over 10 kg of mercury in a single year. About 200 metric tonnes of toxic mercury escapes from industrial chimneys and effluents each year in India. Recent studies suggest that the total global atmospheric mercury burden has increased between 200 and 500 per cent since the beginning of the Industrial Age. Reports also indicate that the levels of mercury in rivers, coastal waters, and soil and food items are way above acceptable levels in India. Mercury's presence in air and water has increased dramatically in the past century owing to emission from thermal power plants. The total mercury pollution potential from coal in India is estimated to be 77.91 tones per annum, considering average concentration of mercury in coal as 0.272 ppm. About 59.29 tones per annum mercury is mobilized from coal-fired thermal power plants alone. The mercury emanating from the thermal power plants' stacks is 58. Percent gaseous and 2.4 per cent in particulate form. About 32.5 per cent is retained in the ashes (fly ash and bottom ash). The remaining 7.05 per cent could not be accounted for. Coal contains mercury as a natural component along with other elements in trace amounts (0.04- 0.7 mg/ kg). As the coal is combusted in the utility boiler (Prashant Agrawal *et al.*, 2008) Pollution controls employed by utilities to curb other pollutants are not effective in removing mercury. At present, there are no commercially viable control technologies for mercury. As a consequence, this highly toxic form of air pollution continues to go largely unabated. Thus coal becomes a repository of toxic metals.[3],[7],[8],[9],[10]

IV. Permissible Limits for Mercury

Mercury Emission from massive coal consumptions enhances the level of mercury more than 1ppm in soil and more than 10 ppm in ground water and ponds. Govt. of India is reviewing the occupational exposure standards

of 0.1 mg/m3 of air, set up by Occupational Safety and Health Administration, USA for its implementation in our country. There is a need to reduce mercury air emissions from coal-fired power plants. Bureau of Indian Standards (BIS) and World Health Organization (WHO) limits the concentration of Mercury only up to 0.001 ppm in drinking water and 0.05 mg/Kg in soil. The maximum allowed concentration of total mercury in fish is 0.50 ppm in India 13. The WHO guideline set for mercury intake by fish is 0.47 mg/kg/day, while the limit set by EPA is 0.1 mg / kg/day, which is one fifth to that of WHO.[11].

TABLE I Use Exposure Routes and Toxicity of Mercury and Its compounds [13]

MERCURY Hg	**ELEMENTAL** (vapourises at room temperature)	**INORGANIC** (mercury salts)	**ORGANIC Methyl mercury** (transformed by bacteria in contact with water)	**ORGANIC Ethyl mercury**
Main Use / Pathway	Dental fillings, Hospital spills – e.g. broken thermometers (Amalgam is a mix of mercury and other metals like Ag, Sn, Cu, In, Zn)	Medicines, cosmetics (used as a preservative)	Fish consumption (the fish have ingested mercury and it is in their muscle tissue)	Vaccines (the preservative Thimerosal is 49% ethyl mercury)
Other uses	Gold mining Chloralkali plants Products (batteries, switches, fluorescent bulbs; measuring and control devices (eg. thermostats) Medical devices (thermometers, gastrointestinal tubes, etc.)	Disinfectants and antimicrobials Electrical equipment Photography		Fungicides (e.g. in paints) and bactericides (phenyl mercury)
Route of exposure	Inhalation Ingestion Transplacentalbioconcentrated (mother's dental during pregnancy & breastfeeding)	Epidermal Inhalation – unusual Ingestion	Ingestion Gastrointestinal Inhalation Transplacentalbioconcentrated	Parenteral (outside the alimentary canal) directly to mother; infant/child Transplacentalbioconcentrated (mother's vaccine prior to pregnancy, during pregnancy or during breastfeeding
Toxicity	Primary: lungs, eyes, gingival, skin Secondary: central nervous system, kidneys, immune system	Primary: kidneys and gastrointestinal tract Secondary: central nervous system (deposits from ethyl and methyl on brain)	Primary: central nervous system Secondary: cardiovascular	Primary: central nervous system Secondary: cardiovascular
Transport in body	Crosses the placenta Enters the brain Found in breastmilk	Does not easily enter the brain or cross the placenta	Crosses the placenta Enters the brain Found in breastmilk	Crosses the placenta Enters the brain Found in breastmilk

V. REMOVAL METHODS

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

(i) Elemental Hg (0)

(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 desulphurizer (FGD). Increasing the emission of Hg (2+) allows for high Hg emission reduction because Hg(2+) or Hg(2+) derived species such as $HgCl_2$ can be removed in downstream equipment such as ESP and Wet FGD systems. Hg (0) 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 :- Coal consumption & coal composition, Type of environmental control equipment installed on the unit, Boiler operating conditions, Fly ash characteristics. 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[12].

The common methods for removal of heavy metal ions include precipitation, solvent extraction, vacuum evaporation, membrane technologies, adsorption and ionic exchange [14 -18]. Phenomenon of adsorption is very common for removal of contaminants. Synthetic ion exchangers, activated charcoals or zeolites utilize phenomenon of adsorption for decontamination of metals [19-25].

Amlathe and co workers have developed paptodes for removal of mercury based on the phenomenon of adsorption. The developed paptodes have been successfully applied for removal of Hg (II) from aqueous solutions. The same can be effectively applied to remove mercury released from TPP smoke as well as from the coal sample [26]. This can be easily done by exposing the smoke to paptodes. Further studies are undergoing to get the data.

VI. CONCLUSION

The presence of mercury in TPP smoke is a severe threat to environment. The paptode can be an effective, cheap and rapid tool for effective removal.

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