

Local Impacts of Mercury from Coal-Fired Power Plants

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Effects of Coal Type and Air Pollution Control Device on Mercury Emissions, Atmospheric Transport and Mercury Deposition

It is well established that mercury emitted by coal-fired power plants is a mixture of 3 chemical species: elemental (Hg^0) oxidized (Hg^{2+}) and particulate-bound. The deposition of mercury in the local environment (and its subsequent impact on human health and the environment) depends on a number of interrelated factors – and each of these factors will be different for each power plant.

- The physical and chemical properties of mercury play an important role in deposition. Once emitted to the atmosphere, the fate of mercury is governed by its chemical species.
 - Elemental mercury can be transported over very long distances with global air masses. The atmospheric residence time of elemental mercury is in the range of months to roughly one year. The global pool of mercury is almost entirely elemental mercury.
 - Oxidized mercury and particulate-bound mercury have a shorter atmospheric lifetime than elemental mercury and will deposit by wet or dry deposition within roughly 50 to 500 miles.
 - Significant conversion between mercury species may occur during atmospheric transport (or even in the plume), which will affect the transport distance. These reactions can involve both the oxidation of elemental mercury to its water-soluble oxidized form or the reduction of oxidized mercury back to its elemental form. The way these reactions are incorporated into deposition models can affect the results.

The physical and chemical forms of mercury that are emitted are highly dependent on both the types of coal being burned and the air pollution control device.

- Eastern bituminous coals have a higher chlorine content (average > 900 ppm) compared to subbituminous and lignite coals (average chlorine content < 200 ppm). Chlorine is thought to be a dominant factor in the oxidation of mercury in flue gas.
- The air pollution control device plays a critical role in determining which chemical species of mercury are emitted as summarized below in Table 1.

Table 1. Effect of Air Pollution Control Device on Mercury Speciation

Air Pollution Control Device	# Units	Average Percent Reduction (All units in ICR)	Flue Gas Composition by Mercury Species		
			Elemental (Hg ⁰)	Oxidized (Hg ²⁺)	Particulate (Hg _p)
NOx Controls		0%	No decrease in emissions but SCR promotes oxidation of Hg ⁰ to Hg ²⁺ , which increases downstream capture. SNCR does not have oxidizing effect.		
ESP cold-side	674	27%	47%	51.5%	1.5%
ESPc +FGDw	117	49%	89%	10.6%	0.4%
ESP hot-side	120	4%	66%	32.7%	1.3%
ESPh + FGDw	20	26%	93%	6.4%	0.7%
FBC FF + ESPc	39	86%	56%	42%	2.0%
FF	58	58%	23%	76.4%	0.6%
FF + FGDw	14	88%	64%	31%	5.0%
IGCC	2	4%	96%	4.5%	0.5%
Spray dryer +ESP	5	18%	83%	16.6%	0.4%
SD + FF	47	38%	94%	5.5%	0.5%
Venturi scrubber	32	4%	96%	2.7%	1.3%
Activated carbon injection	0	90% or higher depending on sorbent injection rate.	Can capture all mercury species to high degree.		

Source: EPRI, 2002. An assessment of mercury emissions from U.S. coal-fired power plants.

The table illustrates that, with the exception of fabric filters (and cold-side ESPs where the 2 predominant species are about evenly split); the majority of the mercury emissions are in the elemental form. This decreases the potential for local deposition. One important note that is not illustrated by the above table is the effect wet FGD scrubbers have on speciation. Wet FGD do not capture any elemental mercury but do capture >90% of oxidized mercury. Thus, addition of an FGD to an existing boiler would preferentially decrease oxidized mercury and skew the composition of the flue gas even further toward elemental mercury emissions.

For the most prevalent source type – boilers with cold-side ESPs – it is generally thought by EPA and DOE that activated carbon injection will be the control technology of choice to reduce mercury emissions. Activated carbon is highly effective in capturing all mercury species. If it were assumed that elemental and oxidized species are controlled equally by activated carbon, a boiler adding this control would still have some oxidized mercury emissions that could deposit

locally. The extent to which this presents a public health or environmental hazard will depend on the mass of emissions and other factors discussed below.

Local Impacts of Mercury Emissions

As discussed above, the local deposition of mercury is highly influenced by the amount of oxidized and particulate-bound mercury in the flue gas. Other factors also influence deposition and ultimate human and wildlife exposure to mercury. These factors include the physical characteristics of the power plant and its location.

- Characteristics of the boiler influence the amount of mercury emitted and its dispersion in the atmosphere. These characteristics include the size (in MW) of the facility and how much coal it burns, stack height and the type of air pollution control device in place. Tall stacks typically cause the plume to disperse further from the facility. As noted above, different types of control devices capture the different mercury species to varying degrees. A large plant burning coal will have more mercury emissions on a mass basis than a smaller plant.
- The location of the boiler is important for a number of reasons:
 - The climate will affect the wet deposition of air toxics with a wet climate generally having higher deposition than a dry climate. Also the predominant wind direction and surrounding terrain influence where pollutants are deposited.
 - Watershed characteristics such as erosion potential affect how much mercury enters the aquatic environment. Erosion potential is influenced by topography, extent of plant cover, soil erodibility, etc.
 - The air quality in a region can affect mercury deposition. Ozone and HCl can promote mercury oxidation, which increases local deposition. High particulate concentrations could increase dry deposition of mercury.
 - The health or environmental impact of the emissions will depend on where people or sensitive ecosystems are located relative to the power plant, how many people or sensitive organisms are in that location and whether they are exposed (e.g., to contaminated fish).

In the 1997 Mercury Study Report to Congress, EPA undertook a modeling exercise to estimate the local deposition of mercury and subsequent impacts. These analyses took into consideration all of the above factors including climate differences and location of sensitive populations.¹ Table 2 summarizes the results. While limited, these analyses still illustrate the potential for localized impacts around power plants and lead to the following conclusions:

¹ EPA, 1997. Mercury Study Report to Congress. Volume III: Fate and Transport of Mercury in the Environment. 452/R-97-005. December.

1. Mercury is deposited to a varying degree in the vicinity of the plant. Again, this variability is impacted by a number of factors including the chemical composition of the emissions and the climate at the site.
2. More mercury is deposited locally in a humid site compared to an arid site. Stack height also affects local deposition. Facilities with shorter stacks will have more local deposition than those with taller stacks. Of course, the smaller coal plants have lower emissions, so the mass of emissions deposited locally by a small plant may still be smaller than emissions deposited from a large plant, even though on a percentage basis the smaller plant has higher deposition.

Table 2. Results of Mercury Deposition Modeling for Coal-fired Power Plants

Boiler Type	Average Stack Height (ft)	Percent of Mercury Emissions Deposited within 30 miles	
		Arid Site	Humid Site
Large coal-fired boiler (975 MW – 506 lbs./yr.)	731	2	7
Medium coal-fired boiler (375 MW – 198 lbs./yr.)	465	4	9
Small coal-fired boiler (100 MW – 22 lbs./yr.)	265	9	14

Estimate of Exposure from Local Power Plant Mercury Emissions

The next step in the analysis was to estimate the public health impact of these deposited emissions. The impact of the deposited mercury emissions depends on the proximity of the plant to an ecosystem where the mercury will be methylated, accumulated in the food chain and ingested by susceptible populations. Table 3 shows the modeling results for a subsistence fisher and his child – populations that would be eating the highest amounts of fish, located in humid climate. Values in **bold** indicate exposure is at or above EPA’s safe health benchmark for ingestion of methylmercury (0.0001 mg/kg/day).² In addition to mercury emissions and deposition from the local source, this analysis also includes the contribution of all other coal-fired power plants in the country to deposition at this location. In the table below, this contribution is labeled “regional sources”.

² U.S. EPA, 1998. Study of hazardous air pollutant emissions from electric utility steam generating units – final report to Congress. Volume 1. 453/R-98-004a. February.

Table 3. Results of EPA's Mercury Exposure Analysis for Individual Power Plants

Boiler Type	Distance from plant to center of lake (miles)	Percent of exposure due to emissions from local/regional sources	MethylHg exposure (mg/kg/day)	
			Subsistence Fisher (~2 oz./day)	Child of Subsistence Fisher (~0.7 oz./day)
Large coal-fired boiler (975 MW – 506 lbs./yr.)	1.5	90/10	0.0037	0.0005
	6	58/42	0.00009	0.0001
	30	32/68	0.00006	0.00008
Medium coal-fired boiler (375 MW – 198 lbs./yr.)	1.5	79/21	0.0018	0.0002
	6	46/54	0.00007	0.0001
	30	27/73	0.00005	0.00007
Small coal-fired boiler (100 MW – 22 lbs./yr.)	1.5	45/55	0.00004	0.00006
	6	22/78	0.00004	0.00005
	30	8/92	0.00004	0.00005

Consequently, given a convergence of factors, there is potential for local populations to be affected by the power plant mercury emissions. Table 4 lists population totals within 1 and 5 miles of coal- and oil-fired power plants.³

Table 4. Populations Totals Near Coal-Fired Power Plants (1990 Census)

	Coal-fired Power Plants	
	Within 1 mile	Within 5 miles
Total Population	836,097	21,145,342
Total Households	316,827	8,119,810
Total Children (under age 20)	245,400	6,009,157

Table 5 summarizes the various factors that influence the fate and transport of mercury and how these factors affect local mercury deposition and human exposure.

³ EPA, 1998b. Technical Background Document for the Supplemental Report to Congress on Remaining Fossil Fuel Combustion Wastes. Ground-water Pathway Human Health Risk Assessment. Revised Draft Final. June.

Table 5. Effect of Various Factors on Local Deposition and Human Exposure

Factor	Effect on Local Mercury Deposition or Human Exposure
Air pollution control device	Generally decrease; more likely to decrease oxidized Hg emissions.
High stack height	Decrease
Terrain	Variable. Increase where air dispersion is minimal.
Climate	Increase in humid climate; decrease in arid climate.
High ambient ozone concentration	Potential increase.
High HCl concentration	Potential increase.
Reduction reactions in clouds or plume	Potential decrease.
Coal type	
Bituminous	Increase
Subbituminous	Decrease
Lignite	Decrease
Proximity to water body	Increase
Consumption of locally caught fish	Increase
Poorly buffered or acidic water body	Increase