Mercury Emissions and Mercury Controls For Coal-fired Electrical Utility Boilers

Final Report

September 1, 2005

North Carolina
Department of Environment and Natural Resources
Division of Air Quality

REQUIREMENT FOR THIS REPORT

Excerpted from the *North Carolina Clean Smokestacks Act*

[**Title**: An Act to Improve Air Quality in the State by Imposing Limits on the Emission of Certain Pollutants from Certain Facilities that Burn Coal to Generate Electricity and to Provide for Recovery by Electric Utilities of the Costs of Achieving Compliance with Those Limits]

SECTION 12. The General Assembly anticipates that measures implemented to achieve the reductions in emissions of oxides of nitrogen (NO_x) and sulfur dioxide (SO2) required by G.S. 143-215.107D, as enacted by Section 1 of this act, will also result in significant reductions in the emissions of mercury from coal-fired generating units. The Division of Air Quality of the Department of Environment and Natural Resources shall study issues related to monitoring emissions of mercury and the development and implementation of standards and plans to implement programs to control emissions of mercury from coal-fired generating units. The Division shall evaluate available control technologies and shall estimate the benefits and costs of alternative strategies to reduce emissions of mercury. The Division shall annually report its interim findings and recommendations to the Environmental Management Commission and the Environmental Review Commission beginning 1 September 2003. The Division shall report its final findings and recommendations to the Environmental Management Commission and the Environmental Review Commission no later than 1 September 2005. The costs of implementing any air quality standards and plans to reduce the emission of mercury from coal-fired generating units below the standards in effect on the date this act becomes effective, except to the extent that the emission of mercury is reduced as a result of the reductions in the emissions of oxides of nitrogen (NO_x) and sulfur dioxide (SO_2) required to achieve the emissions limitations set out in G.S. 143-215.107D, as enacted by Section 1 of this act, shall not be recoverable pursuant to G.S. 62-133.6, as enacted by Section 9 of this act.

GENERAL ASSEMBLY OF NORTH CAROLINA - SESSION 2001 – (SENATE BILL 1078)

Ratified the 19th day of June 2002. (Ch. SL 2002-4 S.13)

Marc Basnight - President Pro Tempore of the Senate
James B. Black - Speaker of the House of Representatives
Michael F. Easley- Governor

PREFACE

The Division of Air Quality of the North Carolina Department of Environmental and Natural Resources presents the Division's findings and recommendations concerning the control of mercury emissions from coal-fired electrical utility boilers. This report is the third and final report to the Environmental Management Commission and the Environmental Review Commission required by the Clean Smokestacks Act of June 2002.

This 2005 mercury report is primarily based on the two prior interim reports. It highlights important findings and includes updates. A more detailed discussion of these findings are documented in the 2003 and 2004 mercury reports that are available on the Division's web site.[1] The Division appreciates the efforts of all stakeholders and other individuals who committed their time and effort to the development of this 2005 report.

The goal of this final report is to present information to:

- update issues related to monitoring and controlling mercury emissions from coal-fired generating units,
- update control technology information,
- provide estimates of cost to benefits of alternative strategies to reduce emissions of mercury, and
- provide a recommendation to reduce the emission of mercury from coal-fired generating units.

Portions of this document were taken directly from other government (non-copyrighted) documents in the interest of time and completeness. Some of these sections may have only minor wording changes from the original documents. Quotations are not strictly used to identify these parts, but a strong effort has been made to reference these documents and acknowledge them. The purpose has not been to claim credit for original work of others, but to provide as much detail and accuracy as possible within a limited time. Additional portions of this document have been transferred and condensed from the prior interim reports for document integrity.

[1] http://daq.state.nc.us/news/leg/hg_csa_int_09012004.pdf

Acronyms and Abbreviations Used In This Report

CAA – Clean Air Act – Primary federal clean air statute
CAIR – Clean Air Interstate Rule
CAMR – Clean Air Mercury Rule
CESP – Cold-side electrostatic precipitator
COHPAC™ - Compact Hybrid Particulate Collector
CSA – NC Clean Smokestacks Act
DAQ – NC Division of Air Quality
DENR – NC Department of Environment and Natural Resources
DHHS − NC Department of Health and Human Services
DWQ − Division of Water Quality
EMC − NC Environmental Management Commission
EPA – U. S. Environmental Protection Agency
EU/ICR- Electric Utility Steam Generating Unit Mercury Information Collection Request
FF – Fabric filter
FGD – Flue gas desulfurization
Hg - Mercury
IGCC - Integrated Coal Gasification Combined Cycle
kWh – Kilowatt hour (1000 watts for one hour)
MACT – Maximum Achievable Control Technology
MW - megawatts (million watts)
NC – North Carolina
NO_x – Oxides of Nitrogen, including NO_2, the primary nitrogen species from combustion.
NSCR − Non-Selective Catalytic Reduction
PAC – Powdered Activated Carbon
PM – Particulate matter
RGM − Reactive Gaseous Mercury
SCR − Selective Catalytic Reduction
SIP − State Implementation Plan
SNCR − Selective Non-Catalytic Reduction
SO_2 – Sulfur Dioxide

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EXECUTIVE SUMMARY

This 2005 mercury report presents the Division of Air Quality's (DAQ) updated study results of information in the 2003 and 2004 interim reports and recommendations for reductions of mercury from electrical generating units (EGUs). It concerns issues related to monitoring and controlling emissions of mercury from coal-fired EGUs.[2] The report includes estimates of costs and benefits of strategies to reduce mercury emissions. Chapter I summarizes the most important information and discusses the DAQ's recommendation. Chapter II describes the scope of the mercury problem, sources, control options, and hot spots. Chapter III updates the science used to capture mercury, efforts being made by North Carolina's electric utility companies, current knowledge and gaps in understanding mercury, and the role of rulemaking. Chapter IV estimates mercury capture as co-benefits of the Clean Smokestacks Act (CSA) and discusses how the Clean Air Mercury Rule requirements might be met. The recommendation is discussed in Chapter V.

BACKGROUND

Methylmercury is a serious health threat to unborn and young children. The mercury health concern is directly related to the health of fetuses and very young children through the consumption of predatory fish contaminated with methylmercury by pregnant and nursing women. Sulfate-reducing bacteria convert waterborne mercury compounds into methylmercury. The Division of Water Quality believes that total mercury concentrations in North Carolina's rainwater are currently above levels necessary to allow natural processes to restore acceptable levels of methylmercury in fish.

EPA finalized two rules on March 15, 2005, that will control nitrogen oxides, sulfur dioxides, and mercury emissions from electric generating units. The first rule, the Clean Air Interstate Rule (CAIR), establishes a cap-and-trade program for nitrogen oxides and sulfur dioxides emissions from power plants in 28 states and the District of Columbia. It sets a cap on emissions of each pollutant and it puts in place a trading program so that companies can decide whether it is more cost-effective to control emissions from an old unit or buy credits from some other company that has over-controlled a unit. This rule does not supercede North Carolina's CSA that requires reductions of those pollutants down to certain caps within the state. The second rule, Clean Air Mercury Rule (CAMR), sets up a cap and trade program for mercury emissions from coal-fired electric generating units that will require national reductions from the current systemwide levels of 48 tons per year down to 15 tons per year in 2018.

Together the CAIR and the CAMR are known as multi-pollutant emission control approach. Emission controls that remove nitrogen oxides and sulfur dioxides emissions also capture mercury emissions. By creating caps for all three pollutants at the same time, the utility companies have an opportunity to design and install an efficient series of controls to capture all three pollutants. The North Carolina Environmental Management Commission has initiated rulemaking for the adoption of the CAIR, and it is developing mercury rules that may be unique to North Carolina while complying with the CAMR.

The North Carolina CSA requires Duke Power and Progress Energy to control the emissions of nitrogen oxides and sulfur dioxide. Each is required to reduce their nitrogen oxides emissions by about 78 percent by 2009 and their sulfur dioxide emissions by about 73 percent by 2013. (These

[2] The 2003 and 2004 reports are available electronically at the DAQ website, http://daq.state.nc.us/news/leg/hg_csa_int_09012004.pdf

reduction percentages are based upon 1999 as a base-year for emissions.) Duke Power and Progress Energy have chosen large base-loaded facilities for controls. Reasons for the choice are based on engineering and economics. In other words, North Carolina required nitrogen oxides and sulfur dioxide reductions on the systems and not each boiler. Electrical ratepayers should get large emission reductions at a more economic cost due to the flexibility of the CSA.

In order to achieve these requirements, Duke Energy and Progress Energy are in the process of installing flue-gas desulfurization scrubbers to reduce sulfur dioxide emissions, and combustion controls and post-combustion controls to lower nitrogen oxides emissions. Scrubbers remove sulfur dioxide from the boiler exhaust gases. As a co-benefit, the same scrubbers remove mercury. Some nitrogen oxides controls assist in the oxidation of mercury, thereby, increasing mercury capture in scrubbers.

North Carolina has 46 coal-fired electrical utility boilers that currently account for up to two-thirds of total estimated air mercury emissions in North Carolina. The DAQ calculates that the CSA will result in approximately a 50 percent decrease in total mercury emissions from 2730 to 1460 pounds per year and approximately a 78 percent decrease in oxidized mercury emissions from 1810 to 380 pounds per year. Oxidized mercury represents the most important species of mercury to control because oxidized mercury is more likely to be deposited within the State. A dramatic drop in oxidized mercury emissions should lead to significant reductions in methylmercury contamination in fish. However, the relative contribution of global versus statewide and local mercury emissions to mercury deposition from the atmosphere is poorly understood and remains an area of scientific debate.

There are mercury emission sources in North Carolina that are not subject to the CSA. These non-CSA mercury sources currently represent approximately 40 percent of the total 2002 mercury emissions in North Carolina. From 2005 to 2012, the installation of SO_2 controls to meet the SO_2 caps are estimated to reduce CSA mercury sources to 44 percent of the total of mercury emissions in North Carolina. Non-CSA mercury sources will account for 56 percent of total pounds of mercury emissions in 2013.

DIVISION OF AIR QUALITY'S RECOMMENDATION

The DAQ recommends that North Carolina adopt a mercury rule for coal-fired utility boilers that is at least as stringent as the CAMR and that also meets any additional requirements that the Environmental Management Commission deems appropriate for North Carolina.

CONSIDERATION FOR A RECOMMENDATION

Unlike at the time the CSA was enacted, North Carolina must now determine how it will best meet its obligations under the Federal CAMR and assure appropriate public health protection for it citizens. The state and EMC are presently in the process of this task. Additionally there are significant mercury reductions expected as a result of the CSA. As of the date of this report, there is not yet a draft rule; however, the following will be considered by the state and the EMC.

CLEAN SMOKESTACK ACT

Significant mercury emission reductions are expected in North Carolina as a direct consequence of controls being installed to meet the NO_x and SO_2 caps in the CSA. It is estimated that 60 percent or more reduction in total mercury emissions from sources subject to the CSA will be achieved. More importantly, oxidized mercury represents a majority of total mercury emissions

from coal-fired boilers in North Carolina and an expected 80 percent reduction or more of oxidized mercury (from 1810 to 380 pounds per year or better) from these utility boilers will significantly reduce mercury deposition in North Carolina. Based on current estimates of mercury removal, North Carolina utilities may achieve the 2010 mercury cap in CAMR through the implementation of the CSA.

The DAQ believes the CSA has given North Carolina a leadership position in the reduction of mercury deposition and we should work to continue that leadership. The cap and trade approach is employed in the CSA for the control of SO2 and NOx and is expected to result in very significant reductions of these pollutants at all of the larger electrical generating units and some reduction at many of the remaining units because the caps for the two systems is sufficiently stringent. Consequently there will be significant mercury reduction across North Carolina even though it is derived through a cap and trade approach. The two utility companies have been able to optimize the economics in their control strategies while complying with the CSA. This optimization will not preclude them from meeting the emissions reduction objective; but, it allows the objective to be reached in the least costly manner. The DAQ recommends the cap and trade aspect of the CAMR be considered for the North Carolina mercury rules at least in a first phase as the CSA is expected to more than meet the first phase of the CAMR through 2013. The North Carolina Environmental Management Commission (EMC) is currently considering what requirements beyond CSA may be appropriate.

UNKNOWNS AND RULEMAKING

Both the CAIR and the CAMR are final federal rules. North Carolina is obligated to adopt these rules or rules at least as stringent as these rules. Technological progress is assumed by rule pressure to drive science and technology toward solutions to unanswered questions. However, unsolved questions remain such as the design of certifiable continuous mercury monitors, the determination of mercury control equipment efficiencies under changing operating loads and conditions, and process development to improve capture efficiency of mercury in scrubbers and of treated activated carbon. Modeling science needs to become a better predictive tool by augmenting modeling improvements with additional field research, data gathering, and a better understanding of atmospheric mercury speciation conversion.

The science and practical knowledge base will improve as mercury capture operating experience and certified data collection bring about an improved understanding of mercury emissions and control. Updated information should be considered in future assessments of mercury control technology which may result in revised regulatory requirements.

DAQ recommends flexibility in mercury rulemaking to allow for adaptive management by the EMC, as the unknowns are resolved.

CHAPTER I HEALTH AND ENVIRONMENTAL CONCERNS

Coal-fired electrical generating units account for two-thirds of mercury compounds and elemental mercury emissions from North Carolina. Water bodies are contaminated by mercury primarily through the air. Sulfate-reducing bacteria convert mercury compounds in water to methylated mercury. Methylmercury accumulates in long-lived animals. As they continue to feed over time, predatory fish at the top of the food chain accumulate methylmercury in their body tissues.

HUMAN HEALTH, MERCURY AND METHYLMERCURY

Methylmercury creates health problems in unborn fetuses and young children. Methylmercury harms the development of their neurological systems. Adults are affected by methylmercury contamination, but at higher exposure levels than for infants. Methylmercury has a relatively long biological half-life in humans; estimates range from 44 to 80 days for the half-life of methylmercury in tissue to be removed by natural body processes. Mothers with unborn fetuses and young children will reduce the risk of neurological damage by following the safe fish eating guidelines issued by the Department of Health and Human Services.

METHYLMERCURY TOXICITY[3]

The toxicity of methyl mercury to the developing brain was first recognized in the 1950s in Minamata, Japan, where consumption of fish with high concentrations of methyl mercury by pregnant women resulted in at least 30 cases of cerebral palsy in children; exposed women were affected minimally if at all. A similar episode followed in 1972 in Iraq when the use of a methyl mercury fungicide led to poisoning in thousands of people; again, infants and children were most profoundly affected. The vulnerability of the developing brain to methyl mercury reflects the ability of lipophilic methylmercury to cross the placenta and concentrate in the central nervous system. Moreover, the blood-brain barrier is not fully developed until after the first year of life, and methyl mercury can cross this incomplete barrier. Three recent, large-scale prospective epidemiologic studies have examined children who experienced methylmercury exposures in utero at concentrations relevant to current U.S. exposure levels.

The first of these studies, a group in New Zealand, found a three-point decrement in the Wechsler Intelligence Scale-Revised full-scale IQ among children born to women with maternal hair mercury concentrations greater than six micrograms per gram.

A second study in the Seychelles Islands in the Indian Ocean found only one adverse effect associated with maternal hair mercury concentration among 48 neurodevelopmental end points examined.

A third prospective study, a Scandinavian population in the North Atlantic in the Faroe Islands, followed a group of children for 14 years and collected data on 17 neurodevelopmental end points, as well as on the impact of methyl mercury on cardiovascular function. The Faroes researchers found significant dose-related adverse associations between prenatal mercury exposure and performance on a wide range of memory, attention, language, and visual-spatial perception tests.

[3] Environmental Health Perspectives • Volume 113, Number 5, May 2005

METHYLMERCURY IN FISH

The most recent safe fish eating guidelines issued by the North Carolina Department of Health and Human Services (DHHS) reflect that methylmercury contamination in fish is a statewide problem in North Carolina. Fish are an important part of a healthy diet. The DHHS safe fish eating guidelines are based on age and gender. The guidelines rule out or restrict the consumption of certain fish species while limiting the consumption of other species for N.C. population groups:

- Women of childbearing age (15-44 years), pregnant women, nursing women, and children under 15 years may eat two meals per week of fish low in methylmercury, like farm-raised fish, canned tuna and other canned fish, fish sticks, shrimp, crab, lobster, clams, oysters, scallops, salmon, trout, cod, whitefish, pollock, mahi-mahi, ocean perch, halibut, haddock, flounder, croaker, herring, crappie, sunfish, white perch, yellow perch, and bream.

- They should not eat any shark, swordfish, tilefish, or king mackerel.[4] Also, they should not eat bowfin (blackfish), chain pickerel (jack fish) or largemouth bass caught in North Carolina waters south and east of Interstate 85.

- Other women, men, and children over 15 years old may eat four meals per week of fish low in methylmercury, such as farm-raised fish, canned light tuna and other canned fish, fish sticks, shrimp, crab, lobster, clams, oysters, scallops, salmon, trout, cod, whitefish, pollock, mahi-mahi, ocean perch, halibut, haddock, flounder, croaker, herring, crappie, sunfish, white perch, yellow perch, and bream.

- They should eat no more than one meal per week of shark, swordfish, tilefish, or king mackerel. Also, they should eat no more than one meal per week of bowfin (blackfish), chain pickerel (jack fish), or largemouth bass caught in North Carolina waters south and east of Interstate 85.

MERCURY IN WATER CONVERTED TO METHYLMERCURY

Sulfate-reducing bacteria convert mercury compounds in water to methylated mercury. Bacteria are at the bottom of the food chain. A number of parameters have been identified as important in influencing the production rates and abundance of methylmercury in aquatic systems. They include inorganic mercury loading, chemical speciation, water temperature and pH, the availability of an organic substrate for sulfate-reducing bacteria, mercury demethylation activity (destruction of methylmercury by bacteria), natural reduction-oxidation conditions, and in some cases photo-demethylation (light induced). Methylation is the creation of methylmercury. Demethylation is the destruction of methylmercury molecules.

[4] On January 12, 2001 EPA and FDA issued national fish consumption advisories due to high levels of mercury in some marine fish. These advisories recommend that women of childbearing age and children should not eat shark, swordfish, king mackerel or tilefish.

MERCURY IN DRINKING WATER

The EPA has found that total mercury in drinking water is a potential cause of kidney damage when people are exposed to it at levels above two parts per billion for relatively short periods of time.[5] EPA has set a maximum contaminant level for total mercury in drinking water at two parts per billion because EPA believes, given present technology and resources, this is the lowest level to which water systems can reasonably be required to remove this contaminant should it occur in drinking water.

MERCURY IN AIR

Mercury in the atmosphere comes both from natural sources and human activities. Most of the mercury in the atmosphere is elemental mercury vapor, which may circulate in the atmosphere for years (global pool) and can be transported thousands of miles from the source.[6] Methylmercury does not represent a health risk in ambient air because it is unable to exist there.

MERCURY IN SOIL

Mercury is a naturally occurring element in the earth's crust throughout the world. Early mercury modeling efforts initially made an assumption that all inorganic mercury compounds that settled on the ground would eventually enter the surface water drainage system. Contrary to that assumption, inorganic mercury compounds have been shown to have a strong propensity to attach to and remain on leafy vegetation and soil particles. Mercury deposited on soil and vegetation does not appear to result in exposures believed to be detrimental to health through terrestrial exposure pathways.[7]

MAJOR MERCURY EMITTERS IN NORTH CAROLINA

2003 INVENTORY OF NORTH CAROLINA SOURCES

North Carolina Mercury Inventory Sources	Data Year	Mercury Pounds/Year Utilities	Mercury Pounds/Year Non-Utilities
Progress Energy - Roxboro Plant	2003	708.2	
Nucor Steel[8]	2003		587.9
Duke Energy Corporation - Marshall Steam Station	2003	513.2	
Duke Energy Corp - Belews Creek Steam Station	2003	347.8	
PCS Phosphate Company Inc. - Aurora	2003		275.1
Duke Energy Corporation - Allen Steam Station	2003	230.5	
Progress Energy - Mayo Facility	2003	219.1	

[5] http://www.epa.gov/safewater/contaminants/dw_contamfs/mercury.html
[6] U.S. EPA, Mercury Study Report To Congress, Volume 1, page 1,EPA-452/R-97-003, December 1997.
[7] U.S. EPA, Emissions of Mercury by Plant, page 18. (www.epa.gov/ttnatw01/combust/ utiltox/pitxplt3.pdf)
[8] Automotive mercury switches in shredded scrapped automobiles are considered the primary mercury source of Nucor Steel's mercury emissions. The General Assembly of North Carolina amended the General Statutes by adding Mercury Switch Removal. The law becomes effective 1 July 2006.

North Carolina Mercury Inventory Sources	Data Year	Mercury Pounds/Year Utilities	Mercury Pounds/Year Non-Utilities
GlaxoSmithKline	2003		192.0
Duke Energy Corporation - Cliffside Steam Station	2003	176.1	
New Hanover County WASTEC	2003		150.1
L V Sutton Steam Electric Plant	2003	141.3	
Duke Energy Corporation - Riverbend Steam Station	2003	133.1	
Duke Energy Corporation - Buck Steam Station	2003	113.8	
Progress Energy - F Lee Plant	2003	96.1	
Progress Energy Carolinas - Cape Fear Plant	2003	71.5	
Cleveland Regional Medical Center	1999		61.0
Duke Energy Corp - Dan River Steam Station	2003	51.8	
University of North Carolina at Chapel Hill	2003		46.3
Weyerhaeuser Company - Plymouth	2003		45.8
DAK Monomers LLC	2003		43.4
Blue Ridge Paper Products - Canton Mill	2003		39.4
Cogentrix of Rocky Mount	2003	36.9	
Progress Energy Carolinas, Inc., W.H. Weatherspoon Plant	2003	33.2	
Duracell Global Business Management Group	1999		27.0
Duke University	2003		25.0
Elementis Chromium	2003		24.3
Miller Brewing Company - Eden Plant	2003		20.6
Marine Corps Air Station	2003		20.1
Carolina Stalite Company	2003		17.4

SOURCES OUTSIDE NORTH CAROLINA

Modeling mercury deposition from in-state facilities' stacks to the ground is very difficult due to the lack of scientific knowledge on the subject. Modeling mercury deposition in North Carolina from out-of-state sources is even more difficult and contains additional educated assumptions of unknowns. Oxidized mercury is deposited in North Carolina from sources in North Carolina and nearby states. Elemental mercury is oxidized in the high atmospheric global pool and contributes to mercury deposition to North Carolina. Two recent studies found that the rate of oxidation in the global pool is less that the oxidation rate assumed in models. This new finding may indicate that the effect of controlling oxidized mercury from local and out of state sources will have a larger positive environmental impact than thought previously.

In modeling mercury deposition from low atmospheric sources, mercury deposition rates (pounds per hour) from coal-fired boiler stacks have been assumed to be constant. Flue gases tend to fan out as the distance from the stack increases. Given the assumption of constant mercury deposition rates, the concentration of mercury deposition onto a fixed unit area becomes smaller as the distance to the stack increases. Thus, modeling mercury deposition from nearby states is difficult.

Modeling problems aside, it is reasonable to assume that nearby upwind states likely contribute more mercury deposition in North Carolina than states further away. On March 18, 2004, North Carolina filed a petition pursuant to Section 126 of the Clean Air Act to the United States Environmental Protection Agency For "Relief From Certain Emissions From Large Electric Generating Units in the Following States: Alabama, Georgia, Illinois, Indiana, Kentucky, Maryland, Michigan, Ohio, Pennsylvania, South Carolina, Tennessee, Virginia and West Virginia." [9] Results of modeling by the North Carolina DAQ and EPA helped North Carolina to identify states contributing nitrogen oxides, sulfur dioxide, and fine particulates to North Carolina's air. It appears reasonable that those same states may also contribute mercury deposition in North Carolina.

MERCURY HOT SPOTS

DISCUSSION OF MERCURY HOT SPOTS

Uncertainties in our knowledge of mercury can make it difficult to identify, assess, and address mercury hot spots. Contributing factors to the development of a mercury hot spot include atmospheric contribution by mercury deposition sources, mercury speciation, "prevailing" wind directions, and aquatic conditions that promote bacteriological conversion of mercury compounds into methylmercury.

Current N.C. air toxic rules are one source of authority to address issues related to mercury and areas that do or may have special mercury problems. Also, the Environmental Management Commission has other authority to require sources identified as causing or contributing to a mercury hot spot to control or further control mercury emissions.

THE ROLE OF MERCURY SPECIATION AND HOTSPOTS

There are three species of mercury: oxidized, particle-bound and elemental. Mercury speciation is an important concept in understanding mercury hot spots. Each mercury species has its unique set of chemical and physical properties leading to distinctive traits in terms of reactivity, toxicity, and collectability in emission controls. Total mercury is the sum of the three mercury species.

Scrubbers, designed to capture sulfur dioxide also capture oxidized mercury. Oxidized mercury is the primary form of mercury deposition and as such contributes the most to mercury hot spots. The CSA coal-fired boilers are estimated to emit 1,800 pounds per year of oxidized mercury emissions, more than 60 percent of their total annual mercury emissions. After coal-fired power plants meet the requirements of the CSA, oxidized mercury emissions in N.C. are estimated to drop to 400 pounds per year, or a 78-percent reduction. Particle-bound represents approximately 3-percent of total mercury emissions from coal-fired boilers.

If not captured on particulate, adsorbed by activated carbon, or oxidized before entering pollution controls, elemental mercury passes through air pollution control devices on coal-fired boilers. Elemental mercury is believed to be a minor contributor to mercury deposition and hot spots.

[9] http://www.ncdoj.com/DocumentStreamerClient?directory=WhatsNew/&file=126%20Petition%20part%201.pdf

MERCURY DEPOSITION SOURCES

The North Carolina 2003 inventory of emissions of total mercury from North Carolina point sources adds up to 4,706 pounds of mercury. CSA coal-fired boilers emitted 60 percent of the total (2,872 pounds). Non-CSA sources reported 40 percent (1,834 pounds). [10]

Upon completion of the CSA requirements, N.C.'s coal-fired boilers will emit an estimated 44 percent (1,416 pounds) of the total. Non-CSA sources will then represent 56 percent of airborne mercury emissions. [11]

An unknown amount of mercury enters the State's atmosphere from nearby states and other global sources. The science of mercury transport and active chemical processes occurring during transport is in its infancy.

[10] ((4,706 - 2,872)/4,706)*100 = 39.97 percent.

[11] ((3,250 - 1,416)/3,250)*100 = 56.43 percent.

CHAPTER II CAPTURING MERCURY EMISSIONS

MERCURY SPECIATION AND CAPTURE

Speciation is a term used to denote relative amounts of elemental mercury, oxidized mercury, and particle-bound in flue gas. No methylmercury is emitted from the stacks of coal-fired boilers. The rate of conversion of elemental mercury into oxidized forms of mercury and mercury particulate is dependent on temperature, flue gas composition, and the amount and properties of entrained particles (fly ash and sorbents). Mercury speciation is a particularly important variable for flue gas cleaning as it directly impacts the capture of mercury. For example, elemental mercury from coal combustion combines with chlorine in flue gas to create mercury chloride ($HgCl_2$). $HgCl_2$ is water-soluble and readily reacts with alkali metal oxides in an acid-base reaction; therefore, conventional acid gas scrubbers used for sulfur dioxide (SO_2) control are effective in controlling $HgCl_2$. Elemental mercury is insoluble in water and must be adsorbed onto a sorbent (activated carbon) or converted to a soluble form ($HgCl_2$) that can be collected in a wet scrubber. Coal burned in North Carolina has a high chlorine content relative to other coal types. The high chlorine content in coal enhances collection of oxidized mercury in scrubbers. Mercury particulate, which represents two to five percent of total mercury emissions, is captured in scrubbers. Electrostatic precipitators and bag filters also capture a high percentage of mercury particulate.

Oxidized mercury represents the most important species to control from the State's perspective because of its tendency to be deposited within the State. A dramatic drop in oxidized mercury emissions should lead to a reduction in methylmercury contamination in fish. The speciation of airborne mercury is important relative to potential methylmercury in water bodies. An EPA study failed to find a correlation of elemental mercury in the air and methylmercury in fish tissue.

The Florida Department of Environmental Protection examined an area of the Florida Everglades and reported finding a linear relationship between airborne mercury emissions and methylmercury concentrations in largemouth bass. It appears that a majority of the total airborne mercury entering the Everglades was oxidized mercury from waste incinerators. A majority, if not all, of the incinerators are no longer operating. Since the peak mercury deposition, monitoring showed a 60 percent decline in methylmercury in Everglades fish and wildlife in less than 15 years. Time required to achieve 50 percent of the ultimate response in fish tissue mercury concentrations is estimated to be approximately 10 years.

The relative contribution of global (elemental mercury) versus statewide and local mercury emissions (elemental, oxidized, and particulate mercury) to atmospheric mercury deposition is poorly understood and remains an area of scientific debate.

MERCURY MONITORING EQUIPMENT

The EPA, Department of Energy, vendors, and electrical utilities are testing and developing continuous mercury monitoring equipment. No current continuous mercury monitoring equipment has successfully proven to be reliable over time. All electrical generating units covered by the CAMR and required to have certified operating continuous mercury monitoring must be accurately recording mercury emissions by January 1, 2009. The EPA anticipates technical problems will be resolved.

MERCURY CONTROL EQUIPMENT[12]

Currently, two mercury capture technology options that are considered viable for North Carolina's utility boilers: flue gas desulfurization scrubbers and activated carbon injection.

FLUE GAS DESULFURIZATION SCRUBBERS

Wet flue gas desulfurization scrubbers can be installed on boilers equipped with cold-side or hot-side electrostatic precipitators. The phrase "cold-side and hot-side" electrostatic precipitators refers to the placement of the electrostatic precipitator relative to a heat exchanger that is used to recover combustion gas waste heat leaving the boiler economizer. Combustion gas leaving the heat exchanger is cold relative to combustion gas entering the heat exchangers. Studies show that flue gas desulfurization scrubbers following cold-side electrostatic precipitators have higher performance and are more cost-effective in mercury removal than those following hot-side electrostatic precipitators.

ACTIVATED CARBON INJECTION

Activated carbon injection has the potential to achieve moderate to high levels of mercury control. The performance of 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 mercury capture generally increases with increasing surface area and pore volume. The ability of mercury 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 elemental mercury and oxidized mercury while avoiding excessive blockage by previously adsorbed reactants. As particle sizes decrease, access to the internal surface area of particle increases along with potential adsorption rates. Carbon sorbent capacity is dependent on temperature, the concentration of mercury in the flue gas, the flue gas composition, and other factors.

Temperature is known to impact the adsorption capacity of powdered activated carbon. In most cases, the gas temperature at the available injection point upstream of the particulate control device is around 300 °F and powdered activated carbon has been shown to work effectively at this temperature. However, as temperatures exceed 350 °F, the effectiveness of standard powdered activated carbon drops off rapidly. This was verified in testing at Salem Harbor, where increasing the ESP inlet temperature from 300°F to 350°F reduced mercury removal from approximately 90 percent to the 10-20 percent range.

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[12] *Control of Mercury Emissions from Coal Fired Electric Utility Boilers: An Update***,** Air Pollution Prevention and Control Division, National Risk Management Research Laboratory
Office of Research and Development, U.S. Environmental Protection Agency, Research Triangle Park, NC
February 18, 2005

In general, the capacity for carbon to adsorb oxidized mercury will be different from that for elemental mercury. The selection of a carbon for a given application would take into consideration the total concentration of mercury, relative amounts of elemental mercury and oxidized mercury, flue gas composition, and the method of capture (electrostatic precipitator, fabric filter, or dry flue gas desulfurization scrubber).

Activated carbon injection may be used in conjunction with existing particulate control technology (electrostatic precipitator or a fabric filter). To date, activated carbon injection has only been evaluated during relatively short-term tests on commercially-operating electrical generating plants.

Some situations may not have adequate chlorine present in the flue gas for good mercury capture by standard powdered activated carbon. Accordingly, halogenated powdered activated carbon sorbents have been developed to overcome some of the limitations associated with powdered activated carbon injection for mercury control in power plant applications.

Halogenated PACs offer several potential benefits. Relative to standard PAC, the use of halogenated powder activated carbon:

1. may expand the usefulness of sorbent injection to many situations where standard PAC may not be as effective;

2. may avoid installation of downstream FF, thereby improving cost effectiveness of mercury capture;

3. would, in general, be at lower injection rates, which potentially will lead to fewer plant impacts and a lower carbon content in the captured fly ash;

4. may result in somewhat better performance with low-sulfur (including low-rank) coals because of less competition from SO3; and

5. may be a relatively inexpensive and attractive control technology option for developing countries as it does not involve the capital intensive FF installation.

CARBON INJECTION ON UNITS EQUIPPED WITH ELECTROSTATIC PRECIPITATORS

Currently, untreated activated carbon injection is used with cold-side electrostatic precipitators and fabric filters. Specially treated carbons, such as brominated carbon, are the only sorbents currently viable on hot-side electrostatic precipitators.

CARBON INJECTION WITH A FABRIC FILTER

Carbon injection can be incorporated with a fabric filter downstream from cold-side or hot-side electrostatic precipitators. A full-scale continuous demonstration with activated carbon injection and fabric filter treating flue gas from a bituminous-fired boiler with hot-side electrostatic precipitators has shown mercury capture results in the 70 to 90 percent range. If a boiler operates without an electrostatic precipitator, carbon injection can be incorporated with a fabric filter downstream from an exhaust gas-cooling unit.

POTENTIAL MERCURY AND MULTI-POLLUTANT CONTROL TECHNOLOGIES

Several other mercury and multi-pollutant control technologies offer potential, but they have not yet undergone enough performance and reliability testing. They include:

FUEL BLENDING

Blending of small amounts of bituminous coal with subbituminous or lignite coal may provide some benefit to capture of mercury by existing equipment. Coal blending has been shown to affect unburned carbon and mercury removal. For example, at Holcomb Station, a 360 MW, Powder River Basin subbituminous coal-fired boiler equipped with dry scrubber with a fabric filter for sulfur dioxide and particulate control, vapor phase mercury capture across the pollution control system could be increased from less than 25 percent to nearly 80 percent by blending small amounts of western bituminous coal with the Powder River Basin coal.[13] Since mercury removal of a dry scrubber with a fabric filter systems firing 100 percent bituminous coals has been shown to be about 90 percent or greater, this allows mercury removal performance approaching that of bituminous coals while firing mostly Powder River Basin coal. The effectiveness of this approach in improving cobenefit mercury controls is likely to be very facility-specific. The long-term effects of blending fuels will need to be evaluated for each application. Blending may change boiler slagging and fouling characteristics or the performance of associated air pollution control equipment.

ADDITION OF OXIDIZING CHEMICALS

The addition of chlorine to the fuel or injection into the flue gas is another approach that is being tested for enhancing intrinsic capture of mercury. At Laskin 2 (firing Powder River Basin bituminous coal) and at Stanton 10 (firing North Dakota lignite coal), chlorine salts were added to the fuel to assess the impact of increasing fuel chlorine on mercury oxidation and capture. Laskin 2 is equipped with a particle scrubber and Stanton 10 with a dry scrubber with a fabric filter. In both cases, mercury oxidation increased, although for some salts the mercury capture did not increase. In the case of Laskin, opacity was observed to increase as a result of salt addition and in the case of Stanton 10, pressure drop across the FF increased. Long-term effects, such as corrosion, plugging, and impacts on combustion equipment, could not be assessed during the short-term parametric tests. Therefore, the use of coal additives offers some promise at improving mercury capture; however, they may have other impacts that need to be evaluated.

INCREASING UNBURNED CARBON IN FLY ASH

Carbon in the fly ash has been shown to be an important factor in mercury capture by particulate control equipment. For example, at Salem Harbor #1, which fires bituminous coal and has a cold-side electrostatic precipitator, mercury removal rates over 80 percent were measured on some occasions. These were attributed in large part to the very high carbon content in the fly ash (on the order of 15 percent or more and sometimes around 30 percent). However, the carbon content in the fly ash may need to be kept within acceptable limits due to constraints on performance or opacity. Since unburned carbon is unavailable for the production of steam and electricity following combustion there is a trade-off between the overall plant efficiency versus mercury adsorption. Additional negative impacts of increased unburned carbon include waste disposal and loss of byproduct use, which could also pose additional constraints on use of this mercury control approach.

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[13] The Powder River Basin spans the Montana - Wyoming border and is the single largest source of coal mined in the United States and contains one of the largest deposits of coal in the world. The low sulfur and ash content of the coal in the region makes it very desirable.

MERCURY CONTROL DEMONSTRATIONS BY NORTH CAROLINA'S UTILITIES

Duke Power and Progress Energy are contributing to studies underway to improve mercury capture at coal-fired electrical utilities.

DUKE POWER

To date, research has centered on trying to quantify the co-benefit assumptions and to determine if impregnated carbon injection is a viable control technology for hot and cold side electrostatic precipitators. Duke Power's research includes:

1. Cold Side Electrostatic Precipitators Removal Potential Testing: Tests at Allen and Marshall in 2002 have shown the collection efficiency of the electrostatic precipitators to range between 25 and 35 percent removal when not operating in the low NOx mode.

2. Oxidation Across Selective Catalytic Reduction: A test of the mercury oxidation across the selective catalytic reduction Cliffside Unit 5 was performed in 2003. The oxidation after the selective catalytic reduction was greater than 90 percent under various firing conditions. Current assumption is that the scrubber will remove approximately 70 percent of the oxidized mercury entering the scrubber for a total removal from the electrostatic precipitators and scrubber of 80 percent. Normally a typical selective catalytic reduction catalyst life is 20,000 hours. The selective catalytic reduction catalyst had less than 5,000 hours of operation when tested. Verification is needed that the oxidation rate of mercury does not decrease as the catalyst ages.

3. Increased Loss of Ignition Impact (LOI) on Mercury Reduction: Low nitrogen oxide operations generally result in increased loss of ignition. Tests at Marshall and Allen were performed in 2003 and 2004 in which the mercury collection and oxidation across the electrostatic precipitator were measured during low nitrogen oxide operation. The testing showed increased oxidation and collection efficiency across the electrostatic precipitator under certain conditions. Oxidation after the electrostatic precipitators ranged between 50 and 90 percent and the collection efficiency of the electrostatic precipitators ranged between 30 and 75 percent. It was found that variables such as coal fineness and temperature entering the electrostatic precipitator are important in the varying oxidation and collection efficiency. Additional study is needed to understand the mechanisms that increased oxidation and collection efficiency and how these variables can be controlled

4. Hot Side Electrostatic Precipitators Impregnated Carbon Injection (Department of Energy Trials): Tests performed at Cliffside Unit 2 in September 2003 and December 2004 found that a 70 to 80 percent mercury removal was achieved at low loads and approximately 30 percent was achieved at full load using between 5 to 7 pound injection rate of activated carbon per million actual cubic feet of air flow. The change in removal potential is assumed to be mainly a function of temperature. A longer trial was performed on Buck Unit 6 in June of 2005, and it demonstrated 40 to 75 percent reduction at a 5 to 7 pound injection rate of activated carbon per million actual cubic feet through out the load range. During the Buck Unit 6 trial the 75 percent removal was not sustainable. In the last week of the test a 25 percent Powder-River-Basin coal was blended with central Appalachian coal and the collection efficiency dropped to less than 30 percent. Confidence in and interpretation of the test results are difficult because of multiple issues with mercury monitors.

5. Mercury Reduction Across A Pilot Scrubber: A pilot wet limestone scrubber (one megawatt) was installed at Marshall Unit 4 in August 2004. The purpose of the trial was to determine the

total mercury collection efficiency across the scrubber and to collect representative wastewater and gypsum samples. The total mercury removal ranged between 60 and 90 percent during the month, but removal of oxidized mercury across the scrubber varied widely. In some cases more elemental mercury left the scrubber than entered. This may indicate that there may have been a conversion of oxidized mercury to elemental mercury within the scrubber (re-emission). This is a critical variable in estimating the co-benefits of controls. Additional longer term testing is needed to determine the reliable collection efficiency of a wet scrubber.

6. Cold Side Electrostatic Precipitators Impregnated Carbon Injection: A carbon injection test was performed at Allen Unit 1 for a week in March 2004. Approximately 70 percent mercury capture was achieved with a 5 to 7 pound injection rate of activated carbon per million actual cubic feet. Based on results from impregnated carbon injection on a cold side electrostatic precipitator with Powder-River-Basin coal, expectations were in the 90 percent reduction range with a 3 pound injection rate of activated carbon per million actual cubic feet. This test demonstrated the need to test the different mercury control technologies on individual systems and not rely on test results from other utilities in evaluating the potential control efficiencies. This test also indicates that the removal potential using carbon injection on a cold side electrostatic precipitator may be limited when firing central Appalachian coal. Until this test was completed, it was thought that 80 to 90 percent mercury control could be achieved by converting hot-side electrostatic precipitators to cold-side electrostatic precipitators while injecting an impregnated carbon.

7. Mercury Monitors: A study to review existing monitors on the market and determine what changes or improvements are needed to meet federal regulatory monitoring requirements was initiated in 2004 by RMB Consulting, the Department of Energy, the Electric Power Research Institute, and utilities. The study goes into 2006. Multiple mercury monitors are being tested on dry and wet stacks but not on the Duke system. To date, only one monitor is meeting the federal monitoring requirements. Duke Power will install 39 mercury monitoring systems prior to 2009 on wet and dry stacks. Monitors will need to be selected by the end of 2006 so that they can be installed and certified prior to 2009. Duke plans to test several types of monitors in 2006 in addition to funding the study above to aid in the selection process.

PROGRESS ENERGY

1. Mercury Control Demonstration by Progress Energy, General Electric, and the Department of Energy: This demonstration involves multi-pollutant testing using a combined approach at Progress Energy's Lee plant. The project is designed to test mercury control potential of a combination of several pollution control equipment operating under different conditions: combustion optimization, electrostatic precipitator, flue gas inlet cooling and trim activated carbon injection. The goal of the project is to maximize the amount of mercury removed by the fly ash and unburned carbon to minimize the amount of activated carbon needed to be injected to meet compliance. Previous testing has demonstrated up to 80 percent mercury removal. The initial stage of this project will include lab scale combustion testing of PGN supplied coal to determine optimum combustion requirements for maximum mercury and nitrogen oxide control.

2. Mercury Control Demonstration by Progress Energy, Sorbent Technologies, and the Department of Energy: Progress Energy and Sorbent Technologies have jointly been selected to field test Sorbent Technologies' B-PAC® mercury control sorbent at the Lee Plant. B-PAC® is a bromated activated carbon sorbent that provides higher mercury removal

effectiveness when compared to standard activated carbon. The B-PAC® sorbent will be injected into the flue gas prior to the electrostatic precipitator. The goal of this project is to provide cost effective mercury control. The Lee Plant demonstration will consist of a thirty-day field test on unit number 1 that utilizes a cold- side electrostatic precipitator.

3. Progress Energy and five monitoring companies are continuing long-term testing and improvements to five continuous mercury monitors at the Cape Fear facility for the EPA.

MERCURY CONTROL COMBINATION EFFICIENCIES

Table 1 from the EPA document, *Control Of Mercury Emissions From Coal-Fired Electric Utility Boiler*, provides emission factors for existing post-combustion control configurations used by pulverized coal-fired boilers. North Carolina utility coal-fired boilers burn bituminous coal.

Table 1.[14]
Mercury Removal Rates from Pulverized Coal Units Assumed by EPA

New Pulverized Coal Mercury Control Efficiency*	
Pollution Controls in Place	**Bituminous Coal**
Cold-Side Electrostatic Precipitator	36%
Cold-Side Electrostatic Precipitator/Flue Gas Desulfurization Unit (Scrubber)	66%
Cold-Side Electrostatic Precipitator/Dry Flue Gas Desulfurization Unit	36%
Cold-Side Electrostatic Precipitator/Selective Catalytic Reduction Unit (SCR)/Flue Gas Desulfurization Unit	90%
Fabric Filter	89%
Fabric Filter/Flue Gas Desulfurization Unit	90%
Fabric Filter/Dry-Flue Gas Desulfurization Unit	95%
Fabric Filter/Selective Catalytic Reduction Unit/Flue Gas Desulfurization Unit	90%
Hot-Side Electrostatic Precipitator	10%
Hot-Side Electrostatic Precipitator/Flue Gas Desulfurization Unit	42%
Hot-Side Electrostatic Precipitator/Dry Flue Gas Desulfurization Unit	40%
Hot-Side Electrostatic Precipitator/Selective Catalytic Reduction Unit/Flue Gas Desulfurization Unit	90%

*Rate based on percentage removal from amount in coal entering boiler.

[14] Correspondence 19 July, 2005 from Mr. Sam Napolitano, Director, Clean Air Markets Division, Office of Air and Radiation, U.S. Environmental Protection Agency

SCIENCE GAPS IN MERCURY CONTROL

The following comments identify areas requiring study due to a shortage of data or where basic scientific knowledge remains inadequate:

1. The role ammonia plays in interfering with mercury oxidation should be studied in greater detail. If ammonia interferes with mercury oxidation, then selective catalytic reduction effectiveness in oxidizing mercury may be reduced as the catalyst ages.

2. The speciation of mercury at the inlet of the selective catalytic reduction, or inlet of the particulate control device (in the case where selective catalytic reduction is not installed), remains difficult to predict because the processes that govern mercury speciation in the boiler are not yet adequately understood. A better understanding of this would improve the ability to predict mercury removal performance of flue gas desulfurization and other air pollution control equipment.

3. Reduction of oxidized mercury in wet flue gas desulfurization and subsequent re-emission requires enhanced understanding.

4. Parallel efforts to improve measurement and data collection accuracy and to reduce the effort necessary for speciated measurements of mercury are critical. These are very challenging, labor intensive measurements. Significant progress has been made over the last few years to improve the reliability and accuracy of on-line measurement systems. However, accurate and dependable measurement of mercury at very low concentrations will be needed to prove the efficacy of mercury control systems.

5. An improved understanding of the behavior of mercury in the boiler and air pollution control systems may offer insights to addressing operational variability. Modeling, supported by verification testing, should be pursued to develop these capabilities.

6. Efforts examining the potential for leaching of mercury and other metals (e.g., selenium, arsenic) from coal combustion residues (fly ash, scrubber sludge, etc.) are ongoing. Based on limited number of samples, results of these efforts have indicated that leaching of mercury from fly ash and fly ash sorbent mixtures does not appear to be of concern. However, the potential for leaching of mercury and other metals should continue to be evaluated over a range of coal combustion residue types and their management practices.

7. The potential for release of mercury in processes involving beneficial use of coal-combustion residues should be evaluated (e.g., wallboard production and other high temperature processes).

OBSERVATIONS AND PROGRESS PREDICTIONS

1. Additional nitrogen oxide and sulfur dioxide emission reduction requirements are expected to result in growing use of selective catalytic reduction and scrubber systems at coal-fired utility boilers.

2. Development and testing of new sorbents or additives has proceeded at a very rapid pace. Sorbent injection systems can be installed quickly and new sorbents or furnace additives can be tested relatively easily. This is in contrast to more capital-intensive technologies like selective catalytic reduction or flue gas desulfurization scrubbers, which require a long time

to engineer and install the equipment or to make any significant changes to it, such as a catalyst change. Therefore, it is anticipated that the rapid pace of technology development for new sorbents and chemical additives will continue.

3. There is increased appreciation for the importance of mass transfer (interaction of mercury with powdered activated carbon in flight) in the sorbent capture process. In-flight mercury removal for both standard and new sorbents is likely to improve performance due to enhanced sorbent injection methods.

4. Halogenated powdered activated carbon injection with a cold side-electrostatic precipitator has the potential to achieve 90 percent mercury control. Standard powdered activated carbon injection with an electrostatic precipitator (hot side or cold side) and a retrofit fabric filter, or a fabric filter alone, has the potential to achieve over 90 percent mercury reduction.

5. The one application that remains particularly challenging is units with hot side electrostatic precipitator. This represents about 12 percent of current coal-fired capacity. Currently, retrofit of a downstream fabric filter after the air preheater and sorbent injection prior to the fabric filter is the only approach that has proven to be effective for these units at all load conditions.

6. Cost estimates will vary depending upon specific conditions including regulatory structure. Nevertheless, for most units, it is projected that the mercury removal would add no more than about 2 mills/kWh to the annualized cost of power production.

7. It is believed that powdered activated carbon injection and enhanced multi-pollutant controls will be available after 2010 for commercial application on most key combinations of coal type and control technology to provide mercury removal levels between 60 and 90 percent.

8. Also optimized multi-pollutant controls may be available in the 2010-2015 time frame for commercial application on most key combinations of coal type and control technology to provide mercury removal levels between 90 and 95 percent. It is noted, however, that broad scale commercial application of control technology to remove mercury will be possible after the technology is available.

9. It is estimated that, once a utility has signed a contract with a vendor, installation on a single boiler could be accomplished in the following timeframes:

    - Sorbent injection upstream of an existing electrostatic precipitator or fabric filter could be installed with commissioning complete in six months to one year;

    - Sorbent injection upstream of a retrofit fabric filter could be retrofitted to an existing ESP in under two years;

    - A new electrostatic precipitator, flue gas desulfurization, or particulate matter mercury control system could be retrofitted in two to three years dependent on the retrofit difficulty; and

    - Existing electrostatic precipitator or flue gas desulfurization to enhance mercury control could be retrofitted in about one to two years.

The installation timeframes described above include the time periods associated with control technology fabrication, delivery, construction, and testing; approval of construction permit; and modification of operating permit.

RELIABILITY OF MODELING MERCURY DEPOSITION

Modeling airborne mercury to deposition sites is a complex exercise involving chemical reduction and oxidation (opposing forces) and dynamic physics with numerous variables and unknowns. More scientific work needs to be completed to refine or improve assumptions. Modeling is a predictive tool that has little value if it is unable to predict existing conditions. Two lists are presented. The first list provides established principles. The second list discusses mercury modeling variables that are currently populated with assumptions instead of known information.

This list includes established principles:

- Freshwater fish contaminated with methylmercury result from atmospheric mercury deposition.

- Gaseous elemental mercury can remain suspended in the atmosphere for weeks or months.

- Areas near local mercury emission sources with a predominance of oxidized mercury will experience deposition flux at higher concentrations than areas more remote from the source.

- Stable forms of mercury compounds (oxidized mercury) in the atmosphere settle faster than elemental mercury.

- Gaseous forms of oxidized mercury compounds (reactive gaseous mercury or RGM) are deposited a short distance from the source unless emitted from tall smokestacks.

- Oxidized mercury compounds in aerosol form travel further than RGM but less than elemental mercury.

- Although there are forces that oxidize elemental mercury and opposing forces that reduce oxidize mercury into elemental mercury, it is believed that the oxidizing forces are predominant over the reducing forces.

- Sources that emit primarily elemental mercury contribute to the global pool of mercury but little to local mercury deposition.

- Oxidized mercury can be adsorbed directly from the air to any surface (water, dirt, and vegetation).

- Gravity causes aerosol mercury with a diameter equal or greater than 2.5 microns to settle as dry deposition, while smaller diameter particles with diameters of approximately 0.1 microns or less act as a gaseous RGM. It is unknown how aerosol mercury in the diameter range of 0.1 microns to 2.5 microns reacts in the atmosphere.

- Net dry deposition is reduced on a smooth surface because the wind tends to recapture mercury particles.

- All surfaces act to capture atmospheric RGM and aerosol mercury. However, some surfaces convert a fraction of species deposited back into elemental mercury.

This second list sets out some of the gaps in knowledge where better information is needed:

- The species of mercury (elemental, oxidized, RGM) that come from particular sources are often unknown. This knowledge is very important regarding mercury's affect on the environment.

- The mechanisms that oxidize elemental mercury and reduce oxidized mercury in air and cloud water are controversial and play an important part in modeling results.

- Photochemical oxidants and halogens are known to oxidize mercury, but their variable atmospheric concentrations need to be known and plotted into the speciation chemistry.

- Mercury sulfite complexes are known to decompose spontaneously in cloud water. However, other unknown decomposition mechanisms need to be identified to explain the amount of decomposition observed.

- Data shows that some oxidized mercury is quickly reduced to elemental mercury very shortly after mixing in the atmosphere. The explanation for this reduction is unknown.

- The rate of recognized reactions is controversial.

- The majority of atmospheric mercury consists of elemental mercury that constitutes the "global pool." Background mercury readings will be readings of the global pool unless a particular area is near a large mercury source. Atmospheric conditions far away and in high altitudes from the area influences mercury speciation affecting the area. The distant chemical reactions are not monitored and create variable mercury flux in the area.

- Mercury transported from distant sources includes some oxidized mercury. The amount of oxidized mercury is variable, but tends to be less than five percent of the total mercury background. However, oxidized mercury tends to be deposited, so although the fraction of oxidized mercury is small relative to the global pool, it is the speciation that affects the environment the most.

- Current models used to predict the fraction of mercury from outside and depositing in the United States estimate foreign mercury contributions at between 25 and 75 percent. This range indicates the current uncertainties that exist.

FEDERAL LEGISLATION AND RULES

FEDERAL LEGISLATION

The proposed Clear Skies legislation would create a mandatory market-based program that would significantly reduce power plant emissions of sulfur dioxide, nitrogen oxides, and mercury by

setting a national cap on each pollutant and allowing trading. However, Clear Skies legislation has not been passed by Congress.

Rep. Henry Waxman introduced the Clean Smokestacks Act of 2005. The bill would require power plants of 15 MW or more, by not later than January 1, 2010, to reduce aggregate sulfur dioxide emissions by 75 percent from the levels allowed under full implementation of Phase II of the Acid Rain program, aggregate nitrogen oxides emissions by 75 percent from 1997 levels, aggregate carbon dioxide to 1990 levels and aggregate mercury emissions by 90 percent from 1990 levels. In addition, the bill would require EPA, within two years of enactment, to issue regulations to allow the use of market-oriented mechanisms, including emissions trading, except in the case of mercury; require that localized adverse health and environmental impacts are prevented; ensure against re-release of captured or recovered mercury; and include incentives for renewable energy. Further, the bill provides for regulations requiring additional power plant emission reductions if EPA determines that the reductions required by the bill are not reasonably anticipated to protect public health and welfare. Finally, Rep. Waxman's Clean Smokestacks Act – which is "in addition to, and not in lieu of," any other requirements of the Clean Air Act are also calls for the modernization of outdated power plants by requiring that on the later of the date that is 30 years after the plant began operation or the date that is five years after enactment, a plant shall comply with the most recent New Source Performance Standards promulgated under Clean Air Act Section 111 and Parts C and D, applicable to modified sources.

FEDERAL MERCURY RELATED REGULATIONS

On March 15, 2005, EPA issued the CAMR, which creates performance standards and establishes permanent, declining caps on mercury emissions. The CAMR will build on the CAIR to cut mercury emissions from utilities by nearly 70 percent at full implementation. Both the CAMR and the CAIR are part of the suite of inter-related rules collectively known as the Clean Air Rules of 2004, which together address ozone and fine particle pollution, non-road diesel emissions, and power plant emissions of sulfur dioxide, nitrogen oxides and mercury.

The CAIR addresses windblown air pollution by requiring states to reduce sulfur dioxide and nitrogen oxide emissions. There are available data that indicate controls for reducing emissions of SO_2 and NO_x also are effective, in some cases, at reducing mercury emissions from coal-fired utilities. This is another important reason to couple the mercury rule with the Interstate Air Quality Rule. States could comply with these requirements through a cap and trade system.

EPA decided to use Section 111 to regulate mercury, instead of the more restrictive Section 112, as part of deliberations over the administration's Clear Skies legislation. Addressing mercury under Section 111 and allowing trading are being challenged in court. The administration simultaneously proposed a second mercury regulation (Utility Mercury Reductions Rule) that would require all plants to install pollution controls.[15] Selection of Section 111 instead of Section 112 has resulted in ten states have filing a lawsuit challenging EPA's decision to revise its December 2000 regulatory finding that removed coal- and oil-fired electric utility steam generating units from the Section 112(c) source category list. EPA's revision rescinds the findings made in 2000 for utility air toxics that supported a requirement that utilities should install MACT, defined under the Clean Air Act. Four environmental groups have petitioned EPA to stay the revised regulatory determination pending the outcome of the states' legal challenge.

[15] http://groups.msn.com/aaea/mercury.msnw

NORTH CAROLINA'S MERCURY RULES

North Carolina's mercury rules are currently in rulemaking by the Environmental Management Commission.

CONSIDERATIONS RELATED TO TRADING MERCURY CREDITS

DEFINITIONS

"Emissions trading" is a system of establishing a cap on emissions and allowing sources (e.g., power plants) the flexibility to choose emissions reduction plans that work best for them. Trading allows a source that can over-control its emissions to sell extra reduction credits to another source for which controls would be prohibitively expensive or technologically difficult to install.

"Banking" is the retention of unused allowances from one calendar year for use in a later calendar year. Banking allows sources to make reductions beyond required levels and "bank" the unused allowances for use later.

TRADING

- Trading provides time to install control equipment. Air pollution control retrofits require major engineering, specialty trades, and equipment assets that limit control equipment availability.

- Retrofits installed over time allow for planned outages at power plants. Impacts on the power grid stability and reliability are minimized with phased control installation.

- Retrofit control costs increase per ounce of mercury captured for small units. Low-emitters may purchase mercury credits to offset expensive mercury retrofit controls.

- A cap and trade program provides flexibility to sources, encourages earlier or greater reductions than required, and encourages efficiency.

- A cap and trade program does not result in an increase in cumulative emissions.

- Significant levels of early reductions would not occur without a cap and trade program.

- Banked allowances can be used at any time, so they provide flexibility and insurance for companies to respond to growth and changing marketplace conditions over time.

- The cap and trade program can result in emissions above the cap level in the later years of the compliance period. This is a trade-off for sources that make earlier reductions beyond required levels mercury emissions. Total mercury emissions over the compliance period do not exceed the cap level.

- Emission controls being installed to meet North Carolina's Clean Smokestacks Act of 2002 are estimated to permit North Carolina to meet its 2010 CAMR allotment. If trading were to be permitted, Duke Power and Progress Energy would be able to transfer some mercury credits to their small generating units.

NO TRADING

- All coal-fired units would have to have mercury controls installed prior to 2010.

- Each coal-fired unit will face enforcement actions if it exceeds its fixed mercury allotment.

- Each coal-fired unit will be operated until it reaches its fixed mercury allotment. Then the unit will cease operations until the twelve-month rolling average is below the fixed mercury allotment. In the interim, electric power will have to be purchased from the open market from out of state generators to make up for the loss of generating capacity.

- If there is an unplanned outage at one of the base-loaded coal or nuclear units, that lost generating capacity will have to be covered by electrical purchases on the open market for the time it takes to make repairs (generally, a period of six months or more).

- By not allowing trading at least within the State, there appears to be a conflict with the multi-pollutant control philosophy of North Carolina's Clean Smokestacks Act of 2002. Although a mercury emission limit was not fixed in the Act, the expectation of mercury emission reductions as a co-benefit was well understood. As a direct result of the Clean Smokestacks Act, the utilities are committed to controlling nitrogen oxides and sulfur dioxides (and mercury) at their base loaded coal-fired units. Each company is allowed the flexibility of intra-company trading to meet the Clean Smokestacks Act's SO_2 and NO_X emission caps. If no trading is permitted, mercury specific controls will have to be retrofitted to the smaller generating units or they will have to stop operations as discussed above.

- Without the availability of mercury credits to purchase, small electrical providers in the State may find it difficult to finance the retrofit of mercury controls and monitoring equipment and may possibly become financially unviable.

NEW COAL-FIRED FACILITY'S MERCURY CREDITS CALCULATION

Based on the methodology in the EPA guidelines for new growth, 1,814 ounces (113 pounds) of mercury would be set aside for new growth from 2010 until 2018. In 2018 and each year thereafter, 423 ounces (26 pounds) would be available for new growth in North Carolina. All new sources will share these fixed set asides proportional to their rated heat input. Any deficit in mercury allocations will have to be purchased under the trading program if trading is allowed.

From §60.45a, Standard for Mercury, the allowable mercury emission factor for bituminous coal is 21×10^{-6} pound per megawatt hour (lb/MWh). The following calculation is to determine the maximum number of annual mercury credits required for a new 1,600 megawatt facility based on its potential to emit.

Hg credits/year = (21×10^{-6} lb Hg/MWh) x (1,600 MW) x (8760 hr/yr) x (16 Hg credits/lb Hg)
Hg credits/year = (0.000021) x (1,600) x (8,760) x (16)
Hg credits/year = 4,709 ounces
Using 95 percent load available 85 percent of the year, 4,709 x 0.95 x 0.85 =
=3,803 ounces or 238 pounds of mercury credits needed each year

If a new 1,600-megawatt facility were built in North Carolina, it would need to purchase 1,989 ounces[16] of mercury credits under a trading program. If two years later a second new facility one-half the capacity of the first plant were built, then the first plant would need to purchase 2,595 ounces[17] of mercury that year. The newest facility would need to purchase 1,298 ounces[18] of mercury credits.

LEGISLATION IN NORTH CAROLINA AND OTHER STATES

The purpose of this subsection is to discuss anticipated and actual action taken by states to reduce mercury emissions from coal-fired electrical utility boilers. The CAMR (CAMR) is applicable to each of the seven states discussed. Connecticut, Indiana, Massachusetts, Maryland, North Carolina, and Wisconsin are planning to or have taken an active role in reducing coal-fired electrical utility boiler mercury emissions.

Each state's legislative act, potential rule or published rule is discussed and presented in a chart with a comparison of the state's allocations of mercury emissions found in the CAMR. A rough value of total power produced megawatt hour (MWh) by coal-fired utility boilers in each state is inserted into the charts to provide a state comparison. Charts showing mercury reductions are not necessarily reflective of each state's final outcome or success due to the dated data used and variability in control efficiency at each boiler site. Thus, the charts are meant be used to reflect different approaches used by legislators and regulators to develop requirements in the face of existing unknowns.

The process to develop these charts started with a calculation of mercury emissions for each boiler covered by CAMR in each of the six states. In 1999, the U.S. Environmental Protection Agency (EPA) conducted the Electric Utility Steam Generating Unit Mercury Information Collection Effort to gather information about mercury emissions from the coal-fired electric utility industry**.** This effort led to the collection of stack test and coal mercury content reports on 80 furnace or boiler units. Information collected during the stack testing included operating control device configurations. Research Triangle Institute used this collected data to build the tool "Electric Power," "*EUCFF*" (Version 3.0.1). The tool was developed in June 2001 for estimating mercury emissions from coal combustion at electrical utilities in the United States. After the 1999 mercury emissions were calculated using "Electric Power," the estimated 2005 mercury emissions were calculated as the product of a ratio of the CAMR average heat input for the three highest annual heat inputs for 1998-2002 and the actual 1999 heat input and the estimated 1999 mercury emissions. Each state's proposed mercury rules were reviewed to establish control dates and mercury reductions in pounds per year. In those cases where rule wording provided flexibility, the least stringent outcome was used for this evaluation. Once more, these charts are reflective of calculated estimates and may or may not predict actual mercury emission reductions.

NORTH CAROLINA

Although no specific mercury reduction is required in the North Carolina CSA, it was known that reductions in sulfur dioxide and nitrogen oxides emissions would reduce mercury emissions as a co-benefit and in doing so improve the environment. North Carolina's estimated mercury reductions resulting from the Act's requirements are important as a comparison to actions taken by other states. To this end, results of North Carolina's CSA are shown first in this discussion.

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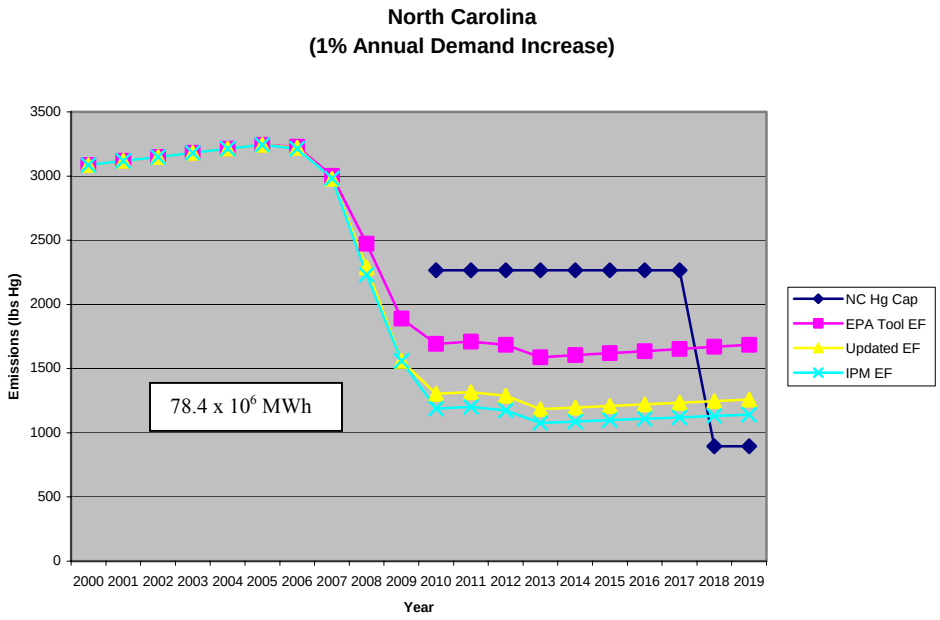
[16] [3,803 Hg ounces minus (1,814) = 1,989 ounces of mercury]
[17] [3,803 Hg ounces minus (1,814 ounces x 0.666) = 2,595 ounces of mercury]
[16] [1,902 Hg ounces minus (1814 ounces x 0.333) = 1298 ounces of mercury]

The "updated emission factors" shown in the North Carolina chart reflect recent improved mercury capture from the combination of selective catalytic reduction with wet scrubbers. These expensive controls are installed normally on large base-loaded boilers. Thus, their influence affects total state mercury capture disproportionate to their numbers. The North Carolina chart shows that more mercury reductions are anticipated when the latest EPA emission factors are compared to the EPA's Tool "Electric Power" calculated values. Mercury emissions are calculated to be slightly lower when EPA's IPM emission factors are compared to the latest EPA emission factors.

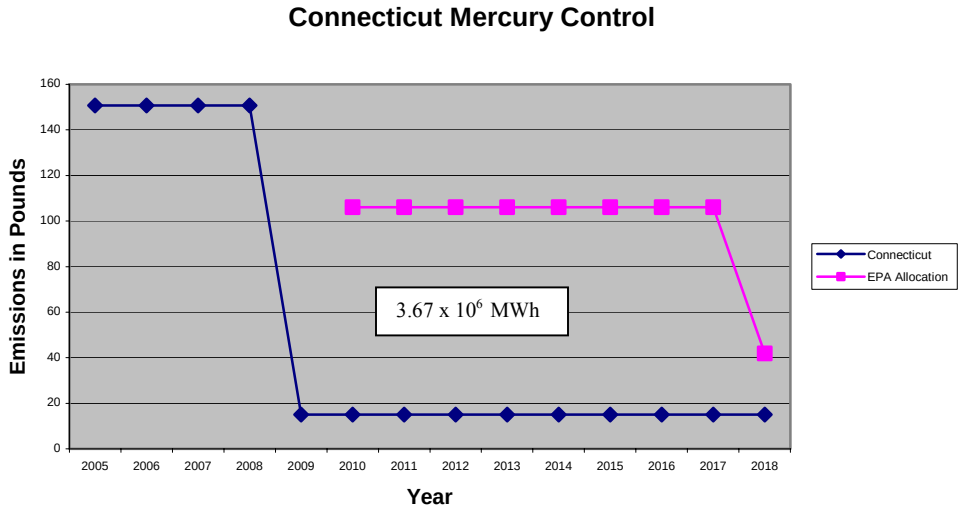


OTHER STATES[19]

CONNECTICUT

Connecticut's Public Act 03-72 HB6048 requires that by July 1, 2009, coal-fired power plants comply with an emission factor equal to or less than 0.6 pound of mercury per trillion BTU of heat input or alternatively, an emissions rate with a 90 percent reduction in mercury emissions from the entry point of the control equipment. The act allows the Commissioner to set an alternative emission limit for a facility if the facility has a properly designed and installed control unit that fails to meet the emissions rate.

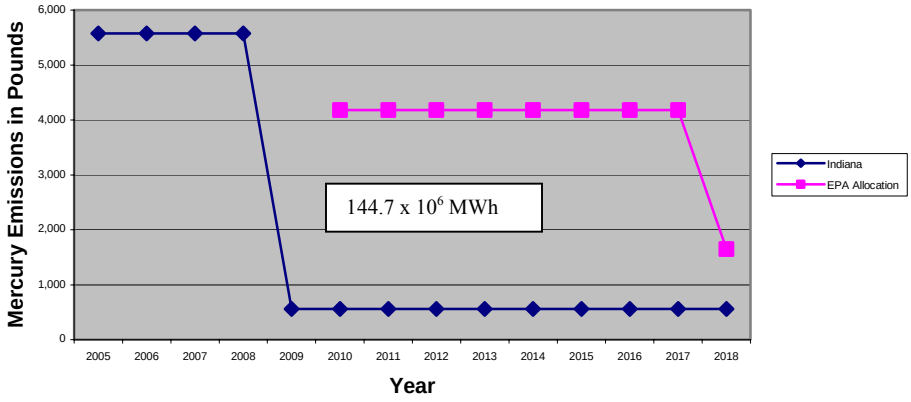
[19] The National Conference of State Legislatures, http://www.ncsl.org/programs/environ/air/MERCURYEMS.htm



INDIANA

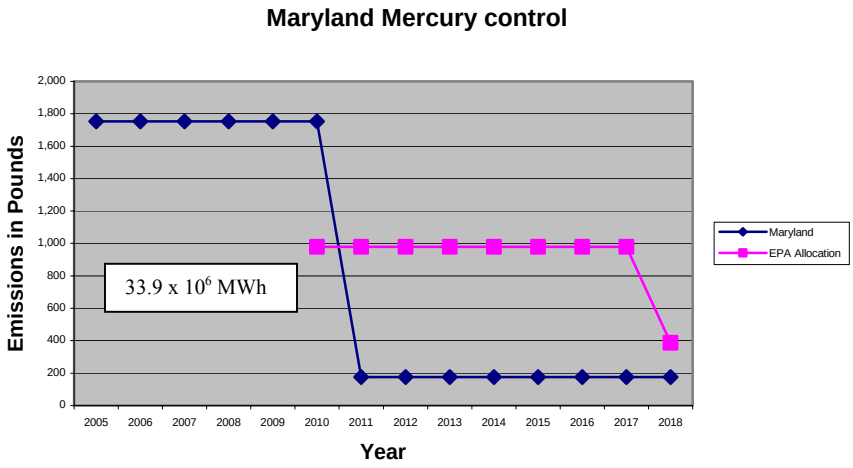
Indiana developed a proposed rulemaking draft rule, "Emission Limitations for Mercury from Coal-Fired Electric Generating Utilities in Indiana," designed as an initial consideration for public hearings on rulemaking. This discussion uses the Indiana draft rule only for illustrative purposes. The proposed rulemaking draft rule is no longer available on the Indiana IDEM website.

Specifically, the draft rule would limit owners or operators to an emission factor equal to or less than 0.6 pound of mercury per trillion BTU of heat input, or alternatively, an emissions rate with a 90 percent reduction in mercury emissions from the entry point of the control equipment, the same requirements as Connecticut's Public Act 03-72. However, Indiana requires applicable facilities to comply prior to July 1, 2008 instead of July 1, 2009. The chart shows Indiana would meet CAMR's allotment limitations in both 2010 and 2018.



MARYLAND

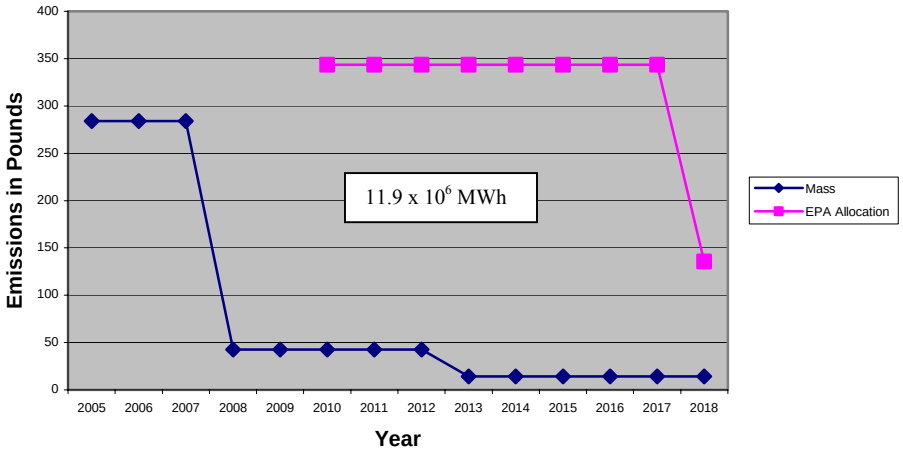
If enacted, Maryland State Senate Bill 744 will set new emission limits from coal-fired power plants for nitrogen oxide, sulfur dioxide, mercury, and carbon dioxide. The bill calls for mercury emissions to be reduced by 90 percent by January 1, 2011, from baseline emissions for seven specific "affected facilities." The bill additionally calls for mercury emissions at "other than affected facilities" to meet the same reduction requirement by January 1, 2015. Contrary to the Maryland chart's appearance as shown on the next page, the installation and operation of controls should commence during the five years preceding January 1, 2011, and thus are expected to reduce mercury emissions below the Maryland's CAMR mercury allotment for both 2010 and 2018.



MASSACHUSETTS

Massachusetts has completed final rule revisions to "The Massachusetts Emission Standards for Power Plants," 310 CMR 7.29. The first phase requires facilities to capture 85 percent of the mercury contained in coal-fired boiler flue gas or 0.0075 pounds of mercury per giga-watt-hour by January 1, 2008. On October 1, 2012, the second phase of the rule requires facilities to capture 95 percent of the mercury or maintain an emission factor of 0.0025 pounds of mercury per giga-watt-hour. These limitations place Massachusetts's expected mercury emissions far below CAMR Massachusetts's allotment.

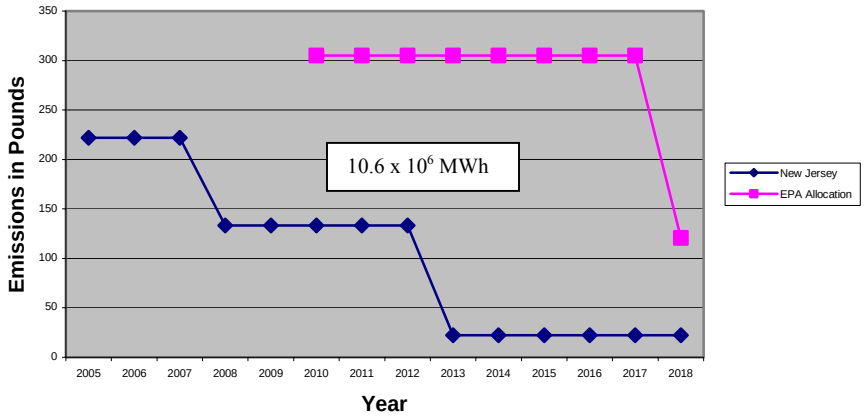
Massachusetts Mercury Control



NEW JERSEY

New Jersey Rule 7:27-27.7, Control and Prohibition of Mercury Emissions, requires that by December 15, 2007, the owner or operator of a coal-fired boiler of any size will not exceed 3.00 mg of mercury per megawatt hour or will maintain a control device efficiency of at least 90 percent. If approximately 50 percent of the total New Jersey's coal-fired megawatt capacity of a utility company meets the required standards by December 15, 2007, then the owner or operator may enter into an enforceable agreement with the Department to install and operate pollution control systems to meet the above standards by December 15, 2012 for the company's remaining coal-fired megawatt capacity. The New Jersey chart shows a worse case scenario of a 50 percent delay in mercury control until December 15, 2012. New Jersey is scheduled to reduce its mercury emissions to less than one-half of New Jersey's CAMR allotment for 2010 and by several times by 2018.

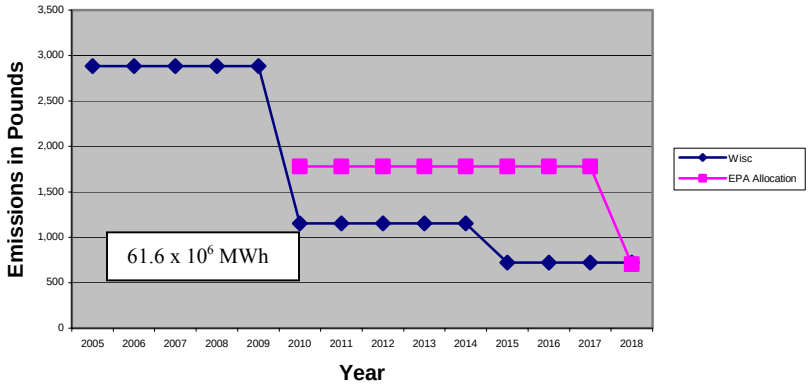
New Jersey Mercury Control



WISCONSIN

Wisconsin has issued Rule NR 446.06, Mercury Emission Limits For Major Utilities, which requires mercury control efficiencies of 60 percent by January 1, 2010, and further increase control efficiency to 75 percent no later than January 1, 2015 for stationary sources of 25 megawatts. The Wisconsin Chart depicts the stated 60 and 75 percent control efficiency rule requirements. However, NR 446.06(b)(6) requires the Department to promulgate a similar standard, including administrative requirements that are consistent with federal administrative requirements if an emission standard regulating mercury emissions from a major utility is promulgated under section 111 or 112 of the federal Clean Air Act. The CAMR is such an emission standard, so Wisconsin will adopt CAMR.

Wisconsin Mercury Control



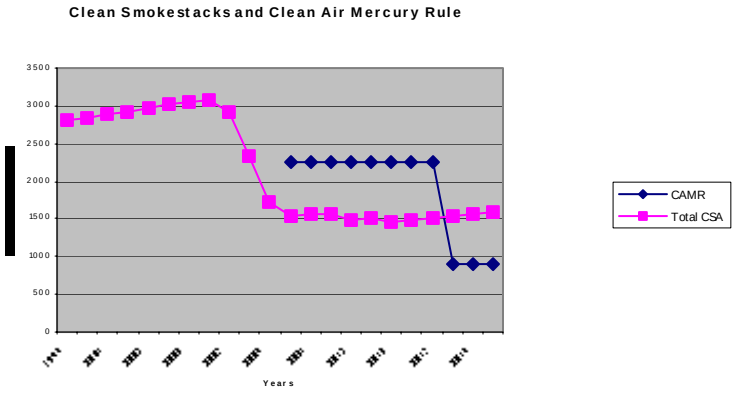
CHAPTER III MERCURY REDUCTION SCENARIOS

CO-BENEFITS OF NORTH CAROLINA'S CLEAN SMOKESTACKS ACT

The co-benefit of mercury removal from coal-fired utility boilers is dramatic in North Carolina due to stringent nitrogen oxides and sulfur dioxide limits created by the Clean Smokestacks Act (CSA) of 2002. Duke Power and Progress Energy are installing emission controls on their larger base-loaded utility boilers where the largest amounts of pollutants are generated.

Chart IV-1 graphically shows the estimated resultant co-benefits of mercury captured. Public record information was used to calculate uncontrolled mercury emissions based on the distribution of electrical demand and boiler capacities using information provided to EPA during their 1999 Electric Utility Steam Generating Unit Mercury Information Collection Request. EPA has assumed some new emission factors. These new emission factors account for all mercury capture, including the percentage currently being adsorbed on fly ash. Mercury emissions were calculated for each utility boiler from 1999 to 2020 using annual average electric sales growth estimates of 1.2 and 1.8 percent for Duke and Progress Energy respectively as reported in 2005 to the North Carolina Utility Commission. Calculated boiler mercury emissions are compared to the EPA's boiler mercury allotment to determine estimated annual mercury credit accumulations from 2010 to 2020.

Chart IV-1
Clean Smokestacks Act Mercury Co-benefits



Duke Power and Progress Energy may reduce mercury emissions early, generating mercury credits that may allow them to use the early reductions to meet the more stringent 2018 mercury allotments. According to The DAQ's independent calculations, Duke Power may create enough credits in the 2010 to 2017 period to satisfy their annual mercury cap for 13 years. Progress Energy similarly may create enough credits for three years. In other words, North Carolina will reduce mercury emissions faster than that required by the CAMR during the 2010 and 2017 period. The use of mercury credits may extend the time period before the State's 2018 mercury emission cap is physically reached. The use of mercury credits from 2018 and later will not

increase total mercury emissions over the years from 2010 to when all mercury credits are exhausted.

Conversely, circumstances and factual discovery may reduce the estimated emission credits. Time will provide answers to the following questions:

- Are the new emission factors “assumed” by EPA correct? Will full-scale emission control equipment over the long-term replicate short- term pilot scale emission control equipment capture efficiencies?

- Will mercury concentration in coal increase due to a shortage of central Appalachian coal?

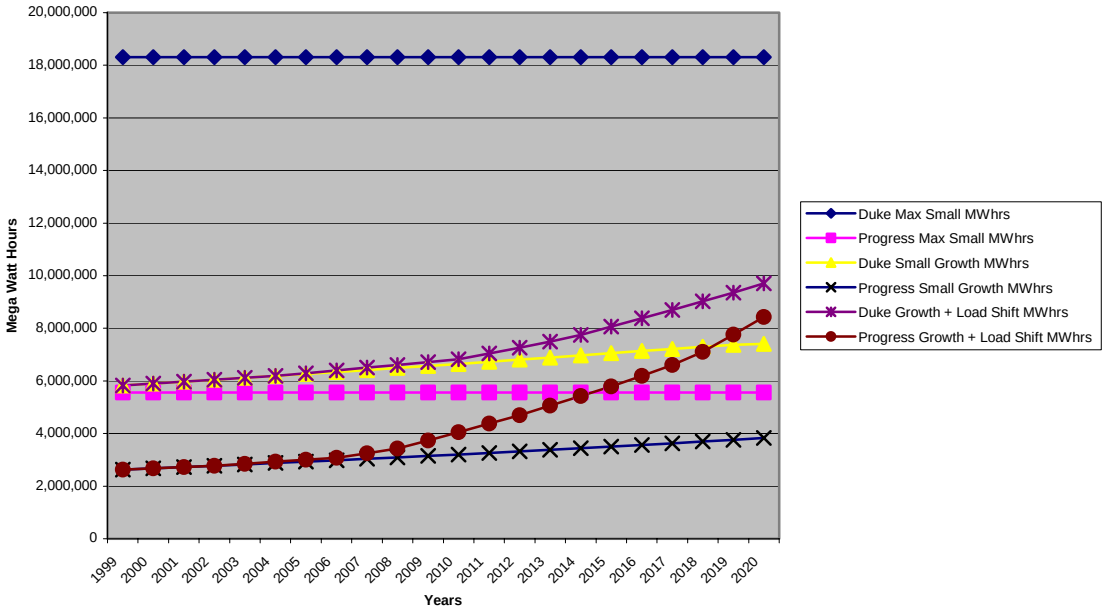
- Is capture efficiency linear to mercury concentration (percent captured remains constant) or does the capture efficiency increase as mercury concentrations increase from 0.08 parts per million to 0.10 part per million?

- Will unplanned maintenance (e.g., boiler tube failure) remove base-loaded electric generating units (nuclear or coal) from the electrical grid, thus, consuming mercury credits during the downtime period?

- Will any base-loaded boilers reach their full annual steam generating capacity? Will additional electric demand growth be shifted to boilers with low mercury emission control efficiency? Initial calculations of electrical demand are based on fuel burned reported in the 1999 Electric Utility Steam Generating Unit Mercury Information Collection and boiler design capacity. These calculation indicate that Duke Power's Belews Creek 1 (2010), Buck 8 (2019), Buck 9 (2016), Cliffside 5 (2019), Marshall 1 (2013), Marshall 2 (2004), Marshall 4 (2014) will reach their full annual steam generating capacity. Progress Energy will be limited similarly for Ashville 1 (2012), Ashville 2 (2002), Mayo 1 (2012), Mayo 2 (2018), Roxboro 1 (2008), Roxboro 2 (2008), Roxboro 3A and B (2006), Roxboro 4A and B (2017). The actual year when any particular boiler's full annual steam generating capacity is reached may be different as these dates are predicated on the reported 1999 steam load distribution. Many variables are included in load distribution determinations each year. This information indicates that some large base-loaded coal-fired boilers with high efficiency mercury emission controls will reach their steam generation design capacity, possibly requiring steam generating capacity to shift to smaller boiler units with low mercury control efficiency. Increased use of smaller boiler units due to electric demand growth may require additional mercury controls at the smaller units or the early consumption generated mercury credits.

Chart IV-2 shows how increasing electrical generating demands on Duke Power's and Progress Energy's smaller electrical generating units might appear. The chart shows their respective maximum generating capacity as straight lines. The affect of growth of electrical sales (Duke Power 1.2 percent, Progress Energy 1.8 percent) are the slightly curved lines, while the lines with the greatest slope reflect the combined generating steam-load shift plus increased electric sales. Progress Energy's combined curve passes through Progress Energy's maximum small generating capacity on or about 2013 without additional new coal-fired units. Duke Power has excess capacity, but the slope of the demand curve for their small units is increasing annually due to demand growth and shifting steam loads. This chart is not a prediction of load distribution for either company. This chart represents a small part of each company's electrical generating capacity and options. It is a single scenario out of many other possible scenarios.

Chart IV-2
Small Boiler Capacity and Demand



CHAPTER IV ESTIMATES OF COSTS AND BENEFITS

COST AND EMISSIONS IMPACTS ESTIMATES FOR ELECTRIC UTILITY STEAM-GENERATING UNITS[20]

Costs were estimated for controls to reduce mercury emissions from coal-fired units based on adaptations of methods given in the EPA Air Pollution Control Cost Manual1 (Manual). The Manual uses sizing information, equipment cost curves, and factors associated with specific controls to arrive at overall capital and annual costs. Four major elements are included in the costing: direct and indirect capital costs, and direct and indirect annual costs (including annualized costs for capital recovery).

Direct capital costs include purchased equipment (control device plus auxiliary equipment, instrumentation, sales tax, and freight) and installation (foundation and supports, handling and erection, electrical, piping, insulation, and painting). Site preparation and buildings are not usually required, but would be included with direct capital costs. Indirect capital costs include engineering, construction and field expense, contractor fees, start-up, performance test, and allowance for contingencies.

Direct annual costs are comprised of operating labor (operator and supervisor), operating materials, maintenance labor and materials, replacement parts, utilities (such as electricity or compressed air), and waste disposal. Indirect annual costs include overhead, administrative charges, property tax, insurance, and capital recovery (the annualized cost of money borrowed to purchase and install the control system).

The annualization of capital recovery is based on estimated equipment life and interest rate. For fabric filters and electrostatic precipitators equipment life is estimated at 20 years. For spray-dryer adsorbers life is estimated at 15 years. Interest rates are taken as 7 percent for all equipment.

Because the costing is for equipment to be installed at existing plants, extra costs are required to accommodate difficulties in working around equipment and structures already in place. These extra costs appear as a retrofit factor included in the total capital investment. Values for retrofit factors use here are 1.4 for baghouses and electrostatic precipitators, and 1.2 for spray-dryer adsorber units.

A major impact is the emission reduction attributed to installation of controls. These emission reductions and the costs with other impacts are given on a nationwide basis. The modeling used for estimation is based in part on the individual units, but the estimate for any single unit may not be accurate.

For example, if the unit is 500 MW, the equivalent capital cost to meet the emission limit would be as shown in the following equation:

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[20] *Methodology for Estimating Cost and Emissions Impact for Coal- and Oil-Fired Electric Utility Steam Generating Units National Emission Standards for Hazardous Air Pollutants*, Memorandum to Bill Maxwell, U.S. Environmental Protection Agency, OAQPS (C439-01) from Jeffrey Cole, RTI International, December 2003.

Capital cost = [8,847 x ln(500) +14,386] x 500 x 0.3 = $10.4 million (1999 dollars).

The term in brackets represents the equation derived for bituminous coals as used for a 500 MW unit. Because the equation is on a MW basis, it must be multiplied by the unit size of 500 MW. Unit incremental capital costs for the fabric filter equations range from about $55/kW to $85/kW in 1999 dollars. Four cases were analyzed for new units and retrofit units. Unit costs for these units ranged from $122/kW to $163/kW. Costs attributed are incremental, representing only costs added to a plant's existing costs for emission control. For example, costs of solid waste handling and disposal for an existing ESP would be increased by a relatively small amount for additional ash collected after upgrading, not by the entire amount of ash handled in the upgraded unit.

As with capital and annual costs, equations were developed from the costing spreadsheets to estimate impacts on a MW basis. For the 500 MW example, incremental electricity usage is found from the following equation:

Electricity = [-56.224 x ln(500) + 791.88] x 500 = 221,235 kWh/y.

MERCURY CONTROL COSTS ASSOCIATED WITH SORBENT INJECTION[21]

The cost of applying any technology is comprised of annualized capital costs, variable operating costs and fixed operating costs. The costs of a sorbent injection system are usually very small compared to other air pollution control equipment if addition of a fabric filter or other major particulate matter control device retrofit is not performed. Capital costs for sorbent injection systems may be in the range of about $5/KW, sometimes less. Being simple pieces of equipment, the fixed operating costs for these systems are also relatively low. So, the major costs associated with a sorbent injection system are the cost of the sorbent and the disposal of additional material.

Estimates are made using halogenated powdered activated carbon sorbent cost of $1.00 per pound and powdered activated carbon sorbent cost of $0.50 per pound; disposal is estimated at a cost of $25 per ton. Halogenated powdered activated carbon is estimated to provide up to about 90% removal at a cost of sorbent and disposal under 1 mill/kWhr (1 mill/kWhr = $0.001 per kilowatt hour). Costs for standard powdered activated carbon are estimated to be greater than those for halogenated powdered activated carbon due to the significantly higher injection rate that is necessary. At a capital recovery factor of 13.3 percent and a capacity factor of 80 percent, levelized capital charge is approximately 0.1 mills/kWhr, which is significantly less than the variable operating cost associated with sorbent injection and disposal. A potential cost that is not included here is the cost of fly ash disposal in the event that fly ash is currently being sold for beneficial reuse but must be disposed of if contaminated with carbon. Since most plants do not currently sell their fly ash, this is not an incremental cost for them. However, for the minority of plants that sell their fly ash, the incremental costs are estimated to be in the range of 0.38 to 1 mill/kWhr, depending upon heating value and ash content of the coal and the heat rate of the unit and assuming a differential between fly ash revenues and disposal cost of $30 per ton.

The cost advantage of halogenated powdered activated carbon over standard powdered activated carbon when injected upstream of a fabric filter is not expected to be as great as when injected

[21] *Control of Mercury Emissions from Coal Fired Electric Utility Boilers: An Update***,** Air Pollution Prevention and Control Division, National Risk Management Research Laboratory, Office of Research and Development, U.S. Environmental Protection Agency, Research Triangle Park, NC, February 18, 2005.

upstream of a cold-side electrostatic precipitator. Regardless of the sorbent, 90 percent removal appears to be possible at sorbent and disposal costs well below 0.50 mills/KWhr when this technology is available. For facilities that sell their fly ash for concrete, if the fly ash is rendered unmarketable, the differential cost to dispose of the fly ash is similar to that described above for a cold-side electrostatic precipitator.

Small North Carolina Coal-fired Boilers

Plant	Unit	Boiler Rating (MW)	CSA Emission Controls	Mercury Emission Factor
Duke Power				
Buck	5	40	Hot-side electrostatic precipitator	10%
Buck	6	40	Hot-side electrostatic precipitator	10%
Buck	7	40	Hot-side electrostatic precipitator	10%
Buck	8	125	Hot-side electrostatic precipitator	10%
Buck	9	125	Hot-side electrostatic precipitator	10%
Cliffside	1	40	Hot-side electrostatic precipitator	10%
Cliffside	2	40	Hot-side electrostatic precipitator	10%
Cliffside	3	65	Hot-side electrostatic precipitator	10%
Cliffside	4	65	Hot-side electrostatic precipitator	10%
Dan River	1	70	Hot-side electrostatic precipitator	10%
Dan River	2	70	Hot-side electrostatic precipitator	10%
Dan River	3	326	Cold-side electrostatic precipitator	36%
Riverbend	4	220	Hot-side electrostatic precipitator	10%
Riverbend	5	220	Hot-side electrostatic precipitator	10%
Riverbend	6	266	Hot-side electrostatic precipitator	10%
Riverbend	7	266	Hot-side electrostatic precipitator	10%
Progress Energy				
Lee	1	79	Cold-side electrostatic precipitator	36%
Lee	2	76	Hot-side electrostatic precipitator	10%
Lee	3	252	Cold-side electrostatic precipitator	36%
L V Sutton	1	97	Hot-side electrostatic precipitator	10%
L V Sutton	2	106	Hot-side electrostatic precipitator	10%
Weatherspoon	1	49	Cold-side electrostatic precipitator	36%
Weatherspoon	2	49	Cold-side electrostatic precipitator	36%
Weatherspoon	3	78	Cold-side electrostatic precipitator	36%

MERCURY REDUCTION BENEFITS (DIFFERING VIEWS)

The estimated value of mercury reduction benefits ranges across the dollar spectrum. All parties estimate the benefits according to their understanding of risk analysis and assumptions. Four differing views are presented.

A Harvard study concluded that mercury controls similar to those the EPA proposed could save nearly $5 billion a year through reduced neurological and cardiac harm. The EPA's National

Center for Environmental Economics said the Harvard study was submitted too late to be factored into the agency's calculations and added that crucial elements of the analysis were flawed.[22]

The EPA estimated that the technology-based option would cost power plants, that is, and therefore the users of electricity, $2 billion per year and provide $15 billion or more in annual benefits. The EPA estimated the cap-and-trade option would cost $3 billion to $5 billion annually and provide anywhere from $58 billion to $73 billion or more per year in benefits. The Government Accounting Office claimed that the agency distorted its cost-benefit analysis to make it appear that the cap-and-trade option was superior to the technology-based option preferred by environmental groups. The Government Accounting Office recommended that the EPA revise its analysis to include in the cost-benefit analysis the human health benefits of reductions in mercury emission from power plants or at least to provide qualitative information on how these benefits are likely to compare under the technology-based and cap-and-trade options. None of the benefits estimated by the EPA for either option are tied to human health improvements resulting from lower mercury emissions, according to the Government Accounting Office. Although mercury emissions from power plants have never been regulated before, no scientific study documents a single adverse health effect attributable to mercury from power plants.[23]

Economic Valuation of Human Health Benefits of Controlling Mercury Emissions from U.S. Coal-Fired Power Plants, describes the results of a comprehensive study to estimate the health benefits of reducing mercury emissions from coal-fired power plants in the United States. Babies are sensitive to the neurotoxic effects of methylmercury. Some babies in the United States are currently exposed to intrauterine methylmercury concentrations above the EPA's reference dose. (The reference dose is considered by some to be an acceptable level of exposure.) Changes in the quantity of mercury deposited are assumed to lead to linear and proportional changes in fish methylmercury concentrations, assuming no other factors change. The model accounts for human exposure through commercially and non-commercially harvested fish. The model also accounts for potential changes in two health effects: cognitive abilities and cardiovascular events. The report assumes that increases in a child's intelligence quotient (IQ) that result from decreases in intrauterine methylmercury exposures captures some of the neurodevelopmental delays reported in epidemiologic studies. Using a cost-of-illness approach, the report equates the value of a lost IQ point to be approximately $16,500. Additionally, credible epidemiological studies have reported an association between methylmercury exposures in males and increased risks of myocardial infarction and premature mortality. The exposed population in a group of these epidemiological studies consumed non-fatty freshwater fish. The study used regression coefficients reported in these studies to estimate dose-response relationships for premature mortality and nonfatal myocardial infarction. These dose-response estimates alternatively apply to males who eat non-fatty freshwater fish and to all fish consumers. Using a cost-of illness approach, estimated value of a myocardial infarction is approximately $50,000. The report estimates the value of a premature fatality to be approximately $6,000,000. Whether there is an increased cardiovascular risk associated with methylmercury exposures is not clear at this time. Thus, it is recommend that the predicted benefits associated with premature mortality and non-fatal myocardial infarction be viewed with caution. A range of possible benefits of U.S. power plant mercury emissions controls are associated with Scenarios 1 and 2 (when power plants face annual mercury emissions caps of 26 tons and 15 tons). As the benefits estimates increase, our confidence that the U.S. population experiences these effects decreases. For Scenario 1, the predicted annual benefit associated with IQ increases in the annual birth group ranges from $75 million to $194 million. The corresponding annual benefit predictions for Scenario 2 are $119

[22] http://www.washingtonpost.com/wp-dyn/articles/A55268-2005Mar21_2.html
[23] http://www.foxnews.com/story/0,2933,150086,00.html

million to $288 million. The monetized benefits associated with avoided cardiovascular events and premature mortality are predicted to be much larger than the neurotoxicity benefits; however, there are additional uncertainties in the external generalization of the results of the epidemiologic studies upon which these estimates are based to the U.S. population. If these cardiovascular effects are only experienced by male populations that consume non-fatty freshwater fish, then the monetized annual benefits are $48 million and $86 million in Scenarios 1 and 2, respectively. If these cardiovascular effects are experienced by the whole U.S. population, then the monetized annual benefits are predicted to be $3.3 billion and $4.9 billion in Scenario 1 and Scenario 2, respectively.[24]

In a report titled "A Regulatory Analysis of EPA's Proposed Rule to Reduce Mercury Emissions from Utility Boilers," the author states that the CAMR is unlikely to provide significant health benefits because mercury exposure at current levels is unlikely to be causing harm, and because even in a best-case scenario the mercury rule could reduce mercury in fish by no more than a few percent. A complete elimination of U.S. utility mercury emissions could move children who are at the 10^{th} percentile on neurological and cognitive test scores to between 10.3 and 10.6 percentile. Further, a similar study of children in the Seychelles reported no harm from mercury exposures several times higher than even relatively highly exposed Americans.[25]

[24] http://bronze.nescaum.org/airtopics/mercury/rpt050315mercuryhealth-execsumm.pdf, February 2005

[25] Joint Center AEI-Brookings Joint Center For Regulatory Studies, Joel Schwartz, Regulatory Analysis 04-07, September 2004. http://www.aei-brookings.org/admin/authorpdfs/page.php?id=1044

CHAPTER V DIVISION OF AIR QUALITY'S RECOMMENDATIONS

DIVISION OF AIR QUALITY'S FINAL RECOMMENDATION

The DAQ recommends that North Carolina adopt a mercury rule for coal-fired utility boilers that is at least as stringent as the CAMR and that also meets any additional requirements that the Environmental Management Commission deems appropriate for North Carolina.

INTRODUCTION

Three potential options were discussed in the interim 2004 Mercury Report. One of the three options was to be chosen that would lead to final 2005 mercury recommendations. The finalized Federal Clean Air Interstate Rule (CAIR) and the Federal Clean Air Mercury Rule (CAMR) overshadowed these options.

The DAQ expects that the North Carolina Clean Smokestacks Act (CSA), CAIR, and CAMR should lessen public health concerns, reduce environmental damage by reducing fish tissue methylmercury contamination, and reduce mercury emissions from sources within and outside the State.

NORTH CAROLINA CITIZEN'S HEALTH

The potential for exposure to elevated levels of methylmercury exists for individuals living in North Carolina. Elevated levels of methylmercury in human hair and blood have been identified among residents living in Columbus and Brunswick Counties in North Carolina.

There are health risks to fetuses and young children exposed to low levels of methylmercury. Researchers have found significant adverse associations between prenatal mercury exposure and children's performance on a wide range of memory, attention, language, and visual-spatial perception tests.

The North Carolina Department of Health and Human Services (DHHS) has had to issue fish consumption guidance in response to existing high levels of methylmercury in fish tissue caught in North Carolina. Even though there are posted advisories, the people may not be aware of the advisories or may choose to ignore them. DHHS recommends fish consumption within their guidelines because of health benefits realized. Maternal consumption of fish during pregnancy may benefit the unborn child's retina and nervous system development. Additionally, fish consumption has been associated with a decreased risk of heart attack and coronary artery disease in adults.

The EPA has found that total mercury in drinking water is a potential cause of kidney damage when people are exposed to it at levels above two parts per billion for relatively short periods of time. EPA has set a maximum contaminant level for total mercury in drinking water at two parts per billion because this is the lowest level to which water treatment systems can remove this contaminant.

The DAQ anticipates a reduction of methylmercury in fish tissue samples but is unable to quantify the percentage or number of years it will take before North Carolina fish consumption is unrestricted.

HOT SPOTS

The knowledge that North Carolina has found elevated levels of methylmercury in human hair and blood samples is cause to redouble investigative efforts to define potential mercury hot spots and identify sources contributing mercury into those areas. However, uncertainties in our knowledge of mercury can make it difficult to identify, assess, and address mercury hot spots. However, the State has authority to require sources identified as causing or contributing to a mercury hot spot to control or further control mercury emissions.

The CSA, the CAIR, and the CAMR should greatly reduce mercury deposition from North Carolina's coal-fired utility boilers on the State's surface waters and contribute to the reduction of methylmercury contamination of North Carolina's fish. The CAIR and the CAMR should also reduce oxidized mercury entering North Carolina from nearby states.

The DAQ will continue to work on methods to identify mercury hot spots and mercury sources that may be contributing to them.

CURRENT REGULATORY REQUIREMENTS

Unlike at the time the CSA was enacted, North Carolina must now determine how it will best meet its obligations under the Federal CAMR and assure appropriate public health protection for it citizens. The state and EMC are presently in the process of this task. Additionally there are significant mercury reductions expected as a result of the CSA. As of the date of this report, there is not yet a draft rule; however, the following will be considered by the state and the EMC.

CO-BENEFITS OF THE CLEAN SMOKESTACKS ACT

Significant mercury emission reductions are expected in North Carolina as a direct consequence of the controls being installed to meet the caps in CSA. It is estimated that 60 percent or more reduction in total mercury emissions from sources subject to the CSA will be achieved. More importantly, oxidized mercury represents a majority of total mercury emissions from coal-fired boilers in North Carolina and an expected 80 percent reduction or more of oxidized mercury (from 1810 to 380 pounds per year or better) from these utility boilers will significantly reduce mercury deposition in North Carolina. Based on current estimates of mercury removal, North Carolina utilities may achieve the 2010 mercury cap in CAMR through the implementation of the CSA.

The DAQ believes the CSA has given North Carolina a leadership position in the reduction of mercury deposition and we should work to continue that leadership.

CAP AND TRADE

The cap and trade approach is employed in the CSA for the control of SO2 and NOx and is expected to result in very significant reductions of these pollutants at all of the larger electrical generating units and some reduction at many of the remaining units because the caps for the two systems is sufficiently stringent. Consequently there will be significant mercury reduction across North Carolina even though it is derived through a cap and trade approach. The two utility companies have been able to optimize the economics in their control strategies while complying with the CSA. This optimization will not preclude them from meeting the emissions reduction objective; but, it allows the objective to be reached in the least costly manner. The DAQ recommends the cap and trade aspect of the CAMR be considered for the North Carolina mercury rules at least in a first phase as the CSA is expected to more than meet the first phase of the

CAMR through 2013. The North Carolina Environmental Management Commission (EMC) is currently considering what requirements beyond CSA may be appropriate.

UNKNOWNS AND RULEMAKING

Both the CAIR and the CAMR are final federal rules. North Carolina is obligated to adapt these rules or rules at least as stringent as these rules. Technological progress is assumed by rule pressure to drive science and technology toward solutions to unanswered questions. However, unsolved questions remain such as the design of certifiable continuous mercury monitors, the determination of mercury control equipment efficiencies under changing operating loads and conditions, and process development to improve capture efficiency of mercury in scrubbers and of treated activated carbon. Modeling science needs to become a better predictive tool by augmenting modeling improvements with additional field research, data gathering, and a better understanding of atmospheric mercury speciation conversion.

The science and practical knowledge base will improve as mercury capture operating experience and certified data collection bring about an improved understanding of mercury emissions and control. Updated information should be considered in future assessments of mercury control technology which may result in revised regulatory requirements.

DAQ recommends flexibility in mercury rulemaking to allow for adaptive management by the EMC, as the unknowns are resolved.

DIVISION OF AIR QUALITY'S FINAL RECOMMENDATION

The DAQ recommends that North Carolina adopt a mercury rule for coal-fired utility boilers that is at least as stringent as the CAMR and that also meets any additional requirements that the Environmental Management Commission deems appropriate for North Carolina.