

Testimony of David C. Schanbacher, P.E. to the Subcommittee on Clean Air
and Nuclear Safety of the Senate Committee on Environment and Public Works
May 16, 2007

Mercury is toxic to the nervous system and potentially associated with cardiovascular disease; however, blood mercury levels in the United States are below levels shown to cause adverse health effects. The U.S. EPA has developed a Reference Dose based on subtle neurological effects seen in children whose mothers consume higher than average amounts of fish. This level of 0.3 mg methylmercury/kg whole fish is 10 times lower than the levels at which effects were actually seen. The Reference Dose is set to protect against adverse effects from daily exposure in sensitive groups. Our review of the 2000-2001 National Health and Nutrition Examination Survey indicates that only 2.5 percent of women of child-bearing age had blood mercury levels greater than the Reference Dose. None of these women had blood mercury levels above doses where adverse effects were seen. Although these values are conservative and health effects are not expected to occur, we would like to maintain conservative levels of mercury in the blood of our citizens. As such, we advise people to limit their consumption of fish that exceed conservative screening values. The Texas Department of State Health Services looked specifically at a group of people who live near and consume fish from Caddo Lake, which has a fish-consumption advisory for mercury. They found that blood mercury levels did increase with increasing fish consumption, but these levels were all well below levels expected to cause adverse effects. All women of child-bearing age in this study had blood mercury levels below the EPA Reference Dose.

A recent study in Texas raised concerns about the association of mercury and autism. This study reported an association between mercury emissions and special education rates; however, it cannot establish that mercury causes autism. In fact, two recent case-control studies indicate no causal relationship between mercury and autism.

Fish consumption is the primary source of methylmercury exposure for humans; however, the amount of mercury in fish is determined by many different factors and varies regionally. These factors include the pH, dissolved organic carbon, sulfate, and oxygen content of the water body where divalent mercury is deposited. These factors influence the rate at which bacteria convert divalent mercury into methylmercury, which is the form that accumulates in fish.

Regional differences also exist in the types of coal used to fuel power plants in the United States. The type of coal burned also affects the amount and form of mercury released. The form of mercury released is very important in determining deposition rates and subsequent bioaccumulation of methylmercury in fish. Bituminous coal is primarily used in the eastern United States, while western states rely more on sub-bituminous coal and lignite, especially in Texas. Bituminous coal, when burned, emits primarily divalent, or reactive, mercury. Sub-bituminous coal and lignite, on the other hand, emit primarily elemental mercury.

Divalent mercury settles out readily from the atmosphere through wet and dry deposition and as such, is subject to local deposition. Elemental mercury, the primary form of mercury emitted from sub-bituminous coal and lignite, is not deposited locally, but rather enters the global pool of mercury, where it is stable and can remain in the atmosphere between six months and two years.

The United States Environmental Protection Agency Clean Air Mercury Rule (CAMR) appropriately regulates mercury emissions from power plants based on the type of coal burned and as such, the form of mercury emitted. The Phase I CAMR rule relies on co-benefits of the Clean Air Interstate Rule or CAIR. CAIR controls to reduce nitrogen oxide (NO_x) and sulfur dioxide (SO₂), such as scrubbers, are also very effective in controlling divalent mercury, the form of mercury primarily emitted from bituminous coal and subject to local deposition. Texas electric generating units are subject to some of the most stringent requirements in the nation for NO_x and SO₂.

EPA's Phase II CAMR controls will rely on mercury-specific control technologies that address control of elemental mercury. Mercury-specific technologies are in various stages of development. Additional testing is required to determine long-term reductions, potential effects on unit performance, and fly ash contamination for the types of coal burned in Texas. Current research has shown that abatement devices do not work equally as well for all boilers. Elemental mercury, specifically from lignite and sub-bituminous coal, can be especially difficult to control, because elemental mercury is not very water-soluble and passes through most abatement devices. Mercury efficiency removal rates for lignite have been recorded anywhere from 0 to 75% depending on the control technology. Lack of full-scale and long-term testing data for all mercury-specific control devices, particularly for lignite-fired boilers, is an important concern for Texas. For example, substantial data for activated carbon in municipal solid waste combustors exists, but these systems, with typically lower flue gas temperatures, are not as complex as utility boilers. Results from activated carbon injection from utility boilers vary, even on systems with similar design. With regard to fly ash contamination, standard sorbents may change the properties of the fly ash and may render it unusable in concrete, potentially resulting in large volumes of ash to be landfilled rather than put into beneficial reuse. Although mercury controls will be available for use on some scale prior to 2018, EPA and Texas do not believe they can be installed and operated on a national scale prior to that date. The potential availability and reliability of these controls provides justification for CAMR Phase II to begin in 2018 and Texas agrees. It is somewhat ironic that most of the mercury-specific controls are designed to convert elemental mercury, which is not subject to local deposition, into divalent mercury, which is. Lastly, EPA modeling of mercury fish tissue concentrations as a result of both CAIR and CAMR controls shows very little, if any, impact of CAMR Phase II over the CAIR controls. This result is expected since CAMR Phase II addresses elemental mercury which is not subject to local deposition.

There are three main interconnected networks or power grids that comprise the electric power system in the continental United States: the Eastern Interconnect, the Western Interconnect, and the Texas Interconnect. The Texas Interconnect is not connected with

the other networks, except through certain direct current interconnection facilities. Limited portions of Texas do fall into the other two interconnects, however the Electric Reliability Council of Texas (ERCOT) manages the flow of electric power in the Texas Interconnect to approximately 20 million Texas customers – representing 85 percent of the state’s electric load and 75 percent of the Texas land area. As the independent system operator for the region, ERCOT schedules power on an electric grid that connects 38,000 miles of transmission lines and more than 500 generation units. In August 2005, ERCOT recorded a new system peak demand of 60,274 megawatts (MW) surpassing the previous record of 60,095 MW set in 2003. With Texas’ continued growth, reliable power is essential.

Texas currently has 17 coal-fired electric generating utilities (EGUs) that have 36 boilers that are covered by the Clean Air Mercury Rule (CAMR). Of the 36 boilers, 15 are lignite (8200 megawatt electrical (MWe)); 20 are subbituminous (8102 MWe); and one uses bituminous coal (600 MWe). In 2003, 39% of the power in Texas was generated by coal (49% natural gas, 9% nuclear and 1.2% renewable). Texas committed to participating in the CAMR cap-and-trade program by adopting the federal rule by reference in July 2006. For CAMR Phase I beginning in 2010 through 2017, the EPA is relying on reductions as a “co-benefit” of NO_x and SO₂ controls from the Clean Air Interstate Rule (CAIR) to assist EGUs in meeting the Phase I requirements of CAMR budgets. CAMR Phase II begins in 2018 and additional controls may be necessary for EGUs to meet their mercury allowance caps.



SFR-085
September 2006

Mercury in Texas: Background, Federal Rules, Control Technologies, and Fiscal Implications

Implementation of Section 2, HB 2481 (79th
Legislature)—A Report to the Texas Legislature

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Prepared by
the Chief Engineer's Office

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List of Acronyms and Abbreviations

ACI	Activated Carbon Injection
BMDL	Benchmark Dose Lower Confidence Limit
BTU	British Thermal Unit
CAIR	Clean Air Interstate Rule
CAMR	Clean Air Mercury Rule
CEMS	Continuous Emissions Monitoring System
CFR	Code of Federal Regulations
CMAQ	Community Multi-Scale Air Quality modeling system
DOC	Dissolved Organic Carbon
DOE	United States Department of Energy
DSHS	Texas Department of State Health Services
EERC	Energy and Environmental Research Center
EGU	Electric Generating Unit
EIA	United States Energy Information Administration
EPRI	Electric Power Research Institute
EPA	United States Environmental Protection Agency
ESP	Electrostatic Precipitator
GWh	Gigawatt Hour
Hg	Mercury
Hg ²⁺ or Hg ^{II}	Oxidized Mercury
Hg ⁰	Elemental Mercury
Hg _p	Particulate Mercury
HUC	Hydrologic Unit Code
ICR	Information Collection Request
IPM	Integrated Planning Model
IQ	Intelligence Quotient
kWhr	KiloWatt-Hour
lb	Pound
MerCAP	Mercury Capture by Adsorption Process
µg	Microgram
µg/m ²	Micrograms per Square Meter
mg/kg	Milligrams per Kilogram
µM	Micro-Molar
MMacf	Million Actual Cubic Feet
MW	Megawatt
MWe	Megawatt Electrical
MWh	Megawatt Hour
NHANES	National Health and Nutrition Examination Survey
NRC	National Research Council
NO _x	Nitrogen Oxides
NETL	National Energy Technology Lab

NSPS	New Source Performance Standards
OIG	EPA's Office of Inspector General
PCB	Polychlorinated Biphenyls
PEESP	Plasma Enhanced ESP
PRB	Powder River Basin, a subbituminous coal
RfD	Reference Dose
RIA	Regulatory Impact Analysis
SCDS	Seychelles Child Development Study
SCR	Selective Catalytic Reduction
SO ₂	Sulfur Dioxide
TAC	Texas Administrative Code
TCEQ	Texas Commission on Environmental Quality
TPY	Tons Per Year
TRI	Toxic Release Inventory
U.S.	United States of America
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey

Executive Summary

House Bill 2481, adopted by the Texas Legislature in 2005 (79th Legislative Session), instructs the TCEQ to:

- study the availability of mercury control technology;
- examine the timeline for implementing the reductions required under the federal Clean Air Mercury Rule (CAMR);
- examine the cost of additional controls both to the plant owners and consumers;
- examine the fiscal impact on the state of higher levels of mercury emissions between 2005 and 2018; and
- consider the impact of trading on local communities.

To address these directives, TCEQ staff reviewed the current scientific and technical literature and developed the detailed responses contained in this report. For this study, the agency used existing resources since no additional funds were appropriated.

Mercury emissions, deposition, exposure, and toxicity are complex issues. Much research has been conducted and more is being carried out. These issues remain controversial. No absolute consistency exists between studies. This report attempts to integrate the most pertinent scientific results for Texas.

Mercury Overview

Mercury is an element emitted globally from both natural and man-made sources. As an element, mercury cannot be created or destroyed. There are three primary forms of mercury found in the environment: (1) elemental (quicksilver); (2) divalent (oxidized or “reactive” mercury); and (3) organic (methylmercury). Elemental mercury is stable and can remain in the atmosphere between six months and two years, during which time it can be globally distributed. In the atmosphere, elemental mercury can be converted to the divalent form that can attach to solid particles (“particle-bound” mercury, subject to dry and wet deposition) or aqueous droplets (subject to wet deposition) and can be deposited on the ground and the surface of water bodies. Once divalent mercury enters a water body, it can undergo chemical conversion to methylmercury, which is retained in fish tissue and is the only form of mercury that accumulates in aquatic food webs. Fish consumption is the primary source of methylmercury exposure in humans.

Human activity since the Industrial Revolution has increased the amount of mercury present globally in the atmosphere. About half of global mercury emissions are natural—from oceans, erosion, vegetation, vegetation burning, and volcanoes—while slightly less than half of mercury emissions are the result of man-made sources. About three percent of total global mercury

emissions originate from man-made sources in the U.S., with approximately one percent of the global total from U.S. power plants. Asia contributes about half of the global emissions of mercury from man-made sources, while the U.S. contributes about six percent of emissions from man-made sources.

Availability of Controls

Texas electric generating units (EGUs) are currently regulated for nitrogen oxides (NO_x) and sulfur dioxide (SO₂) under state and federal regulations and will be further regulated under the Clean Air Interstate Rule (CAIR). CAIR controls, such as scrubbers, have the additional benefit of reducing divalent mercury. While CAIR is expected to provide sufficient mercury control to meet CAMR Phase I limits, additional mercury-specific technologies will be needed to attain CAMR Phase II limits. The choice of mercury-specific controls will vary for each boiler and is dependent upon fuel type, furnace type, and existing controls. Mercury-specific control technologies are in various stages of development, with injection of activated carbon as a mercury sorbent having been most extensively tested with the most extensive data to date. Although testing for EGUs has been short-term and limited, data show 30 to 60 percent reductions for Gulf Coast lignite. Test results for Powder River Basin coal in Texas have not been announced; however, studies in other states have indicated reductions up to 80 percent with brominated carbon additives. Additional testing is required to determine long-term reductions, potential effects on unit performance, and fly-ash contamination for all types of coal burned in Texas. Standard sorbents change the properties of fly ash and may render it unusable in concrete. Processes such as Toxecon, which separate the bulk of the fly ash from the sorbent, or halogenated sorbents, which are injected at lower amounts, are being developed to address this issue.

Implementation Timeline

On March 15, 2005, the United States Environmental Protection Agency (EPA) finalized the CAMR to permanently cap and reduce mercury emissions from new and existing coal-fired EGUs nationwide in two phases. Texas has been given an annual mercury budget of 4.656 tons for Phase I (2010–17) and 1.838 tons for Phase II (2018 and thereafter).

The EPA provided states with two compliance options: (1) meet the state's emission budget by requiring new and existing coal-fired EGUs to participate in an EPA-administered cap-and-trade system that caps emissions in two stages; or (2) meet an individual state emissions budget through measures of the state's choosing. In 2005, the 79th Texas Legislature passed House Bill 2481 in its regular session, which requires Texas to adopt the CAMR by reference and participate in the cap-and-trade program. CAMR requires Texas to prepare and submit a state plan pursuant to Federal Clean Air Act section 111(d) by no later than November 17, 2006.

Cost of Controls

Costs of complying with the CAMR in Texas include costs of installing mercury monitors; costs of complying with Phase I, which EPA has asserted are negligible due to "co-benefits" of the

CAIR; and costs of complying with Phase II using mercury-specific controls or purchasing allowances.

For a coal-fired unit to install a mercury continuous emissions monitoring system (CEMS), the EPA estimates capital costs to range from \$95,000 to \$135,000 per EGU, with annual operating and maintenance costs of \$45,000 to \$65,000. For sorbent trap monitors, another monitoring option, the EPA estimates the capital cost to be \$18,000 per EGU, with annual operating, maintenance, and laboratory costs of \$65,000 to \$125,000. Based on these estimates, total monitoring costs in Texas could range from about \$650,000 to \$4.9 million for installation, depending on the type of monitor selected, with corresponding annual operation and maintenance costs of \$1.6 to \$4.5 million.

Under the cap-and-trade program, sources have the choice of controlling emissions or purchasing additional allowances to meet their obligations. Costs may vary substantially depending on whether a source chooses to control emissions or to purchase allowances for compliance. Under the CAMR, EPA is relying on mercury “co-benefit” reductions from CAIR to assist sources in meeting the CAMR Phase I budgets. Based on fiscal information provided by the EPA for the CAIR, EPA estimates that only three additional scrubbers will be installed in Texas to control SO₂ emissions during CAIR Phase II. EPA estimates SO₂ control costs to range from \$400 to \$800 per ton to achieve 30 to 40 percent mercury removal efficiency in subbituminous coal-fired units. No corresponding estimate for lignite-fired units is available.

The EPA performed extensive computer modeling using the Integrated Planning Model (IPM) to forecast outcomes of mercury control and trading. The IPM predicts that with currently available controls and no improvements made over time in performance, a pound of mercury allowances would cost roughly \$23,200 (\$1,500 per ounce) in 2010 (expressed in 1999 dollars), \$30,100 per pound (\$1,900 per ounce) in 2015, and \$39,000 per pound (\$2,400 per ounce) in 2020. With the assumption that efficiencies in capturing mercury improve over time, the cost estimates dropped considerably: \$11,800 per pound (\$700 per ounce) in 2010, \$15,300 per pound (\$1,000 per ounce) in 2015, and \$19,900 per pound (\$1,200 ounce) in 2020. Based on EPA estimates of mercury-control costs in 2020, Texas sources could face costs ranging from \$112 million to \$220 million, using either control technologies or allowance purchases, to move from compliance with the CAMR Phase I cap (4.656 tons) to compliance with the CAMR Phase II cap (1.838 tons).

The EPA forecasts that retail electricity prices are likely to fall from 2000 to 2020, whether or not the CAMR is implemented, due to projected decreases in energy prices, fuel switching, and other responses. Whether or not these predictions hold true, the model predicts prices will drop less under the CAMR than in its absence. A typical household using 1,000 kilowatt hours (kWh) of electricity per month would see an overall decrease of \$1.70 in its monthly electric bill with the CAMR, as opposed to an overall decrease of \$2.50 without CAMR. Therefore, the net increase in electricity costs due to CAMR is forecast to be about 80¢ per month for the typical household in Texas. For comparison, a preliminary Department of Energy report estimated

increases in electricity costs of 86¢ to \$2.37 per month for electricity generated with subbituminous coal, and \$2.57 to \$3.92 per month for electricity generated with lignite coal.

Fiscal Impacts

Fiscal concerns regarding potential increased mercury emissions include health impacts on children, and impacts on the recreational and economic value of fishing. Fuel-switching to limit mercury emissions could impact the coal mining industry in Texas.

As discussed previously, divalent mercury is the primary form associated with deposition and bioaccumulation. While the CAMR will reduce overall mercury emissions, it primarily targets removal of elemental mercury. As a result, early introduction of the CAMR would have only negligible effects on deposition and bioaccumulation that are linked to health and recreation.

The EPA acknowledges, “There is limited evidence linking IQ and methylmercury exposure.” Nonetheless, using IQ as a surrogate for neurobehavioral performance, the EPA estimated an average loss of 0.052 to 0.063 IQ points in children in Texas exposed prenatally to mercury from all sources in 2001. Average IQ is 100 points, and the CAMR is estimated in 2020 to reduce IQ loss by 0.0003 to 0.0004 points on average for prenatally exposed children in Texas, above estimated reductions in IQ losses achieved by CAIR alone of 0.0045 to 0.0067 point. The resulting total lost wages per child are estimated to range from \$454 to \$557. In Texas, EPA estimates that implementation of the CAIR alone will increase income by no more than \$35 to \$54 per child, relative to the 2001 base-case estimate. The CAMR is projected to contribute further, but only marginally: by no more than \$3 per child. If complete elimination of utility-attributable mercury emissions were required, net earnings losses would not fall to zero, but would still range from roughly \$427 to \$514 due to other sources of mercury.

Impact of Trading on Local Communities

To assess the potential effects of the CAMR, including its trading provisions, the EPA modeled utility-attributable mercury deposition and fish-tissue methylmercury concentrations for a 2001 base year prior to CAMR-related emission reductions, and for a 2020 future year approximately corresponding to the implementation of CAMR Phase II. Because of additional benefits from reduced mercury emissions from the CAIR, the EPA addressed the effects of CAIR as well as the CAMR in the analysis. The EPA’s analysis predicts that after implementation of the cap-and-trade programs of the CAIR and the CAMR, neither utility-attributable mercury deposition nor utility-attributable methylmercury concentrations in fish tissue will increase relative to the base-case levels, either nationally or in Texas. The modeling also showed no utility-attributable mercury “hot spots” from the implementation of the CAMR, where a mercury hot spot is a body of water having utility-attributable mercury concentrations in fish tissue at or above the federal fish tissue criterion of 0.3 mg/kg.

The modeling results show relatively large decreases in utility-attributable mercury deposition between the 2001 base case and the 2020 CAIR case, yet the differences between deposition for the 2020 CAIR and the 2020 CAIR plus CAMR cases are much smaller. This outcome is

attributable to the type of controls implemented in response to CAIR and CAMR. CAIR controls will be highly effective in reducing emissions of divalent mercury, which settles readily through wet and dry deposition. CAMR controls will primarily reduce elemental mercury, which is not readily deposited and enters the global pool of mercury. Because Texas EGUs primarily emit elemental mercury, CAMR controls will not appreciably reduce deposition in the state. Even removing all mercury emissions from power plants in the state would reduce mercury deposition very little compared to CAMR controls.

Chapter 1

Mercury Background

Introduction

Mercury is an element emitted globally from both natural and man-made sources, circulated and deposited by various processes at widely varying rates, and subject to complex chemical transformations. As an element, mercury cannot be created or destroyed. However, human activity since the Industrial Revolution has increased the amount of mercury present globally in the environment.

Forms of Mercury

Three primary forms of mercury are found in the environment: (1) elemental (quicksilver); (2) divalent (oxidized or “reactive” mercury); and (3) organic (methylmercury) (Tchounwou 2003). Mercury continually cycles among these three forms in the environment. Although the detailed processes of this complex cycle remain largely unknown, mercury cycling begins with the release of elemental mercury vapor into the atmosphere from natural sources, such as erosion and volcanic eruptions, and with the release of various forms of mercury from human activities, such as gold mining and burning of fossil fuels.

Elemental mercury is stable and can remain in the atmosphere between six months and two years, during which time it can be globally distributed (Clarkson 2002, Watras 1994). In the atmosphere, elemental mercury can be converted to the divalent form that can attach to solid particles (“particle-bound” mercury, subject to dry and wet deposition) or aqueous droplets (subject to wet deposition) and can be deposited on the ground and surface of water bodies. Once divalent mercury enters a water body, it can undergo chemical conversion to methylmercury. Both divalent and methylmercury can exist in the water column or in the sediment due to particle settling (Watras 1994). However, methylmercury is retained in fish tissue and is the only form of mercury that accumulates in aquatic food webs (Kidd 1995). Fish consumption is the primary source of methylmercury exposure in humans.

Methylation of mercury appears to be dependent upon several factors, including pH, dissolved organic carbon (DOC), sulfate, and oxygen. In freshwater lakes, one of the primary factors affecting fish methylmercury levels is pH. Lakes with lower pH, or more acidic water, contain fish with higher methylmercury content. One possible explanation of this phenomenon is enhanced uptake of divalent mercury by methylating bacteria at lower pH (Kelly 2003). Water column acidity may also remove DOC, which normally inhibits methylation rates. It is possible that divalent mercury may form complexes with the organic carbon, making it unavailable for methylation by bacteria (Barkay 1997). Conversely, a recent study indicates that the organic content of sediment is directly correlated with methylation rates in estuarine sediments. Importantly, this study found that estuarine environments with no direct mercury sources had sediment methylmercury concentrations equivalent to those of polluted marine environments (Lambertsson 2006). However, other differences may exist between freshwater and marine environments. In addition to pH, the sulfate concentration in the water body can influence the

methylation rate of mercury in sediment. Increased sulfate has been found to enhance methylation of mercury in sediment, porewater, and wetland experiments (Jeremiason 2006). Finally, oxygen plays an important role in mercury methylation. Because sulfate-reducing bacteria are anaerobic, increased oxygen inhibits their ability to methylate mercury (DeLaune 2004). Therefore, poor oxygen conditions, which can exist when algae or other organisms thrive on the surface of a water body, actually support mercury methylation. The applicability of these biogeochemical properties in East Texas water bodies is discussed by Twidwell (2000).

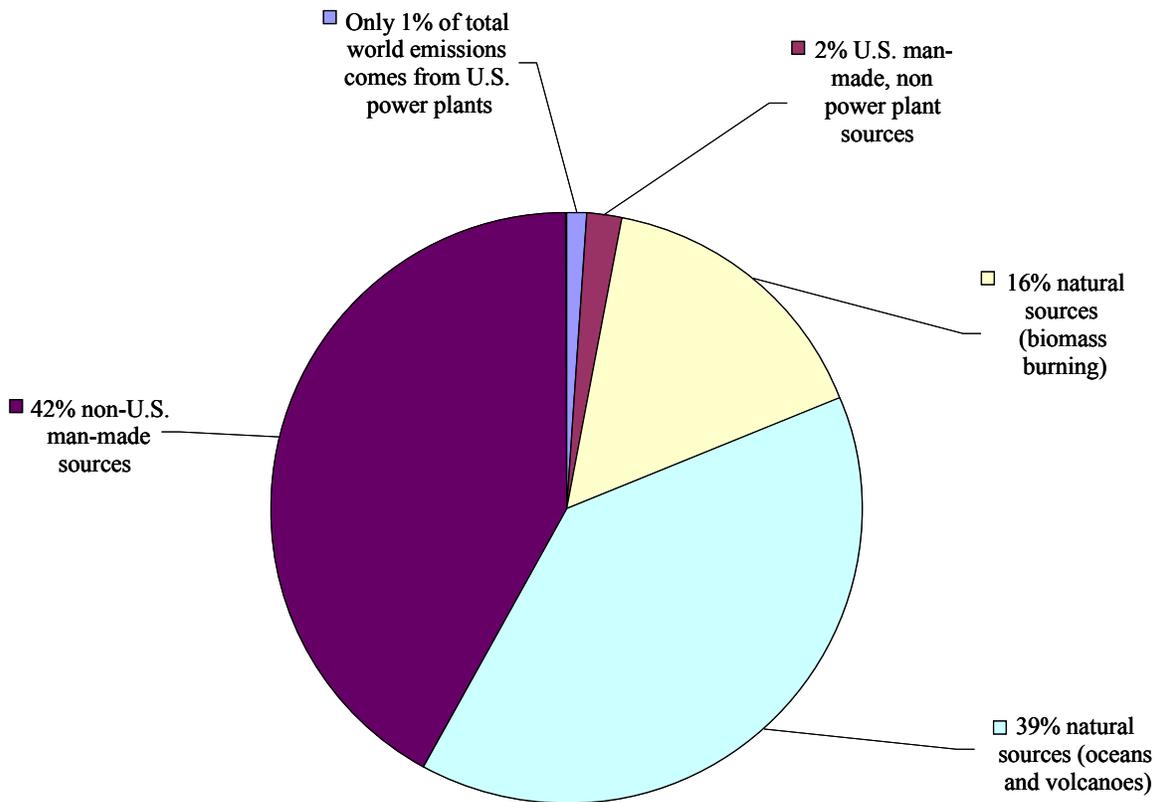
Global and United States Distribution of Mercury Emissions

Figure 1-1 shows the percentage of global mercury emissions from natural and man-made sources, based on 1995 data (Pacyna 2003). Based on these data, over half of global mercury emissions are naturally occurring from oceans, biomass burning, and volcanoes, while slightly less than half of mercury emissions are the result of man-made sources. Some portion of naturally-occurring emissions is actually re-emitted mercury. Re-emitted mercury is transferred to the atmosphere from biologic and geologic processes drawing on a pool of mercury that was deposited to the earth's surface following initial emissions from man-made or natural activities (EPA 1997).

Recent research indicates that emissions of elemental mercury from vegetation in the United States may be substantial. Mercury can be taken up through the leaves of plants and from the soil and then re-emitted through transpiration (Lin 2006). Researchers have concluded that in the United States overall, re-emitted mercury from vegetation may be comparable to mercury emitted from man-made sources during the summer. Vegetative emissions of mercury decrease greatly in winter (Lin et. al 2006).

As Figure 1-1 shows, only about three percent of total global mercury emissions originate from man-made sources in the United States, with approximately one percent of the global total from United States power plants.

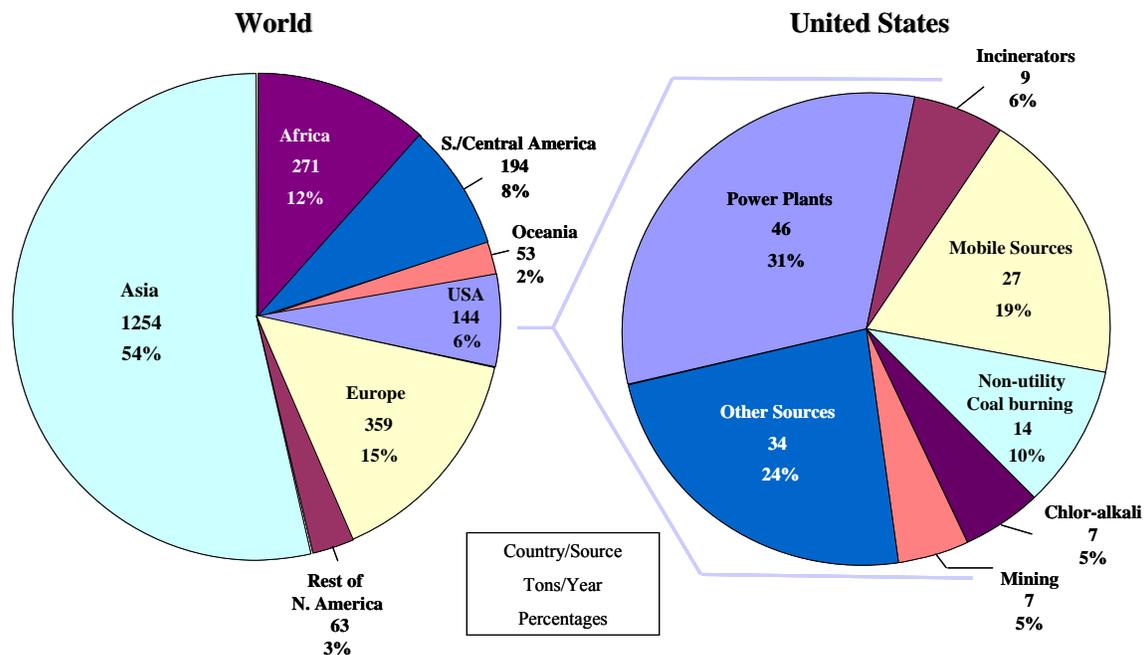
Figure 1-1. Global Emissions of Mercury



Source: Pacyna 2003

Figure 1-2 depicts annual emissions of mercury from man-made sources only, apportioned to the world's continents that emit the largest amounts of mercury. Emissions shown for power plants are for 1999, while emissions for other source types are for 1998 (Seigneur 2006). Values are shown in tons per year as well as in percentages of total man-made emissions. Based on these data, Asia contributes about half of the global emissions of mercury from man-made sources, while the United States contributes about six percent of emissions from man-made sources.

Figure 1-2. Man-Made Emissions of Mercury

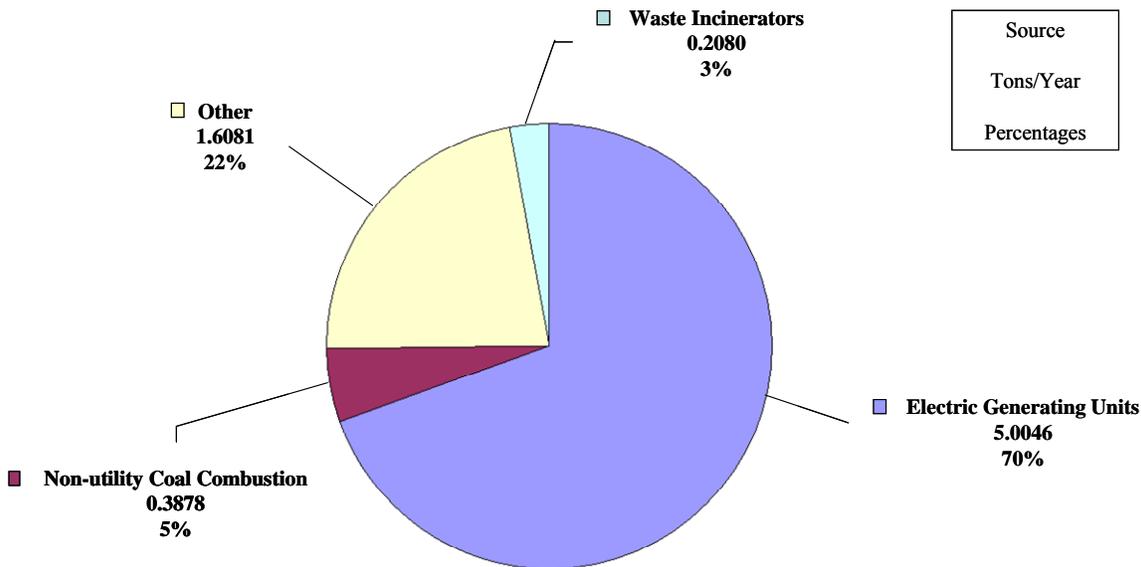


Adapted from Seigneur 2006

Figure 1-2 also shows the distribution of annual mercury emissions from man-made sources in the United States only, in tons per year and as percentages, and for the same years noted above (Seigneur 2006). This pie chart shows that power plants accounted for approximately 31 percent of mercury emissions from man-made sources in the United States in 1999.

Figure 1-3 shows a similar pie chart for Texas mercury emissions for 2003, although mercury emissions from mobile sources were not available in the examined databases. Emissions from power plants are for Clean Air Mercury Rule (CAMR)-applicable electric generating units (EGUs) (see Chapter 2 for a discussion of CAMR). The pie chart shows that EGUs accounted for about 70 percent of the mercury emissions in Texas in 2003, excluding mobile sources (TCEQ 2006).

Figure 1-3. Man-Made Emissions of Mercury in Texas



Source: TCEQ 2006

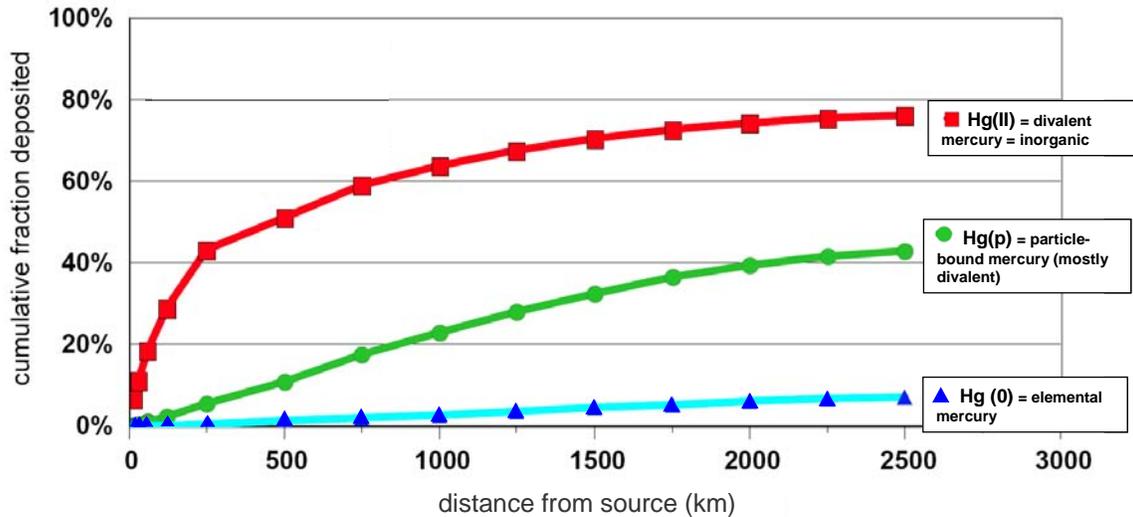
Within the past 100 years, human activities have increased the amount of mercury sustained in the global atmosphere. Estimates from atmospheric sampling over the Atlantic Ocean in 1977, 1978, 1980 and 1990 indicated a yearly increase of approximately one percent in elemental mercury, the form of mercury that serves as an indicator for the global mercury pool. Estimates were slightly higher for the Northern Hemisphere than for the Southern Hemisphere, indicating the possibility of greater emissions from man-made sources of elemental mercury in the Northern Hemisphere (Slemr 1992).

Mercury Deposition

When emitted from natural or man-made sources, the various chemical forms of mercury deposit to the ground or bodies of water at much different rates. Thus, the downwind distances from sources at which cumulative amounts are deposited vary considerably. Figure 1-4 depicts deposition versus downwind distance. The cumulative amount of deposition is plotted against downwind distance from the emitting source for elemental, divalent, and particle-bound mercury (Cohen 2005). This plot is based on modeling of a hypothetical electric generating unit with a stack height of 250 meters; thus, the plot shows only an example of relative distances of deposition for the types of mercury emitted. As an example, for divalent mercury, which deposits fairly readily, the plot shows that about twenty percent of the emissions would be deposited at a distance of about 50 kilometers. Deposition distances for particle-bound and elemental mercury would be much greater, though, due to lower deposition rates for these forms of mercury. In the example provided in Figure 1-4, twenty percent of particle-bound mercury would be deposited at about 800 kilometers downwind, while twenty percent of elemental mercury would be deposited

at a distance considerably greater than 3,000 kilometers downwind of the source. Because elemental mercury settles out at great distances from the source, controlling this form is important to reduce the global mercury pool. In contrast, divalent mercury settles out relatively close to the source, thus controlling this form will help reduce the potential for local impacts from sources.

Figure 1-4. Cumulative Fraction of Mercury Deposited Out to Different Distance Ranges From a Hypothetical Source

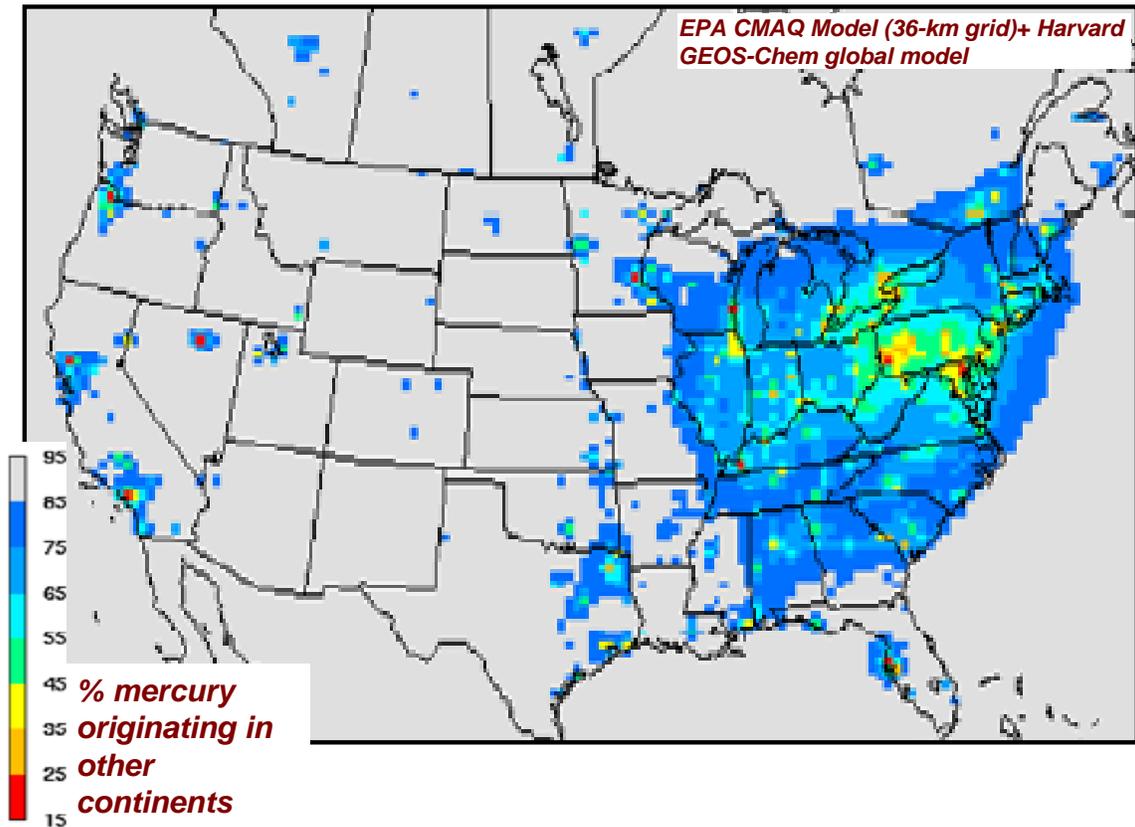


Source at Lat = 42.5, Long = -97.5; modeling simulation for entire year 1996

Source: Cohen 2005

Based on the global mercury emissions balance shown in Figure 1-1 and discussed previously, it should be expected that a large percentage of mercury deposition in the United States would originate from emissions outside of the country. Figure 1-5 shows the estimated amount of mercury deposition across the United States from non-United States natural and man-made sources of emissions, based on modeling for 2001 performed by the United States Environmental Protection Agency (EPA) (Levin 2006). As the map in Figure 1-5 shows, the model predicts the percentage contribution to mercury deposition from non-United States sources to be over 85 percent over much of the United States. Another study indicates that most of the mercury deposition affecting the United States from non-United States sources originates from Asia (Seigneur 2004). The map in Figure 1-5 shows that the percentage contribution to deposition from non-United States sources decreases from west to east since mercury emissions from United States sources are generally higher in the east than in the west, and because precipitation is relatively high in the east, enhancing wet deposition of mercury.

Figure 1-5. Estimate of U.S. Mercury Deposition Originating from Non-U.S. Sources



Source: Levin 2006

Characterization of Mercury from Combustion of Coal

Based on 2003 emissions data, which show about five tons of mercury from Texas coal-fired power plants, about 67 percent of mercury from these plants was emitted as elemental mercury, 32 percent was emitted as the divalent form, and one percent was emitted as particle-bound mercury (Santschi 2005). These percentages can vary considerably on a source-specific basis, depending on such factors as fuel type and control equipment (Cohen 2005).

Generally, there are four “ranks” of coal ranging in geological age from the oldest anthracites to bituminous, subbituminous (including Powder River Basin coal), and the youngest, various lignites. Potential heat capacity and other characteristics vary substantially both within and across coal ranks, with older, higher rank coals generally capable of producing more heat per unit mass than younger, lower rank coals. Variation among coals extends to mercury and other inorganic compounds, such as chlorine, that may affect mercury control efficiency (EPA 2002). In Texas, one of the primary fuel sources for power plants is Gulf Coast lignite. Although the average mercury content of lignite, as shown in Table 1-1, is comparable to bituminous coal (EPA 2005), the low calorific value or average heating value of lignite gives it the highest potential for mercury emissions (USGS 2001). That is, to generate the same amount of energy,

more lignite must be burned, resulting in the potential for increased mercury release. Due to the relatively low boiling point of mercury (357°C), when lignite is burned, 90 percent or more of the mercury exists in the elemental vapor phase and escapes with the flue gases (Menounou 2003). In addition, Table 1-1 indicates that lignite contains significantly lower concentrations of chloride on average compared to bituminous coal (EPA 2005). In the presence of chloride, elemental mercury is oxidized to divalent mercury and forms an inorganic salt known as mercuric chloride. Mercuric chloride is less volatile than elemental mercury and is significantly more water-soluble (Sliger 2000). Therefore, due to the low chloride content of lignite, very little mercury salt formation occurs, and the mercury that does escape is composed primarily of elemental vapor rather than more easily removable divalent mercury salts.

Subbituminous Powder River Basin (PRB) coal is also widely used in Texas. On average, the mercury content of PRB coal is lower than bituminous coal and lignite (Table 1-1). However, the table also indicates that the average chloride content is even lower than that for lignite (EPA 2005). Therefore, the elemental form of mercury dominates emissions from power plants burning PRB coal as well.

Table 1-1. General Characteristics of Coal Burned in U.S. Power Plants

Coal Type	Average Mercury Content (ppb)	Average Chlorine Content (ppb)	Average Higher Heating Value (BTU/lb)
Bituminous	0.113	1,033	13,203
Subbituminous	0.071	158	12,005
Lignite	0.107	188	10,028

Adapted from EPA 2005.

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Chapter 2

Clean Air Mercury Rule (CAMR)

Clean Air Mercury Rule (CAMR) Overview

On March 15, 2005, EPA finalized the Clean Air Mercury Rule (CAMR). The final rule was published in the *Federal Register* on May 18, 2005. EPA's goal for CAMR is to permanently cap and reduce mercury emissions from new (commencing operation on or after January 1, 2001) and existing (commencing operation before January 1, 2001) coal-fired electric generating units (EGU) nationwide in two phases. EPA provided states with two compliance options: 1) meet the state's emission budget by requiring new and existing coal-fired EGUs to participate in an EPA-administered cap-and-trade system that caps emissions in two stages; or 2) meet an individual state emissions budget through measures of the state's choosing. Per EPA, the CAMR rule makes the United States the first country in the world to regulate mercury emissions from utilities. When fully implemented, these rules will reduce EGU emissions of mercury from 48 tons a year to 15 tons nationwide, a reduction of nearly 70 percent (EPA 2005).

In 2005, the 79th Texas Legislature passed House Bill 2481 in its Regular Session, which requires Texas to adopt the CAMR rule by reference. Therefore, Texas is statutorily required to participate in the EPA-administered cap-and-trade program, and the Texas Commission on Environmental Quality (TCEQ) adopted CAMR [40 Code of Federal Regulations (CFR) Part 60, Subchapter HHHH] by reference in 30 Texas Administrative Code (TAC) Chapter 101, Subchapter H, Division 8. The CAMR program is designed after the Acid Rain or Title IV program in the Federal Clean Air Act. In addition to being subject to the caps, CAMR requires any EGU for which construction commenced after January 30, 2004, to comply with the mercury new source performance standards (NSPS) in 40 CFR Part 60.45(a) (Texas Legislature 2005).

CAMR applies to any stationary, coal-fired boiler or stationary, coal-fired combustion turbine meeting the applicability requirements under 40 CFR Part 60.4104. The referenced applicability requirements under 40 CFR Part 60.4104 apply to stationary, coal-fired boilers or combustion turbines serving at any time, since the start-up of the unit's combustion chamber, a generator with a nameplate capacity of more than 25 megawatt electrical (MWe) producing electricity for sale. CAMR also applies to co-generation units serving at any time a generator with nameplate capacity of more than 25 MWe and supplying in any calendar year more than one-third of the unit's potential electric output capacity or 219,000 megawatt hours (MWh), whichever is greater, to any utility power distribution system for sale. Integrated gasification combined cycle units are also subject to the final rule (EPA 2005).

As part of the regulatory mechanism for controlling mercury, CAMR requires Texas to prepare and submit a state plan pursuant to Federal Clean Air Act section 111(d) by no later than November 17, 2006. Regulations in 40 CFR Part 60 contain requirements that establish a State Implementation Plan-like procedure under which each state submits to EPA a plan that establishes standards of performance for existing sources of certain air pollutants and that provides for the implementation and enforcement of those standards. The cap-and-trade program

is a standard of performance for the control of mercury emissions from existing sources. The CAMR state plan is the mechanism by which the standard of performance for existing sources is applied to existing EGUs (TCEQ 2006a).

As stated previously, CAMR will be implemented in two phases. Phase I of the CAMR program, years 2010 - 2017, will take advantage of the co-benefit of the Federal Clean Air Interstate Rule (CAIR). EPA has concluded that mercury reductions achieved as a co-benefit of controlling sulfur dioxide (SO₂) and nitrogen oxides (NO_x) under CAIR should dictate the appropriate cap level for mercury. EPA has also stated that requiring SO₂ and NO_x controls beyond those needed to meet the requirements of CAIR solely for the purposes of further reducing mercury emissions by 2010 is not reasonable because the incremental cost effectiveness of such a requirement would be extraordinarily high. Therefore, additional Phase I mercury reductions will not be required beyond the co-benefit of CAIR (EPA 2005).

The 2003 emissions inventory for CAMR EGUs in Texas is 5.0046 tons per year (TCEQ 2006b). Under the Federal CAMR rule, Texas has been given an annual mercury budget of 4.656 tons for Phase I (2010-2017) and 1.838 tons for Phase II (2018 - and thereafter). Therefore, there will be a decrease of 0.3486 tons per year based on the 2003 reported emissions inventory and the CAMR allocations for 2010. According to EPA's predictions, CAMR compliance in Texas will result in a mercury reduction of seven percent or 0.4 tons annually by 2010 and a total of 63 percent or 3.2 tons annually by 2018. These reductions are based on EPA's 1999 mercury emissions for Texas. However, because Texas will be participating in the EPA administered cap-and-trade program for CAMR, reductions could be higher if EGUs elect to over control beyond their CAMR allocations or the reductions could be less if EGUs choose to purchase CAMR allowances to stay in compliance. Regardless of the number of new coal-fired EGUs in Texas, the state's budget from EPA will not change (EPA 2005). However, EGUs within the state could purchase mercury credits annually from other states participating in the CAMR trading program.

Phase II of the CAMR program, 2018 and thereafter, will require new and existing coal-fired EGUs to use mercury-specific air pollution control technologies. Phase II reductions are based on the combined co-benefit from CAIR reductions and mercury-specific controls. Table 2-1 outlines the mercury caps under CAMR for Phase I and Phase II (EPA 2005).

Table 2-1. Mercury Caps under CAMR

	National Annual Mercury Cap	Texas Annual Mercury Cap
Phase I - 2010-2017	38 tons per year	4.656* tons per year
Phase II - 2018 and thereafter	15 tons per year	1.838 tons per year

*Texas's CAMR cap was lowered from 4.657 tons per year to 4.656 tons per year on April 28, 2006 by EPA (EPA 2006a)

Control Strategy

EPA requires states to submit a CAMR state plan that will show the state's legal authority to adopt emission standards and compliance schedules necessary for attainment and maintenance of the state's relevant annual mercury budget, and require owners or operators of EGUs in Texas to meet monitoring, recordkeeping and reporting requirements.

Title V permit revisions are required to reflect EGU participation in CAMR. The mercury update to the Title V permit must be submitted by June 1, 2007.

Compliance with CAMR is determined by EGUs maintaining an adequate mercury allowance to cover the previous year's emissions. If EPA determines that an EGU exceeded its mercury allowance requirements in EPA's cap-and-trade program, the EGU will be required to surrender allowances sufficient to offset the excess emissions. The EGU must also surrender allowances to EPA from the next control period equal to three times the excess emissions (EPA 2005).

Cap-and-Trade

Cap-and-trade programs, such as CAMR for EGUs, are market-based mechanisms for reducing pollution from a group of sources at lower cost than if sources were regulated individually. The CAMR cap-and-trade program first sets an overall mercury cap, or maximum amount of emissions per compliance period, that will achieve the desired environmental effects. Authorizations to emit in the form of emission allowances are allocated to states, and the total number of allowances cannot exceed the nationwide cap. Individual control requirements are not specified. Sources are required to completely and accurately measure and report all emissions and then surrender allowances equal to total emissions at the end of the compliance period.

Cap-and-trade provides sources, such as EGUs, flexibility in compliance by either choosing to control emissions through technology or through purchase of additional allowances to meet compliance obligations (EPA 2006b).

Monitoring and Reporting

CAMR requires monitoring of total vapor phase mercury concentrations from coal-fired EGUs through either a mercury continuous emission monitoring system (Performance Specification 12A) or a mercury sorbent trap monitoring system (40 CFR Part 75, Appendix K). In addition to the mercury concentrations, CAMR also requires monitoring of heat input, stack gas flow rate, and stack gas moisture (if moisture correction is necessary). Low mass emitters (less than or equal to 29 pounds mercury/year) have the option of using periodic mercury stack testing in lieu of the continuous mercury concentration monitoring systems. Low mass emitters between nine pounds mercury/year and 29 pounds mercury/year must test twice per year, while low mass emitters with nine pounds mercury/year or less must test once per year (EPA 2005).

Compliance Plan and Schedule

Owners or operators of a coal-fired EGU CAMR unit that commences commercial operation before July 1, 2008, must be in compliance with the monitoring requirements by January 1,

2009. Owners or operators of a unit that commences commercial operation on or after July 1, 2008, must comply with the monitoring requirements by the later of the following dates: January 1, 2009, or 90 unit operating days or 180 calendar days, whichever occurs first, after the date the unit commences commercial operation (EPA 2005).

Clean Air Mercury Rule (CAMR) Activity Time Line

March 15, 2005 – CAMR finalized by EPA.

May 18, 2005 – CAMR published in the *Federal Register*.

August 4, 2005 - D.C. Circuit Court of Appeals Refuses to Stay Mercury Rule – EPA opposed the stay sought by environmental groups, arguing that if it were granted, mercury would be unregulated and implementation of the cap-and-trade program for the toxic pollutant would not be possible. The fourteen states that sued EPA on the rule did not join in the request for the stay.

October 21, 2005 – In two separate actions, EPA granted requests from petitioners to reconsider certain aspects of its March 15, 2005, CAMR.

The first action addressed four petitions. EPA agreed to reconsider and accept comments on the following aspects of the final rule:

- method used to apportion the national caps to individual states;
- definition of "designated pollutant;"
- EPA's subcategorization for new subbituminous coal-fired units subject to NSPS;
- statistical analysis used for the NSPS;
- highest annual average mercury content used to derive the NSPS;
- definition of covered units as including municipal waste combustors; and
- definition of covered units as including some industrial boilers.

The second action addressed other petitions for reconsideration, with EPA agreeing to reconsider and accept comments on the following aspects of the final rule:

- legal issues underlying EPA's determination that the regulation of electric utility steam generating units under Section 112 of the Federal Clean Air Act was neither necessary nor appropriate, and removing certain utility units from the list of source categories; and
- the methodology used to assess the amount of utility-attributable mercury levels in fish tissue and the public health implications of those levels.

March 1, 2006 - The TCEQ staff requested the Commissioners' approval to publish for public comment the proposed CAIR SIP and CAMR State Plan, with the associated rules.

March 17 - April 17, 2006 - Comment period for CAIR and CAMR, with a public hearing held on April 11th at the TCEQ headquarters in Austin, April 12th at the TCEQ Regional Office in Fort Worth and April 13th at the TCEQ Regional Office in Houston.

June 9, 2006 – EPA took final action on petitions to reconsider two actions regarding mercury air pollution. EPA reaffirmed the determination it had made in the final Section 112(n) Revision Rule to remove certain utility units from the list of §112(c) source categories, and reaffirmed its decision that regulation of these units under §112 is neither necessary nor appropriate. EPA also granted requests from petitioners to reconsider certain aspects of its March 15, 2005, Clean Air Mercury Rule (CAMR) in two separate actions. Based on these requests, EPA is making the following changes to CAMR: adjusting the heat input values for a single unit in Alaska that will cause a decrease of 0.001 ton per year of mercury allowances for Texas in 2010-2017; increasing the NSPS limit for subbituminous coal-, lignite- and coal refuse-fired units and decreasing the limit for bituminous coal; amending the regulatory language to clarify that CAMR does not apply to municipal waste combustors; and correcting technical aspects to clarify the final rule. Additional rule changes are expected during the summer of 2006 from EPA.

July 12, 2006 – The Commission adopted the CAMR State Plan and associated rules.

October 31, 2006 – CAMR allocations due to EPA.

November 17, 2006 – CAMR State Plan is due to EPA.

January 1, 2009 – CAMR monitoring must be in place to continuously monitor mercury emissions.

January 1, 2010 – Phase I of CAMR begins.

January 1, 2018 – Phase II of CAMR begins.

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Chapter 3

Assessment of the CAMR Trading Program on Local Communities

Introduction

In addition to requiring the commission to adopt the Clean Air Interstate Rule (CAIR) and the Clean Air Mercury Rule (CAMR), HB 2481 provides that the commission shall “consider the impact of trading on local communities.” The commission has interpreted this directive to mean an assessment of the potential for mercury emissions trading under CAMR to result in local, “utility-attributable” increases of methylmercury in fish caused by future increases in mercury deposition. Such an increase related to trading might occur if the downwind effect of any increase in mercury emissions at an electric generating unit (EGU) were to outweigh the effects of emission decreases from other sources, either nearby or distant. If a utility-attributable increase in fish tissue methylmercury concentration exceeds EPA’s fish tissue criterion of 0.3 mg/kg, such an increase is considered by EPA to be a “utility hot spot” (EPA 2005a).

This section assesses the potential for CAMR to result in utility-attributable local increases of mercury deposition and methylmercury in fish, as well as utility-attributable hot spots, based on a review of technical work conducted primarily by EPA in developing CAMR.

EPA’s Technical Approach and Results

To assess the potential effects of CAMR, including the CAMR trading provisions, EPA conducted modeling to estimate utility-attributable mercury deposition and fish tissue methylmercury concentrations for a base year (2001) prior to CAMR-related emission reductions, and for a future year (2020) approximately corresponding to the implementation of CAMR. EPA conducted the modeling with the peer-reviewed Community Multi-Scale Air Quality (CMAQ) modeling system, with meteorological inputs derived from the Fifth-Generation National Center for Atmospheric Research/Penn State Mesoscale Model. Because of mercury emission reduction co-benefits from the implementation of CAIR, EPA addressed the effects of CAIR together with the effects of CAMR in the analysis (EPA 2005b).

For the 2001 base year deposition modeling, EPA used utility mercury emissions from the National Emissions Inventory for 1999, the closest available year to 2001. For non-utility sources, EPA used data for 2002, the year closest to 2001, where available. EPA developed utility emissions for the 2020 future year using the Integrated Planning Model (IPM) (EPA 2005b). IPM is designed to project the impact of environmental policies on the electric power sector in the 48 contiguous states and the District of Columbia. It provides forecasts of least-cost capacity expansion, electricity dispatch, and emission control strategies for meeting energy demand and environmental, transmission, dispatch, and reliability constraints (EPA 2006a). In its IPM modeling, EPA assumed that all of the 48 contiguous states will implement the trading program prescribed in CAMR (EPA 2005b).

To ensure appropriate geographical representation for modeled deposition, values calculated for the modeled grid cells were averaged over units called Hydrologic Unit Codes (HUCs), which are representations of watersheds. Averaging of modeled deposition values over the watersheds

is a reasonable methodology for predicting the impact of mercury deposition on fish tissue levels in water bodies within a given watershed, since processes occurring over a watershed likely influence methylmercury concentrations in fish at any given location within the watershed ecosystem (EPA 2005a).

EPA examined samples collected from multiple sites in the National Listing of Fish Advisories and National Lake Fish Tissue Survey to determine fish tissue methylmercury concentrations for the 2001 base year. To estimate utility-attributable fish tissue concentrations for the future year after implementation of CAIR and CAMR, base year values of total fish tissue concentration at the sampling sites were scaled with the ratio of utility-attributable mercury deposition modeled in the base year to that predicted for the future year (EPA 2005c).

Summaries of modeling results for utility-attributable mercury deposition for United States and Texas watersheds are presented in Tables 3-1 and 3-2, respectively. Summaries of results for utility-attributable fish tissue concentrations of mercury for the United States and Texas are shown in Tables 3-3 and 3-4, respectively.

Table 3-1. Utility-Attributable Mercury Deposition ($\mu\text{g}/\text{m}^2$) – U.S.

Deposition	2001 Base Case	2020 Future Case with CAIR Implemented	2020 Future Case with CAIR and CAMR Implemented
Minimum	0.00	0.00	0.00
Maximum	19.71	4.03	3.85
50 th percentile	0.39	0.31	0.26
90 th percentile	4.08	1.38	1.16
99 th percentile	10.15	2.56	2.17

Source: EPA 2005c

Table 3-2. Utility-Attributable Mercury Deposition ($\mu\text{g}/\text{m}^2$) – Texas

Deposition	2001 Base Case	2020 Future Case with CAIR Implemented	2020 Future Case with CAIR and CAMR Implemented
Minimum	0.06	0.06	0.04
Maximum	9.84	1.94	1.46
50 th percentile	0.37	0.27	0.25
90 th percentile	1.89	0.69	0.63
99 th percentile	6.82	1.53	1.18

Source: Hubbell 2006

Table 3-3. Utility-Attributable Fish Tissue Mercury Concentration (mg/kg) – U.S.

Fish Tissue Concentration	2001 Base Case	2020 Future Case with CAIR Implemented	2020 Future Case with CAIR and CAMR Implemented
Minimum	0.00	0.00	0.00
Maximum	0.85	0.25	0.19
50 th percentile	0.03	0.01	0.01
90 th percentile	0.11	0.03	0.03
99 th percentile	0.26	0.10	0.09

Source: EPA 2005c

Table 3-4. Utility-Attributable Fish Tissue Mercury Concentration (mg/kg) – Texas

Fish Tissue Concentration	2001 Base Case	2020 Future Case with CAIR Implemented	2020 Future Case with CAIR and CAMR Implemented
Minimum	0.00	0.00	0.00
Maximum	0.09	0.04	0.03
50 th percentile	0.01	0.00	0.00
90 th percentile	0.05	0.02	0.02
99 th percentile	0.08	0.03	0.03

Source: Cakir 2006

In these tables, data are presented for minima, maxima, and three percentile categories. As an example for the percentile categories, the “99th percentile” means that 99 percent of the values fall below the deposition or fish tissue concentration values in the applicable rows of the tables. EPA’s 2020 future case analysis predicts that after implementation of the cap-and-trade programs of CAIR and CAMR, there will be neither increased utility-attributable mercury deposition nor increased utility-attributable fish tissue methylmercury concentrations relative to the base case levels, either nationally or in Texas. The modeling for the 2020 future case also predicts no utility-attributable hot spots (i.e., no utility-attributable fish tissue concentrations at or above EPA’s methylmercury fish tissue criterion of 0.3 mg/kg) (EPA 2005c). Furthermore, the modeling predicts no utility-attributable fish tissue concentrations in excess of the Texas Department of State Health Services mercury advisory level of 0.7 mg/kg. See Chapter 4 for additional information on the state’s mercury advisory level. The commission agrees it is unlikely that utility-attributable hot spots will occur after implementation of CAIR and CAMR, but cannot rule out the possibility of such an occurrence, due to uncertainties discussed in subsequent sections.

The modeling results in Tables 3-1 and 3-2 show relatively large decreases in utility-attributable deposition between the 2001 base case and the 2020 CAIR case, yet differences between deposition for the 2020 CAIR and the 2020 CAIR plus CAMR cases are much smaller. This outcome is attributable to the type of controls implemented in response to CAIR and CAMR. CAIR controls will be highly effective in reducing emissions of divalent mercury, which settles readily through wet and dry deposition. CAMR controls will primarily reduce elemental mercury, which is not readily deposited and enters the global pool of mercury. Because Texas EGUs primarily emit elemental mercury, CAMR controls will only negligibly reduce deposition

in the state. As Table 3-2 shows, even removing all mercury emissions from EGUs in the modeling domain would only reduce mercury deposition by 0.04 to 1.46 $\mu\text{g}/\text{m}^2$ compared to CAMR controls.

Tables 3-3 and 3-4 show that trends for utility-attributable fish tissue concentrations of mercury are similar to those shown for utility-attributable deposition, since the fish tissue concentrations calculated by EPA were based on a proportional relationship between deposition and fish tissue concentration. Notably, EPA's modeling does not account for the time lag between decreases in mercury deposition and decreases in fish tissue concentrations. The response times for changes in fish tissue concentration in freshwater ecosystems typically range between five and 30 years, and some systems will likely take more than 50 to 100 years to reach steady state (EPA 2005c).

Assessment of Uncertainties in the Analysis of CAMR

On May 15, 2006, EPA's Office of Inspector General (OIG) issued a report assessing EPA's determination that CAMR would not result in utility-attributable mercury hot spots (EPA 2006b). OIG recommended that the following uncertainties be acknowledged in EPA's analysis:

- Gaps in available data and science for mercury emissions estimates;
- Limitations in the model used for predicting mercury deposition;
- Uncertainty in how mercury reacts in the atmosphere; and
- Uncertainty in how mercury methylation occurs in water bodies, and how methylmercury accumulates in fish.

Given the uncertainties noted above, OIG concluded that EPA should develop and implement a monitoring plan to assess the impact of CAMR on mercury deposition and fish tissue concentrations. The office also recommended that EPA evaluate and refine mercury estimation tools and models as necessary (EPA 2006b).

EPA responded to the OIG comments by stating that EPA believes it has clearly explained the science and uncertainties in the CAMR documentation. In response to the OIG recommendations that EPA develop and implement a monitoring plan and evaluate and refine scientific tools, EPA explained that it currently operates the Mercury Deposition Network, which is located predominantly in the eastern United States and monitors only wet deposition. EPA further explained that in the CAMR technical support documents, the agency has continually highlighted the need for and the willingness to support additional ambient monitoring, including development of dry deposition monitoring, to enhance its ability to assess the numerical accuracy of sophisticated simulation tools such as the CMAQ model. EPA responded that it has been heavily involved, over the past decade, in developing the CMAQ model and is actively engaged in utilizing ambient data and the latest scientific information to update the model to reflect the best possible chemistry and physics. EPA stated that it is committed to using the best possible information to assess the transport, transformation, deposition, and fate of United States mercury emissions (EPA 2006b).

Trading Issues and Impact on CAMR Modeling Results

EPA's future case mercury inventory for EGUs, developed with the IPM model, is based on EPA's assumption that all of the 48 contiguous states will implement the trading program prescribed in CAMR (EPA 2005b). The specific values resulting from EPA's analysis of mercury deposition and fish tissue concentrations would vary according to the number of states participating and the type of mercury reduction programs actually implemented. However, the commission believes that, for Texas, EPA's modeling prediction of no increases in these values would still hold. The commission believes the most likely scenario is that sources buying credits under the trading program would do so to maintain current emissions, not to increase emissions. In addition, although new EGUs within the state could purchase mercury credits from other states, the Texas budget from EPA will not change.

Other Mercury Assessments

Environmental Defense assessed the potential impact of mercury emissions on deposition at mercury hot spots, defined by the organization as "locations where mercury deposition is highest" (Environmental Defense 2003). Environmental Defense reviewed modeling conducted by EPA for the year 1998 based on use of the Regional Modeling System for Aerosols and Deposition (EPA 2003). The modeling showed that Texas mercury emissions contributed about 50 percent of the deposition at the location in the state having the highest deposition. However, it is not clear from the EPA modeling the extent to which various types of sources, including EGUs, may have contributed to the predicted deposition, or where the contributing sources were located. The commission believes that, based on EPA's modeling output, a primary contributor to the maximum deposition may have been a non-utility industrial source or sources.

The EPA modeling results that Environmental Defense cites, however, are conceptually consistent with deposition information provided earlier in Chapter 1. As depicted in Figure 1-5, United States sources of mercury can have a notable impact on deposition in some areas. CAMR and CAIR are designed to help mitigate the deposition through reductions in mercury emissions. As discussed earlier and as shown by EPA's modeling results provided in Tables 3-2 and 3-4, the CAIR and CAMR programs, particularly CAIR, are predicted to have a beneficial effect on the utility-attributable portion of mercury deposition and fish tissue concentration in Texas.

In comments on the CAMR proposal submitted to EPA, Environmental Defense expressed concern that additional reductions in mercury beyond those occurring from the collateral benefit of CAIR would not be required until 2018 (Environmental Defense 2004). As discussed earlier, however, EPA's CMAQ modeling conducted in support of CAMR indicates only a small additional reduction in deposition within Texas from CAMR, since CAMR controls mainly emissions of elemental mercury which does not deposit readily. Thus, the commission believes it is not critical that the final CAMR reductions be required before 2018 in Texas.

The Electric Power Research Institute (EPRI) studied the impact of CAMR, with its trading provisions, on mercury deposition as did EPA. EPRI's modeling tools and procedures were somewhat different from EPA's (Levin 2006). In its study, EPRI concluded that all states in the country will experience overall reductions in mercury deposition due to the implementation of

CAMR. EPRI also concluded that reductions in deposition will vary somewhat by location depending on variables such as coal type and types of controls (EPRI 2004).

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Chapter 4

Health Issues

Methylmercury

A small fraction of divalent mercury deposited to water and soils ends up in sediments of waterbodies where it is transformed by microbes into methylmercury (Jackson 1998). Methylmercury is retained in fish tissue and is the only form of mercury that accumulates in aquatic food webs (Kidd 1995). Methylmercury is the most toxic of the three primary forms of mercury. Fish consumption is the primary source of methylmercury exposure in humans. Once ingested, 90 to 95 percent of methylmercury is absorbed into the blood from the gastrointestinal tract (EPA 2001). It crosses the blood-brain barrier as a complex with the amino acid, L-cysteine, and accumulates in brain tissue. The half-life of methylmercury varies from tissue to tissue, but is generally between 45 to 70 days. During this time, methylmercury is slowly demethylated and primarily excreted through the feces as divalent mercury (Clarkson 2002).

Health Effects of Mercury

Methylmercury is primarily toxic to the central nervous system. Symptoms vary depending on the dose to which a person is exposed. The primary concern is for the developing brain *in utero*, as methylmercury readily crosses the placental barrier in humans and animals (EPA 2001). At high, acute doses, fetal brain development is severely affected and exposure is often fatal. Mercury intoxication can lead to mental retardation, cerebral palsy, and seizures (Tchounwou 2003). In the mature nervous system, there is often a significant delay between exposure and the onset of symptoms. Some individuals experience numbness or a “pins and needles” sensation in their limbs at low dose which may progress to shaky, unsteady movements caused by damage to the cerebellum, difficulty articulating words, constriction of the field of vision, and hearing loss (Clarkson 2002).

Although the nervous system appears to be the most sensitive target, the cardiovascular system may also be susceptible to mercury toxicity. Correlations have been found between mercury levels and cardiovascular disease in Finnish men (Salonen 1995, Vertanen 2005). However, this association may be the result of the influence of abnormally high data points (Clarkson 2002). One study in the *New England Journal of Medicine* found that mercury levels in European men who experienced heart attacks were 15 percent higher than in controls (Guallar 2002). However, in the same journal issue, another group found no association between mercury levels in American men and coronary heart disease, although these results were based largely on men occupationally exposed to relatively high doses of elemental mercury (Yashizawa 2002). Therefore, effects of mercury on the cardiovascular system are conflicting, and additional research is required.

Health Effects Studies of Methylmercury Exposure

Although acute mercury poisoning brought the toxic effects of mercury to the forefront of public attention, typical exposure in the United States is limited to chronic, low dose exposure through fish consumption. EPA evaluated three primary epidemiological studies based on populations that consume higher than average amounts of fish to derive the most recent reference dose (RfD)

for methylmercury. The RfD is defined (EPA 2001) as, "...an estimate of daily exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious health effects during a lifetime." For mercury, neurotoxicity is the health effect of greatest concern, and fetuses are considered the most sensitive subgroup. Recent data indicate that cardiovascular and immunological effects may occur at low mercury doses, but neurological defects remain the most sensitive health effect (EPA 2001). Carcinogenic effects have been noted only at extremely high doses in animals and are believed to be secondary to organ damage. Therefore, typical environmental doses of methylmercury are unlikely to be carcinogenic for humans (EPA 2001).

The three epidemiological studies reviewed by EPA included the Seychelles Child Development Study (SCDS), the Faroe Island study, and the New Zealand study. The SCDS was not used to develop the RfD, because neurological defects were not identified with increasing methylmercury exposure. In contrast, both the Faroe Island and New Zealand studies found dose-related neurological deficits. However, the Faroe Island study was chosen to derive the RfD due to its large sample size, good statistical power, use of two different biomarkers of exposure (fetal umbilical cord blood and maternal hair concentrations), comprehensive neurological assessment at stages of development where they would most likely be detected, and extensive review and analysis in the scientific literature (EPA 2001). An external peer review panel and the National Research Council (NRC) reviewed the EPA assessment of the literature and agreed that the Faroe Island study was appropriate for derivation of the RfD.

EPA performed an analysis to determine the lower 95 percent confidence limit of the benchmark dose (BMDL). It is generally accepted by the scientific community that the BMDL is the best quantitative alternative method for determining the no observed adverse effect level (NOAEL) for a chemical. The BMDL was derived by identifying a small but measurable (five percent) change in neurological effects as measured by the Boston Naming Test. This test, originally designed to identify subtle neurological effects in the elderly, was administered to children in the Faroe Island cohort at seven years of age. Multiple regression analysis indicated a statistically significant functional decrease with increased prenatal mercury exposure. Based on these results, the NRC recommended a BMDL of 58 ppb mercury in umbilical cord blood. An external review panel recommended a higher BMDL of 71 ppb mercury in umbilical cord blood to account for potential confounding effects of polychlorinated biphenyls (PCBs), which are present at high levels in the whale blubber consumed in the Faroe Islands. EPA chose to apply the more conservative estimate of 58 ppb to maternal blood levels, assuming a 1:1 ratio between umbilical cord and maternal blood concentrations. This value was then divided by an uncertainty value of ten to account for variability, including potential differences between umbilical cord blood and maternal blood mercury levels and interindividual variability in mercury metabolism, as well as potential long-term effects not yet measured by the Faroe Island study. Therefore, a value of 5.8 ppb mercury in maternal blood was used to estimate a health-protective oral dose. Consumption of 0.1 µg mercury/kg body weight/day was set by EPA as the RfD to protect against neurological effects in the developing fetus. Since the RfD protects the most sensitive subpopulation, it is assumed that adverse health effects for the general population over a lifetime of exposure are prevented (EPA 2001).

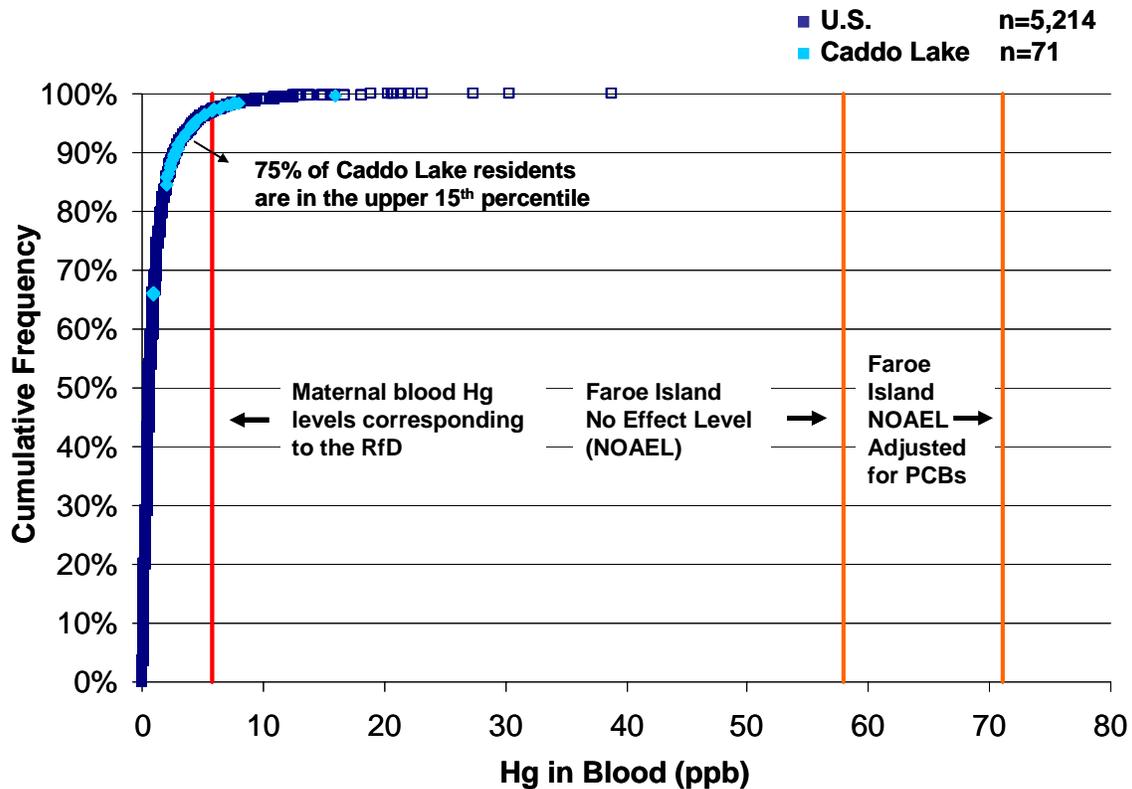
Because methylmercury exposure in humans occurs primarily through fish consumption, EPA also developed a criterion for methylmercury concentrations in freshwater fish tissue to protect human health under the Federal Clean Water Act. To calculate the fish tissue criterion, average default values were applied, including 70 kg (154 lbs) for average adult body weight and 0.0175 kg fish/day (approximately four ounces fish/week or two average fish meals/month) for average adult human fish intake. In addition, because this criterion was established for freshwater fish only, a value accounting for consumption of marine fish (0.027 µg mercury/kg body weight/day) was subtracted from the RfD of 0.1µg mercury/kg body weight/day. The resulting fish tissue criterion is 0.3 mg methylmercury/kg whole fish.

The Texas Department of State Health Services (DSHS) issues species-specific fish consumption advisories when fish fillet testing indicates mercury levels at or above 0.7 mg/kg. The state advisory level was derived using the Agency for Toxic Substances and Disease Registry's minimal risk level of 0.3 µg/kg/day (ATSDR 1999). To calculate the fish tissue concentration, a value of 70 kg (154 lbs) was applied as the average adult body weight and an average fish consumption value of 0.03 kg fish/day (approximately eight ounces fish/week or four average fish meals/month) was used (EPA 2000). Although the Texas DSHS advisory level is less conservative than the EPA fish tissue criterion of 0.3 mg/kg, the estimated blood mercury levels for a person consuming fish containing 0.7 mg/kg methylmercury remain well below the estimated NOAEL.

In 1995, the Texas DSHS issued a consumption advisory due to elevated muscle tissue mercury levels in largemouth bass and drum in Caddo Lake. To determine whether or not additional efforts were needed in the area to protect against potential adverse health effects, DSHS recruited and tested blood mercury levels in 71 area residents (34 male/37 female) in 2004. In addition to blood testing, DSHS issued questionnaires to establish residency duration and fish consumption habits. Average fish consumption ranged from zero to seven meals per week. Average blood mercury levels increased with increasing weekly fish consumption. Higher blood mercury concentrations also corresponded with consumption of fish (largemouth bass and drum) with higher average fillet mercury concentrations (Texas DSHS 2005).

In Figure 4-1, dark blue points indicate the cumulative frequency of blood mercury levels for each individual tested in the nationally representative 1999-2000 National Health and Nutrition Examination Survey (NHANES) study, 96 percent of whom had blood mercury levels below 5.8 ppb (CDC 2006). For comparative purposes, data specific to a sub-population of Caddo Lake residents (represented by the light blue points) are superimposed on the national sample. This Caddo Lake population had higher average blood mercury concentrations, which is expected, due to higher than average fish consumption rates.

Figure 4-1. Cumulative Frequency of Blood Mercury Levels in Caddo Lake Area Residents Relative to the U.S. Population



Data Source: Texas DSHS 2005 and Centers for Disease Control 1999-2002

No observable adverse effects are anticipated at current blood mercury levels for the Caddo Lake sub-population or the representative United States sub-population sampled by NHANES. Total blood mercury levels for Caddo Lake residents ranged from 1.0 to 15.9 ppb, with an average of 2.63 ppb (Texas DSHS 2005). In comparison, total blood mercury levels in the broader United States population ranged from 0.07 to 38.9 ppb, with an average of 1.26 ppb. The current RfD is set to prevent methylmercury blood levels exceeding 5.8 ppb to protect against neurological effects in the developing fetus. Therefore, the primary population of concern is women of child-bearing age. Five of 37 female Caddo Lake residents were of child-bearing age, all of whom had blood mercury levels below 5.8 ppb. Higher mercury concentrations (>58 ppb) can produce visual and motor problems in adults. However, no Caddo Lake or NHANES study participants had blood mercury levels above the NOAEL of 58 ppb.

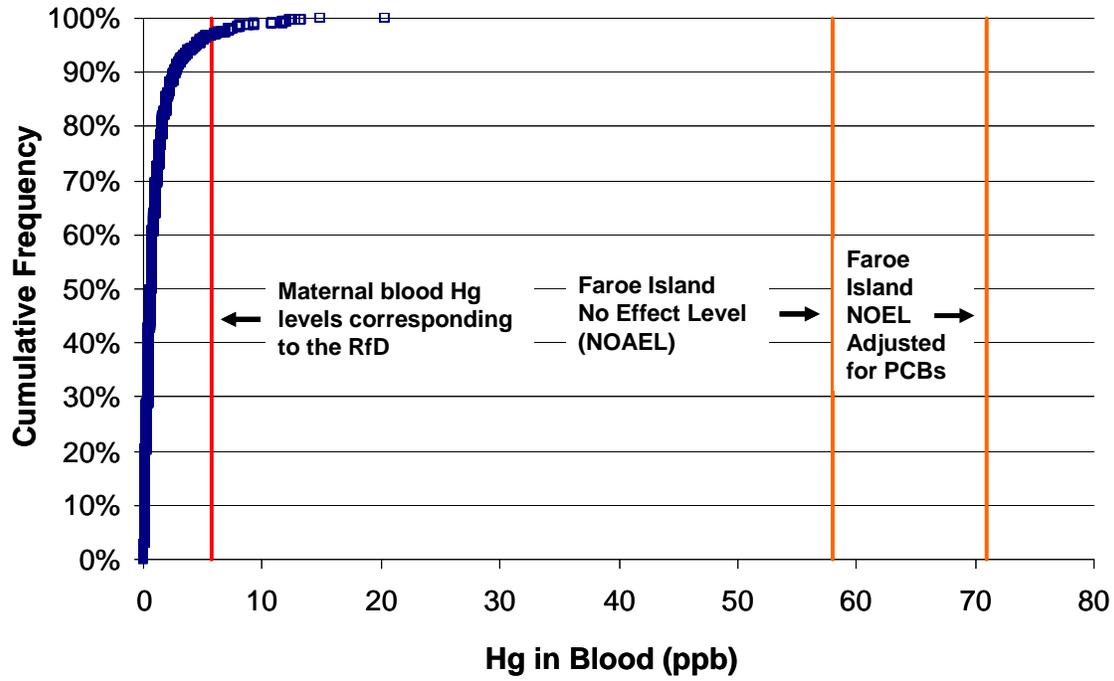
Recently, an ecological study linked autism rates to environmental mercury releases in the state of Texas. This paper asserts there is a 43 percent increase in special education students for every 1000 lbs of mercury released into the environment, and that autism alone accounts for this increase (Palmer 2006). However, as the authors acknowledge, several study limitations exist. One critical limitation is that a link between toxic release inventory (TRI) data and actual

mercury exposure is unclear. As the authors concede, a causal association between environmentally released mercury and autism cannot be established from these data (Palmer 2006). In addition, the only case-control study published in the peer-reviewed literature to date also indicated no causal relationship between mercury and autism (Ip 2004). Finally, although mercury in sediment cores analyzed by Menounou et al. (2003) indicate that coal-fired power plant emissions may have local impacts, other data indicate that a substantial portion of mercury deposited in Texas comes from man-made sources outside of the United States, primarily from Asia (Seigneur 2004). Regardless of its origin, the primary source of human exposure to methylmercury is through fish consumption, which was not evaluated by Palmer et al.

Tresande et al. (2005) conducted an analysis of the financial consequences of reduced intelligence quotient (IQ) due to methylmercury toxicity. Their analysis is based on the assumption that umbilical cord blood levels at or above the EPA RfD of 5.8 ppb, rather than being protective of the fetus, result in observable developmental effects. Due to recent evidence that mercury concentrations in umbilical cord blood may be 70 percent higher than concentrations in maternal blood, the authors contend that children exposed to maternal blood mercury concentrations greater than 3.5 ppb *in utero* may experience adverse neurological effects. The TCEQ believes the RfD provides adequate protection of human health. As mentioned previously, EPA established a BMDL of 58 ppb in umbilical cord blood as the NOAEL and then reduced this value by a factor of 10 to account for various sources of uncertainty, including the assumption that maternal blood and umbilical cord blood levels are equivalent.

The authors' evaluation of the 1999-2000 NHANES data indicates that 15.7 percent of women in the United States between the ages of 16 to 49 had blood mercury levels greater than 3.5 ppb (Tresande 2005). However, TCEQ analysis of the raw data available on the NHANES website indicates that 7.6 percent, rather than 15.7 percent, of women of child-bearing age had blood mercury levels greater than 3.5 ppb, and only 4.1 percent of these women had levels greater than 5.8 ppb. More recent NHANES data (2000-2001) are available than were used by Tresande et al. TCEQ analysis of these more recent raw data indicates only 2.5 percent of women of child-bearing age had levels greater than 5.8 ppb (Figure 4-2).

Figure 4-2. Cumulative Frequency of Blood Mercury Levels in Women of Child-Bearing Age (16-49 years) in the U.S.



Data Source: Centers for Disease Control 1999-2002

In their economic evaluation, Tresande et al. assumed a 30 percent difference (rather than 70 percent) between umbilical cord blood and maternal blood and therefore assumed IQ loss would occur at maternal blood mercury greater than 4.84 ppb. Based on data from the Faroe Islands (Budtz-Jorgensen 2002) and assuming a linear relationship between blood mercury levels and IQ, the authors used an average theoretical loss of 1.5 IQ points for each doubling in maternal blood mercury levels greater than 4.84 ppb (Tresande 2005). The authors concede that this loss in IQ is small compared to the loss in IQ that can occur as the result of other genetic or environmental causes, but argue that the economic impacts over a lifetime are substantial. Using an economic forecasting model, the authors estimated the aggregate cost of lost wages for American children due to mercury exposure from all sources to be \$8.7 billion annually, with a range of \$4.9 to 13.9 billion. The study further characterized the percentage of lost wages attributed to coal-burning power plants in the United States and estimated these costs to be approximately \$1.3 billion annually. However, these calculations do not consider global mercury source contributions and the fact that 42 percent of the fish consumed in the United States are imported from other countries (Tresande 2005). Therefore, it is likely that these estimates overstate the potential cost of mercury exposure in the United States.

Whereas Tresande et al. used an average theoretical IQ loss based solely upon effects seen in the the Faroe Island study, others have performed aggregate analysis of all three primary

epidemiological studies to determine potential methylmercury-related IQ loss. L.M. Ryan provided a report to EPA indicating a central estimate of IQ loss between 0.1 to 0.25 IQ points for every one μg increase in mercury per gram of maternal hair (Ryan 2005). A separate aggregate analysis reported a range of 0 to 1.5 IQ points lost per one μg increase in mercury per gram of maternal hair (Cohen 2005). This range includes the values calculated by Ryan; however, Cohen's central estimate of 0.7 IQ point loss per μg increase in mercury per gram of maternal hair from this study exceeds Ryan's estimates. Several confounding factors should be noted. First, although full-scale IQ was the primary outcome measure, it was not conducted in the Faroe Island study. Second, assumptions regarding the distribution of the data were made which cannot be confirmed. Finally, the normal standard deviation for a full-scale IQ test is 15 points, and therefore, the calculated IQ loss can only be measured on a population basis, not for an individual.

For Texas, EPA utilized the report by Ryan to evaluate the Clean Air Mercury Rule base case scenario in 2001 with no specific mercury control requirements for coal-burning electric generating units. This evaluation predicted an average loss of 0.052 to 0.063 IQ point in children in Texas exposed prenatally to mercury from all sources in 2001. Average IQ is 100 points, and CAMR is estimated in 2020 to reduce IQ loss by 0.0003 to 0.0004 point on average for prenatally exposed children in Texas, above estimated reductions in IQ losses achieved by CAIR alone of 0.0045 to 0.0067 point. Although less conservative than Tresande et al., these values may also overestimate costs associated with mercury exposure, due to confounding factors, including lack of IQ testing in the Faroe Islands and assumption of a linear response in addition to the difficulty in distinguishing the effects of mercury from potentially more influential genetic variability.

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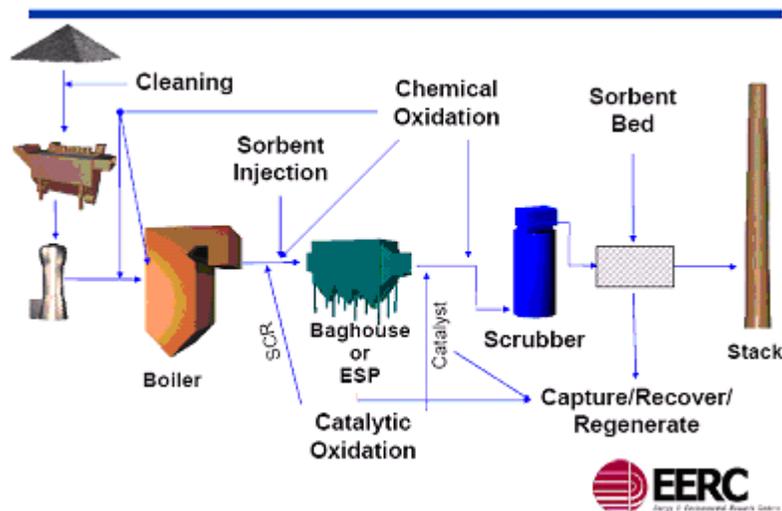
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Chapter 5

Emissions Control Technologies

The type and effectiveness of the particular mercury control approach selected by a plant will depend on the unique characteristics of the coal and electricity generating system being considered. Figure 5-1 indicates many points along the process from the coal pile to the stack exist at which mercury could be removed before it reaches the atmosphere, although not all control strategies are used in one configuration. For example, in some plant configurations, it may be most effective to remove the mercury from the coal before it enters the boiler using "coal cleaning." In other configurations, sorbent injection after the boiler, followed by capture in a particulate control device, may be more successful. Still other coal and system combinations may require a catalyst bed or sorbent bed customized for mercury capture. Research focusing on each of these approaches, and many others, is underway.

Figure 5-1. Mercury Control Options



Source: Energy and Environmental Research Center 2006

Coal-Fired Utility Profile

Mercury allowances and control efficiencies are both impacted by the type of coal combusted. Nationally, 53 percent of coal reserves are estimated to be bituminous, 36 percent are subbituminous and nine percent are lignite (EPA 2002). Texas has 17 coal-fired EGUs with a total of 36 boilers having a total capacity of 19,602 megawatt electrical (MWe) based on TCEQ permit allowable information. Of this capacity, fifteen boilers (representing 8,200 MWe) use lignite, twenty boilers (8,102 MWe) use subbituminous coal, and one boiler (600 MWe) fires bituminous coal. Many of the plants use blends of more than one type of coal. In 2003, almost 39 percent of the total electricity generated in Texas was from coal. The largest amount of electricity was generated from natural gas (49 percent); nuclear generation was almost 9 percent with hydroelectric and other renewables 1.2 percent of the state's generation (EIA 2006).

Mercury Control

Selection of a mercury control method is site specific. It is dependent upon the boiler characteristics, type of coal combusted, operational parameters, intended use of fly ash, and existing environmental controls at the site.

Several ranks of coal are segregated based on thermal properties. Besides the thermal properties, each rank has different levels of mercury and chemical compositions (especially chlorine) that affect the mercury abatement efficiency. Anthracite is the highest grade, followed by bituminous, subbituminous (including Powder River Basin coal), and then the lowest rank, lignite. Lignite, due to its lower grade, is fired at higher temperatures, resulting in higher flue gas temperatures. The higher flue gas temperatures impact the effectiveness and selection of a control strategy. Lignite has high and variable mercury content. For example, the mercury content of Gulf Coast lignite may be double that of North Dakota lignite, making targeted control levels more difficult to achieve (AEMS 2004, Shea 2005). High selenium levels may also impact the mercury emitted. Powder River Basin (PRB) coal has moderate levels of mercury. Numerous tests have shown that mercury capture at plants burning either Powder River Basin (PRB) coal or North Dakota lignite is similar, whether capture is achieved by existing air pollution controls, sorbent injection, or through halogen enhancement of fuel. Researchers believe this is due to the near-absence of chlorine in the flue gas (EPRI 2006).

During combustion, mercury is volatilized and converted to elemental mercury vapor in the high temperature region of the boiler. As the flue gas cools, the elemental mercury is converted, in part, to divalent, or particulate mercury. The reactions are limited and result in the mercury entering control devices as a combination of elemental, divalent, and particulate mercury. The percentage of each is dependent upon the properties of each type of coal. The majority of gaseous mercury in bituminous coal-fired boilers is divalent while the majority of gaseous mercury in subbituminous and lignite-fired boilers is elemental. Elemental mercury is more difficult to control as it is not very water-soluble and passes through most abatement devices.

Chlorine compounds in the flue gas decrease the amount of gaseous elemental mercury at the inlet to air control devices and increase the amount of divalent mercury. The chlorine content of the coal can affect the variation in the removal of mercury across both wet and dry scrubbers. Wet scrubbers remove divalent mercury with approximately 90 percent efficiency. They do not remove elemental mercury because that form is not highly water-soluble. Spray dryer absorbers remove both divalent and elemental mercury for bituminous flue gas but they only remove divalent mercury for low rank coal flue gas. Because of the higher levels of chlorine and divalent mercury in bituminous coals, mercury removal rates are higher. Removal rates for subbituminous and lignite coals are lower.

Multi-pollutant Control Technologies

Two main approaches exist to control mercury emissions. The first is to reduce mercury emissions using technologies, such as selective catalytic reduction and scrubbers, which are primarily designed to control nitrogen oxides (NO_x) and sulfur dioxide (SO₂), or fabric filters and electrostatic precipitators (ESP) designed to control particulate matter. These approaches that remove mercury along with other pollutants are known as multi-pollutant control technologies.

The second approach is to reduce mercury emissions using strategies designed specifically for that purpose, such as sorbents.

For the Clean Air Mercury Rule (CAMR), EPA is relying on mercury reductions as a “co-benefit” of NO_x and SO₂ controls from the Clean Air Interstate Rule (CAIR) to assist EGUs in meeting the Phase I CAMR budgets. Reduction of a pollutant other than the primary one for which a control device is designed is referred to as a “co-benefit.” EPA estimates that only three additional scrubbers will be installed in Texas to control SO₂ emissions during CAIR Phase II. However, traditional controls for NO_x and SO₂ will not be as effective for Gulf Coast lignite as they are for bituminous coals because of greater elemental mercury emissions from lignite and subbituminous coals versus divalent mercury emissions from eastern bituminous coals.

Abatement devices do not work equally well for all boilers even when firing configurations and abatement devices are similar (Table 5-1). When the same air pollution control configurations are used, mercury removal is higher for bituminous than for other coals. Mercury removal for a fabric filter is higher than for either cold-side ESPs or hot-side ESPs for both bituminous and subbituminous coal (EPA 2005a). Data for lignite were not available (EPA 2005b) but are assumed to follow the same trend. In several cases, there were high levels of variation in mercury removal over time.

Table 5-1. Mercury Removal Efficiencies

Control Technology	Typical Mercury Removal Efficiency, %*			
	Bituminous	Subbit.	Lignite	All Coals
Cold-Side ESP	30-40	0-20	0-10	0-40
Cold-Side ESP + Wet Scrubber	60-80	15-35	0-40	0-80
Dry Scrubber + Cold-Side ESP	35-50	10-35	0-10	0-50
Fabric Filter	40-90	20-75	0-10	0-90
Fabric Filter + Wet Scrubber	75-95	30-75	10-40	10-95
Dry Scrubber + Fabric Filter	65-95	20-40	0-20	0-95
Coal Cleaning	20-40	-	-	0-40

*Typical values based on EPA Notice of Data Availability, Information Collection Request (ICR) data, field tests, and observations. Some values are based on single data points and may not reflect removal for all plants.

Adapted from EERC (2006)

Scrubbers

Many Texas power plants have already installed scrubbers whose main purpose is to control SO₂ but have the added benefit of reducing mercury. Divalent mercury is generally water-soluble and can absorb in the water slurry in a wet scrubber system. However, the gaseous elemental mercury is insoluble and therefore does not absorb in these slurries. Boilers at sixteen Texas EGUs have wet scrubbers installed. Other devices such as selective catalytic reduction (SCR) used to control NO_x and fabric filters used to control particulate emissions also control mercury.

The oxidation to divalent mercury is significant (85 to 90 percent) for bituminous coal but not for subbituminous and no data are available for lignite (Srivastava 2006). EPA and Energy Information Administration (EIA) modeling indicate that coal plants using subbituminous or lignite coals will not be able to comply with a 90 percent removal requirement using SO₂, NO_x, or particulate matter control technologies alone (EIA 2005).

Selective Catalytic Reduction

The role that SCR plays in removing mercury remains uncertain. Evidence suggests that combining an SCR with a wet scrubber shows significant reductions in mercury for bituminous coals but the same has not yet been found for lower grade coals (EIA 2005). Short-term tests on PRB coal have indicated some overall mercury reductions. Research is ongoing with vendors changing SCR catalysts to improve oxidation and capture of mercury (Richardson 2005).

Electrostatic Precipitators and Fabric Filters

ESPs and fabric filters are installed on coal-fired boilers to control particulate matter, but also have a limited ability to control mercury. For lignite, mercury control may be limited due to the high proportions of elemental mercury and low levels of chlorine in the flue gas. Speciation of mercury in flue gases indicates elemental concentrations ranging from 56 to 96 percent and divalent ranging from 4 to 44 percent (Freeman 2004).

City Public Service (San Antonio, Texas) Spruce Station burns PRB coal and is equipped with a reverse jet fabric filter (baghouse) and a wet scrubber. Current studies indicate approximately 65 to 90 percent of elemental mercury is oxidized in the baghouse. Because it is not water-soluble, elemental mercury is more difficult to control than divalent. Conversion of elemental to divalent mercury improves overall capture efficiency. This conversion rate is higher than the typical rate of less than 25 percent experienced for most plants burning PRB coal (EIA 2005). The reason for the higher oxidation is not yet understood but is believed to be intrinsic to the design of the baghouse. Further study is necessary to assess the applicability to lignite and to other control configurations.

Coal Cleaning

Coal can be cleaned of contaminants by physical, thermal, or chemical methods prior to combustion. Coal cleaning has been used more extensively on higher rank eastern bituminous and anthracite coals to reduce ash and sulfur compounds. EPA estimates that 77 percent of the eastern and mid-western bituminous coals are cleaned prior to use in an electric facility (EPA 1997). Pressure and heat are used to increase thermal capacity, reduce sulfur content, and reduce ash. The coal is treated at around 450° F to drive off water and mercury. The water is condensed and passed through a carbon bed where the mercury is captured. Mercury reductions up to 70 percent have been achieved in some tests (Hasse 2005). An additional benefit of cleaned coal is removal of up to 30 percent sulfur and nitrogen from the pre-combusted coal (Richardson 2005). Some coal cleaning operations have resulted in instability of the coal's physical properties, but newer methods claim higher coal stability. This process may or may not be applicable to subbituminous and lignite coals.

Fuel Blending

Many Texas plants already blend lower rank lignite with higher thermal capacity coal, primarily subbituminous. Blending higher chlorine coal to increase oxidation of elemental mercury in flue gas improves mercury removal in the control systems. Reductions of up to 50 percent have been demonstrated at some sites with wet scrubbers (Richardson 2005). Tests in other states have indicated mercury reductions as high as 80 percent for units with spray dryer absorbers and fabric filters (Durham 2005). Some plants may require modifications to accommodate additional material handling for fuel blending.

Mercury-Specific Control Technologies

Several newer technologies are being studied to control mercury. The choice of control technologies used will be specific to each boiler type. Each boiler has its own configuration for fuel and furnace type, boiler operation, fly ash properties, and existing controls. While some boilers may provide significant mercury reductions in their existing configurations, others will require additional controls to meet their mercury budgets. The developing technologies fall into four main categories: adsorption, mercury oxidation, combustion control, and multi-pollutant control. These technologies are in development, but vendors are currently unable to offer unqualified performance guarantees. Although controls for lignite systems have been tested, the testing emphasis has been towards the more commonly combusted coals: bituminous and subbituminous.

Adsorption is a separation process by which mercury in the flue gas is transferred to the surface of a solid adsorbent. The performance of the mercury adsorption depends upon many parameters including contact time between the flue gas and sorbent, the temperature of the flue gas and the type of sorbent. A limited number of full-scale trials up to two months in duration have been carried out that represent short-term continuous operation for some plant configurations. The potential long-term impacts, such as corrosion, are not known.

Oxidation technologies are processes that modify the chemical form of mercury from elemental to divalent to enhance removal across existing control devices. Combustion control involves changing the operation parameters of the boiler to reduce mercury.

Activated Carbon Injection Based Technology

Activated carbon injection (ACI) is the most mature adsorption technology. Vendors assert that ACI has the potential to achieve up to 90 percent control for some types of coal and boiler configurations under some conditions. However, guarantees of control at this rate have not yet been made. At some sites, where the contact time between the carbon and gas is short, the total mercury removal may be only 50 percent (Richardson 2005). Activated carbon performance tends to be poorer in flue gases from lower rank coals with low chlorine content, such as lignite and PRB coal. Testing indicates that sorbent type and properties, gas-phase mercury species, temperature of the flue gas, concentration of acid gases, overall residence time of the sorbent, and dispersion of the sorbent in the flue gas also affect ACI performance (EPA 2005a).

There may be upper limits on the control efficiency achieved with carbon injection. In the Wisconsin Energy Corporation Pleasant Prairie plant, mercury control efficiency of approximately 60 percent was achieved. Additional carbon injection resulted in only minimal improvement. The upper limit may be caused by the lower levels of free chlorine in the flue gas from the subbituminous coal combusted (Srivastava 2006). Increased injection also increases the cost of carbon itself as well as additional collection and disposal processes.

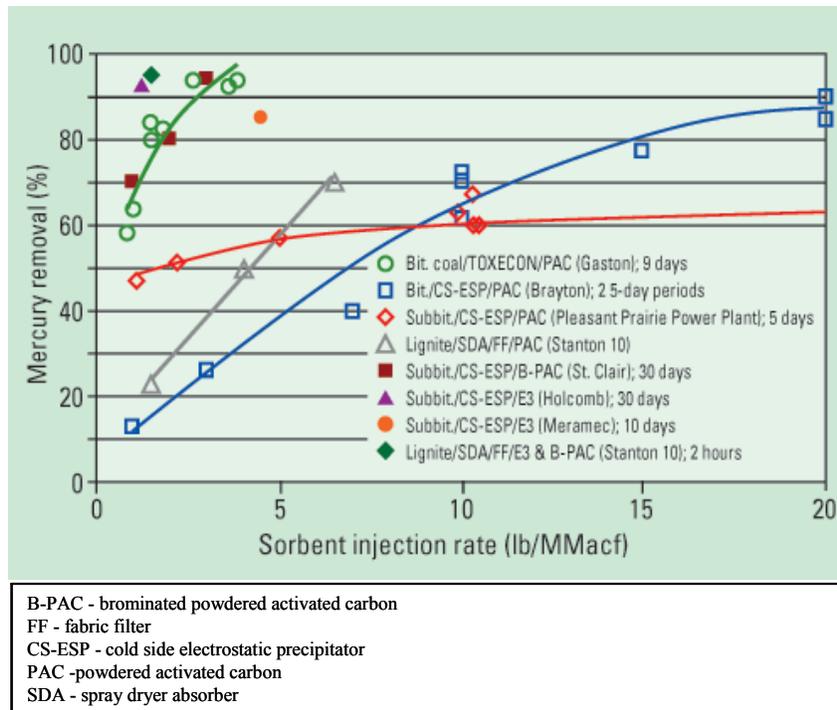
Increasing carbon injection rates results in higher mercury control but changes the composition of fly ash and may decrease its usability in concrete, resulting in increased landfill disposal. Injection of carbon upstream of a baghouse yields higher mercury removal than injection upstream of an ESP, but increases carbon contamination of the fly ash. Approaches are being tested that limit the amount of carbon in the fly ash, such as injection of carbon after a baghouse. These include the Toxecon I and Toxecon II processes. In the Toxecon I process, activated carbon is injected into the ESP after the bulk of the ash has been collected by the ESP but before the baghouse. Toxecon II also preserves the composition of fly ash by delaying the injection of carbon until after the front end of the ESP has collected the bulk of the fly ash (Richardson 2005). Only the ash collected in the back end of the ESP contains activated carbon. A Toxecon system was tested at TXU's Big Brown unit, and testing was completed in March 2006. Results are not yet available (Pavlish 2006). For one plant using Toxecon, the DOE's National Energy Technology Laboratory has estimated the cost of adding an ACI system, complete with a new fabric filter, at \$126 per kilowatt (DOE/NETL 2006).

ACI may be used either in conjunction with existing emissions control equipment or with the addition of a fabric filter. However, small-scale ESPs may be overloaded by additional particulate matter in the flue gas (Richardson 2005). A fabric filter provides better contact than an ESP between the sorbent and the flue gas and results in higher mercury removal rates at lower sorbent injection rates. In some cases, carbon injection without a downstream fabric filter may be limited in its mercury removal rates regardless of the amount of activated carbon injected (EPA 2005a).

Halogenated Activated Carbon Injection

The addition of halogens such as chlorine and bromine to the activated carbon may improve its performance in low chloride flue gases. Several full-scale tests using brominated activated carbons show increased mercury control over non-brominated carbon. For example, tests on North Dakota lignite have indicated mercury control around 90 percent at lower brominated sorbent injection rates. These mercury removal rates are similar to eastern bituminous coals with a Toxecon system (Srivastava 2006). Halogenated additives have not been tested long enough to identify potential corrosion and other plant impacts. A typical graph of carbon injection performance on mercury removal is shown in Figure 5-2. Increasing carbon injection improves mercury removal with some tests indicating an upper limit of removal. The brominated carbons have higher mercury removal rates at lower sorbent injection rates.

Figure 5-2. Performance of Halogenated Activated Carbon Compared with Standard Carbon



Source: Srivastava 2006

Mercury Capture by Adsorption Process (MerCAP)

Parallel plates in the flue ducts are coated with sorbent (such as gold or silver) in a non-carbon-based fixed sorbent process. The process is best for back end polishing of flue gases where the SO₂ was removed in a scrubber. The process recovers mercury by adsorbing mercury onto the plates. The plates are kept in service until the mercury removal falls below a target value. The plates are then removed and regenerated to extract the mercury, then restored to service. Average mercury removal rates can vary from 30 to 35 percent on a boiler burning PRB coal. However, regeneration of acid-treated gold plates may not return the plates to their original effectiveness (EIA 2005). Short-term tests with MerCAP and a wet scrubber have been completed at a power plant firing Gulf Coast lignite; however, results are currently unavailable (Richardson 2005).

Low Temperature Catalyst Oxidation

In plants lacking SCR, installation of a catalyst bed in the low dust region after the baghouse can oxidize elemental mercury. Where the flue gas comes into contact with the catalyst surface, elemental mercury is converted to the divalent form for capture in a scrubber. Pilot tests with six-month durations have been completed with overall mercury removal rates of 60 to 88 percent for lignite fuel and 70 to 90 percent for PRB coal. A regeneration process is required to restore catalyst function after its performance falls below a target value. Full-scale tests with two-year durations are planned for 2007 (Richardson 2006).

Plasma Enhanced ESP (PEESP)

A retrofit has been developed for modifying an ESP to improve mercury removal. Steam and oxygen droplets are injected, become electrically charged, and travel to the ESP plates where they absorb and react with elemental mercury to form divalent mercury. Laboratory scale tests have indicated up to 79 percent removal of elemental mercury (Richardson 2005). Full-scale testing would be required to confirm these results.

Chemical Addition (Halogen) for Oxidation

Another option is to boost the halogen content of the gases by directly adding halogenated species (e.g. bromide or chloride) into the furnace or flue gas stream to improve oxidation of elemental mercury. Most of the chemicals used are common salts. Full-scale tests up to two weeks in duration have been completed with overall mercury removal in the 50 to 80 percent range for a PRB/lignite blend. Long-term potential impacts of corrosion due to increased chlorides in the scrubber are not yet known.

Testing at Texas plants has been summarized by URS and is shown in Table 5-2.

Table 5-2. Mercury Control Technology Testing at Texas Plants

Mercury Control Technology	Fuel Type	Plant Config.	Overall Mercury Removal	Test Scale	Test Duration
Activated Carbon Injection	PRB/Lignite	ESP-Baghouse	To Be Determined: on-going test	Full-scale	1 month
		ESP-Scrubber	TBD: Jan. 2007	Full-scale	2 months
		Toxecon II	TBD: Jan. 2007	Full-scale	1 week
	Lignite	ESP-Scrubber	30 – 60% *	Slipstream	2 – 4 hours
Chemical Addition (Halogen)	PRB	ESP-Scrubber	40 – 65%	Full-scale	24 – 48 hours
	PRB/Lignite	ESP-Scrubber	50 – 80%	Full-scale	2 weeks
Low-Temperature Catalyst Oxidation	Lignite	ESP-Scrubber	60 – 80% **	Pilot	6 months
	PRB	ESP-Scrubber	70 – 90% **	Pilot	6 months
	PRB	ESP-Scrubber	TBD: 2007 test	Full-scale	2 years
SCR Catalyst	PRB	Baghouse-Scrubber	SCR impact <15% Mercury Removal	Full-scale	Short-term evaluation

* Multiple plants; results indicative of short-term data collected across slipstream fixed bed or particulate control device.

** Projected removal based on pilot-scale test data

Adapted from: Richardson 2006

Issues

Lack of full-scale and long-term testing data for all mercury-specific control devices, particularly for lignite-fired boilers, is an important concern. For example, substantial data for activated carbon in municipal solid waste combustors exist, but these systems, with typically lower flue gas temperatures, are not as complex as utility boilers (EPA 1997). Results from activated carbon injection from utility boilers vary, even on systems with similar design.

The increase in particulate matter from a carbon injection system may be less than expected from natural variations in the coal supply. EPA's calculations indicate that the increase in particulate matter to the ESP or baghouse would be about four percent or less with an injection rate of ten pounds per million actual cubic feet (lb/MMacf) of flue gas. Halogenated sorbents will likely be injected at about half that rate (EPA 2005b). Potential loss of fly ash sales, combined with the costs associated with the resulting waste management, remain issues for facilities considering ACI for mercury control.

While EPA assumed that a sufficient supply of activated carbon would become available with increased demand, they recognized that availability of sufficient boilermaker labor may be a limiting factor in timely installation of all controls. EPA states that activated carbon and enhanced multi-pollutant controls for SO₂ and NO_x have been demonstrated also to remove mercury effectively and are expected to be available after 2010 for commercial application on most or all key combinations of coal rank and control technology to provide mercury removal rates between 60 and 90 percent. Halogenated sorbents and other chemical injection approaches may also be available after 2010 for commercial application on most, if not all, key combinations of coal rank and control technology but will provide mercury removal between 90 and 95 percent. EPA further maintains the potential availability of these controls provides justification for a 2018 mercury cap at a level below what is projected to be achieved from SO₂ and NO_x based controls alone. Although mercury controls will be available for use on some scale prior to 2018, EPA does not believe they can be installed and operated on a national scale prior to that date. EPA maintains that the cap-and-trade approach selected for the final regulation is the best method for encouraging the continued development of these technologies (EPA 2006).

Time Necessary for Control Installation

The time necessary to install control devices in existing EGUs depends upon the complexity and scale of retrofit required. A boiler could be retrofitted with SCR, scrubber, particulate matter controls, and mercury controls in approximately three years depending on vendor availability (EPA 2005b). An ACI system could be installed on a new unit in approximately 15 months including initial engineering review, design, installation, and equipment testing. Retrofitting an existing unit may take approximately 26 months (EPA 2005b). As stated previously, EPA recognized that availability of sufficient boilermaker labor may be a limiting factor in timely installation of all controls (EPA 2005c).

Emissions Limitations for New Sources

New EGUs (units that were constructed, modified or reconstructed commencing after Jan 30, 2004) will be subject to new emissions limitations and cannot contribute to an exceedance of the

Texas mercury cap. EPA re-examined the 1999 ICR data and examined the mercury limits in recently issued permits. In their June 9, 2006, revision EPA announced the following New Source Performance Standards (NSPS) mercury limits for new coal-fired power units (EPA 2006):

Bituminous units): 20×10^{-6} lb/MWh (or 0.020 lb/GWh output)

Subbituminous units (areas with greater than 25 inches/year precipitation): 66×10^{-6} lb/MWh (or 0.066 lb/GWh output)

Subbituminous units (areas with less than or equal to 25 inches/year precipitation): 97×10^{-6} lb/MWh (or 0.097 lb/GWh output)

Lignite Units: 175×10^{-6} lb/MWh (or 0.175 lb/GWh output)

In addition to NSPS, new sources in Texas are subject to best available control technology (BACT). The TCEQ recently issued two air permits for subbituminous coal-fired EGUs with mercury BACT limits of 20×10^{-6} lb/MWh output, 70 percent lower than the corresponding NSPS.

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Chapter 6

Costs of Additional Controls

Cost of Controls to Plant Owners

Costs to comply with the Clean Air Mercury Rule (CAMR) in Texas include costs of installing mercury monitors; costs of complying with CAMR Phase I, which EPA has asserted are negligible due to “co-benefits” of the Clean Air Interstate Rule (CAIR); and costs of complying with CAMR Phase II using mercury-specific controls or purchasing allowances. Based on extensive modeling, EPA maintains that, “no coal-fired generation is projected to be uneconomic to maintain under CAMR” (EPA 2005a).

CAMR requires sources to install and operate monitoring systems. Sources may choose to monitor mercury using a continuous emissions monitoring system (CEMS) or sorbent trap monitor. For a coal-fired unit to install a mercury CEMS, EPA estimates capital costs to range from \$95,000 to \$135,000 per electric generating unit (EGU), with annual operating and maintenance costs of \$45,000 to \$65,000. For sorbent trap monitors, EPA estimates the capital cost to be \$18,000 per EGU, with annual operating, maintenance, and laboratory costs of \$65,000 to \$125,000. Based on these estimates, total monitoring costs in Texas could range from about \$650,000 to \$4.9 million for installation, depending on type of monitor selected, with corresponding annual operation and maintenance costs of \$1.6 to \$4.5 million (EPA 2004).

Under the cap-and-trade program sources have the choice of controlling emissions or purchasing additional allowances to meet their allowance obligations. Costs may vary substantially depending on whether a source chooses to control emissions or purchase allowances for compliance. Under CAMR, EPA is relying on mercury “co-benefit” reductions from CAIR to assist sources in meeting the Phase I CAMR budgets. Based on fiscal information provided in the docket for CAIR, EPA estimates that only three additional scrubbers will be installed in Texas to control SO₂ emissions during CAIR Phase II. EPA estimates SO₂ control costs to range from \$400 to \$800 per ton to achieve 30 to 40 percent mercury removal efficiency in subbituminous coal-fired units. No corresponding estimate for lignite-fired units is available (EPA 2005c).

To comply with CAMR Phase II, coal-burning EGUs may choose to invest in controls specifically designed to capture mercury, such as sorbent injection, or they may attempt to purchase allowances to meet their caps, presuming sufficient allowances are available. Costs for emerging mercury control technologies are largely undetermined.

EPA performed extensive computer modeling using the Integrated Planning Model (IPM) to forecast outcomes of mercury control and trading. IPM predicts that with currently available controls and no improvements made over time in performance, a pound of mercury allowances would cost roughly \$23,200 (\$1,500 per ounce) in 2010 (expressed in 1999 dollars), \$30,100 per pound (\$1,900 per ounce) in 2015, and \$39,000 per pound (\$2,400 per ounce) in 2020. With the assumption that mercury capture efficiencies improve over time, the cost estimates dropped considerably: \$11,800 per pound (\$700 per ounce) in 2010, \$15,300 per pound (\$1,000 per ounce) in 2015, and \$19,900 per pound (\$1,200 ounce) in 2020 (EPA 2005a). Based on EPA

estimates of mercury control costs in 2020, Texas could face costs ranging from \$112 million to \$220 million, using either control technologies or allowance purchases, to move from compliance with the CAMR Phase I cap (4.656 tons) to compliance with the CAMR Phase II cap (1.838 tons).

Preliminary cost estimates from pilot scale testing are available for North Dakota lignite, Powder River Basin subbituminous coal, and bituminous coal. However, these estimates were not generated using a general equilibrium economic model that considers changes in fuels or other market responses, as EPA estimates were. Further, sponsors strongly caution about generalizing results for specific plants, configurations, coals, or other characteristics, to those that have not been directly studied. Because of these, and other, uncertainties, interpretation of preliminary findings must be done cautiously: results are substantially dependent on the unique operating characteristics of the subject facility, existing pollution controls, properties of the coal being burned, target mercury removal rate, and other factors. Table 6-1 illustrates this variability with cost data recently generated by URS Corporation for mercury-specific control approaches.

Table 6-1. Mercury Control Cost Estimates at a PRB-Fired Plant*

Mercury Control Technology	Target Removal Percentage	Capital Costs	Annual Operation & Maintenance
Chemical Addition	45%	\$513,000	\$479,000
Carbon Injection	45%	\$513,000	\$310,000
Carbon Injection	80%	\$513,000	\$620,000
Toxecon	80%	\$17,100,000	\$510,000
Toxecon	90%	\$17,100,000	\$659,000

*The average coal-fired boiler in Texas is around 600 megawatt (MW) These results were obtained at a 100-150 MW Powder River Basin (PRB)-Fired Plant with an electrostatic precipitator (ESP).

Modified from Richardson 2006

Substantial uncertainty surrounds existing cost estimates for mercury-specific control. Estimates presented above were generated using data from pilot testing of relatively short durations. Few, if any, approaches have been demonstrated and verified in actual operation over extended durations in commercial EGUs. While a number of pilot tests have been performed, these tests generally last for short periods (e.g., 30 days), are conducted during off-peak periods, and are used to provide guidance on which coals and generating systems respond best to certain technologies. Many promising approaches remain to be tested, having been identified for future scrutiny in very short term testing in laboratory environments. The United States Department of Energy (DOE) and its partners are currently exploring numerous technologies at various stages of development.

Another major source of uncertainty in these estimates is the effect of improvements in technologies over time. EPA ran the IPM model with the assumption of no improvement in mercury control technology, to generate what it considers to be conservative estimates. Sensitivity analyses were conducted to estimate the impact of changing this assumption, i.e., enabling the IPM model to forecast improvements in technologies. As EPA states in the Regulatory Impact Analysis (RIA), “Mercury emissions control is a fast moving area with new developments nearly monthly. Actual costs may be lower than those presented since modeling assumes no improvements in the cost of mercury control technology, while in reality, control costs are expected to improve over time” (EPA 2005a).

Participants in the CAMR trading system may not know the decisions and actions of other participants for many years. They must estimate future costs under conditions of uncertainty. If the assessments regarding whether or not to invest in controls are incorrect, participants could expend more than necessary to achieve compliance (EPA 2005a).

Despite these uncertainties, with appropriate caution in their use and interpretation, the estimates provided here may offer some guidance as to the magnitude of control costs that might be expected for Texas EGUs, as well as the relative difference in costs for different target rates of control for a particular coal type or plant configuration.

Cost of Controls to Consumers

The market for electricity in Texas is substantially deregulated. Deregulated power suppliers pursue strategies that minimize costs to remain competitive. Expenditures required to comply with CAMR must be recouped in product sales; therefore, electricity consumers ultimately pay the expense of pollution control.

Data from the United States Energy Information Administration (EIA) indicate that, of the 106.0 million tons of coal used in Texas in 2004, 96 percent was burned to generate electricity (EIA 2004). EIA also reported that residential electricity consumers in Texas consumed 121,355 gigawatt-hours (GWh) of electricity in 2003 (EIA 2006a), and spent \$11.1 billion on electricity (EIA 2006b).

EPA’s IPM forecasts that retail electricity prices are likely to fall from 2000 to 2020, whether or not CAMR is implemented, due to projected decreases in energy prices, fuel switching, and other responses. Whether or not these predictions hold true, the model predicts prices will drop less under CAMR than in its absence. Prices in the Electric Reliability Council of Texas region are forecast to drop from 6.51 cents per kilowatt hour (kWh) to 6.34 cents, but they are forecast to fall to 6.26 cents without CAMR (EPA 2005a). Other regions in Texas were predicted to experience similar decreases. Based on these estimates, a typical household using one thousand kWh of electricity per month would see an overall decrease of \$1.70 in its monthly electric bill with CAMR, as opposed to an overall decrease of \$2.50 without CAMR. Therefore, the net increase in electricity costs due to CAMR is forecast to be about 80¢ per month for the typical household in Texas.

For comparison, a preliminary DOE report on the economics of mercury control technologies estimated that a target mercury capture rate of 50 percent for subbituminous coal would translate into a possible range of increases in electricity costs of 86¢ to \$1.75 per month for the typical household. A higher mercury capture rate of 90 percent on PRB coal was estimated to increase electricity costs by \$1.09 to \$2.37 per month. Monthly electricity costs for lignite were estimated to be between \$2.57 and \$3.50 per month for 50 percent capture, and between \$2.77 and \$3.92 per month for 70 percent capture (DOE/NETL 2006). However, these results were generated using North Dakota lignite and may or may not be representative of costs experienced by customers consuming electricity generated at EGUs burning Gulf Coast lignite.

DOE/NETL based their cost analysis on the EPA RIA. EPA has recognized key uncertainties in their benefit-cost analysis of the final CAMR program. They include: “[their] inability to quantify potentially significant benefit categories; uncertainties in population growth and baseline incidence rates; uncertainties in projection of emissions inventories and air quality into the future; uncertainty in the estimated relationships of health and welfare effects to change in pollutant concentrations; uncertainties in exposure estimation; and uncertainties associated with the effect of potential future actions to limit emissions” (EPA 2005b).

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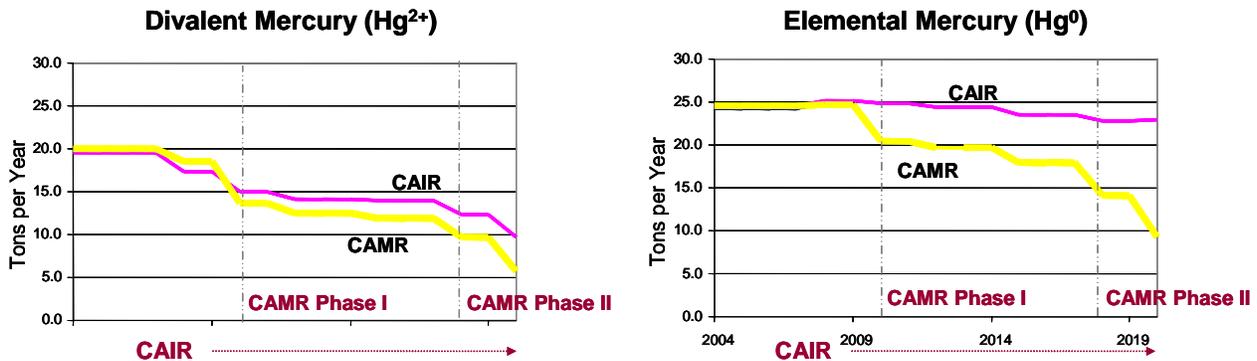
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Chapter 7

Fiscal Impacts of Mercury Emissions

House Bill 2481 instructs TCEQ to examine the fiscal impact on the state of higher levels of mercury emissions between 2005 and 2018. TCEQ interprets this directive to mean that the commission will examine the impact of mercury emissions between 2005 and 2018 that could be higher than they would be if more strict emissions reductions were implemented before 2018. Fiscal concerns regarding potential increased mercury emissions include health impacts on children, impacts on the recreational and economic value of fishing, and potential impacts on the coal mining industry in Texas. Risk is defined by exposure. Therefore, even if emissions increase, risk remains unchanged if people are not exposed. As discussed previously, divalent mercury is the primary form associated with deposition and bioaccumulation. While CAMR will reduce overall mercury emissions, it primarily targets removal of elemental mercury (Figure 7-1). As a result, early introduction of CAMR would have only negligible effects on deposition and bioaccumulation that are linked to health and recreation.

Figure 7-1. CAIR and CAMR Control Efficiencies for Divalent Versus Elemental Mercury



Adapted from Levin 2006

Impacts on Exposed Individuals

While a number of possible fiscal impacts of mercury contamination of fish exist, EPA reports economic values for only one: the value of lost wages attributable to lower cognitive functioning of adults who were exposed to mercury as fetuses through their mothers' ingestion of fish containing mercury. Expressed differently, when mercury-exposed fetuses grow into adults, they are predicted to suffer cognitive deficits that translate into lower wages over their lifetimes than they would have earned, on average, had they not been exposed. Such predictions are based on estimates of cognitive deficits due to mercury exposure, coupled with correlations between measures of intelligence, such as intelligence quotient (IQ), and earnings. However, as EPA notes, "evidence directly linking IQ and [methylmercury] exposure" is limited (EPA 2005).

Although the link between methylmercury exposure and IQ loss is limited, EPA used estimates of mercury exposure and resulting IQ decrements to estimate net present value in 2001 of total

foregone earnings averaging \$454 to \$557 per child in Texas exposed prenatally to mercury from all sources. EPA estimates that implementation of CAIR alone will increase income by no more than \$35 to \$54 per child, relative to the 2001 base case estimate. CAMR is projected to contribute further, but only marginally: by no more than \$3 per child. If complete elimination of utility-attributable mercury emissions were required, net earnings losses would not fall to zero, but would still range from roughly \$427 to \$514 due to other sources of mercury. (EPA 2005).

Impacts on Recreation

Mercury contamination of fish can have fiscal impacts beyond those associated with prenatal exposure. Angler avoidance of recreational activities on waters with advisories could impact the recreational angling economy. Over 17 million people visited Texas's 668,000 acres of parks in 2003, generating nearly \$13.4 billion in economic activity (DOI/FWS 2003). Many more thousands of acres of private recreational land are maintained for fishing, hunting, hiking, mountain biking, and other outdoor pursuits. The Texas Department of Parks and Wildlife licensed over 1.2 million anglers in 2005, and these anglers are estimated to have spent 34.1 million person-days fishing and over \$2.1 billion on travel and supplies for recreational fishing trips that year (DOI/FWS 2003). For comparison, using different methods and sources, EPA estimated 1.8 million freshwater anglers in Texas who spent a total of 28 million person-days fishing in 2001 (EPA 2005).

Twelve mercury fish consumption advisories have been issued for Texas water bodies since the state began issuing such advisories in 1988 (Figure 7-2). The Texas Department of State Health Services considers issuing fish-specific mercury advisories if testing indicates mercury concentrations at or above 0.7 mg/kg. Nine of these advisories pertain to freshwater lakes totaling roughly 363,000 acres of surface water, or approximately one in five lake acres in the state. The balance of advisories covers one 40-mile river segment, one 17-mile estuary, and one advisory for the entire Texas Gulf Coast. Of the lake acres covered by advisories, over half are contained in Toledo Bend Reservoir, and another third are in Sam Rayburn Reservoir. Both of these advisories were issued in 1995.

Figure 7-2. Texas Mercury Advisories for 2005



While mercury fish consumption advisories have garnered much public attention, mercury impairments accounted for only three percent of impairments of Texas water bodies, as reported in the 2004 Texas Water Quality Inventory 303(d) List (TCEQ 2006). Other impairments included pathogens, low oxygen, salinity, and other contaminants (dioxins, poly-chlorinated biphenyls, other metals, sulfates, pesticides, nitrates, and others). Despite its low incidence, however, mercury impairments represent the largest number of acres for which impairments have been recorded. Texas mercury advisories are limited to consumption of specific aquatic life and do not include “recreational” advisories, such as swimming bans.

Determining the impact of mercury fish consumption advisories on angling behavior, and therefore the value of angling, is a complex endeavor. A Maine study found that while roughly two-thirds of anglers in the state were aware of mercury advisories on the water bodies they fished, fewer than one in four altered their fishing behavior (fished other water bodies, fished less often, or limited fish consumption) in response to this knowledge (MacDonald 1997). Although it might be expected that Texas anglers would respond similarly, reliable estimates of economic losses to Texas anglers, and the impact to tourism, due to mercury advisories, are unavailable.

Impacts on Coal Mining

Coal mining sustains the economies of many small communities in Texas. In 2003, the United States Census Bureau estimated roughly 3,700 miners were employed in 13 mines across 11 counties in Texas, generating \$166.2 million in payroll income (DOC/BOC 2003). Besides those directly involved in mining, the mining industry also benefits those involved in follow-on industries, such as support services, truck drivers, equipment suppliers, and even restaurants. The United States Energy Information Administration reported that Texas mines extracted 45,939 tons of coal in 2005 (EIA 2006), which, at market rates, would have been valued at roughly \$600 million.

Fuel switching away from coal due to increased regulatory burden is possible, though EPA has forecast that consumption of coal for electric generating will increase between 2000 and 2020 (EPA 2005). More stringent mercury emissions regulations could lead to fuel switching among types of coal, negatively impacting lower rank Gulf Coast lignite. Forecasts of future impacts on coal consumption patterns are inconclusive.

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Glossary

Allowance - an authorization to emit a fixed amount of a pollutant

Allowance trading - buying or selling of allowances on the open market

Amino acid - the building blocks of proteins, a simple class of organic compounds containing carbon, oxygen, hydrogen, nitrogen, and sometimes, sulfur

Autism - a brain disorder affecting communication, social interaction, and creativity or imagination that begins in early childhood and persists throughout adulthood

Benchmark dose - the dose causing a predetermined change in response

Benchmark dose lower confidence limit - the lower statistical confidence level of the benchmark dose

Bioaccumulate - the accumulation of a chemical or other substance in various tissues of a living organism

Biomass - a common term used to represent vegetation, as in “biomass burning”

Boston Naming Test - a test, originally designed for the elderly, that assesses word retrieval capacity and naming deficits in learning disabled children and brain-injured adults using 60 line drawings of common objects. Subjects are presented with drawings of objects and are then asked to name them. If a correct response is not produced within 20 seconds, a clue is given describing the type of object represented. If the subject remains unable to identify the object, the first two letters in the object name are given. The test is scored upon the number of correct answers given with and without clues.

Compliance - at the end of each compliance period, each source must own at least as many allowances as its emissions

Deposition - transport of a gaseous or particulate air contaminant from the atmosphere to the soil, water, and vegetation. Dry deposition is deposition that occurs in the absence of precipitation. Wet deposition occurs with precipitation scavenging.

Dissolved organic carbon - the concentration of organic material in a defined freshwater sample that passes through a 0.45 mm filter

Divalent mercury (Hg^{2+} or Hg^{II}) - ionic form of mercury containing two fewer electrons than elemental mercury

Electric Generating Unit (EGU) under CAMR - coal-fired boilers or combustion turbines serving a generator with a nameplate capacity of more than 25 megawatt electrical (MWe) producing electricity for sale. CAMR also applies to co-generation units serving at any time a generator with nameplate capacity of more than 25 MWe and supplying in any calendar year more than one-third of the unit's potential electric output capacity or 219,000 megawatt hours (MWh), whichever is greater, to any utility power distribution system for sale.

Electric Power Research Institute (EPRI) - research group for power production, transmission, and distribution operators

Elemental mercury - a shiny, silver-white, odorless liquid element. Mercury is the only common metal existing as a liquid at room temperature. Elemental mercury vaporizes at 357°C.

Emissions Cap - a limit on the total amount of pollution that can be emitted (released) from all regulated sources (e.g., power plants); the cap is set lower than historical emissions to cause reductions in emissions

Epidemiology - study of the causes, distribution, and control of a disease in a population

ESP, cold-side - electrostatic precipitator located after the air pre-heater and operating in a temperature range of 130-180°C

ESP, hot-side - electrostatic precipitator located before the air pre-heater where the operating temperature is in a range of 300-450°C

Estuarine - an area where a river empties into an ocean resulting in a mixture of salt water and fresh water

Flexibility - as related to the Clean Air Mercury (CAMR) or Clean Air Interstate Rules (CAIR), sources can choose how to reduce emissions, including whether to buy additional allowances from other sources that reduce emissions.

Food chain - a chain of food energy transfer in which each organism is eaten, in turn, by another organism

Food web - interrelated food chains within an ecological community

Gigawatt - one billion watts or one million kilowatts

Half-life - the time required for half the quantity of a substance deposited in a living organism to be metabolized or eliminated by normal biological processes

Hydrologic Unit Codes - a means of identifying the drainage basins in the United States in a nested arrangement from largest to smallest. A drainage basin is an area or region of land that

catches precipitation falling within that area, and funnels it to a particular creek, stream, river, or other body of water until the water drains into an ocean.

Integrated Planning Model (IPM) - a computer model developed by the United States Environmental Protection Agency. It is a multi-regional, dynamic, deterministic linear programming model of the United States electric power sector. The model generates forecasts of least cost capacity expansion, electricity dispatch, and emission control strategies to meet energy demand and environmental, transmission, dispatch, and reliability constraints. IPM can be used to evaluate the cost and emissions impacts of proposed policies to limit emissions of sulfur dioxide (SO₂), nitrogen oxides (NO_x), carbon dioxide (CO₂), and mercury (Hg) from the electric power sector. For more information, see “Documentation of EPA Modeling Applications (V.2.1) Using the Integrated Planning Model,” U.S. Environmental Protection Agency, EPA 430/R-02-004 (March 2002).

Kilowatt (kW) - one-thousand Watts; a unit of power, or energy per unit of time

Kilowatt-hour (kWh) - one kilowatt of power provided for one hour

Ion - an atom, group of atoms, or subatomic particle with a net electrical charge

Measurement - accurate tracking of all emissions

Megawatt (MW) - one million watts or one-thousand kilowatts

Megawatt-hour (MWh)-one megawatt of power provided for one hour

Methylmercury - a methyl group bonded to a single mercury atom. This compound is primarily formed from divalent mercury in the environment by sulfate-reducing bacteria.

Methyl group (CH₃) - an organic compound derived from methane by the removal of one hydrogen atom

Mill - one-tenth of a penny (0.1¢). A standard unit for expressing costs in the electric industry.

Modeled Grid Cells - three-dimensional grid system that can consist of thousands of individual grid cells usually used in complex air quality models of the atmosphere. Values of pollutant emissions, meteorological parameters, and other information are input to the grid cells by the modeler so that the model can be run to simulate atmospheric processes. The output of the model can be designed so that values of the pollutant of interest are available for each grid cell (e.g., mercury concentration or deposition).

Organic - a class of chemical compounds containing at least one carbon atom

Oxidation - a chemical reaction in which electrons are added to an atom

pH - a measure of the acidity or alkalinity of a solution

Reference Dose - an estimate of a daily oral exposure to the human population, including sensitive subgroups, that is likely to be without an appreciable risk of deleterious effects over a lifetime

Transpiration - the passage of vapor from a living body through a membrane or pore; e.g., the transpiration of elemental mercury vapor from vegetation

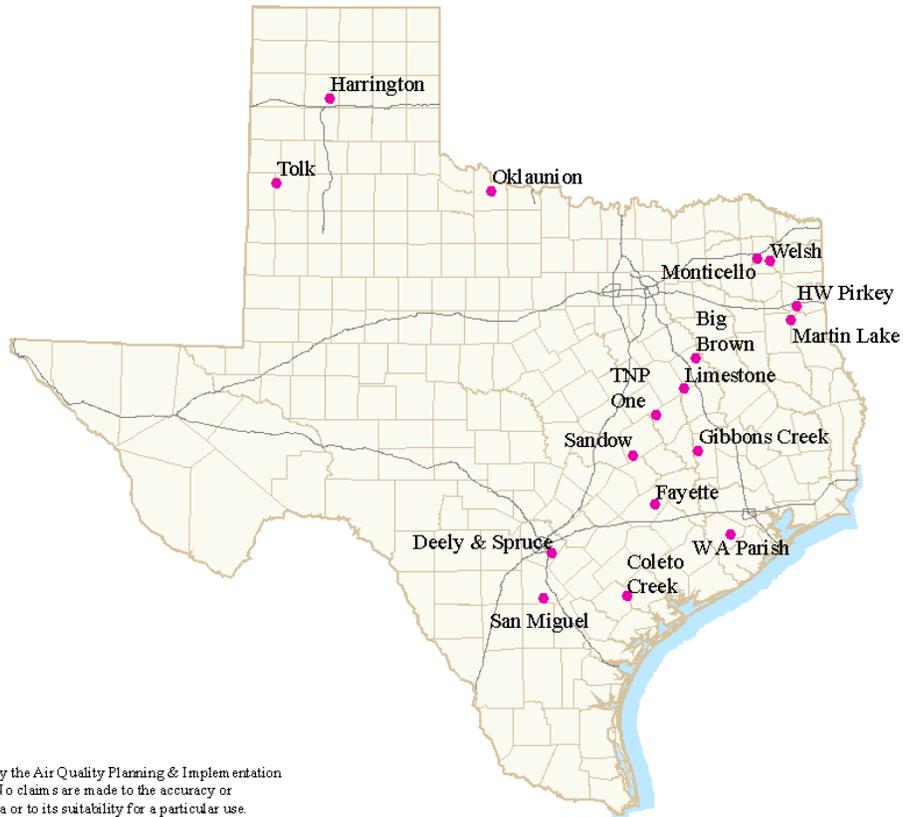
Water Column - the volume of water between the surface and bottom of a water body

Watershed - a region draining into a river, river system, or other body of water

Utility Hot Spot - As related to the Clean Air Mercury Rule (CAMR), a utility-attributable increase in fish tissue methylmercury concentration that exceeds EPA's threshold of 0.3 mg/kg.

Appendix

Coal-Fired Power Plants in Texas Participating in the Clean Air Mercury Rule Program (2006)



This map was created by the Air Quality Planning & Implementation Division of the TCEQ. No claims are made to the accuracy or completeness of the data or to its suitability for a particular use. For information concerning this map, please contact Shannon Herritt, sherrit@tceq.state.tx.us July 19, 2006

Existing Sulfur Dioxide (SO₂) Scrubber and Particulate Control Devices at Texas Clean Air Mercury Rule Electric Generating Units (2006)

Plant Name	Unit ID	Coal type	SO ₂ Control	Particulate Matter Control Type
Big Brown	1	Lignite		Cold-side ESP+ Fabric filter
Big Brown	2	Lignite		Cold-side ESP+ Fabric filter
Coletto Creek	1	Bituminous		Hot-side ESP
Gibbons Creek	1	Subbituminous	Wet Scrubber	Cold-side ESP
Harrington Station	061B	Subbituminous		Cold-side ESP
Harrington Station	062B	Subbituminous		Fabric filter
Harrington Station	063B	Subbituminous		Fabric filter
J K Spruce	BLR1	Subbituminous	Wet Scrubber	Fabric filter
J T Deely	1	Subbituminous		Cold-side ESP
J T Deely	2	Subbituminous		Cold-side ESP
Limestone	LIM1	Lignite	Wet Scrubber	Cold-side ESP
Limestone	LIM2	Lignite	Wet Scrubber	Cold-side ESP
Martin Lake	1	Lignite	Wet Scrubber	Cold-side ESP
Martin Lake	2	Lignite	Wet Scrubber	Cold-side ESP
Martin Lake	3	Lignite	Wet Scrubber	Cold-side ESP
Monticello	1	Lignite		Cold-side ESP+ Fabric filter
Monticello	2	Lignite		Cold-side ESP+ Fabric filter
Monticello	3	Lignite	Wet Scrubber	Cold-side ESP
Oklauion	1	Subbituminous	Wet Scrubber	Cold-side ESP
Pirkey	1	Lignite	Wet Scrubber	Cold-side ESP
Fayette	1	Subbituminous		Cold-side ESP
Fayette	2	Subbituminous		Cold-side ESP
Fayette	3	Subbituminous	Wet Scrubber	Cold-side ESP
San Miguel	SM-1	Lignite	Wet Scrubber	Cold-side ESP
Sandow	4	Lignite	Wet Scrubber	Cold-side ESP
TNP One	U1	Lignite	Wet Scrubber	Fabric filter
TNP One	U2	Lignite	Wet Scrubber	Fabric filter
Tolk Station	171B	Subbituminous		Fabric filter
Tolk Station	172B	Subbituminous		Fabric filter
W A Parish	WAP5	Subbituminous		Fabric filter
W A Parish	WAP6	Subbituminous		Fabric filter
W A Parish	WAP7	Subbituminous		Fabric filter
W A Parish	WAP8	Subbituminous	Wet Scrubber	Fabric filter
Welsh	1	Subbituminous		Hot-side ESP
Welsh	2	Subbituminous		Hot-side ESP
Welsh	3	Subbituminous		Hot-side ESP