S.730, The Mercury Emission Act of 2005

Columbia University
School of International and Public Affairs
Workshop in Applied Earth Systems Management
ENVP U 9229

PROJECT MANAGER: RACHAEL GARRETT

DEPUTY MANAGER: BRANDON LEE

TRACI BETHEA

KRISTEN CADY-SAWYER

LARA ETTENSON

KARA HARRIS

DEBRA MANDL

KATRINA MARTYNOWICZ

AREZOU RAEISGHASEM

DAVID WESTMAN

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EXECUTIVE SUMMARY

On April 6, 2005, Senators Patrick Leahy (D-VT) and Olympia Snowe (R-ME) introduced S.730 - the Mercury Emission Act of 2005 to the United States (U.S.) Senate. By amending the Clean Air Act (CAA) and the Solid Waste Disposal Act (SWDA), S.730 will reduce 1999 levels of mercury air emissions by over 90 percent no later than 2009 and reduce the amount of mercury entering the waste stream. If passed, S.730 will be the first comprehensive federal law that specifically addresses mercury emissions from all major sources.

After mercury is emitted into the environment, it can be incorporated into microorganisms, which in turn are consumed by other species, including humans. Ingestion, inhalation, or dermal absorption of large concentrations of mercury may result in neurological, immune, or digestive problems in anyone who has been exposed. Women who are pregnant or of child-bearing age should avoid consuming fish known to have high levels of mercury, because mercury can harm the developing brains of small or unborn children. Additionally, people who subsist primarily on fish are particularly vulnerable to the adverse effects caused by mercury contamination, as they consume higher quantities of this toxic pollutant.

Mercury is emitted into the environment through a variety of anthropogenic sources, the largest of which is the combustion of coal. The predominant mercury sources include fossil fuel-fired electric steam generating units, commercial and industrial boiler units, solid waste incineration units, chlor-alkali plants, and Portland cement plants. In addition, mercury is often used in household products and then disposed of in municipal waste streams. Municipal waste is not currently regulated under the SWDA. When household products that contain mercury are incinerated or deposited in municipal landfills, mercury is discharged into the air, land, and water.

The Mercury Emission Act regulates air sources by requiring specific emissions reduction criteria at each facility. Existing air pollution control technologies may be modified to achieve overall emissions reductions between 60 to 90 percent. Such capabilities, however, are highly site- and industry-specific. Thus, additional research and development is needed. Additionally, the Act aims to eventually phase-out mercury-containing products. Until the complete removal of mercury is feasible, the Act will require companies to clearly label mercury-containing products. S.730 also encourages households to separate and properly dispose of products containing mercury.

To analyze the effectiveness of S.730, employing technologies that measure mercury air emissions and analyze water concentrations will be necessary. The quantity of mercury entering the municipal waste stream must also be assessed by monitoring effective recycling and proper disposal of mercury-containing products. The long-term success of S.730 can be evaluated by tracking mercury concentrations in human and biotic systems.

While comprehensive data exists concerning the total quantity of human-induced emissions into the environment, great uncertainty remains regarding how far mercury

may travel from its respective emission source. Increased research about how mercury cycles through the environment, the international sources of mercury, and the availability of control technologies must be pursued to resolve controversies regarding how to best regulate mercury. In addition, research is needed to determine methods to effectively reduce domestic mercury emission sources not addressed by S.730, such as medical waste incinerators.

Mercury continues to adversely harm ecosystems and negatively affect human wellbeing. By removing over 90 percent of national mercury emissions, the Mercury Emission Act will reduce such contamination in the environment, in turn bringing greater overall protection to human health.

INTRODUCTION

While it has long been recognized that mercury is a toxic pollutant, large quantities of mercury continue to be released into the environment and the negative health impacts of such emissions penetrate nearly every community in the United States (U.S.). It is estimated that one in six women of child-bearing age have unsafe levels of mercury in their blood.[1] As a result, between 300,000 and 600,000 children are born every year with neurological problems, such as a decreased intelligence quotient.[2] The most common route of child exposure occurs in the fetus when the mother ingests large amounts of fish and shellfish contaminated with mercury.

The prevalence and magnitude of mercury pollution in the U.S. is evident in studies by the U.S. Environmental Protection Agency (EPA). This research concludes that at least 32 percent of lakes and 20 percent of rivers are contaminated with mercury.[3, 4] Over 117 tons of mercury are emitted into the air in the U.S. due to the use and combustion of mercury in fossil fuel-fired electric utility steam generating units, commercial and industrial boiler units, solid waste incineration units, medical waste incinerators, hazardous waste combustors, chlor-alkali plants, and Portland cement plants.[5] Mercury is also contained in common household products such as thermostats, thermometers, button cell batteries, and fluorescent lights.

As Senator Leahy (D-Vermont) stated when he introduced S.730, the Mercury Emission Act of 2005, to the Senate on April 6, 2005, "we have known about mercury pollution for decades, and it remains one of, if not the last, major toxic pollutant without a comprehensive plan to control its release. We know where the sources of mercury pollution are, we know where the pollution deposits, and we definitely know what harm it causes to people and to wildlife."[6] Clearly, mercury pollution is a serious problem in the U.S. that must be addressed. If passed, this Act will amend the Clean Air and Solid Waste Disposal Acts and will work to reduce national mercury emissions by more than 90 percent, and will phase out the use of mercury in household products over the next decade.

PROPOSED LEGISLATION: THE MERCURY EMISSION ACT OF 2005

Given the contamination concerns and the origins of mercury pollution, S.730, the Mercury Emission Act of 2005, will significantly reduce air, water, and land mercury emission levels.[7] The Act primarily focuses on: 1) lowering mercury air emissions from coal fired power plants, 2) reducing mercury discharges into the atmosphere from waste incinerators, and 3) working with the public and manufacturers to greatly reduce the amount of mercury that enters the waste stream and winds up in landfills.

Specifically, S.730 addresses mercury emission reductions from coal fired electric utility steam generating facilities (power plants), coal- and oil-fired industrial boilers, chlor-alkali plants, Portland cement plants, and solid-waste incinerators (see Table 1 for mandated reductions and Appendix for calculations). The bill also supports emission research for medical waste and hazardous waste incinerators. This proposed legislation also promotes cost-effective methods of controlling and recovering mercury. International efforts include researching and reporting North American mercury discharges and providing recommendations for pollution control measures between the U.S., Canada, and Mexico.

Table 1: U.S. Sources of Mercury Emissions as Regulated by S.730[8]

Source	Facilities Regulated	Emissions in 1999 (tons)	Emissions in 2009 (tons)	Reduction mandated by S.730
Fossil-fuel Fired Electric Generating Units	Existing and new emitting in excess of 2.48 grams of mercury per 1000 MW hour (emission/quantity of electricity generated)	48.7	5	90%
Industrial Boiler Units	Existing and new with max design heat input capacity of 10mmBTU per hour or greater	9.73	0.97	90%
Portland Cement Plants	All	2.36	0.12	95%
Clor-alkali Plants	All	6.53	0.33	95%
Solid Waste Incinerators	All	5.1 (Approx. 180mg/m^3)	0.0013 (Approx. 0.08 mg/m^3)	99.97%
Total		72.42	6.42	>90%

S.730 takes a command and control approach to the regulation of sources that emit mercury into the air. Under command and control regulations, specific and binding emission standards are designated for each facility. This Act aims to reduce total national mercury emissions by 90 percent from 1999 levels.[9]

Along with strengthening emission standards, reducing the volume of mercury-containing items that enter the waste stream is an effective way of decreasing emissions to land and water. Through this Act, a prohibition of sale will be established to prevent manufacturers and importers from selling any mercury-containing product.[10] Where mercury-containing products are essential to the item or no alternatives exist at a reasonable cost, products may be granted an exemption from the phase-out.[11] In the interim, all products containing mercury will be clearly labeled by the manufacturer to indicate the presence of mercury. The EPA and other agencies will work to ensure that these products, once discarded, are properly sorted out of the municipal waste stream and transferred to mercury recycling facilities for proper treatment or safe disposal in a hazardous waste facility.[12] In this crucial step concerning the waste stream, proper public education is a necessary component in order to ensure the reduction in mercury emissions.

Through this Act, the specific mercury goals set are to achieve maximum reductions in all media, ensure and enact compliance and proper monitoring, and analyze all emission sources. A specific timeline is established to ensure proper compliance with the Act.

HISTORY OF MERCURY REGULATION IN THE U.S.

The Mercury Emission Act of 2005 proposes a series of amendments to existing federal acts of Congress, which together aim to improve air and water quality with respect to mercury pollution and the protection of the health of the American population. To date, the Mercury-Containing and Rechargeable Battery Management Act of 1996 (Battery Act) is the only federal law that directly addresses the issue of mercury pollution in the U.S. The Battery Act has significantly reduced the amount of mercury entering municipal waste streams by phasing out the use of mercury in most batteries. Mercury emissions in the U.S., however, are indirectly regulated by the Clean Air Act (CAA), Clean Water Act (CWA), Safe Drinking Water Act (SDWA), and Resource Conservation and Recovery Act (RCRA). While these existing acts do not explicitly target sources of mercury emissions, each gives the EPA authority to regulate mercury. If the Mercury Emission Act of 2005 is passed, these new provisions will supercede the rules previously established by the EPA, creating much stricter controls than those currently in place.

Under the CAA, mercury is currently classified as one of 188 toxic air pollutants. The CAA instructs the EPA to create technology-based standards for point-source mercury emissions. In order to operate, industries that use mercury must obtain a permit from the EPA and/or the state in which they are located and comply with all designated standards. The Act also gives the EPA the authority and flexibility to determine whether utilities should meet "performance standards" or be required to install "maximum achievable control technology" (MACT). These two options have very different implications for mercury contamination in the U.S. The Mercury Emission Act of 2005, if passed, would not require utilities to meet MACT standards, but it would rather require each facility meet specific emission criteria. The Clean Air Mercury Rule issued on March 15, 2005 requires utilities to meet performance standards. This rule enables mercury emission credits to be traded between power plants throughout the country, and establishes declining caps on mercury emissions over the next decade. Contrary to the Clean Air Mercury Rule, the Mercury Emission Act of 2005 will not allow trading of mercury emission permits between power plants, but instead only between units within a plant (see Table 2 for a comparison of the Mercury Emission Act and Clean Air Mercury Rule).

Table 2: Comparison of Mercury Emission Act of 2005 and Clean Air Mercury Rule[13]

Policy	Mercury Emission Act of 2005	Clean Air Mercury Rule
Regulation type	Command and control – Establishes specific emission criteria for each facility and facilities are allowed to use any available technology.	Cap and trade – Establishes national emission levels for all facilities and distributes emissions permits to each facility. These permits may be traded by facilities.
Sources regulated	Coal-fired electric generating units, fossil fuel-fired industrial boilers, Portland cement plants, chlor-alkali plants, and solid waste incineration units	Coal-fired electric generating units
Anticipated air emission reductions	90% from 1999 levels by 2009	70% from 1999 levels by 2018

Currently, the CWA establishes water quality standards for mercury and a host of other pollutants. Under this law, the EPA or a state may issue permits to ensure that the standards are reached. The CWA also instructs states to warn residents about the dangers of eating fish with high levels of methylmercury and to issue advisories when a body of water does not meet mercury water quality standards. As a corollary, the SDWA establishes drinking water standards that limit mercury levels. The Mercury Emission Act will further reduce mercury contamination in water in two ways: 1) Amending the CAA to reduce atmospheric emissions, which are often deposited in water bodies, and 2) Amending the Solid Waste Disposal Act (SWDA) to reduce the amount of mercury entering landfills, which may leach into and directly contaminate ground and surface water.

RCRA calls for the sound management of mercury-containing waste, which is categorized as hazardous waste. Under RCRA, waste known to contain mercury must meet treatment and recycling standards established by the EPA. The Mercury Emission Act also establishes emissions standards for hazardous waste incinerators. RCRA, however, does not regulate the management of hazardous material in municipal solid waste-streams or the incineration of such waste. The Mercury Emission Act addresses mercury in municipal solid waste by educating the public about the proper disposal of mercury-containing products, phasing out mercury from products commonly used by households and establishing mercury emissions limitations on municipal solid waste incinerators.

Unlike the CAA, CWA, SWDA, and RCRA, S.730 is a multimedia policy that will address mercury in the air, water, and waste stream. Before examining how mercury emissions will be regulated through S.730; however, it is necessary to understand how mercury cycles through the environment and how mercury affects human health.

SCIENCE OF MERCURY

The current problem of mercury contamination is a national dilemma and the sources of mercury must be regulated. Furthermore, the rising number of states that have mercury fish advisories and statewide bans on the consumption of local fish underscores the need for more aggressive controls on the release of this toxic pollutant.[14] The breadth of mercury contamination also necessitates government action. Mercury pollution threatens 32 percent of American lakes and 20 percent of American rivers. [15, 16] Although the health effects of mercury are well known and documented, it is one of the last major toxic pollutants to be federally regulated.

Mercury in the Environment

Mercury enters the environment in three ways, from: 1) natural sources, such as volcanic activity and weathering of rocks, 2) anthropogenic emissions, and 3) the re-mobilization of mercury previously deposited in sediments, water, and landfills (see Table 3). Anthropogenic sources include the combustion of coal and oil for industrial processes, the combustion of waste containing mercury, and the manufacturing processes that use mercury based technologies.

Table 3: Annual Global Mercury Emissions[17]

Emissions from Natural Sources	1540 tons
New Anthropogenic Emissions	2820 tons
U.S. Coal-fired Power Plants	48 tons
Re-emission of Prior Anthropogenic Emissions	440 tons

Background

Mercury is a natural element that exists in two main forms: elemental or metallic (Hg^0) and divalent or ionic (Hg^{2+}) (see Table 4). In the elemental form, mercury is a liquid at room-temperature. Liquid mercury is used in familiar products such as thermometers, thermostats, and fluorescent light bulbs. Elemental mercury has a low vapor pressure and easily evaporates to form an odorless and toxic gas. This form accounts for 95 percent of the mercury in the atmosphere and can remain in the air for up to one year. This high residence time allows elemental mercury to travel globally before being deposited on the Earth's surface.[18]

Ionic mercury occurs as a vapor and accounts for the remaining five percent of mercury - in the atmosphere. Ionic mercury is water soluble and readily associates with water particles in the air. This contaminated water vapor is then incorporated into clouds and can be deposited onto the land and water as a result of precipitation. Ionic mercury has a shorter residence time than elemental mercury and is usually re-deposited from 100 to1000 kilometers from the emission source.[19]

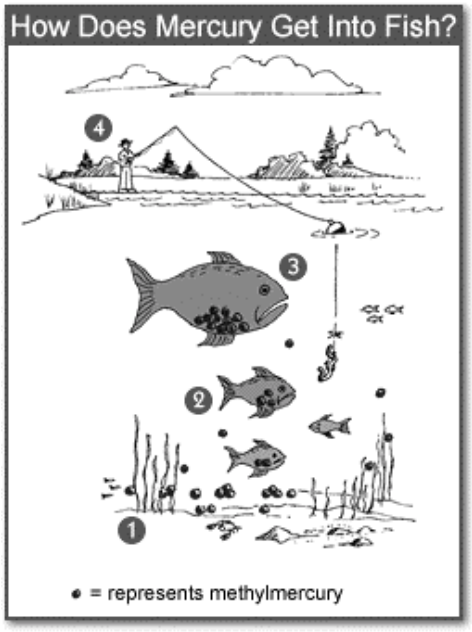
Table 4: Key Forms of Mercury[20]

Form	Elemental or metallic (Hg^0)	Ionic or Divalent (Hg^{2+})	Methylmercury (CH_3Hg^+)
Properties	95percent of atmospheric mercury	Bound to airborne particles; 5percent of atmospheric mercury; found in soil and water as a number of complex ions; may form mercuric salts, which are inorganic mercuric compounds	An organic mercury compound Lipophylic ion produced by bacteria in the water column or sediment; nearly all mercury in the biota is methylated
Transport and Fate	Long residence time, remains airborne for months or years and may travel long distances before converted to other forms	Easily deposited on Earth's surface in dry form or via precipitation; once in water may volatize or partition into particulates and be transported to sediment	Enters food chain through aquatic biota and uptake into fish tissue; bioaccumulates as it travels up the food chain, reaching highest concentrations in organisms at highest trophic level

Microorganisms break down mercury as they metabolize the surrounding particulate matter in aquatic and terrestrial systems. When the mercury is ingested by these organisms, inorganic ionic mercury is turned into monomethylmercury (CH_3Hg^+) or dimethylmercury [$(CH_3)_3Hg$] by the addition of a carbon atom in a process called methylation.[21, 22] These two organic mercury compounds are the most toxic form of mercury and are commonly referred to as "methylmercury" (MeHg). Monomethylmercury is the form of organic mercury that is most easily incorporated into animal muscle, due to its properties as a protein-soluble compound. [23, 24]

Once mercury enters the biota, it begins to accumulate in organisms over time through a process called bioaccumulation (see Figure 1). As small fish eat contaminated plankton, they begin to accumulate mercury in their tissue. The process by which organisms that are higher on the food chain accumulate greater amounts of contaminants is referred to as biomagnification.[26] As a result of these processes, the effects of methylmercury can most notably be seen in organisms that are older, larger, and at the top of the food chain.[27] The other means by which methylmercury can be incorporated into an organism is through dermal absorption or, in the case of aquatic organisms, by water passing over their gills. [28, 29] The affects of can be seen in deformities in developing fish and decreases in loon chick production are examples of the effects of the

Figure 1: Bioaccumulation of Mercury[25]



bioaccumulation and biomagnification of mercury in the biotic system. [30, 31]

Scientific Uncertainties of Mercury Emissions and Distribution

Despite available scientific information, many uncertainties related to mercury still exist.[32] The chemical and physical properties of different mercury forms dominate its behavior in the atmosphere and influence its deposition into the environment.[33] Thus, reliable data must be obtained on the physical and chemical speciation of both natural and anthropogenic emissions. Unfortunately few studies have been designed to identify spatial gradients in atmospheric mercury.[34]

The mercury concentrations in the atmosphere from geological sources such as volcanic, fossil, and geothermal activity, metal deposits, and organic-rich sedimentary rock are not well defined.[35] More accurate data is available for mercury released into the air by anthropogenic sources. Recent work suggests that mercury emissions from natural sources and diffuse anthropogenic sources such as landfills, sewage sludge, and mine waste, constitute larger amounts than the estimations produced in global models[36]. Emissions from such sources must be quantified on a regional and global scale in order to determine the effectiveness of point source controls and the impacts to local, regional and global ecosystems.[37]

Current mercury air emissions inventories have proven to be incomplete and inaccurate, yet one of the most critical elements of any air quality modeling study.[38] The development of a comprehensive inventory of all sources of emissions with spatial and temporal definitions is required for better air quality simulation models. Furthermore, the link between mercury emissions, atmospheric deposition, and mercury concentrations in fish requires a multi-media model. This air, water, sediment, and biology model is not yet completely developed. Additional field research is needed to provide accurate definitions of such processes, bringing more accurate representations.[39] Although scientists do not completely understand all of the governing factors in cross media fluxes and the bioaccumulation of mercury, scientists do know that the global mercury cycle is a multi-media process. Greater consensus on these uncertainties may be reached when scientific studies more adequately quantify mercury emissions and deposition pathways.

Mercury and Human Health

Toxicology

The two major routes of mercury exposure for humans are through the inhalation of elemental mercury and the ingestion of methylmercury-contaminated fish. Mercury can also be ingested through contaminated groundwater. The inhalation of elemental mercury can occur when products containing mercury break or leak, allowing mercury to vaporize into toxic fumes. Many industries also release mercury into ambient air; thus, people can inhale dangerous mercury vapors and particulates. [40, 41] People who use groundwater as a potable water source or for irrigation can ingest mercury in their water or in food products.[42]

Upon inhalation, about 80 percent of elemental mercury is absorbed by lung tissue, while the rest passes into the brain and a small amount enters the intestines. Once inside living tissue, elemental mercury may be oxidized into an inorganic mercury compound. When ingested, methylmercury easily passes through the placental and blood-brain barriers. Once inside brain cells, methylmercury is converted to an inorganic form which sticks to and disables structural proteins and enzymes that are essential to proper cell function.[43]

Populations at Risk

The populations at risk for mercury poisoning include people who consume substantial amounts of fish, women who are pregnant or may become pregnant, and children exposed to mercury in the fetus or at an early age through nursing or the consumption of tainted fish. Populations who subsist on fish are at risk because mercury bioaccumulates in living tissue. Women who are pregnant or may become pregnant must monitor their fish consumption because mercury easily passes through the placental barrier. Developing children are susceptible to neurotoxicity, which can result in mental retardation, cerebral palsy, seizures, deafness and blindness. Even low doses of mercury may affect a child's development, causing delays in walking and talking, shorter attention spans and learning disabilities.[44]

Adults who are exposed to large concentrations of mercury, either by ingestion or inhalation, may face digestive, cardiovascular, and neurological impairment. The toxicity of mercury can produce a wide range of symptoms including nausea; vomiting; lack of appetite; weight loss; abdominal pain; kidney failure; skin burns; respiratory disease; swollen gums; mouth sores; drooling; numbness and tingling in the lips, mouth, tongue, hands and feet; tremors and lack of coordination; vision and hearing loss; memory loss; personality changes; and headache.[45]

Fish to Avoid

According to the EPA, consumers should avoid shark, king mackerel, tilefish and swordfish.[46] Also, no more than one meal per week of albacore tuna and two meals per week of shrimp, light tuna, salmon, pollock and catfish should be consumed (see Table 5). These larger, carnivorous fish aggregate mercury concentrations because they consume substantial quantities of smaller, contaminated fish. In addition, such fish live longer, and a longer lifespan allows the mercury concentration to build over time. The

geographical location of the fish also affects the severity of mercury contamination. Fish in the Gulf of Mexico, the San Francisco Bay, the Great Lakes and Northeast U.S., the North central U.S., and some areas in the Florida Everglades display higher mercury concentrations due to high levels of mercury emissions in these regions.[47] For example, tile fish from the Gulf of Mexico have almost ten times the average mercury concentration of tile fish from the Atlantic Ocean.[48] Oysters and blue crab from the Gulf of Mexico also exhibit higher levels of mercury than their Atlantic counterparts.[49]

Table 5: Fish Containing Mercury by Concentration Level[50]

***Fish with Highest Levels of Mercury above .3 ppm:**	***Fish With Levels of Mercury (.3 to .1 ppm):**	***Fish with Levels of Mercury less than .1 ppm:**
Tilefish (Gulf of Mexico)	Croaker white (Pacific)	Tuna (Canned, Light)
Shark	Scorpionfish	Squid
Swordfish	Bass (Saltwater)	Crab
Mackerel King	Halibut	Mackerel (N. Atlantic)
Grouper	Weakfish (Sea Trout)	Catfish
Orange Rough	Sablefish	Scallops
Marlin	Snapper	Anchovies
Mackerel (Gulf of Mexico)	Monkfish	Trout (Freshwater)
Tuna (Fresh/frozen)	Mackerel (S.Atlantic)	Sardine
Tuna (Canned, Albacore)	Tilefish (Atlantic)	Salmon (Fresh/Frozen)
Bluefish	Carp	
	Perch (freshwater)	
	Skate	
	Sheepshead	

***Order based on quantity of mercury, with highest numbers at top**

ANTHROPOGENIC SOURCES OF MERCURY

Mercury enters the environment from a variety of anthropogenic sources. The main source of mercury emissions into the air is the combustion of materials which contain mercury in facilities such as fossil fuel-fired electric generating units, industrial boiler units, Portland cement plants, chlor-alkali plants, and solid waste incinerator units (see Figure 2). Mercury may also enter land and water directly through leachate from landfills.

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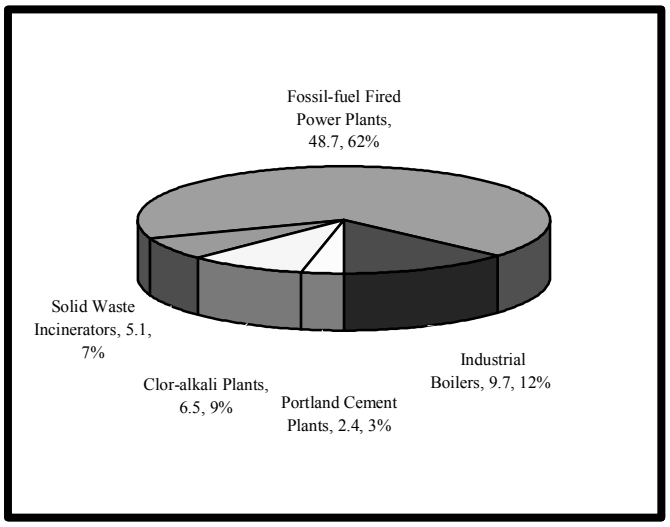
Figure 2: Sources of Mercury Regulated by S.730 (tons, % of total)[51]



Emissions into Air

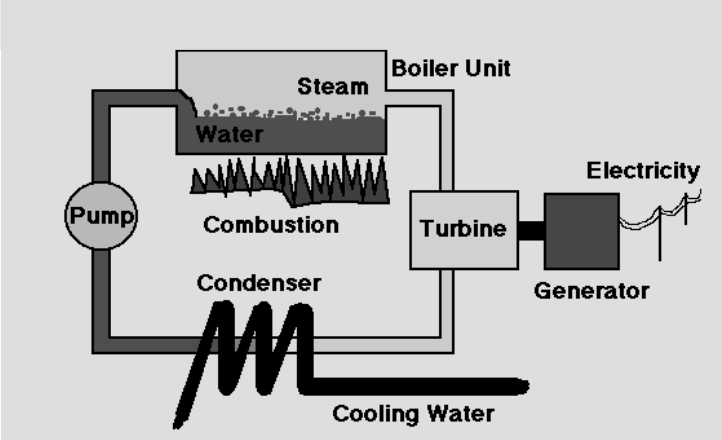
Fossil Fuel-fired Electric Generating Units and Industrial Boiler Units

The largest contributors of mercury into the environment are fossil fuel-fired electric generating units (commonly known as power plants) and fossil fuel-fired industrial boiler units that use coal as an energy source. In 1999, the EPA estimated that coal-fired power plants emitted over 47 tons of mercury per year, while industrial boilers emitted nearly ten tons per year.[52] Elemental mercury occurs naturally in coal and, upon coal combustion; this mercury is vaporized and released as both ionic mercury and elemental mercury through the smoke stacks.

Electric power plants consist of a boiler unit, a turbine-generator, and an area of cool water (see Figure 3). For coal-fired power plants, coal is burned below the boiler unit, which is filled with water. When the water boils, it creates steam which is transferred by pipes to the turbine-generator. Here, the steam turns the turbine, which then turns coils of wire associated with magnets in the generator. It is this rotating coil of wire within the generator that produces electricity. Once the steam moves through the turbine, it passes by a source of cooling water which reduces its temperature and condenses it back into liquid water to start the cycle again.[53]

Mercury is released from an industrial boiler unit during the steam generation process in the same way that it is released from a power plant. The only difference between the power plant and the industrial boiler unit is that the power generated by the boiler in the industrial boiler unit is used directly for industrial processes, while the power generated by the boiler in the electric power plant is used for the production of electricity.

Figure: 3: Fossil Fuel-fired Electric Generating Plant[54]



Portland Cement Plants

Portland cement is the most widespread type of cement manufactured in the U.S. and is used most commonly for the production of concrete. In 1999, Portland cement plants emitted over two tons of mercury per year.[55] Portland cement is made by the heating of limestone, clay or sand, and other materials to a temperature of 1480°C to produce a powdered mixture of calcium, silicon, aluminum, and ferric and magnesium oxides that can then be mixed with water to form a hydrated solid. This heating process requires the combustion of large quantities of fossil fuels, including coal, which contain mercury.[56]

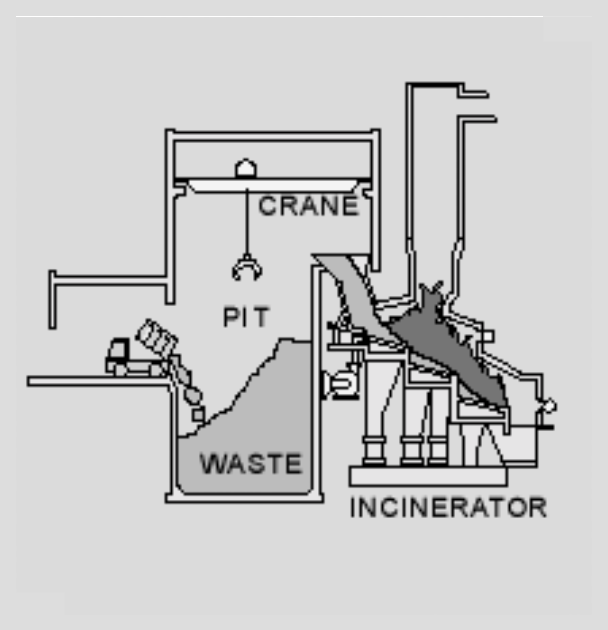
Chlor-alkali Plants

In a chlor-alkali plant using mercury cell technology, elemental mercury (Hg^0) is used as a cathode, which is a source of electrons, to convert sodium chloride (NaCl) into chlorine gas and caustic soda, which are then used in soaps and detergents. As of 2001, 10 out of 13 chlor-alkali plants in the U.S. still used mercury cell technologies for the conversion process. [57] In 1999, the emissions from this source were over six tons per year.[58] The mercury cell consists of two major parts: an electrolyzer and a decomposer. In the electrolyzer section, sodium chloride is passed along the mercury cathode and is separated into chlorine gas and sodium amalgam. In the decomposer, the amalgam is used to produce hydrogen (H_2) gas and sodium hydroxide (NaOH). The amalgam is converted back into elemental mercury. Any mercury that does not escape during the process is recycled back into the electrolyzer.[59] Chlor-alkali production can occur without the use of mercury, as will be discussed in, "Solutions to the Problem as Regulated by S.730".

Solid Waste Incineration Units

Mercury is present in a number of common household products including batteries, thermometers, thermostats, electrical circuits, fluorescent bulbs, pigments, and paints. [60] When these products are disposed of improperly, they enter the municipal solid waste stream. When solid waste is collected, it is delivered to either a solid waste incineration unit or a landfill. As of 1999, approximately five tons of mercury per year was emitted from solid waste incineration units.[61] When solid waste enters an incineration plant, it is put into a pit and mixed. Once mixed, a crane takes this waste and deposits it onto a conveyor belt where it is transported across the combustion chamber (see Figure 4). Here, the solid waste is incinerated, which releases mercury into the environment through vapor and ash. The vapor undergoes a cleaning cycle before it is released into the atmosphere. Although filters are intended to capture toxic waste material being released, they do not fully capture all mercury emissions.[62] The ash, containing metals and toxins, will be deposited into a landfill where it can potentially to seep into the ground. The steam produced by burning the waste is transferred to generators and produces a minor amount of energy.[63]

Figure 4: Solid Waste Incineration Unit[64]



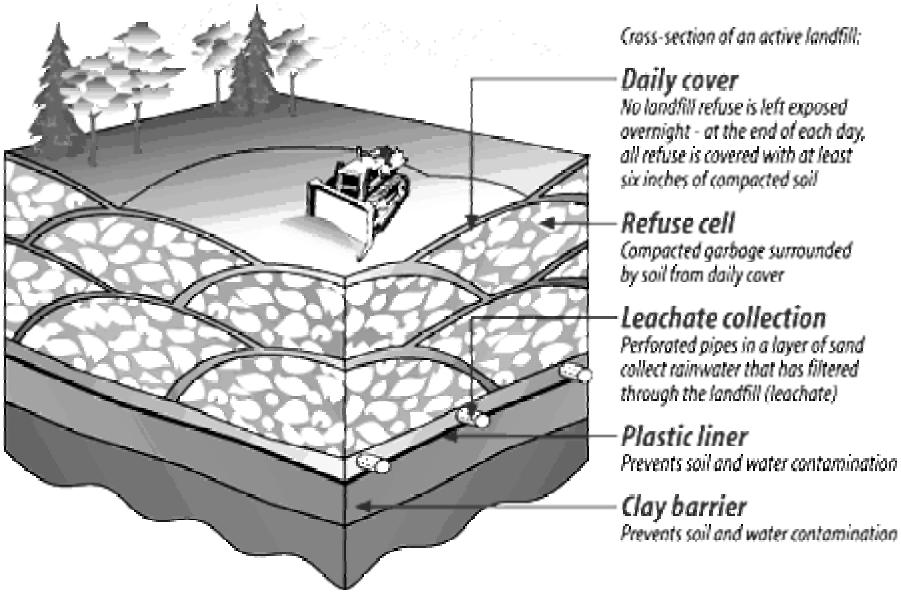
Emissions into Land and Water

Landfills

As mentioned above, solid waste containing mercury is delivered to landfills. From the bottom up, a modern landfill consists of a compacted clay barrier, a plastic lining, and a leachate collection system (see Figure 5). Each component is intended to minimize the seepage of fluids into the groundwater, which may lie just beneath the landfill. It is important to remember that many older landfills do not contain these protective measures to prevent the escape of contaminants like mercury. Above the leachate system are

bundles of solid waste that are added to the landfill daily. At the end of each day, these bundles are covered with gravel and soil to prevent the escape of contaminants, including mercury, into the atmosphere.[65] In addition, landfills contain a methane collection pipe system that redistributes the methane gas produced as a byproduct during the breakdown of trash by anaerobic bacteria. These pipes lead from within the landfill to the open air.[66] Mercury undergoes a similar methylation process in the landfill as it does in soil and water. The methylmercury produced can be emitted to the environment either by seepage through the plastic and clay barriers to the soil and groundwater or through the methane gas pipes that lead to the air.[67] Notably, contaminated groundwater ultimately drains to an aquatic body or is used as drinking water.

Figure 5: Landfill[68]



SOLUTIONS TO THE PROBLEM AS REGULATED BY S.730

Because the presence of mercury in the environment poses a threat to the health of humans and the environment, it is crucial that proper solutions be implemented. A key element in formulating a successful remediation plan is an understanding of the technologies behind the solutions of reducing mercury into the atmosphere, water bodies, and land.

As discussed previously, mercury can be released into the air, soil, or water naturally or from anthropogenic sources such as fossil fuel-fired electric utility steam generating units, solid waste incineration units, chlor-alkali plants, and coal- and oil-fired commercial and industrial boiler units. S.730 has proposed various solutions for reducing mercury emissions in the environment for each output source. The bill proposes to diminish exposure pathways by significantly cutting air emissions and reducing the amount of mercury in the waste stream. Numerous options exist to achieve reductions in the quantity of mercury emissions for many of the sources.

All mercury emitting facilities mentioned in the Act will be required to apply for and maintain a Title V permit under S.730. The Title V permit was established with the 1990 Clean Air Amendments and introduced the concept of a facility-wide air permit that brings all applicable state and federal air pollution control requirements under the umbrella of a single permit. Title V permits regulate major sources, which are defined as "any stationary source (or any group of stationary sources located within a contiguous area and under common control)."[69] To maintain a permit, a facility must sustain emissions limitations and standards, submit monitoring and analysis information, and pass inspections. S.730 offers various methods to reduce mercury emissions and allows a combination of these techniques. The Act recommends a reduction by increasing efficiency of the facility and its processes and by substituting from fuel high in mercury to fuel with lower concentrations of mercury. The Act also discusses enclosing the systems of processes to eliminate mercury emissions. Additionally, S.730 addresses the collection, capture, and treatment of mercury emissions when released from various points throughout the system and suggests modifications to the design, equipment, work practice, or operational standards to achieve compliance.

Reducing Mercury Emissions into the Air

Fossil Fuel-Fired Electric Utility Steam Generating Units

As previously mentioned, fossil fuel-fired electric utility steam generating units that produce energy by burning coal, emit mercury into the air. S.730 establishes that facilities that emit an excess of 2.48 grams of mercury per 1000 megawatt hours will be limited to an emission level, so that all facilities in the country emit a total of five tons combined by the year 2009.[70] In cases where there is more than one electrical generating unit in a facility, the emissions may be averaged over all the units, though trading between facilities will not be allowed.

As discussed earlier, mercury is a naturally occurring element found in nearly all forms of coal. Ninety percent of the coal in the U.S. can be categorized as bituminous or sub-bituminous.[71] Of these two categories of coal, bituminous generally has higher mercury concentrations than sub-bituminous.[72] Bituminous is the most plentiful form of coal in the U.S. and is a readily available source for electricity generation. Bituminous coal has a carbon content ranging from 46 percent to 86 percent and a heat value of 10,500 to 15,000 British Thermal Units (BTU) per pound with highly variable average mercury content of 10 lbs/Tbtu (pounds per trillion BTU).[73, 74] The less widely used sub-bituminous coal contains lower levels of carbon, 35 percent to 45 percent, as compared to bituminous coal. Sub-bituminous coal has a heat value between 8,300 and 13,000 BTUs per pound, which makes it less efficient for electricity generation. Sub-bituminous coal generally has lower sulfur and chlorine content than other types and an unsteady mercury content averaging 8.5 lbs/Tbtu.[75, 76] Lower concentrations of sulfur and chlorine have been known to decrease the effectiveness of technologies that reduce mercury air emissions. After coal is combusted, sulfur and chlorine react with ionic mercury in the flue gasses of the smokestack. These compounds are more easily captured by existing technologies than vaporous elemental mercury. According to the EPA, existing technologies can successfully capture 36% of mercury emissions from coal-fired power plants.[77]

The majority of mercury emitted by a power plant is transported by flue gases through the smoke stacks. The gas exiting the combustion chamber is collectively referred to as flue gas. Flue gas enters various converters, scrubbers and detoxifying chambers from the combustion chamber before its release into the atmosphere. Mercury enters the flue gas cleaning device as dimethylmercury and can have a significant impact on mercury control approaches. The four commonly accepted methods of reducing mercury in flue gases include the following:

1. *Activated Carbon Injection Systems*
   Activated carbon injection systems introduce carbon as a sorbing agent to flue gasses before mercury is released into the environment (see Figure 5). Vaporous mercury binds onto carbon, which is then collected for disposal. Studies show that this technology has achieved mercury air emission reductions as high as 90 percent for bituminous and 65 percent for sub-bituminous coals.[78]

2. *Scrubbers: Wet*
   Utilizing existing sulfur dioxide and nitrous oxide controls can also reduce mercury emissions (see Figure 6). Many electric generating plants currently have technologies that clean flue gases of sulfur dioxide and nitrous oxide in various concentrations and, with this technology, mercury is also captured. Such technologies are called scrubbers and include two types: wet and dry. Each varies in the amounts of mercury that can be removed from the flue gases.

   Water-based flue gas de-sulfurization scrubbers (FGDs) are already being used in coal-fired electric generating plants in the U.S. Water-based scrubbers are utilized primarily to reduce sulfides in flue gases, however, it is generally understood that

gaseous compounds of dimethylmercury are water soluble, and thus are captured in the same manner as the sulfides. Similarly, ionic mercury is able to remain in aqueous solution in a wet scrubber alongside recovered sulfide compounds such as hydrogen sulfide. In slurry, (a mixture of water and insoluble products) mercury reacts with dissolved sulfur to form mercury sulfide. This compound then precipitates from the liquid solution sludge and can be disposed of in the normal upkeep of a scrubber device.[79] Significant amounts of research and technological innovation are still needed in order to discover how this technology could further increase mercury absorption. In addition, wet scrubber technology by itself is not capable of reducing elemental mercury.

The addition of selective catalysts (SCRs) to a wet FGD scrubber, however, has the potential to increase elemental mercury absorption (see Figure 7). SCRs, such as lime and advanced carbon, may convert a significant portion of elemental mercury in flue gas into the ionic form, thereby enhancing the capture rate of the FGD scrubber. These oxidized chemicals bond with mercury compounds to cause precipitation of the mercury compounds out of the system and into a hazardous waste container. While this technology is largely untested, it is generally believed that the oxidation of elemental mercury by a catalyst may be dependent on the following five criteria: 1) the space velocity of the catalyst, 2) the temperature of the reaction, 3) the concentration of ammonia, 4) the age of the catalyst, and 5) the concentration of chlorine in the gas stream.[80] This technology has only recently been introduced and is still being tested.

Portland cement plants, fossil fuel-fired electric utility steam generating units, and waste incineration units may also use wet scrubbers to reduce mercury emissions into the atmosphere because each source releases emissions through smoke stacks.

3. *Scrubbers: Dry*

Dry FGD scrubbers use a different form of de-sulfurization technology. Rather than using an aqueous solution, flue gas is mixed with lime slurry. Sodium dioxide is absorbed into the slurry and reacts with the hydrated lime reagent to form solid calcium sulfite and calcium sulfate. Dimethylmercury is then absorbed in the lime reagent. Sorbent particles containing sodium dioxide and mercury are later captured in a particulate matter control device. If such a device is a fabric filter, additional elemental mercury may be captured as the flue gas passes through the bag filter cake, which is composed of fly ash and dried slurry particles.[81] Dry scrubber technology produces average mercury capture rates ranging from 98 percent for units burning bituminous coal to 24 percent for units burning sub-bituminous coal.[82] Portland cement plants also use dry scrubbers for the capture of volatized mercury compounds.

Figure 6: Activated Carbon Injection System[83]

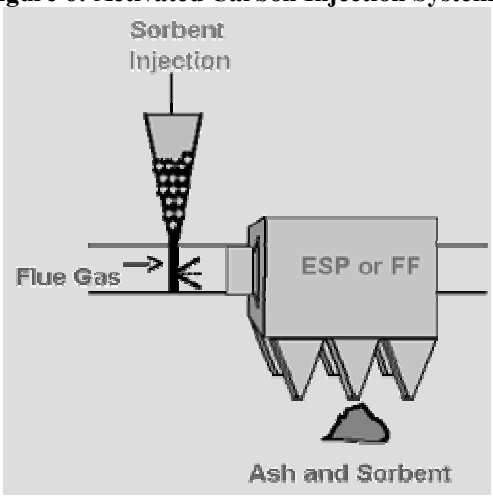
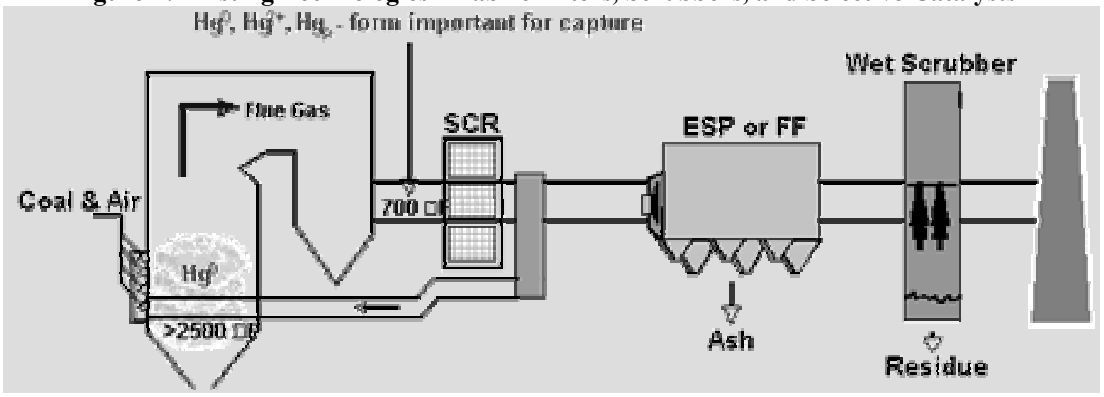


Figure 7: Existing Technologies – Fabric Filters, Scrubbers, and Selective Catalysts[84]



Coal- and Oil-Fired Commercial and Industrial Boiler Units

S.730 proposes that, within two years of enactment, all coal- and oil-fired boilers will be required to obtain a Title V permit. In order to qualify for the permit, the boiler units will be required to reduce emissions of mercury by 90 percent from1999 levels. A reduction in mercury emissions is a challenge due to a lack of commercial technologies designed to capture mercury emissions from the coal and oil used in boilers. Newly developed technologies are still being evaluated and are somewhat unreliable, but it is believed they can be implemented within ten years. [85]

When coal and oil are used to create hot water, volatized mercury is transported through the smoke stack by steam and ash..[86] Wet scrubbers, described above, can also be used to reduce mercury emissions from industrial boilers. This process, while reducing mercury emissions to the air, increases the amount of pollutants in the wastewater. This water must then be cleaned before discharge.

Carbon injection systems with fabric filters create a somewhat closed loop process that can be installed into units that require more than a scrubber to alleviate mercury from the waste stream. [87] With assistance from wet or dry scrubbers, carbon is injected directly

into the flue gas emissions stream, where it binds with mercury particles and prevents them from exiting the system along with other airborne particles. Scientific studies have indicated that an installed scrubber and catalytic reduction system for burning bituminous coal can result in an 85 percent reduction in the mercury emissions rate.[88]

Portland Cement Plants

Portland cement plants will be regulated through permits. Each plant will be required to reduce its annual poundage of mercury below 95 percent of 1999 levels. As mentioned earlier, Portland cement plants use coal for the production of cement. Mercury is emitted during the burning process of the cement when fumes are heated and coal is combusted, causing volatization. Measures can be taken to ensure that volatized mercury compounds do not exit the facility from the coal combustion. One solution is the installation of dry scrubbers, similar to those installed in the coal- and oil-fired commercial and industrial boiler units. In addition, electrostatic precipitators (ESP) and fabric filters (FF) can be employed to capture ionic mercury that is bound to particulates such as ash (see Figure 7). These filters, however, are not effective in retaining elemental mercury and should be combined with SCRs, which convert elemental mercury to ionic mercury, to achieve greater reductions in mercury emissions.

Mercury is also emitted from Portland cement plants through the use of contaminated recycled wastewater. Due to fuel and electricity price increases, cement plants often reuse liquid wastes, specifically residues developed from their own solvent and chemical recycling and recovery process, to create cement paste. This recovery process can lead to a 50 percent production cost decrease and more money from handling companies.[89] Burning wastes increases profits, but can lead to the emission of mercury into the air. Eliminating mercury from the cement mix will begin to reduce the amount of mercury vaporizing and transported by fugitive dust emissions. By reducing their use of wastewater containing mercury, Portland cement plants could cut back emissions of mercury by 55 percent.[90]

Efficacy of Control Technologies for Coal Combustion

Reductions of concentrations of mercury in the air from control technologies greatly varies, depending on the specific facility[91] No single technology currently exists that reduces all mercury emissions from fossil fuel-fired electric generating units.[92]

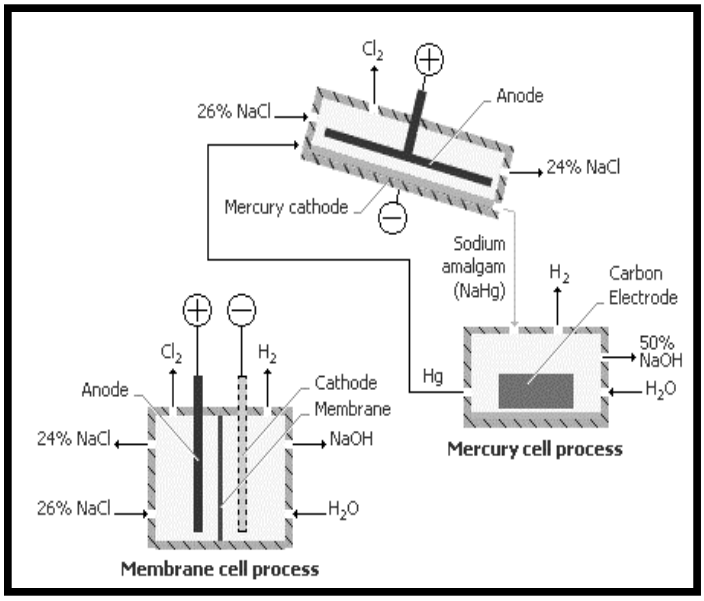
Most research and development for mercury control technologies primarily focuses on electric generating units. Reducing mercury emissions is greatly dependent on coal and fly ash properties, existing air pollution control device (APCD) configurations, as well as the other factors of any given plant.[93] Existing APCD technologies do not effectively capture elemental mercury, however, selective catalytic reduction (SCR) flue-cleaning technologies have recently been brought to the market to capture various forms of mercury, including elemental mercury, mercury chlorides, and mercury oxides.[94]

The varying effectiveness of different types of coal is another major area of uncertainty concerning mercury air reductions. Many industries currently use low-rank coal, such as sub-bituminous and lignite coals, which have a limited mercury reduction capability. Activated carbon injecting (ACI) equipment can be utilized by utilities and is identical for all coal types. Therefore, ACI equipment can be purchased for use with all coals and plant configurations. However, the specific sorbents may vary for different coals and operating conditions. For this reason, the Department of Energy is currently sponsoring tests for injecting chemical additives directly into the coal and flue-gasses in order to increase oxidized mercury levels from combustion and aid in the capture of mercury.[95] This research may help to resolve the uncertainty as to whether current technologies can be used to meet the emissions criteria outlined by S.730.

Chlor-Alkali Plants

Chlor-alkali plants will be regulated through permits. Each plant will be required to reduce its annual emissions of mercury below 95 percent from 1999 levels. Chlor-alkali plants use a mercury cell process in electrolysis for the production of caustic soda and chlorine gas, but new processes have been developed to curtail mercury emissions during production. [96] This technology, such as the membrane cell process, does not require mercury in the system, thus alleviating mercury pollution into the ecosystem. [97] Electrolysis is a process of degenerating products back to their native state to produce sodium.

Figure 8: Mercury and Membrane Cell Processes [98]



In a chlor-alkali plant using a mercury technology, sodium hydroxide and chlorine are formed from the breakdown of the aqueous solution of sodium chloride using mercury and diaphragm cells. [99] The sodium chloride, known to many as table salt, is often called brine when in a solution. A mercury cell contains a carbon anode, or negative electrode, in which brine passes through and flows against a mercury concentration for separation (see Figure 8). Mercury compounds can dissolve in the brine solution and are then emitted into the atmosphere.

The new membrane technology for chlor-alkali process relies on, an ion-exchange membrane, for the separation method. The ion-exchange membrane filters the brine without mercury interaction in the process. For this method, ion-exchange is accomplished by exchanging the anions with hydrogen (H^+) cations. [100] This new process

eliminates the ionic mercury vapors entering the steam (see Figure 8).[101] Other practices that can be taken into account are covering the waste containment cells to reduce the amount of chemicals volatilizing.

Today only 9 chlor-alkali plants in the U.S. still use mercury cell technologies to separate sodium hydroxide into sodium and chloride ions needed for the production of caustic soda and chlorine gas. The mercury control technique of substituting mercury cell production with membrane cell technology has an elimination of mercury recovery rate of 100 percent [102] The membrane cell production uses less electricity than the mercury cell, thus keeping costs down for the substitution. It is also more feasible to use because most plants retain the same machinery after a thorough cleaning.[103], [104]

Waste Incineration Units

The leading cause of mercury emissions from solid waste incineration units is from burning waste that contains mercury. One goal of S.730 is to reduce mercury emissions from solid waste incinerator units. In order to do this, S.730 requires the Administrator of the EPA to publish a list of mercury-containing items that will be required to be separated and removed from a waste stream that feeds a solid waste management facility. The list will include items such as fluorescent bulbs, batteries, pharmaceuticals, laboratory chemicals and reagents, and electrical devices such as thermostats, relays, switches, and medical scientific instruments. The bill also requires clear labeling of products containing mercury. All waste incineration units will be required to hold permits. Permits will be issued for no greater than 12 years, and will be reviewed every five years.

The Administrator will determine whether a solid waste incinerator unit has achieved and is continuously maintaining a mercury emission rate of no more than 0.08 milligrams per dry standard cubic meter. If this rate is not achieved during the reporting period or over any two out of three reporting periods thereafter, the Administrator will require the solid waste incineration unit to install control equipment and implement technologies that will result in an emission rate of not more than 0.06 milligrams per dry standard cubic meter within three years.

Wet scrubbers can be installed in the smoke stack of a waste incineration unit to capture c volatized mercury before it exits the system. Less than 90 percent of mercury is removed by a wet scrubber, yet this technology does limit the particulate matter escaping the system.[105] Scrubbers are added to incinerators to bring a polluted gas stream into contact with a liquid, so that the pollutants can be absorbed.[106] After the waste is burned, carbon dioxide, water vapor, heated air, and nitrogen oxides are sprayed onto the particulates, which forces the particulates down to be captured while bringing the clean air up through the scrubber.[107]

Three years after the enactment of S.730, it will be illegal for a manufacturer to sell any mercury-containing product unless the product has been granted an exemption. Exemption will only be granted if: a determination is made that the mercury-containing product is essential; there is no comparable product that does not contain mercury and

that is available in the marketplace at a reasonable cost; and the manufacturer establishes a program to take back, after use by the consumer, all mercury-containing products. An exemption may be granted for no more than three years.

Reducing Mercury from Waste Streams

Recycling and Reclamation

Under RCRA, an amendment to SWDA, most mercury-containing products are classified as hazardous waste and should be properly disposed of or recycled. Household hazardous waste, however, is excluded from these regulations. Many manufacturers attempt to use less mercury in products; nevertheless, mercury is still in products where no feasible alternatives exist, such as fluorescent bulbs. Recycling mercury-containing devices for households, businesses, and industries is currently a growing industry. There are several ways to remove mercury from the waste stream. Such methods include implementing various mercury collection and recycling programs, as well as laws such as S.730 that eliminate mercury from products. The EPA has initiated voluntary recycling programs such as the Lamp Recycling Outreach Program, Mercury Switch and Auto Recycling Program, and Chemical Management Services to improve the management of mercury and prevent it from entering into waste streams.[108]

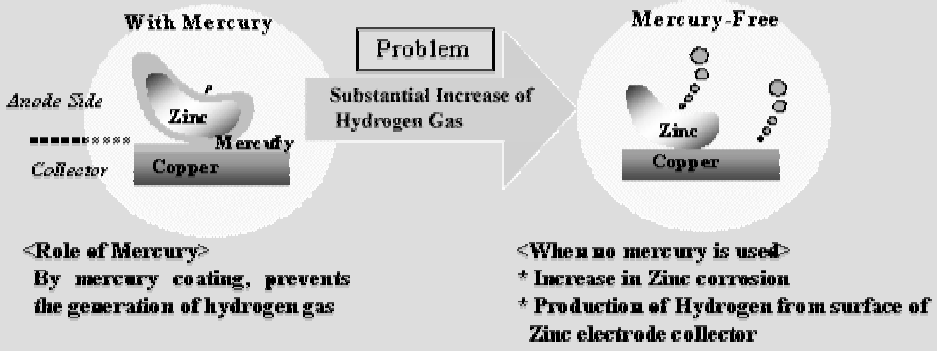
Upon collection of mercury-containing items, the recovered mercury is transported to a mercury reclamation facility. Here, mercury is retorted into elemental mercury and is properly disposed of or sold for new products. Retorting mercury is the process by which mercury is heated to 300° Celsius in a retort machine until it vaporizes.[109] Upon vaporization, the mercury is then condensed back into the liquid elemental form for re-use in other products.[110]

Recycling is the most effective way to alleviate mercury incineration and consequent volatilization in waste incineration units, Portland cement plants, and chlor-alkali plants.

Case Study1: Batteries

Batteries have historically been one of the largest inputs of mercury to the municipal waste stream.[111] However, the contribution of batteries to mercury in the waste stream has been decreasing over the past decade since the passage of the Mercury-Containing and Rechargeable Battery Management Act of 1996.[112] The Mercury Emission Act aims to completely eliminate the sale of most types of mercury-containing batteries. Mercury is traditionally used in conventional silver oxide battery cells to prevent the oxidation of zinc. Zinc is the activator in the negative electrode but it produces hydrogen gas upon corrosion, thus reducing the efficiency and longevity of the battery (see Figure 9)[113] However, alternative batteries use new technologies to replace mercury. The most common household battery alternative is the alkaline manganese battery. Instead of using mercury to reduce the oxidation that leads to degradation, alternative batteries employ electrolytic manganese dioxide as a reagent. This reagent has a higher reactivity while decreasing the hydrogen gassing rate.[114]

Figure 9: Mercury and Mercury-free Batteries[115]

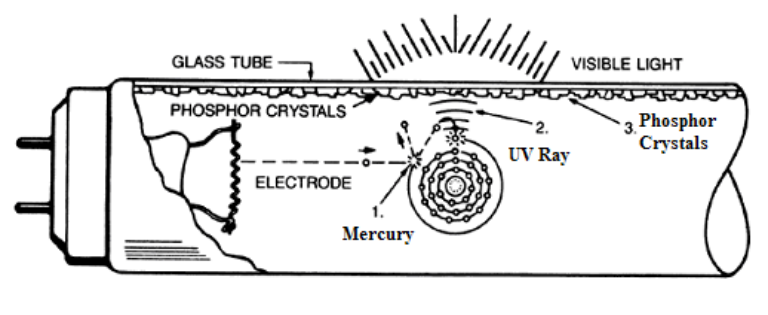


While such technologies can eliminate mercury from the majority of batteries, they are not effective on button cell batteries, which are used in hearing aids, cameras, and other electronic devices. One alternative mercury-containing button cell batteries is the zinc-air battery which operates similarly to conventional methods but relies on an external source of oxygen as a reagent. This oxygen enters the battery through designated holes, reacts with the molecules present inside the battery, and produces electrons, thus creating electricity. The downside of such a technology is that the constant interaction with air dries out the reagents within the battery more quickly than those used in the conventional method.[116] Consequently, the zinc-air battery cell is a possible alternative that is not currently in widespread use.[117]

Case Study 2: Fluorescent Bulbs

Manufacturers of fluorescent lighting have used this low-cost, energy-saving source of power to light homes and offices for more than 65 years. The two major components in fluorescent bulbs include plasma and phosphors (see Figure 10). Fluorescent lighting contains mercury as a reactant[118]*. Mercury vapor is used in the plasma that emits ultraviolet photons. The photons then hit a phosphorescent surface on the inner tube, thereby emitting visible light. Fluorescent lamps are highly efficient because the mercury serves to convert electrical energy into low-energy ultraviolet photons. Furthermore, fluorescent bulbs last longer, save energy, and have helped to reduce strain on power plants. The downside of fluorescent lighting is that when bulbs are broken or discarded, the mercury escapes, causing the toxic vapors to be released into the environment.*[119]

Figure 10: Typical Schematic of a Fluorescent Bulb.[120]



A typical fluorescent lamp contains about 20 milligrams of mercury. Only one gram is needed to pollute a two acre pond, causing negative environmental and health effects. The EPA estimates that 800 million fluorescent lamps are discarded each year, causing contamination in 20 million acres of water[121]*. Increased state and federal restrictions on the disposal of mercury containing products has made research and development of new technologies with lower, or no levels of mercury important for manufacturers. Phillips Lighting, a company that makes fluorescent lights, significantly reduced mercury contained in bulbs while maintaining the same lamp-life, light-output, and energy-efficiency as standard lamps; mercury reductions averaged 22.8 mg of mercury per lamp. Through the invention of an off-line mercury capsule injection system, Phillips developed a method to precisely control the amount of mercury injected into the lamp. The mercury filled capsules are mounted into the lamp and sealed, allowing for a standardized dose for each lamp*[122]*. Although smaller amounts of mercury continue to be used in this latest technology, it is a significant step in achieving a comparable energy-efficient lighting mechanism. As Phillips Lighting is able to change technologies to include smaller amounts of mercury in their products, clearly other companies in such industry may be capable of making such switch.*

CONTROVERSIES OVER METHODS OF MERCURY REGULATION

Over the past year two very different policies have been introduced to regulate mercury emissions. The major controversy fueling these two competing policies is whether it is best to regulate mercury through a cap and trade or command and control approach. Cap and trade is a regulation which establishes a specific emissions level for the entire country. Plants are allowed to buy and sell these permits as if they were commodities. Command and control, on the other hand, issues permits for specific emissions levels at each facility. Plants are not allowed to trade these permits.

The Mercury Emission Act uses command and control as a method to achieve a 90 percent reduction in mercury emissions from coal fired power plants by 2009. Although the Act allows electric facilities flexibility between units, it does not allow trading between facilities. By comparison, the Clean Mercury Rule is a cap and trade program that aims to reduce national emissions from coal-fired power plants by 70% by 2020.

Proponents of the cap and trade method of regulation argue that it is more cost effective than command and control, as some plants can more efficiently achieve emissions reductions than others.[123] The Sulfur Dioxide (SO_2) trading program has been used as an example of the benefits of cap and trade type of regulation, because national emissions were reduced more quickly and efficiently than projected under a command and control policy.[124] It has been estimated that using a permit trading program rather than a command and control approach will result in a net saving of 700 million to 800 million dollars per year.[125]

Opponents of cap and trade regulations believe that trading between facilities throughout the U.S. may lead to "hot spots" of mercury pollution in some parts of the country, where mercury concentrations are disproportionately higher in communities immediately surrounding plants that purchase extra emissions credits. These "hotspots" are likely to develop if the ionic form of mercury is emitted by these plants, because this form of mercury is often redeposited 100 to1,000 kilometers from its source.[126]

An important difference to take into account when considering a cap and trade approach to mercury emission reduction is that the success of SO_2 reductions was in part due to its chronic, rather than acute nature. Acid rain occurs when SO_2 is emitted into the atmosphere and converted into sulfuric acid, which then falls and creates acid rain. Sulfur is relatively light in weight, and therefore causes regional problems since it disperses over a large area. This characteristic of SO_2 has led to successful trading since because reductions do not target a particular time or location. In contrast, mercury is a heavy metal which can accumulate, therefore, levels of mercury emissions are determined by the total emissions over a long period of time.

Proponents of command and control regulation of mercury argue that the achievement of SO_2 reductions is unlikely to be replicated with mercury because of historical differences in their regulation as well as natural differences in their chemical composition and behavior. SO_2 was first regulated under the 1970 CAA which limited the SO_2 emissions

of new coal-burning units to 1.2 pounds per million Btu (mmBtu). Although existing units were not federally regulated, states had varying standards for older units. Therefore, in 1990, when permits were introduced for the emission of SO_2, coal burning plants were greatly varied in their ability to comply with the 90 percent reduction standard set by the CAA. Since mercury has never been regulated at the federal level, a simultaneous requirement for all operation boilers, both old and new, will not have as wide a variance of control costs as it did at the start of SO_2 permit trading.[127]

Those opposing command and control regulations, however, argue that a cap and trade policy is more effective at reducing pollution than command and control, because an overall cap on national emissions is created – if new plants come online it will not affect the overall emissions level. A command and control policy, on the other hand, establishes specific emissions criteria for each plant, therfore if new plants that emit mercury come online, the overall amount of emissions in the country will be greater than if a national limit is established.[128]

MEASURING SUCCESS

To analyze the effectiveness of S.730, it will be necessary to employ monitoring technologies that can measure the emissions of mercury into the air and analyze mercury concentrations in the water. Effective technologies to monitor mercury emissions currently exist, although additional research is necessary for advancement in the precision and efficiency of monitoring procedures. The quantity of mercury entering the municipal waste stream must also be assessed by examining the recycling and proper disposal of mercury containing products. In the long-term, the success of S.730 can be evaluated by monitoring improvements in human health and concentrations of mercury in the biota.

Monitoring Mercury Emissions into the Air

The EPA has verified technology that may be utilized for monitoring emissions of mercury into the air. These technologies allow the EPA to validate a facility's compliance with emissions reduction criteria.[129] Mercury Continuous Emissions Monitors (CEMs) are one of the proposed tools that the EPA sanctions for the analysis of mercury concentrations in flue gasses. CEMs take direct measurements on a continual basis instead of intermittently collecting data. This technology is similar to monitors that currently evaluate other air pollutants. These monitors operate by taking a sample of the flue gas and measuring the mercury content.

An issue that exists with CEMs is that the technology is not yet up to date in measuring all the different forms of mercury in the air. Many monitors are capable of measuring elemental mercury, though mercury can exist bonded to other particles.[130] These mercury particles are currently being filtered out before being recorded, which will distort the overall mercury emissions. Research is being conducted to investigate whether these monitors can heat air parcels to temperatures high enough to completely dissociate mercury.[131]

CEMs utilize different methods of how to measure mercury levels, typically employing different types of spectroscopy. Spectroscopy is the process by which an electrical current or light is introduced to a gaseous mixture containing mercury. The light structure that is re-emitted from the particles is then analyzed to determine what chemical compounds are present. The mercury signature can then be calculated, and the strength of the signature indicates the concentration of mercury in the sample.

There are two major methods of spectroscopy: cold-vapor atomic absorption and cold-vapor atomic fluorescence. Atomic fluorescence is merely one type of absorption that is more sensitive than regular absorption and can detect lower levels of mercury. Atomic fluorescence is a more sensitive measure than atomic absorption because electromagnetic radiation is used to excite the atoms. Additionally, the fluorescent light used to evaluate the mercury concentrations in the emissions contains lower background levels than other forms of light. The level of mercury that can be detected using atomic fluorescence is one part per trillion.[132]

Mercury can exist in the same sample in elemental and ionic forms, but only the ionic mercury is measurable. Cold vapor atomic spectroscopy analysis utilizes chloride to convert ionic mercury into gaseous elemental mercury in an aqueous solution.[133, 134] The vaporized mercury is excited by electromagnetic radiation and channeled into the atomic absorption cell. [135] Within the cell, a mercury vapor lamp emits light, which the mercury gas absorbs. Then, external calibrations are compared with the results of the absorption to determine the presence of mercury.[136] Instead of the atomic absorption cell, the vapor can be concentrated on gold foil where an atomic fluorescence detector verifies the concentration of mercury.[137, 138] In addition, gas chromatography atomic fluorescence spectroscopy can differentiate between organic and elemental forms of mercury. In this technique, samples are filtered and injected into a detector rather than converted into an aqueous solution.[139]

Currently, there are at least nine different CEM models that have been verified by the EPA, but many of these measurement and monitoring technologies are not entirely accurate or complete. To more accurately assess the effectiveness of S.730, efforts to increase and improve monitoring techniques for mercury air emissions must continue.

Though conventionally employed to detect radiation or evaluate noise, dosimeters can be used to monitor ambient mercury levels. The U.S. Occupational Safety and Health Administration recommends the use of a solid sorbent passive dosimeter for the evaluation of gaseous mercury.[140] This device diffuses vaporous mercury through polyethylene mesh disks. These disks, which lie on the front of a badge, allow a mercury sample to penetrate to a solid sorbent capsule for collection.[141] The sample is then analyzed using cold vapor atomic spectroscopy. Dosimeters are often incorporated into Jerome meters, which are used to directly analyze ambient concentrations of mercury vapors from mercury spills, and monitor the exposure of workers.[142]

Some states have developed their own protocols for the monitoring mercury concentrations in the air. For example, the state of Massachusetts utilizes methods for the collection of volatile organic compounds to evaluate low levels of ambient mercury.[143] In this process, gaseous mercury is absorbed onto a medium such as activated carbon, gold annual denuders, and gold-coated sand adsorbent traps.[144] Samples with particulate mercury are collected with devices and samplers according to the size of the mercury-containing particles.

Gold traps may also be utilized to collect mercury in the ambient air. The samples must be heated and the mercury must be desorbed prior to analysis with cold vapor atomic fluorescence spectroscopy. The accuracy of this method depends upon the proper calibration and collection efficiency of the gold traps, as well as the standard deviation of the data.[145]

Monitoring Mercury in the Waste Stream

Monitoring Mercury in the Waste Stream – Water

The monitoring of ground and surface water immediately surrounding landfills is a potential indicator of the success of removing mercury from municipal solid waste landfills. Mercury is emitted from landfills via the leachate, which is the concentrated contaminated solution that forms when water passes through a landfill.[146] Over the past decade, major advances in measuring mercury concentrations in water have been made. Specifically, new mercury analyzers for monitoring mercury concentrations in ground and surface-water use the atomic fluorescence method described above, which can detect much lower levels of mercury than the traditional atomic absorption method. Measuring mercury concentrations in groundwater is a better indicator of mercury in landfills than surface water, because atmospheric mercury from other sources may be deposited in surface waters. Although S.730 does not provide provisions for reducing mercury in decommissioned landfills, monitoring the emissions at older sites is useful for the determination of reductions in mercury emissions over time.

The quantity of mercury in landfill leachate can also be measured by directly evaluating the amount of mercury in the leachate. Measurements of leachate must be taken at many locations within a landfill due to the variation in contamination levels at one location. The leachate quality must then be compared to the background water quality. Leachate is a difficult parameter to measure and is highly variable because the leachate material undergoes a number of chemical processes which change its quality. The site-specific factors that affect leachate quality include the bacteria population**,** clay content, organic content, and permeability of the soil as well as groundwater quality, flow rates, temperature, and pH.[147]

The first step in monitoring groundwater for contamination of any pollutant is to install monitoring wells. No wells are necessary for surface water monitoring as the samples can be taken directly. Monitoring wells should be installed around landfills that are known to leach into nearby ground and surface water. Samples for monitoring groundwater should be taken quarterly for groundwater and more frequently for surface waters, which have a faster flow rate. For water monitoring, samples must be taken upstream from the landfill to determine a background mercury level and immediately downstream from the landfill to measure the concentrations of mercury leaching from the landfill. Sampling and monitoring the ground and surface water surrounding landfills will show any statistically significant changes in the levels of mercury leaching from the landfill.[148]

Plant and animal life inhabiting a body of water can also be analyzed as a direct measure of long-term surface water quality. Measuring mercury levels in plants and fish, however, is not the best indicator of the success of the Mercury Emission Act because levels of mercury contamination in fish will continue to rise, even after mercury emissions in the U.S. are reduced. This delayed increase will occur because mercury is continuously deposited in the U.S. from global sources and the remobilization of previous anthropogenic releases.[149] It is more accurate, therefore, to measure the emissions

directly at the sources that S.730 targets, than indirectly in fish near to source of mercury. The vegetation surrounding landfills can also be tested for mercury, but the levels of mercury in the biota are cumulative and do not reflect changes in mercury concentrations over time.[150]

Monitoring Mercury in the Waste Stream – Products

Presently, the air emissions of mercury from landfills cannot be monitored. As a result, monitoring the amount of mercury contained in products in the waste stream provides a measure of emissions for landfills. In addition, the public education and outreach campaign initiated by S.730 focuses on the proper use and recycling of mercury-containing products.

Beginning in the 1990s, approximately 790 to 990 tons of mercury have been recycled and placed back on the market for resale and approximately 44 to 88 tons are recycled per year.[151, 152] With continued recycling practices, studies have estimated that over the next decade, 14,000 tons of mercury will be available for resale. The majority of this recovered mercury has been obtained from newly closed chlor-alkali facilities; however, the weaning chlor-alkali demand has led to an estimated phase-out within the next ten years. At the present time, there are only nine chlor-alkali plants remaining in use in the U.S.

To facilitate proper recycling, mercury-containing products such as batteries are considered "universal wastes," "hazardous wastes," and non-hazardous "industrial waste" and are handled as such when disposed of in landfills.[153] Because these products are not regular waste, they should be placed in segregated areas, containers, or in reinforced hazardous waste landfills to reduce mixing and leaching. Putting mercury-containing products in satellite accumulation areas helps retain the mercury constituents until they can be disposed of properly. Non-radioactive waste control forms are filled out and placed on each container to ensure the safe handling of each product. For batteries, these labels state "universal waste battery/batteries" or "used battery/batteries," including information on the type of battery and the date of the first battery. These labels ensure proper handling and compose an updated log of the allotment of batteries until they are shipped to a disposal or recycling facility.

Even though mercury is naturally contained in groundwater, it has been confirmed that large amounts are leaching from landfills. If possible, all mercury containing products should be retorted before being placed into landfills. However, the efficiency rating of retorting is variable, as it depends on the rate of recycling and package labeling. Measures are needed to assess the amount of mercury leaching into the groundwater adjacent to landfills. Most natural waters contain low levels of mercury, however freshwater concentrations have been being reported as high as 0.07 parts per million.[154]

CONCLUSION

While it is widely accepted that mercury is a toxic pollutant that degrades in the environment and impairs human health, mercury emissions continue to be largely unaddressed by federal legislation. The Clean Mercury Rule issued by the EPA on March 15, 2005 was the first major attempt to deal with mercury pollution in the U.S., but this rule is not nearly as comprehensive as S.730 the Mercury Emission Act of 2005. While the Clean Mercury Rule will begin to incrementally reduce emissions from coal fired power plants, the Mercury Emission Act will drastically reduce such emissions from coal combustion and virtually eliminate releases of mercury from the household product incineration within the next five years.

The control technologies necessary to achieve a large portion of these reductions are already commercially available. Over the course of the bill, the labeling and separation of products containing mercury will increase awareness about mercury in household products. As the public responds by recycling mercury-containing products, the improper disposal of mercury into municipal waste will decrease. Over the past decade the amount of mercury in products has been greatly reduced and, over time, a near complete phase-out of mercury in products will be achieved as manufacturers continue to pursue alternatives. Reductions in the amount of mercury in products are already evident in many locations throughout the country. Few batteries still contain mercury and the concentrations of mercury in fluorescent lights have been greatly reduced. Many states have already instituted voluntary bans on the sale of many mercury-containing products.

If S.730 is implemented, national mercury emissions will significantly be reduced by more than is mandated by the current Clean Mercury Rule. In addition, due to the specific emissions criteria required for each polluting facility, there is a less likelihood that “hotspots” of mercury contamination will develop and expose some communities to particularly high levels of mercury. The Mercury Emission Act will address all major sources of mercury emissions into the environment, further safeguarding human health.

APPENDIX

Calculations for Table 1:

Calculation of emissions allowed by industrial boiler units:

Amount emitted in 1999 = 9.73 tons
Reduction from 1999 levels to be allowed in 2009 mandated by S.730 = 90%
Amount allowed in 2009 = 0.97 tons

Calculation of emissions allowed by Portland cement plants

Amount emitted in 1999 = 2.36 tons
Reduction from 1999 levels to be allowed in 2009 mandated by S.730 = 95%
Amount allowed in 2009 = 0.12 tons

Calculation of emissions allowed by chlor-alkali plants

Amount emitted in 1999 = 6.53 tons
Reduction from 1999 levels to be allowed in 2009 mandated by S.730 = 95%
Amount allowed in 2009 = 0.33 tons

Calculation of emissions allowed by solid waste incinerators and reduction percentage.

Hg = mercury, W = municipal solid waste, T = tons, g = grams, kg = kilograms

1. Amount of mercury emitted from solid waste incinerator units in 1999 =
   $5\ THg = 5x10^{6}\ gHg$
2. Amount of solid waste generated in 1999 =
   $230x10^{6}\ TW = 230x10^{12}\ gW$
3. Amount of waste incinerated in 1999 if 15% of solid waste is incinerated =
   $(230x10^{12})\ gW \times 0.15 = 34.5x10^{12}\ gW$
4. Amount of mercury emitted per unit of weight of waste incinerated =
   $(5x10^{6})\ gHg / (34.5x10^{12})\ gW = (1.45x10^{-7})\ gHg/gW$
5. Density of waste =
   $200\ kg/m^3 - 400\ kg/m^3 = (2x10^{5})\ g/m^3 - (4x10^{5})\ g/m^3$
6. Mercury emitted per unit of volume of waste =
   $(1.45x10^{-7})gHg/gW \times (2 \times 10^{5})\ gW/m^3W = 2.9x10^{-2}\ gHg/m^3W$
   or
   $(1.45x10^{-7})\ gHg/gW \times (4x10^{5})\ gW/m^3W = 5.8x10^{-2}\ gHg/m^3W$
7. Standard established by S.730 to be reached by 2009 for mercury emitted per cubic meter of waste =
   $8x10^{-3}\ mgHg/m^3W$
   and
   $(8x10^{-3})\ mgHg/m^3W / (2.9x10)\ mgHg/m^3W = 2.8x10^{-4}$
   or
   $(8x10^{-3})\ mgHg/m^3W / (5.8x10)\ mgHg/m^3W = 1.5x10^{-4}$
8. Total reduction =
   $1 - 0.00028 = 0.99972 = 99.97\%$
   or
   $1 - 0.00015 = 0.99985 = 99.99\%$

A reduction of 99.97% - 99.99% from 1999 levels of mercury emissions from solid waste incinerators
We can also calculate how much mercury in tons will be emitted from solid waste incinerators in 2009 if the standard is reached.

1. Amount of mercury emitted per cubic meter of waste.

$$\mathbf{8x10^{-3}\ mgHg/m^3W = 8x10^{-6}\ gHg/m^3W}$$

2. Density of waste:

$$\mathbf{2x10^5\ gW/m^3W - 4x10^5\ gW/m^3W}$$

3. Amount of mercury per gram of waste =

$$\mathbf{(8x10^{-6})\ gHg/m^3W / (2x10^5)\ gW/m^3W = 4x10^{-11}\ gHg/gW}$$

4. Amount of waste incinerated in United States in 1999 =

$$\mathbf{(34.5x10^{12})\ gW}$$

5. So the amount of mercury emitted in 2009 based on incineration levels of 1999 =

$$\mathbf{(4x10^{-11})\ gHg/gW \times (34.5x10^{12})\ gW = 1.38x10^3\ gHg = 1.33x10^{-3}\ THg}$$

Source: Personal Communication with Professor Patrick Louchouarn Columbia University, 2005.

ACRONYMS

List of Acronyms

ACI	Active Carbon Injection
APCD	Air Pollution Control Device
BTU	British Thermal Units
CAA	Clean Air Act
CEM	Continuous Emissions Monitoring
CWA	Clean Water Act
EPA	United States Environmental Protection Agency
ESP	Electrostatic Precipitator
FF	Fabric Filter
FGD	Flue Gas-Desulfurization
MACT	Maximum Achievable Control Technology
MWC	Municipal Waste Combustor
MWI	Municipal Waste Incinerator
PPM	Parts Per Million
PPT	Parts Per Trillion
RCRA	Resource Conservation and Recovery Act
SCR	Selective Catalytic Reduction
SDWA	Safe Drinking Water Act
SWDA	Solid Waste Disposal Act
UNEP	United Nations Environment Programme
USGS	United States Geological Survey

GLOSSARY OF TERMS

Anthropogenic - Human caused.[155]

Baghouse - Baghouses are used at many facilities to prevent particles, created by industrial processes, from entering the air. Particles in an airstream are filtered out on the surfaces of bags housed inside the unit.[156]

Bioaccumulation - A general term for the accumulation of a substance, such as methylmercury or other organic chemicals, in an organism. The accumulation process involves the biological sequestering of substances that enter the organism, such as fish or humans, through respiration, food intake, or epidermal contact with the substance. The sequestering results in the organism having a higher concentration of the substance than the concentration in the organism's surrounding environment. The level at which a given substance is bioaccumulated depends on the rate of uptake, the mode of uptake (through the gills of a fish, ingested along with food), how quickly the substance is eliminated from the organism, transformation of the substance by metabolic processes, the fat content of the organism, the hydrophobicity of the substance, environmental factors, and other biological and physical factors. As a general rule the more hydrophobic a substance is the more likely it is to bioaccumulate in organisms, such as fish. Another way of saying this is that bioaccumulation of a substance is correlated to the octanol-water partition coefficient of the substance. Increasing hydrophobicity (lipophilicity) leads to an increasing propensity to bioaccumulate. Some substances do not conform to this relationship, such as methlymercury. Methlymercury accumulates in fish to a much greater degree than methlymercury would indicate.[157]

Biomagnification - The process by which the concentration of toxic substances increases in each successive link in the food chain.[158]

Bituminous (and Sub-bituminous) Coal - A dense, black, soft coal, often with well-defined bands of bright and dull material. It is the most common coal, with moisture content usually less than 20 percent, generally used for generating electricity, making coke, and space heating. Sub-bituminous coal generally has a lower heat, chlorine and sulfur content than harder coal. Most of it lies near the surface. It has a medium capability of producing heat.[159]

British Thermal Units - The quantity of heat required to raise the temperature of one pound of water from 60° to 61°F at a constant pressure of one atmosphere.[160]

Cation - An ion or group of ions having a positive charge and characteristically moving toward the negative electrode in electrolysis.[161]

Continuous Emissions Monitoring – A method to directly measure air pollutants in real time, resultant data is used to evaluate the performance of systems and control technologies.[162]

Dosimeter - A device used to measure and record the exposure of an individual to a pollutant or another hazard especially when exposure occurs over an extended period of time, typically used to evaluate exposure to radiation.[163]

Dry Standard Cubic Meter - A measurement for waste products entering an incineration plant. Specifically, a unit of volume for dry waste (no liquid sludge or fluid products) measured 1mX1mX1m.

Flue Gas - Gas from combustion, which exit a combustion chamber by passing through various scrubbers and chambers before it is released into the atmosphere.

Fossil Fuel-fired Electric Utility Steam Generating Unit - Any fossil fuel fired combustion unit of more than 25 megawatts that serves a generator that produces electricity for sale. A unit that co-generates steam and electricity and supplies more than one-third of its potential electric output capacity and more than 25 megawatts electrical output to any utility power distribution system for sale shall be considered an electric utility steam generating unit.[164]

Jerome Meter - The Jerome mercury vapor analyzer uses a patented gold film sensor for accurate detection and measurement of toxic mercury vapor in the air.[165]

Landfill Leachate Systems - A system that handles water percolating through waste in a landfill, which becomes leachate. Leachate management systems include leachate collection systems to direct leachate to extraction points and minimize leachate head on the liner; leachate extraction and transmission designed to safely remove accumulated leachate from the landfill; leachate treatment and disposal facilities providing onsite or offsite treatment of the extracted leachate; and a liner system and stable foundation designed to contain leachate and prevent it from exiting the site.[166]

Leachate - A contaminated liquid resulting as water percolates through a landfill and reacts with chemicals or collects other materials.[167]

Loon Chick - Loons are water birds like ducks, geese, and grebes, but they are classified separately by scientists. The five species are Red-throated Loon *Gavia stellata*, Pacific Loon *Gavia pacifica*, Arctic Loon *Gavia arctica*, Yellow-billed Loon *Gavia adamsii*, and Common Loon *Gavia immer*. The Common Loon is the species best known to most of us, as its breeding range lies across most of Canada. The Loon chick can swim right away, but spends some time on the back of a parent to rest, conserve heat, and avoid predators. It has many bones that are solid, rather than hollow like those of other birds, which aid its diving ability. It can stay under water for almost a minute and dive to depths of 80 meters. Additionally, the loon chick may have to run as far as several hundred meters on the surface of the water on a calm day before gaining enough speed to take off.[168]

Mercury - A chemical that occurs in several forms in the environment. Elemental mercury (Hg^0) is a shiny, silver-white, odorless liquid that was commonly used in

thermometers. Elemental mercury contamination can be found at abandoned gold mine sites where it was used to extract gold from gold-bearing ores. Divalent mercury (Hg(II)) can combine with sulfur, oxygen, and chlorine to form mercury salts. Mercuric chloride ($HgCl_2$), which has been used as a preservative for water-quality samples for nutrient analysis, can cause gastrointestinal and kidney problems. Mercury sulfide (HgS) is the mineral cinnabar, which is mined as a source for mercury. Organic mercury is mercury that has formed compounds with carbon. Methylmercury is the most common example of this form of mercury. Phenylmercury and dimethylmercury are other examples of organic mercury that had medical and commercial uses. They are rarely found in the environment. Methylmercury and ethylmercury compounds were once used as fungicides; however, their use was banned in the 1970s due to their adverse health effects.[169]

Methylmercury (CH_3Hg^+) - An organic form of mercury, created from metallic or elemental mercury by bacteria in sediments. Methylmercury is easily absorbed into the living tissue of aquatic organisms and is not easily eliminated. Therefore, it accumulates in organisms at the top of food chains such as tuna or humans. Methylmercury is a neurotoxin, and the form of mercury that is most easily bioaccumulated in organisms. Mercury biomethylation is the transformation of divalent inorganic mercury (Hg(II)) to CH_3Hg^+, and is primarily carried out by sulfate-reducing bacteria that live in anoxic (low dissolved oxygen) environments, such as estuarine and lake-bottom sediments. Methylmercury can also be degraded in the environment, either by photodegradation reactions that take place without the help of bacteria or other organisms, or by bacteria through a variety of pathways.[170]

Methylation - To combine with the methyl radical. An organic compound in which the hydrogen of the hydroxyl group of methyl alcohol is replaced by a metal.[171]

Multimedia - Multiple intervening substances through which something else is transmitted or carried on.[172]

Neurotoxin - A toxin that damages or destroys nerve tissue.[173]

Point Source - A source, especially of pollution or radiation, occupying a very small area and having a concentrated output.[174]

Reagent - A substance used in a chemical reaction to detect, measure, examine, or produce other substances.[175]

Resource Conservation and Recovery Act (RCRA) - An act passed in 1976, which clarified the definitions of solid waste and responded to the growing public concerns about leakage and contamination of groundwater supplies from waste sites and underground storage tanks containing hazardous substances or petroleum products. RCRA tightly regulates all hazardous waste from "cradle to grave," as well as controls garbage and industrial waste. Some wastes are managed by other federal agencies or state laws.

Satellite Accumulation Area - A site for the collection of waste containers, usually located where waste is generated.[176]

Slurry - A thin mixture of a liquid, especially water, and any of several finely divided substances, such as cement, plaster of Paris, or clay particles.[177]

Solid Waste Incineration Unit - A distinct operating unit of any facility which combusts any solid waste material from commercial or industrial establishments or the general public (including single and multiple residences, hotels, and motels).[178]

Sorbent - A material that sorbs another substance; i.e. that has the capacity or tendency to take it up by either absorption or adsorption.[179]

Scrubber - The equipment that removes sulfur dioxide from combustion gases using a chemical reaction. Whether a scrubber is "wet" or "dry" depends on the amount of water used in the process and the state of the new compound formed from the chemical reaction.[180]

Solid Waste Disposal Act - An act passed by Congress in 1965 to properly manage and dispose solid waste. This legislation established grant programs to support the use of improved methods for disposal and the development of solid waste disposal plans by states agencies.

Spectroscopy - A method of identifying substances through the measurement of frequencies, uses a spectrometer to record spectra.

a. atomic absorption spectroscopy – method of spectroscopy where the analysis of the substance is based on the amount of light that a sample absorbs after passing through a flame.

b. atomic fluorescence spectroscopy – method of spectroscopy where the analysis is based on the amount of light emitted by a sample when it is exposed to lamplight while in a flame.[181]

Title V Permit - Permit established with the 1990 Clean Air Amendments which introduced the concept of a facility-wide air permit that brings all applicable state and federal air pollution control requirements under the umbrella of a single permit. Title V permits regulate major sources, which are defined as "any stationary source (or any group of stationary sources located within a contiguous area and under common control)."[182]

Toxin - A poisonous substance produced by living cells or organisms and is capable of causing disease when introduced into the body tissues, but is often capable of inducing neutralizing antibodies or antitoxins.[183]

Volatization - To evaporate or cause to evaporate.[184]

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