Can North American Mercury policies help China?

Submitted to: Dr. Gail Krantzberg

Supervisor: Dr. Gail Krantzberg

Author: Xu Zhang - 1082353

Department: Walter G. Booth School of Engineering Practices

Program: Master of Engineering & Public Policy

Table of Contents

1. Introduction

Mercury (Hg) contamination in the environment is now recognized as a serious and widespread problem in the world, not only in countries or regions that emit Hg, but also in remote areas with no point sources (Francis et al., 1998). Hg is emitted into the environment by both manmade and natural activities.

Mercury has many useful applications in industrial, medical and household due to its unique property among metals to exist in liquid state at nearly all temperatures (Jasinski, 1994). Notwithstanding its usefulness, Hg is a highly toxic metal that affects the nervous and cardiovascular system. Exposure to high doses of Hg over a short period of time may result in severe damages to liver and kidney, hallucinations, memory loss, nerve damage, inability to concentrate, tremors, loss of dermal sensitivity, slurred speech and in rare cases even paralysis and death (Mohapatra et al., 2006). Consumption of fish and wildlife is the principal route by which Hg enters the human body (Mahaffey, 2004) and can result in chronic Hg poisoning affecting mothers and fetus (Grandjean & Weihe, A new era of mercury hazards, 1998). Hg is bioavailable and remains in the environment for long periods of time imposing a risk to future generations (Grandjean et al., 1998).

The Great Lakes

The Great Lakes constitute one-fifth of the world's total fresh water resources. The Great Lakes Strategy has been important to the economic development of the eight states of the USA and two provinces of Canada that surround them. The Great

Lakes are a very essential source of hydroelectricity and drinking water for a large population in both countries. They allow shipment of goods to and from these countries and promote industrial, commercial, agricultural, and urban development within their vicinity plus providing a range of recreational opportunities (Mohapatra et al., 2007). Agricultural, industrial, and municipal activities, both within the Great Lakes basin and in upwind areas, have resulted in pollution by a variety of contaminants including Hg, resulting in degradation of ecosystem health and serious risk to human health (Marvin et al., 2004).

China

The economic boom sparked in 1980 resulted in China becoming the worlds' manufacturing factory. However, by following in the footsteps of many western countries that opted to "pollute first and clean up later," China built its economic success on a foundation of ecological destruction. This environmental destruction continues to threaten China's economy, human health, the ecosystem and social stability. China consumes more energy and emits more GHG than any other country ("Study Finds", 2007). The lack of widespread coal-washing infrastructure and scrubbers at Chinese industrial facilities and power plants exacerbates the problem. Regionally, sulfur dioxide and Hg emissions from coal burning are some of the main pollutants spreading from China. Acid rain caused by emission of sulfur dioxide (SO_2) from the combustion of coal and fossil fuel has damaged nearly one-third of China's limited cropland. Information on Chinese emissions is sketchy since the government has not publicly disclosed Carbon dioxide (CO_2) or Hg emissions data since 2001.

The most commonly cited numbers attribute 25-40% of global Hg emissions (from coal burning) to China (Kim & Turner, 2007).

2. Hg Pollution

2.1 Sources of Hg

Mercury emission can be divided into natural mercury emission and anthropogenic mercury emission. The latter can be continuously divided into point sources and non-point sources. Point source referees to an identifiable localized source such as industrial processes (Pai et al., 2000). Non-point source refers to pollution of water and air due to diffused sources such as agricultural activities.

Natural deposits of Hg are relatively rare and are generally found as cinnabar (HgS), an ore containing Hg. Mercury is also released to the environment through emissions from volcanic eruptions, forest fires, erosion of Hg-bearing soils and rocks, evaporation of Hg containing water, and animal secretions.

Combustion of coal accounts for most of the Hg emissions in the USA, Canada and China. The second contributor is metal mining and smelting. (Fig.1 shows atmospheric mercury emission in Canada, 2005) Combined incineration of municipal and medical waste is also a main source of Human-related Hg. Hg exists in many forms in the environment such as: elemental, inorganic and organic. While all forms are considered hazardous some are more toxic than others e.g. organic Hg which is considered most dangerous to health (Francis et al., 1998). Chemical and microbial

activities can convert elemental and inorganic Hg to highly toxic methylmercury which accumulates in lakes and other water bodies (Winfrey & Rudd, 1990).

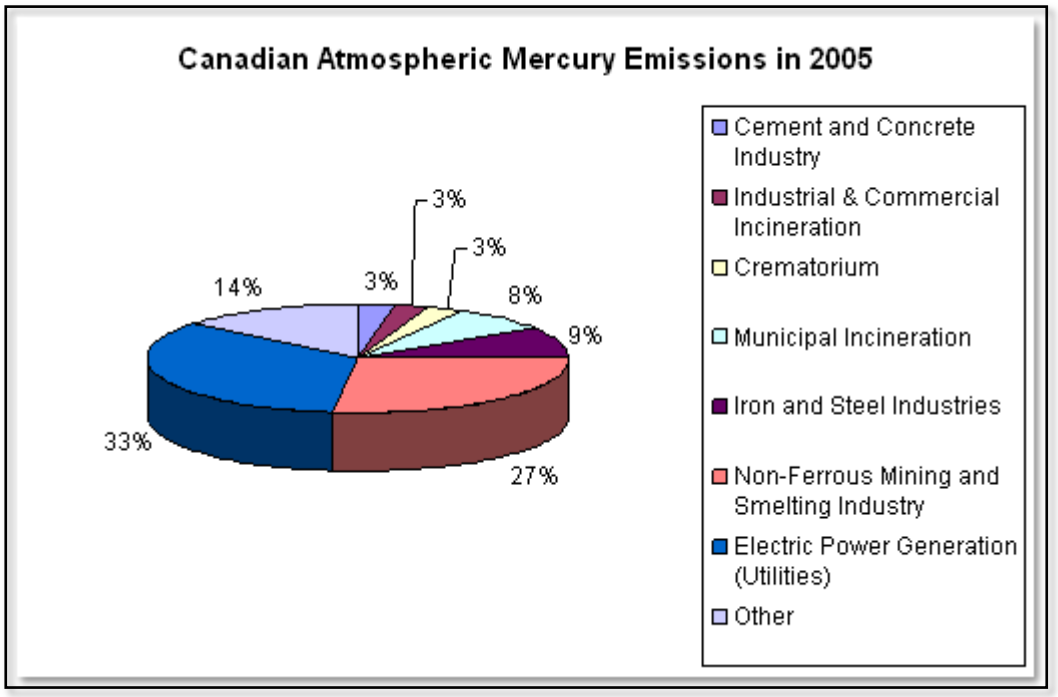

Figure 1 Canadian Atmospheric Mercury Emissions in 2005 (EC, Main Emission Sources, 2010)

2.2 Impacts of Hg pollutants

The methylmercury may bioaccumulate in living organisms and can be passed along to other organisms in the food chains. So it can lead to different level of damages from low-level consumers to high-level consumers.

Methylmercury can bioaccumulate from 100,000 to a million times the concentration in water to fish tissue (Boudou et al., 1979). Those fish on the top of the aquatic food chain are more likely allowing for inputs of contaminants from numerous sources and increased intake rates.

Birds and mammals that eat fish are more exposed to methylmercury than any other animals in water ecosystems. Similarly, predators that eat fish-eating animals are at risk. Effects of methylmercury exposure on wildlife can include death, reduced fertility, slower growth and development and abnormal behavior that affects survival, depending on the level of exposure (MedicineNet, 2011).

More than 60,000 children are born each year in the United States with neurodevelopmental impairments caused by exposure in the womb to methylmercury compounds (USGS, Mercury in the Environment, 2000). More moderate exposure in fetuses and during brain development during the first few years of life have been suggested as an important cause of infantile cerebral palsy. There was some preliminary evidence of a significantly elevated frequency of cerebral palsy in male children at three of five Areas of Concern located near former chlor-alkali plants in the Great Lakes basin (Weis, 2004).

3. Hg Policies for the Great Lakes Region

3.1 International Policies

3.1.1 Binational Policies

The Great Lakes are shared be the United States and Canada, which are very essential for industrial, agricultural and social use in both countries. Thus, some binational policies and programs were proposed to resolve mercury problems in the

Great Lakes basin.

Great Lakes Water Quality Agreement (GLWQA)

GLWQA was first signed in 1972 and later reenacted in 1978 to protect the lakes from persistent toxic substances, including Hg. In 1987, Canada and the USA signed the 1987 Protocol to the GLWQA to restore degraded areas identified around the lakes, prevent and control pollution and to conserve and protect human and ecosystem health.

Binational Toxics Strategy

This strategy was developed jointly by Canada and the USA in 1996–1997 with the goal of virtual elimination of persistent toxic substances including Hg in the Great Lakes basin. According to the strategy, the USA would achieve a 50% reduction nationally in the use of Hg and a 50% reduction in the release of Hg from sources resulting from human activity by 2006. The release challenge applied to the aggregate of emissions to the atmosphere nationwide and releases to the Great Lakes basin. Similarly, Canada vowed to achieve, a 90% reduction in the release of Hg by 2006 (Mohapatra et al., 2007).

NEG-ECP Mercury Action Plan

NEG-ECP Mercury Action Plan was adopted in June 1998 by New England States in US and Eastern Provinces in Canada (NEG/ECP, 1998). This plan specifies actions to protect the region's citizens and its environment from Hg by a coordinated and powerful set of tools to reduce anthropogenic releases of Hg in the region and remove Hg from the region's waste streams. Outreach and education activities include

increasing public awareness of fish consumption advisories; reducing Hg releases and use in hospitals and dental offices; diverting Hg from the waste stream through source separation and recycling; and eliminating Hg hazards in the classroom. Pollution prevention programs include efforts to address the Hg content of consumer and commercial products through implementation of state legislation and through development of standards. Hg collection programs and thermometer exchanges have also contributed to successful efforts to reduce the Hg burden in the solid waste stream (NEG/ECP, 1998).

3.1.2 Other International Polices

Hg migrates from one part of the globe to another hence international approaches has been developed to reduce emissions.

North American Agreement on Environmental Cooperation

NAAEC includes management of chemicals with the goal of phasing out hazardous chemicals, such as bioaccumulative toxic substances like Hg (NAAEC, 1994).

Basel Convention

The BC on control of transboundary movements of hazardous wastes and their disposal aims to ensure that the generation of hazardous waste is reduced; disposal of hazardous wastes remains within the country of their generation; and enhance controls on export and import of hazardous waste (BC, 1992).

Rotterdam Convention

The Rotterdam Convention on the prior informed consent procedure for certain chemicals and pesticides in international trade aims to limit and control the trade in hazardous chemicals. The convention is a legally binding procedure that requires exporters trading in a list of hazardous substances including Hg and Hg compounds to obtain the prior informed consent from importers before proceeding with the trade (RC, 1998).

Aarhus Protocol

In 1998 Aarhus Protocol targets to control and reduce heavy metals such as cadmium, lead and Hg from Central and Eastern Europe, Canada and USA. The Protocol also aims to cut emissions from industrial sources, combustion processes and waste generation. The Protocol suggests best available techniques, such as filters, scrubbers or Hg-free processes to limit emissions from point source. The Protocol introduces measures lowering emissions from Hg in batteries and proposes the introduction of management measures for other Hg-containing products (Aarhus Protocol, 1998).

United Nations Environment Program

The UNEP undertook a global assessment of Hg and Hg compounds in 2002**.** Later it announced a new Hg program with a long-term objective to facilitate national, regional, and global actions and to reduce or eliminate the use and release of Hg. However, at its meeting in Kenya in February 2005, countries rejected the treaty to curb the production and export of Hg. Instead, the countries agreed to adopt voluntary actions to improve Hg management, a strategy endorsed by the US (Khamsi, 2005).

3.2 Federal Policies

3.2.1 Policy in the USA

Toxics Release Inventory (TRI)

In 1988, the Toxics Release Inventory (TRI) regulated mandatory reporting of releases of nearly 650 toxic chemicals including mercury. The reporting threshold for Hg at that period was 10 lb per year. In the USA, the TRI has been a publicly available EPA database that contains information on toxic chemical releases and other waste management activities which is reported annually.

Clean Air Act 1990

Compared to previous Clean Air Act between 1970 to 1990 that only 7 pollutants were regulated, the 1990 Clean Air Act Amendments required EPA to identify categories of industrial sources for 187 listed toxic air pollutants including mercury and to take steps to reduce pollution by requiring sources to install controls or change production processes. The 1990 Clean Air Act also required EPA to first set regulations using a technology-based or performance-based approach to reduce toxic emissions from industrial sources. After EPA sets the technology-based regulations, the Act requires EPA to evaluate any remaining risks, and decide whether it is necessary to control the source further (USEPA, Reducing Toxic Air Pollutants, 2011).

Solid Waste Combustion Rules

EPA has also issued final rules to control emissions of certain air toxics from

solid waste combustion facilities. These rules set emissions limits for new solid waste combustion facilities and provide emissions guidelines for existing solid waste combustion facilities. Municipal Waste Combustors Rule was published on December 19, 1995 and then amended on August 25, 1997. The rule affected an estimated 164 municipal waste combustion units and has significantly reduced air toxics emissions (dioxins, lead, cadmium, and mercury). The rule would have reduced mercury emissions by 90 percent, compared with 1990 emissions levels from these sources. Hospital/Medical/Infectious Waste Incinerators Rule was published on September 15, 1997, and it affected an estimated 2,400 existing incinerators and has reduced air toxics emissions (dioxins, lead, cadmium, and mercury) by more than 25 tons per year (USEPA, Summaries of Related Solid Waste Incineration Rules, 2011). The implementation of emissions standards on incinerators was anticipated to result in up to 95% reduction in Hg emissions (Murray & Holmes, 2004).

Water Quality Guidance for the Great Lake Systems

Under the Clean Water Act, in 1995, EPA and the Great Lakes states agreed to a comprehensive plan to restore the health of the Great Lakes. The Final Water Quality Guidance for the Great Lakes System, also known as the Great Lakes Initiative, includes criteria for states to use when setting water quality standards for 29 pollutants, including bioaccumulative chemicals of concern, and prohibits the use of mixing zones for these toxic chemicals (USEPA, Great Lakes Initiative, 2011). EPA also issued water quality criteria for methyl-Hg to be used by every state in determining methyl-Hg levels in fish tissue.

Battery Act

Mercury-Containing and Rechargeable Battery Management Act (Battery Act) in 1996, phases out the use of mercury in batteries, and provides for the efficient and cost-effective disposal of used nickel cadmium (Ni-Cd) batteries, used small sealed lead-acid (SSLA) batteries, and certain other regulated batteries. The statute applies to battery and product manufacturers, battery waste handlers, and certain battery and product importers and retailers (USEPA, Mercury-Containing and Rechargeable Battery Management Act, 1997).

Safe Drinking Water Act

Under the Safe Drinking Water Act, EPA sets standards for drinking water that apply to public water systems. These standards protect people by limiting levels of mercury and other contaminants in drinking water. Mercury contamination in drinking water can come from erosion of natural deposits of mercury, discharges into water from refineries and factories, and runoff from landfills and cropland. U.S. states have the primary responsibility for enforcing drinking water standards (USEPA, Safe Drinking Water Act, 1996).

Clean Water Act 2002

Under the Clean Water Act amended in 2002, states adopt water quality standards for their rivers, streams, lakes, and wetlands. These standards identify levels for pollutants, including Hg, that must be met in order to protect human health, fish, and wildlife. No person may discharge pollutants, including mercury, into waters

unless the person has a permit. Under the Act, either EPA or U.S. states issue permits, which must include limits that ensure the water quality standards are met. In addition, EPA and U.S. states issue information to the public on waters contaminated with mercury and on the harmful effects of mercury, identify the mercury sources and reductions needed to achieve water quality standards, and warn people about eating fish containing high levels of methylmercury (USEPA, Clean Water Act, 2002).

Universal Waste Regulations

This regulations promulgated in 2002, Stream-lined collection requirements for certain wastes, including mercury-containing batteries, pesticides, lamps, and thermostats.

Reduction of Toxic Air Pollutants from Mercury Cell Chlor-alkali Plants

On December 19, 2003, the final rule reduces mercury emissions from mercury cell chlor-alkali plants that are considered “major sources” of hazardous air pollutants as well as facilities considered to be “area sources”. Mercury cell chlor-alkali plants produce chlorine and caustic using mercury cells.

Clean Air Mercury Rule

On March 15, 2005, EPA issued the Clean Air Mercury Rule, which creates performance standards and establishes permanent, declining caps on mercury emissions. The Clean Air Mercury Rule marks the first time EPA has ever regulated mercury emissions from coal-fired power plants (USEPA, 2005).

Mercury Export Ban Act

This Act was signed into law on October 14, 2008. The Act includes provisions on both mercury exports and long-term mercury management and storage. The Act has three main provisions: Federal agencies are prohibited from conveying, selling or distributing elemental mercury that is under their control or jurisdiction. This includes stockpiles held by the Departments of Energy and Defense; export of elemental mercury is prohibited from the United States beginning January 1, 2013; the Department of Energy (DOE) shall designate one or more DOE facilities for long-term management and storage of elemental mercury generated within the U.S. This designation must occur no later than January 1, 2010 (USEPA, Mercury Export Ban Act, 2008).

3.2.2 Policy in Canada

Similarly, there are many federal regulations in Canada to control Hg emissions.

Canada Water Act

Promulgated in 1985, it regulates waste including Hg, that may be released into any water body in any water quality management area (Minister of Justice, Canada Water Act (R.S.C., 1985, c. C-11), 2011).

Canada Shipping Act

The Act was regulated in 1985 to prevent discharge of pollutant including Hg from any ship within the Great lakes (Minister of Justice, Canada Shipping Act (S.C. 2001, c. 26), 2011).

Fisheries Act

This Act imposed in 1985, regulates discharge of any deleterious substances including Hg into waters (Minister of Justice, Fisheries Act (R.S.C., 1985, c. F-14), 2011).

Fertilizers Act

Government promulgated this act in 1985 to restrict sale of any fertilizer/supplement considered a hazard to the ecosystem (Minister of Justice, Fertilizers Act (R.S.C., 1985, c. F-10), 2011).

Hazardous Products Act

This Act regulated in 1985 is to prohibit the use of Hg or its compounds in children's toys production (Minister of Justice, Hazardous Products Act (R.S.C., 1985, c. H-3), 2011).

Chlor-alkali Mercury Release Regulation

Promulgated in 1990, it regulates release of Hg from Chlor-alkali plants, aiming to reduce direct Hg releases into Great Lakes (Minister of Justice, Chlor-Alkali Mercury Release Regulations (SOR/90-130), 2011).

Transportation of Dangerous Goods Act (TDGA)

The Act promulgated in 1992 is to control the handling and transport of dangerous goods (Minister of Justice, Transportation of Dangerous Goods Act,1992 (S.C. 1992, c. 34) , 2011).

National Pollutants Release Inventory (NPRI)

NPRI established in 1992, requires companies to report information on releases and transfers of pollutants to the Government of Canada on an annual basis. NPRI

lowered the reporting threshold for Hg and its compounds from 10 ton to 5 kg for the 2000 reporting year (EC, 2000).

Canadian Environmental Protection Act (CEPA)

Proposed in 1999, CEPA began to implement pollution prevention and control/elimination of toxic substances including Hg (Minister of Justice, Canadian Environmental Protection Act, 1999 (S.C. 1999, c. 33), 2011).

Canada-wide Standards

The Canadian Council of Ministers of the Environment (CCME) in 2002 developed and implemented standards for Hg emissions from base metal sector and waste incineration (CCME, 2000). In 2005 standards were imposed to reduce Hg emissions from the coal-fired power generation by 2010 (CCME, Notice on a Canada-wide standard for Hg emissions from coal-fired power plants, 2003). However, the Canada-wide Standard set by CCME does not establish a cap on total emissions from metal smelting or incineration sectors.

Surface Water Standards

CCME implemented guidelines for contaminants including Hg in surface water for the protection of community, agriculture, and aquatic life. Provinces have developed surface water quality objectives on the basis of these guidelines, such as the Ontario Provincial Water Quality Objectives. However, these objectives are not legally enforceable and are yet to be achieved.

3.3 Provincial and States Policy

Relevantly, there are many provincial and states policies that aim to prevent/control mercury pollutants and remove mercury pollution from communities. Some examples are shown below:

Indiana

HB 1901 was adopted to prohibit the sale and distribution of most mercury-added novelties after July 1, 2003. Limits the circumstances under which a mercury fever thermometer may be sold or supplied to an individual after July 1, 2003. The bill restricts a public or nonpublic school from using or purchasing a mercury commodity, mercury compounds, or mercury-added instructional equipment and materials after July 1, 2003. It also provides that a person may sell or provide a mercury commodity to another person after July 1, 2003, only if the person meets certain conditions. Then it requires the department of environmental management and solid waste management districts to implement mercury education programs (Indiana General Assembly, 2001).

Michigan

HB 4599 prohibits the sale of mercury thermometers. In the House Committee on Commerce on April 17, 2001 and voted out on January 29, 2002. House Bill 4599 would add a new part to the Natural Resources and Environmental Protection Act to prohibit the sale, offering for sale, or offering for promotional purposes of mercury thermometers in the state or for use in the state beginning on January 1, 2003. The law would make an exception for selling, offering for sale, or offering for promotional

purposes a mercury fever thermometer for which there was a prescription. The manufacturer would have to supply clear instructions on the careful handling of the thermometer to avoid breakage and proper cleanup should a breakage occur with each thermometer sold by prescription (Michigan Lagislature, 2011).

Minnesota

HF 274 and SF 70 prohibit the sale of mercury thermometers. Since 1992, the state has passed numerous bills into law related to mercury product issues and has served as the model for others to mirror and build upon (Bender, 2004).

New York

AB 4209 and **SB 3084** are the same bills in the two houses entitled "Mercury Free Water Resources and Mercury Reduction Management Strategy Act of 2001"; provide for: disclosure of mercury content, phase-out of mercury-added products, disposal prohibition, labeling, source separation, collection, requirements for sewage treatment plants, point source release containment traps, ban on sale or distribution of certain mercury products, replacement of manometers and gas pressure regulators (agriculture department to handle for dairy industry), regulates dental use and bans health insurance discrimination therein, requires lamp recycling; adds all mercury-added products to state universal waste rules; provides for a state advisory committee on mercury pollution; provides for penalties for violations (Bender, 2004).

Wisconsin

NR 446 is an administrative rule that is being modified to limit mercury emissions from coal burning plants and industrial operations that have mercury

emissions of more than 10 pounds a year. A 15 year phase-in of a 90% reduction is called for. As proposed, part of the required mercury reductions can be offset by removing mercury from products (Bender, 2004).

Ontario

Canada-Ontario Agreement 2002

This agreement is more stringent and envisages an 85% reduction in Hg releases by 2005, compared to releases in 1988, and a 90% reduction by 2010. The strategies involved developing standards for Hg emissions from coal-fired plants, developing technical information to guide municipalities in identifying and reducing sources of Hg discharges to sewer systems, developing and implementing life cycle management programs to divert Hg-containing products from the waste stream and public education program on Hg (COA, 2002).

Canada-Ontario Agreement 2007

The 2007 COA is guided by the vision of a "healthy, prosperous and sustainable Great Lakes Basin for present and future generations." Through its four Annexes (Area of Concern, Harmful Pollutants, Lake and Basin Sustainability and Coordination of Monitoring, Research and Information), the Agreement establishes the priorities and goals for the environmental protection and rehabilitation of the Great Lakes over its three-year term. The Harmful Pollutants Annex works towards the virtual elimination of legacy pollutants, including mercury, as well as the reduction of ongoing sources of pollution, such as wastewater effluents and air pollutants. Other goals include reducing other harmful pollutants, and enhancing the

knowledge necessary to reduce releases and mitigate risks (COA, Canada-Ontario Agreement Respecting the Great Lakes Basin Ecosystem 2007, 2007).

3.4 Municipal Policy

Many municipalities have by-laws specifying a maximum concentration of Hg that can be released by industrial units to the sewer system and have been successful in regulating the release of Hg. For example, the Toronto by-law specifies the requirement for dental practices and operators to install, operate and maintain dental waste amalgam separators. Installation of the separators is one of the process changes expected as a result of pollution prevention planning (City of Toronto, 2010).

3.5 Evaluation of such policies

Successfully, the effective implementations of such policies have brought many satisfactory consequences in mercury reduction. The Annual release of mercury into Great Lakes basin was cut from more than 14 tons in 1988 to less than 3 tons in 1994 (EC, Reducing Mercury in the Great Lakes, 2001). For instance the Binational Toxics Strategy, in Ontario, releases of mercury have been reduced by slightly more than 90% between the 1988 baseline and 2006, thus achieving the Canadian 90% reduction target (EPA & EC, Great Lakes 2009 Biennial Report Binational Toxics Strategy, 2009). Total mercury use in the U.S. is estimated to have declined by more than 50% between 1995 and 2003. According to the National Emissions Inventory, U.S. mercury emissions decreased approximately 58% between 1990 and 2005 (EPA &

EC, 2009).

However, there are still some unsatisfactory facts that have made potential risks to mercury management. There is no federal/provincial ban to stop mercury thermometer selling in Canada, that has resulted in Canada becoming the dumping ground for North American mercury thermometers that are rapidly being phased-out of use in the USA (Pollution Probe, 2001). Lack of research and political activities aiming to resolve health impacts and compensate individuals or communities who are suffering Hg-related diseases has made adults and children in concerned regions still dangerous in mercury exposure. Less effective public education leads to people's continuous consumption of sport fish without awareness especially for kids and pregnant women (Gilbertson & Carpenter, 2004). An emissions trading system for mercury included in Clean Air Mercury Rule would allow poorly performing power plants to buy credits from plants with lower mercury emission levels instead of cleaning up. Such a scheme may result in the creation of so-called mercury hotspots in areas downwind of plants that rely on buying credits (Mohapatra et al., 2007). In addition, because of different discharge limit standards for toxic compounds in different municipalities, incentive might be provided for an industry to move to less strict location. There is no international ban to restrict Hg-related industry transfer to developing countries from developed countries, thus it would cause no reduction of mercury emission at global level (Hylander, 2001).

4. Policies for Hg reduction in China

4.1 The trend of Hg consumption and emission in China

Jaffe says highly–toxic Hg is a particularly troubling part of China's growing emissions (Nadvornick, 2010). China is the most Hg production and consumption country in the world, more than the US, India and Europe combined. Till now there are only two countries which still mine virgin Hg from ground in the world, Kyrgyzstan and China. China’s production is utilized domestically but to meet demand China continues to import several hundred additional tons of Hg each year (NRDC, Natural Resources Defense Council, 2011).

Before the 1990s, the production of Hg was always above 1,000 tons. After 1990s, the production declined year after year as the Hg resources suitable for exploitation became smaller and smaller. Until 2001, the production was 193 tons. Then, the production increased rapidly, to approximately 1140 tons in 2004 (China Nonferrous Metal Industry, 2005). Fig 2 indicates Hg production 2003 to 2009 in China. The temporal decrease during 2005 to 2008 may be influenced by clean manufacturing aiming to welcome the Olympic Games held in Beijing. In 2009 the recovered production jumped to nearly 1500 tons.

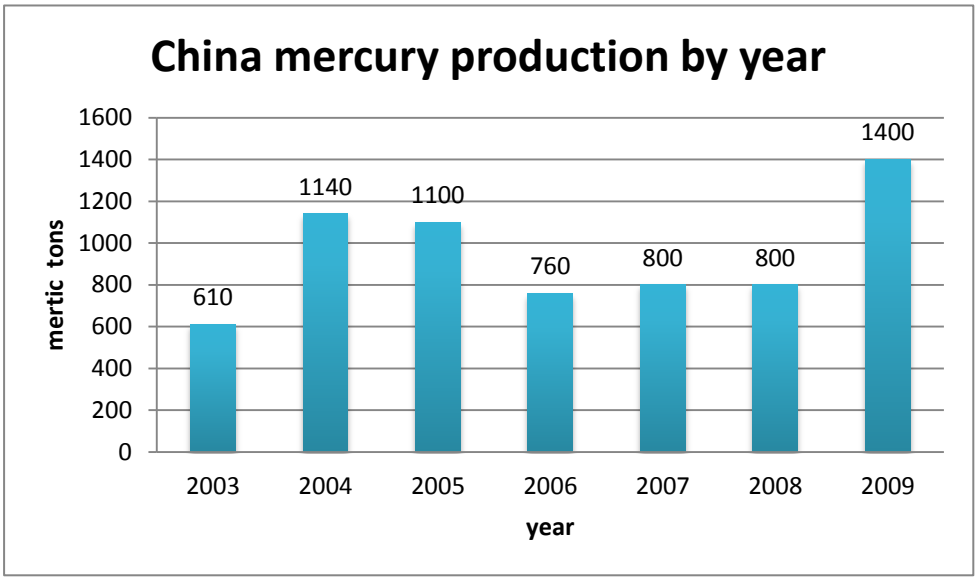

Figure 4 Hg production from 2003 to 2009 in China (USGS, 2011)

The most significant use of Hg in china is the manufacturing of poly vinyl chloride (PVC) plastic which can be used as a catalyst, and is also used for water and sewer pipes, plastic toys and clothing. The second and third essential legal uses of Hg are battery manufacturing and artisanal gold mining (NRDC, NRDC Fights to Stop Hg Pollution in China: China is Cornerstone in Solving Global Hg Problem, 2007).

Researchers at the Chinese Academy of Science in Changchun calculated that in 1995, the most recent year for which data is available, China spewed nearly 215 tons of Hg into the air. Electric power production proved the biggest single Hg polluter, sending more than 70 tons skyward each year. Residential coal burning released only a quarter as much. Manufacturing sectors together released another 100 tons ("Study Find", 2011).

In Discover magazine, David Kirby wrote “China is full of the two biggest contributors to human-generated Hg, metal smelting and coal combustion. (Kirby, 2011)” Manmade Hg emission in China for 1999 is calculated and reported that about

590 tons were emitted in China, comparing 117 tons in the US. In China almost half came from metals smelting, especially zinc, because of its high concentration of Hg in ores. Second is coal-fired power plants, which made up 38 % of Chinese Hg emissions (Hays, 2008). According to Streets, China's Hg emission in 2003 was calculated at 767 tons. The annual growth rate during those years is about 5% - 6%.

Based by John Ashton on the Chinese power industry China was building two new power plants a week to achieve the requirement for daily accelerated urbanization. Hg emission from coal combustion averaged an annual increase rate of 5.1% from 1995 to 2005 (Streets et al., 2009). Research on coal component between China and the United States, depicts that China coal contains 50% more Hg than the US.

4.2. Hg Control and Reduction policies in China

In 1970s China commenced a research on controlling Hg pollution but there were not many measures to effectively monitor, prevent, control, reduce and manage Hg contamination (Liu, 2010).

In recent years, Chinese government paid great attention to prevention and control of Hg pollution and a series of laws and regulations have been promulgated and implemented in order to reduce production and use of Hg (China Nonferrous Metal Industry, 2005).

There are some main policies or regulations related Hg in China: (Table 1)

Policy or regulation	Time	Description

Listed in Catalogue of Toxic Chemicals Prohibited or Strictly Controlled	1994	Hg and its compounds were included in the "banned or severely restricted list of toxic chemical". Their export and import require registration and environmental management approval.
Principle of setting the import amount	2002	The annual approval of import is less than 300 tons.
"Hg-free batteries" standard	1995	Hg in a battery cannot exceed $1\times10^{-4}\%$ of the total battery weight
Restriction on Hg content in batteries	1997	It prohibits production or sales of any battery with Hg fraction > 0.025%; production, sales and import were prohibited for Alkaline Zn-Mn batteries with Hg fraction > 0.0001%.
Standard for Hg contents in batteries	2005	Concentration of Hg in Zn-MnO2 cells ≤ 1ug/g; concentration of Hg ≤20 mg/g in Zn-AgO button cells, alkaline Zn-MnO2 button cells and Zn-air button cells.
Technical requirement for environmental labeling of products-energy saving lamps	2006	Hg ≤ 10mg in one fluorescent lights
list of eliminating backward production capacity, technology and products (first)	1999	Hg-process caustic soda and indigenous Hg extraction process as out-of-date production technology that shall be phased out at once; Hg containing battery as an out-of-date product and phasing out the gold extraction by Hg process by 2002.
National list of hazardous wastes	1998	Hg and its compounds are included, and their transport, disposal, waste management are required to follow regulation.
National Construction plan for establishing Medical and Hazardous Waste Disposal Centers	2004	encourages the centers to install facilities to deal with fluorescent tubes and batteries containing Hg, cadmium, lead, nickel and so on.
Catalogue for the Guidance of Industrial Restructuring	2005	the mercuric chloride catalyst, Hg glass thermometer, Hg sphygmomanometer, arquerite dental material projects as restricted development projects.
Environmental Quality Standards		specifies Hg limits for the quality of water, air, soil and marine environment.
Emission Control Standards		specifies Hg pollution release/control standards for water, air and solid wastes. Such as leaching toxicity of pollutants MethylHg: <10ng/L, EthylHg: <20ng/L, Total Hg: ≤0.1mg/L.

Food Hygiene Standards		provides concentration limit of Hg in food, such as meat and egg (no shell) Hg concentration < 0.05 mg/kg; edible fish methyl-Hg concentration < 1.0 mg/kg; no edible fish and others methyl-Hg concentration < 0.5 mg/kg.

Table 1 main Hg policies and regulations in China (Department of Pollution Prevention and Control, 2009; Liu, 2010; Zhu, 2010)

5. Measure and Policy Recommendations for China

China lags behind when compared to North America in terms of Hg regulations and reduction. In mid-1990s, China began to promulgate acts and regulations to control/prevent Hg pollution while the US and Canada started regulation and procedures since the early 1980s. Because of mandatory management on reporting accurate and specific data of Hg production, consumption, pathways, routes, emission and recycling, both countries can give feasible and effective measures to avoid Hg contamination. More ecological and medical researches on Hg exposure would give a better understanding between methyl-Hg toxicity and public and ecosystem health.

Emission inventory

Currently due to the lack of reliable data it is impossible to confirmed Hg emission inventory in China. The first attempt at data collection was through NRDC collaboration with China's central government and research institutions to produce the first comprehensive inventory of Hg use within key manufacturing sectors (NRDC China, 2011). The estimated inventory of anthropogenic Hg emission in China which

includes: Aluminum extraction and processing, other non-ferrous metals-extraction and processing, Pulp and paper production, production of lime and light weight aggregates kilns, VCM (vinyl-chloride-monomer) production with Hg-dichloride, thermometers, electrical switches and relays, electrical lights, batteries, biocides and pesticides, paints, pharmaceuticals for human and veterinary uses, production of recycled metals, incineration of hazardous waste and medical waste, incineration of sewage sludge, and informal waste disposal (Tsinghua University, 2006). However the list lacks life cycle of the products and evaluation of amount of Hg within the products. However, to reduce Hg there is the need for source management. Due to the amount of coal-fired power plants and power plants emitting Hg into the atmosphere, the difficulty for data collection at a national level may be impossible for China however, reliable data collection at local and municipal level will play a core role in development of policy emissions reduction.

Develop clean technologies

Although no Hg use is real at present, advanced technologies which do not use or use less Hg can be helpful for eliminating emission. Using alternative materials will help reduce emissions in China e.g. PVC production in China uses coal as the raw material however petroleum discharges less Hg. Increasing coal chemical industry and coal washing can effectively decline the Hg contents in coal combustion. Giving incentives such as lower tax and low rate loan to industries can promote use of better technology and material more industry to improve the production technology. Moreover, relevant political supports, for example prior registration to those

industries with advanced and “green” technology, may encourage more stakeholders increase investment on clean production. Like setting mercury emission caps to industry in the Clean Air Mercury Rule, but with stringent or unallowable emission trading systems can help to close the most polluted factories and limit buying credits between industries.

Renewable energy

Most small coal-fired power plant operates on tight a budget. These small plants can be replaced by power plants with large scale production with sufficient financial support to promote mercury-free and renewable technology. Because of the present energy crisis throughout the world, developing renewable energy will help cities and regions compensate the energy supply/demand gap as well as reduce mercury emission during electricity generation. To keep pace with the fast-growing urbanization in China, it is unrealistic to phase out or divert coal-fired power plants with substitution of renewable energy in short term. However, that should be considered as a long term goal to virtually eliminate mercury emission and polluted power generation aiming to reduce risks of mercury exposure to human health, fish and wildlife. In short term, maintaining coal-fired power plants to meet the demands of growing city population is necessary, but the pace of establishing renewable energy should increase and gradually take up more percentage in energy supply. There are sufficient renewable energy resources in China which can be used to generate clean electricity, such as abundant wind power on north and northwest, rich hydro resources on southeast and solar on the west.

Reduce and recycling

Hg-containing products such as thermometers and lamps should be declined their production and gradually seeking its substitution products in the future. In terms of current Hg-containing products, should be monitored in order to implement recycling products. Efficient recycling technology is required to process these products separately to ensure non migration into the food chains. In addition, energy conservation directions will help to increase the life time of electric facilities like lamps with decreasing the operating time on daily use.

Advisories for fish consumption

Research on fish Hg concentration should collected with the aim of reducing health problems people who eat fish or fish products in Hg polluted regions. Governments should give specific information to citizens on fish consumption. Such media like newspapers, TV programs and Internet would play important roles in promote the public attentions to eat fish follow the confirmed consumption advisories. This kind of advisories with yearly updated information based on latest research will do more helpful to decline the risks to expose mercury to children and pregnant women.

Regular physical examination

The regular free physical examination will help researchers or medical officials learn clear about the current status of mercury pollution and the level of risks for local residences as soon as possible through detecting Hg concentration in people's hair or blood. In that case, relevant strategies to prevent mercury exposure and treat

mercury-related diseases would be proposed to keep people being influenced.

Raise public awareness and education

Awareness, training and education on Hg, its products, effects and exposure must be part of public health program. This program must be part of the elementary school programs. Inviting students to visit exhibition of mercury reduction, risks of mercury and ecological protection is helpful to raise the awareness within youths. Kind of campaigns that city officials give courses in schools and communities to teach students and senior people about environment protection including mercury reduction, prevention and control, energy conservation, battery and thermometer collection can effectively increase the realization of hazardous waste and how to prevent.

Enhance international collaboration

International collaboration is very important to reduce the total amount of Hg in the world. Norway and China started the first bilateral project on Hg in 2006, using Guizhou Province as the case study ("Study Find", Training on Mercury Monitoring Technology in Beijing, 2011). China has 14 neighbouring countries inland and 6 neighbour countries at sea. Joint programs can effective promote the monitoring and management of Hg emission across borders. Restriction on Hg import and export can encourage China with those countries reduce Hg production and outflow.

The latest international cooperation in China is a research team on the Special Policy Study on Mercury Management in China in 2010. Consisting of 13 renowned Chinese and foreign scientists, this team would mainly engage in studying mercury and mercury-related industry in China and its impact on human health and social

economy, and make policy suggestions on mercury convention and management in China. In this year's meeting, a work report was delivered which briefed about the latest development of mercury management in China, progress of inter-government negotiation on mercury convention and its impact on China (Chinese Academy of Sciences, 2011). I believe more and more research will be operated under global collaboration to reduce mercury emission.

6. Conclusion

The mercury pollution and its relevant problems indeed cause much more attention throughout the world. To reduce the total amount of mercury emissions, efforts of few countries or regions cannot reach the goal of reduction and removal. Thus reduction of mercury emission needs participation of all countries and regions. After the inquiry of mercury related policies in Great Lakes region and in China, I found policies in China are not open that gave me many limitations when doing research. And there would be a long journey for China to catch pace with the enforcement of mercury policies. However, there are many shortcomings among the policies in Great Lakes basin where more amendments need to make up. I recommend mercury policies for China by learning good points and supplementing those shortcomings from policies in North America. I believe polices, regulations and political activities will be open to public and the consequence in resolving mercury pollution will be satisfactory in the future.

7. Reference

China Nonferrous Metal Industry. (2005). *Year Book of China Nonferrous Metal Industry.* China Nonferrous Metals Industry Yearbook Editorial Board.

"Study Find". (2011). *China: A Mercury Megapolluter.* Retrieved from http://www.dumbellnebula.com/methylmercury.htm

"Study Find". (2011). *Training on Mercury Monitoring Technology in Beijing.* Retrieved from http://www.norway.cn/News_and_events/Environment-and-development/Environment/Training-on-Mercury-Monitoring-Technology-in-Beijing/

"Study Finds". (2007, June 20). *China overtakes U.S. in greenhouse gas emissions.* Retrieved from The New York Times: http://www.nytimes.com/2007/06/20/business/worldbusiness/20iht-emit.1.6227564.html

Aarhus Protocol. (1998). *The 1998 Aarhus Protocol on Heavy Metals*. Retrieved from http://www.unece.org/env/lrtap/hm_h1.html

BC. (1992). Retrieved from Basel Convention: http://www.basel.int/Home/tabid/2202/Default.aspx

Bender, M. (2004). *Status of State and Federal Mercury Legislation in the United States.* Mercury Policy Project.

Boudou, A., Delarche, A., Ribeyre, F., & Marty, R. (1979). Bioaccumulation and bioamplification of Hg compounds in a second level consumer, Gambusia affinis-temperature effects. *Bull Environ. Contam. Toxico.*, pp. 22, 813-818.

CCME. (2000). *Canada-wide standards for Hg emissions.* Canadian Council of Ministers of the Environment.

CCME. (2003). *Notice on a Canada-wide standard for Hg emissions from coal-fired power plants.* Canadian Council of Ministers of the Environment.

Chinese Academy of Sciences. (2011). *China acts on mercury convention and management.* Retrieved from http://english.ihep.cas.cn/prs/ns/201111/t20111124_79322.html

City of Toronto. (2010). *Toronto Municipal Code.* Retrieved from http://www.toronto.ca/legdocs/municode/1184_toc.html

COA. (2002). *Canada-Ontario Agreement 2002.* Retrieved from http://www.on.ec.gc.ca/laws/coa/agreement_e.html#harmful_pollutants

COA. (2007). *Canada-Ontario Agreement Respecting the Great Lakes Basin Ecosystem 2007.* Retrieved from http://www.ecoissues.ca/index.php/Canada-Ontario_Agreement_Respecting_the_Great_Lakes_Basin_Ecosystem_2007

Department of Pollution Prevention and Control. (2009). Management and control measures of Hg issues in China. China.

EC. (2000). *Overview of changes to year 2000 reporting criteria.* National Pollutants Release Inventory, Environment Canada.

EC. (2001). *Reducing Mercury in the Great Lakes.* Retrieved from http://www.on.ec.gc.ca/coa/2001/mercury-e.html

EC. (2010). *Main Emission Sources.* Retrieved from

http://www.ec.gc.ca/air/default.asp?lang=En&n=445F1FB1-1

EPA, & EC. (2009). *Great Lakes 2009 Biennial Report Binational Toxics Strategy.* EPA & EC.

Francis, D. R., Jude, D. J., & Barres, J. A. (1998). Hg Distribution in the Biota of a Great Lakes Estuary: Old Woman Creek, Ohio. *Great Lakes Res.*, pp. 24(3):595-607.

Gilbertson, M., & Carpenter, D. O. (2004). An ecosystem approach to the health effects of mercury in the Great Lakes basin ecosystem. *Environmental Research*, pp. 95, 240-246.

Grandjean, P., & Weihe, P. (1998). A new era of mercury hazards. *Environmental Research*, pp. 77(A), 67.

Grandjean, P., Weihe, P., White, R., & Debes, F. (1998). Cognitive performance of children prenatally exposed to "safe" levels of methylHg. *Environmental Research*, pp. 77(A), 165–172.

Hays, J. (2008). *ENVIRONMENTAL PROBLEMS IN CHINA: POLLUTION, MERCURY, LEAD POISONING, CANCER VILLAGES, AND HEALTH PROBLEMS.* Retrieved from http://factsanddetails.com/china.php?itemid=394&catid=10&subcatid=66

Hylander, L. D. (2001). Global mercury pollution and its expected decrease after a mercury trade ban. *Water, Air, and Soil Pollution*, pp. 125, 331–344.

Indiana General Assembly. (2001). *House Bill 1901*. Retrieved from http://www.in.gov/apps/lsa/session/billwatch/billinfo?year=2001&request=getBill&docno=1901

Jasinski, S. M. (1994). *The materials flow of Hg in the United States* . United States Department of the Interior.

Khamsi, R. (2005). *Countries reject global mercury treaty: UN meeting decides on voluntary actions rather than export bans.* Retrieved from http://www.nature.com/news/2005/050228/full/news050228-2.html

Kim, J. S., & Turner, J. L. (2007, January 16). *China's Filthiest Export.* Retrieved September 2011, from Foreign Policy In Focus: http://www.fpif.org/articles/chinas_filthiest_export

Kirby, D. (2011). *Made in China: Our Toxic, Imported Air Pollution.* Retrieved from http://discovermagazine.com/2011/apr/18-made-in-china-our-toxic-imported-air-pollution

Liu, C. (2010). Prevention and Control of Hg Pollution in China.

Mahaffey, K. R. (2004). Fish and shellfish as dietary sources of methylHg and the o-3 fatty acids, eicosahexaenoic acid and docosahexaenoic acid: risks and benefits. *Environmental Research*, pp. 95, 414-428.

Marvin, C., Painter, S., & Rossmann, R. (2004). Spatial and temporal patterns in mercury contamination in sediments ofthe Laurentian Great Lakes. *Environmental Research*, pp. 95, 351–362.

MedicineNet. (2011). *Mercury Poisoning.* Retrieved from http://www.medicinenet.com/mercury_poisoning/article.htm

Michigan Lagislature. (2011). *House Bill 4599.* Retrieved from http://www.legislature.mi.gov/(S(gtucgknab1bt3ummcmc5xc45))/mileg.aspx?page=getObject&objectName=2011-HB-4599

Minister of Justice. (2011). *Canada Shipping Act (S.C. 2001, c. 26).* the Minister of Justice Canada.

Minister of Justice. (2011). *Canada Water Act (R.S.C., 1985, c. C-11).* the Minister of Justice Canada.

Minister of Justice. (2011). *Canadian Environmental Protection Act, 1999 (S.C. 1999, c. 33).* the Minister of Justice Canada.

Minister of Justice. (2011). *Chlor-Alkali Mercury Release Regulations (SOR/90-130).* the Minister of Justice Canada.

Minister of Justice. (2011). *Fertilizers Act (R.S.C., 1985, c. F-10).* the Minister of Justice Canada.

Minister of Justice. (2011). *Fisheries Act (R.S.C., 1985, c. F-14).* the Minister of Justice Canada.

Minister of Justice. (2011). *Hazardous Products Act (R.S.C., 1985, c. H-3).* the Minster of Justice Canada.

Minister of Justice. (2011). *Transportation of Dangerous Goods Act,1992 (S.C. 1992, c. 34)* . the Minister of Justice Canada.

Mohapatra, S. P., Nikolova, I., & Mitchell, A. (2007). Managing mercury in the great lakes:An analytical review of abatement policies. *Environmental Management*, pp. 83, 80–92.

Murray, M., & Holmes, S. A. (2004). Assessment of Hg emissions inventories for the Great Lakes states. *Environmental Research*, pp. 95, 282-297.

NAAEC. (1994). *North American Agreement on Environmental Cooperation (NAAEC).* Retrieved from http://www.jus.uio.no/english/services/library/treaties/06/6-01/environmental-cooperation.xml

Nadvornick, D. (2010). *UW Scientist Tracks Airborne Mercury From China.* Retrieved from http://www.kuow.org/program.php?id=21565

NEG/ECP. (1998). *Mercury Action Plan 1998.* New England Governors/Eastern Canada Premiers.

NRDC. (2007). *NRDC Fights to Stop Hg Pollution in China: China is Cornerstone in Solving Global Hg Problem.* Natural Resources Defense Council.

NRDC. (2011). Retrieved from Natural Resources Defense Council: http://china.nrdc.org/english/E_index.php

NRDC China. (2011). *TOXIC CHEMICALToxic Chemical Policy Advisor.* Retrieved from http://www.cdb.org.cn/iafajobview.php?id=3640

Pai, P., Niemi, D., & Powers, B. (2000). A North American inventory of anthropogenic Hg emissions. *Fuel Processing Technology*, pp. 66, 101-115.

Pollution Probe. (2001). *Mercury Backgrounder.* Pollution Probe.

RC. (1998). Retrieved from Rotterdam Convention: http://www.pic.int/

Streets, D. G., Hao, J., Wang, S., & Wu, Y. (2009). *Hg emissions from coal combustion in China.*

Tsinghua University. (2006). *Improve the Estimates of Anthropogenic Hg Emissions in China.* Tsinghua University.

USEPA. (1996). *Safe Drinking Water Act.*

USEPA. (1997). *Mercury-Containing and Rechargeable Battery Management Act.* United States Environmental Protection Agency.

USEPA. (2002). *Clean Water Act.* United States Environmental Protection Agency.

USEPA. (2005). *Clean Air Mercury Rule.* United States Environmental Protection Agency.

USEPA. (2008). *Mercury Export Ban Act.* United States Environmental Protection Agency.

USEPA. (2011, October). *Great Lakes Initiative*. Retrieved from http://water.epa.gov/lawsregs/lawsguidance/cwa/criteria/gli/index.cfm

USEPA. (2011). *Reducing Toxic Air Pollutants.* Retrieved from http://www.epa.gov/airquality/peg_caa/toxics.html

USEPA. (2011, August). *Summaries of Related Solid Waste Incineration Rules.* Retrieved from http://www.epa.gov/airquality/takingtoxics/p3.html

USGS. (2000, October). *Mercury in the Environment.* Retrieved from http://www.usgs.gov/themes/factsheet/146-00/

USGS. (2011). *China Mercury Production by Year.* Retrieved from http://www.indexmundi.com/minerals/?country=cn&product=mercury&graph=production

Weis, M. (2004). Hg concentrations in fish from Canadian Great Lakes areas of concern: an analysis of data from the Canadian Department of Environment database. *Environmental Research*, pp. 95, 341-350.

Winfrey, M. R., & Rudd, J. W. (1990). Environmental factors affecting the formation of methylmercury in low pH lakes. *Environmental Toxicology and Chemistry*, pp. 9, 853–869.

Zhu, X. (2010). Hg Containing Waste Management in China. Tokyo, Japan.