Special Policy Study on Mercury Management in China

Preface

In order to propose policies regarding China's approach to the protection of the environment and public health from mercury, the China Council for International Cooperation on Environment and Development (CCICED) carried out the following Special Policy Study of Mercury Management in China. It focuses on mercury pollution and management measures, and offers recommendations for priority actions to reduce mercury release and use in China.

> The Issues
>
> i. Preventing the Exposure of Chinese Citizens to Mercury.
> ii. Reducing Mercury Releases to the Environment.

1 Background

Mercury① is a naturally occurring element that is persistent, bio-accumulative and toxic at very low levels to human health and aquatic and terrestrial ecosystems.

Mercury is also an important environmental contaminant that is long lived in the atmosphere and can be transported globally. It is unlike any of the other metals, and several characteristics that are unique to mercury — liquid at room temperature, readily transported in the atmosphere and in water — give rise to risks from its release to the environment that must be addressed.

① When the word "mercury" is used in these recommendations, it should be interpreted to include all species particularly total-mercury and methyl-mercury.

The Arctic
The Arctic Monitoring and Assessment Programme reports that a substantial amount of the mercury arrives via long-range transport from human activities at lower latitudes.

Mercury is released from many industrial processes (coal-fired power generation, mining, non-ferrous metal smelting, etc.) and is used in the production of numerous manufactured products (PVC, medical devices, compact fluorescent lights, batteries, dental fillings, etc.). Its control thus requires complex and widespread measures. International action is required to reduce environmental and health risks at local, regional and global scales[①].

There are several different chemical forms of mercury, including elemental, inorganic and organic forms. Methyl mercury, an organic form, is particularly toxic and is formed in the environment through microbial activity. Methyl mercury in a local environment accumulates in living organisms and is concentrated as it moves up the food chain (bioaccumulation). Human exposure can cause damage to the brain, nerves, kidneys, and lungs, and in extreme cases can result in coma and death. Exposure to even low levels of methyl mercury can cause neurodevelopmental effects in humans and mammals, particularly during the vulnerable development stages of fetuses and children. Young women of childbearing age are therefore a particularly vulnerable segment of the population.

Mercury released from either natural and anthropogenic[②] sources can travel long distances through air and water (see Figure 1), and inorganic forms of mercury will change into methyl mercury under certain environmental conditions, for example in sediments and wetland environments.

The toxic properties of mercury have been known for centuries, but the first evidence of the severe impacts through environmental exposure, emerged in Japan in the 1950s. In the fishing village of Minamata, more than 20,000 people were poisoned after a factory released methyl mercury into the local bay and area residents consumed fish from that same water. Among other things, the disaster demonstrated the elevated sensitivity of the human fetus to methyl mercury: mothers whom themselves had minimal symptoms of poisoning gave birth to severely damaged infants[③]. Additional evidence of the severe impacts of

① UNEP Report on “A general qualitative assessment of the potential costs and benefits associated with each of the strategic objectives set out in Annex 1 of the report of the first meeting of the Open Ended Working Group.” June 30, 2008.

② Human activities.

③ Mahaffey KR. Fish and shellfish as dietary sources of methyl mercury and the omega-3 fatty acids, eicosahexaenoic acid and docosahexaenoic acid: risks and benefits. Environmental Research 2004; 95: 414-428.

methyl mercury became evident in Iraq in the 1970s where about 6,500 people were affected after consuming methyl mercury-impregnated grain.

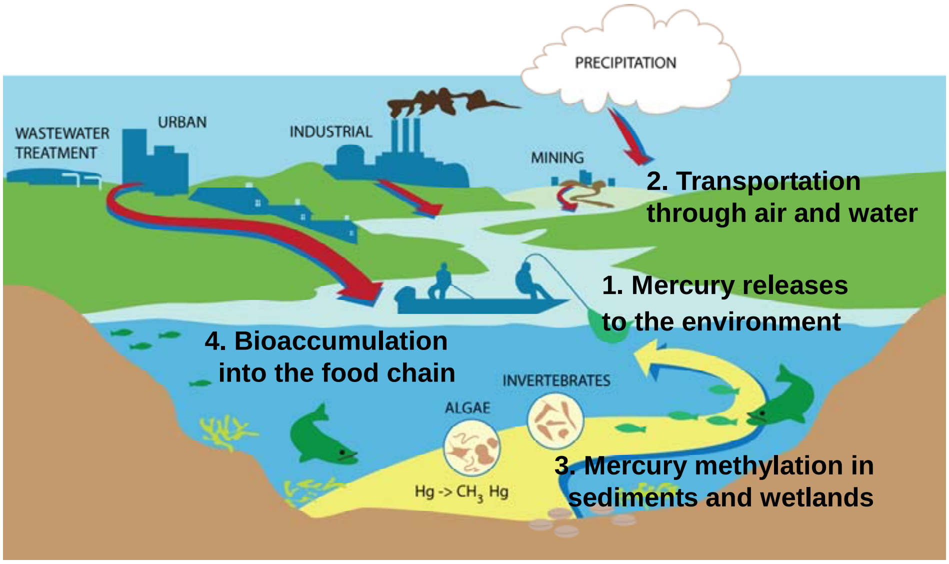


Figure 1　A Simplified Illustration of the Mercury Cycle①

Evidence of the transformation of methyl mercury from releases of inorganic mercury and subsequent accumulation in fish emerged from research in Swedish lakes in the late 1960s and early 1970s. Shortly after, bioaccumulation of methyl mercury was also found elsewhere in Europe and North America. Today, mercury exposure is a widespread concern. For example, the US-EPA estimates that more than 300,000 newborns each year in the United States have an increased risk of learning disabilities associated with in utero exposure to methyl mercury②.

Historically, Europe and North America have been the major regions for anthropogenic mercury releases. However, after substantial reductions of the releases in these regions over the past three decades, Asia is today by far the largest source of mercury releases (see Figure 2), and China is the largest contributor.

An Arctic Monitoring and Assessment Program reported recently that mercury continues to present risks to Arctic wildlife and human populations as levels are continuing to rise in some species despite reductions in mercury emissions from human activities over

① United States Geological Survey (USGS) Fact Sheet FS-102-97　by Martha L. Erwin and Mark D. Munn　August 1997.　available at: http://wa.water.usgs.gov/pubs/fs/fs.102-97 (accessed Oct. 25, 2011).
② http://www.epa.gov/hg/exposure.htm (Accessed: Sept. 6/2011).

the past 30 years in some parts of the world[①].

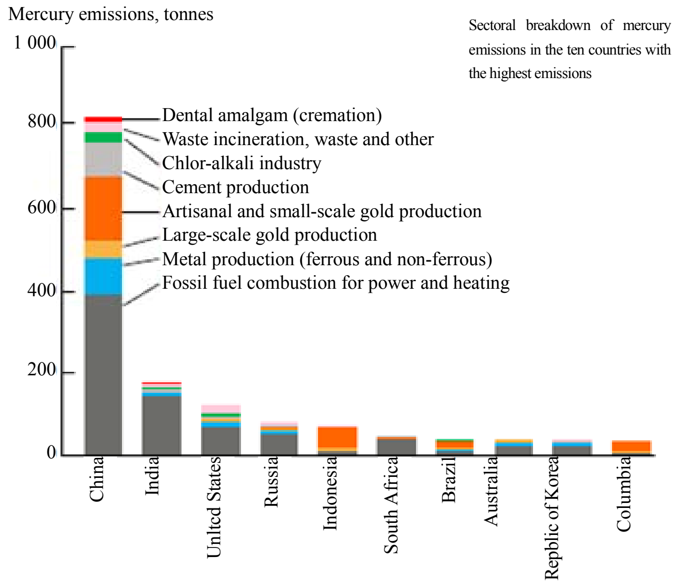
Mercury pollution has gained global attention. At present 140 member countries of the United Nations are negotiating a binding treaty to reduce risks to human health and the environment because mercury pollution is an important global concern. Action is needed in China to ensure that it can continue its remarkable economic growth while reducing its contribution to global mercury emissions and domestic mercury pollution. Due to the special chemical properties of mercury, it can remain in the atmosphere for a long time (months to years) and be transported to the most remote places. China, as the world's largest emitter of mercury, is therefore particularly important when targets are being set for reducing total global releases and reducing impacts of mercury. Hence China is a crucial country in the negotiations of a global mercury treaty.

Meaningful treaty obligations will allow China to have a track record on mercury that is consistent with its green development plans. Reduced use and releases of mercury in China will benefit China not only by protecting its environment and human health, but also by safeguarding its international trade which could otherwise be compromised by restrictive measures as trading nations seek to limit their exposure to mercury (illustrated by recent EU measures to restrict trade in mercury).

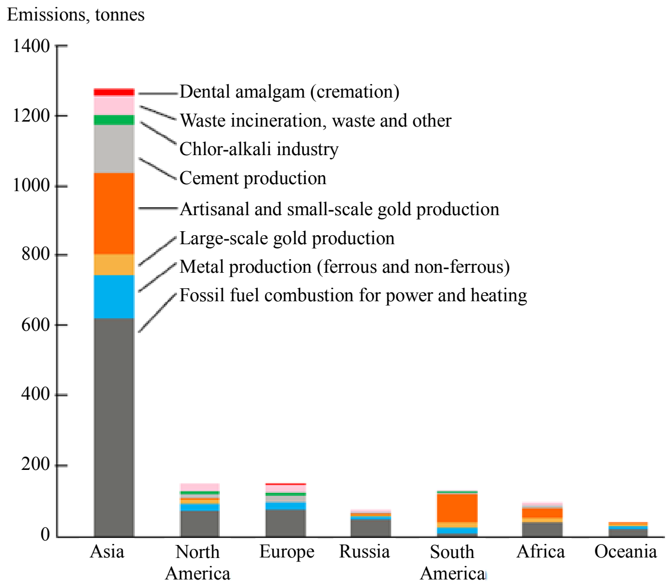
In facing these great challenges China has the benefit of its proven capacity to bring innovation and modern techniques to bear in the search for solutions. China has set itself on an exemplary course with its commitments to clean energy strategies, energy conservation and green production systems. These efforts, including China's ambitious climate change undertakings, will offer direct and indirect benefits through reduced mercury pollution. The co-benefits[②] of action to address climate change and other atmospheric pollutants can be optimized through improved coordination in planning and implementation. In turn, actions to reduce mercury pollution will also assist in reducing pollution from other heavy metals.

① AMAP, 2011. Arctic Pollution 2011. Arctic Monitoring and Assessment Program (AMAP), Oslo. Vi + 38pp ISBN-13 978-82-7971-066-0.

② When equipment is installed to capture or reduce air pollutants such as particulates, SO_2 and NO_x, then mercury emissions may also be captured or reduced as an additional benefit of the processes. Energy efficiency measures or a switch to clean fuels can also reduce mercury emissions from the burning of coal.



(a)



(b)

Figure 2(a)(b) Anthropogenic Atmospheric Emissions of Mercury (2005) ①

① The Global Atmospheric Mercury Assessment: Sources, Emissions and Transport. United Nations Environment Programme. Chemicals Branch, DTIE. Geneva Switzerland, December 2008. Page 18. Available at: http://www.unep.org/hazardoussubstances/LinkClick.aspx?fileticket=Y0PHPmrXSuc%3d&tabid=3593&laguage=en-US (Accessed Oct 25/2011).

2 Mercury pollution in China

2.1 Mercury pollution in China: status, trends and problems

The historic use of mercury in China dates back to 1100 BC, as early as the Shang Dynasty, when people began to use cinnabar (HgS) as a coloring pigment. Currently China is by far the world's largest producer, consumer, and releaser of mercury. The intentional mercury use in China exceeds 1000 tonnes annually①, which accounts for about 50% of the world's total. Almost all the 11 categories and 59 sub-categories of emission sources defined by the UNEP Toolkit for Identification and Quantification of Mercury Release② are present in China.

China is one of the few countries still undertaking mercury mining. Some of its core industries will continue to use mercury in the near future. The PVC production process, for example, is the largest intentional user of mercury in China. A large part of PVC is produced from coal and this process currently requires the use of a mercury-containing catalyst (most other countries produce PVC using oil or natural gas, ingredients for which the process does not require a mercury catalyst). The other major use of mercury is in the production of goods to which mercury is deliberately added: these include: medical equipment (thermometers and blood pressure monitors), batteries, and fluorescent lamps (see Figure 3). Unless measures to reduce mercury use are taken, the consumption of mercury is projected to increase rapidly.

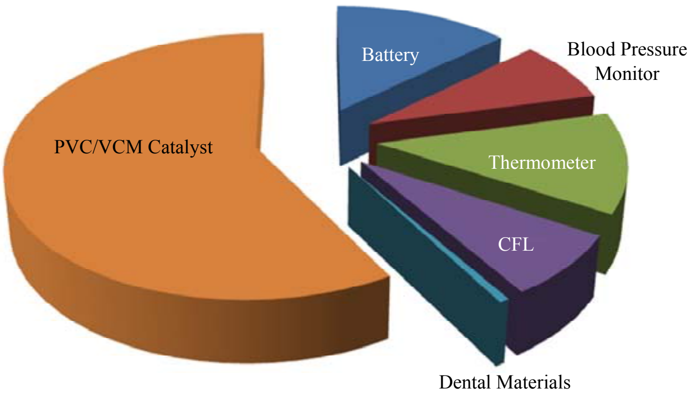


Figure 3 Major Sectors and Their Scale of Mercury Use in China in 2007③

① There are uncertainties in the figures regarding mercury use and different sources of data report different numbers. Details are given in the sectoral descriptions in Section 2.3.

② www.chem.unep.ch/mercury/toolkit or www.unep.org/hazardoussubstances/mercury/publications - Toolkit for identification and quantification of mercury releases; revised level 2; March 2010.

③ Source: SPS Mercury Team 2011.

The industrial use of mercury in China has caused severe pollution incidents in the past, for example in the Second Songhua River in the northeast and in the Jiyun River in Hebei Province in the 1970s. Today, as a result of past practices, very high mercury levels are found in water, soil and rice near abandoned mercury mining and smelting areas, for example in some areas of Guizhou Province.

The release of mercury to the environment is also high from industrial activities of which mercury is an unintentional by-product. Mercury is incidentally released to air, water and soil, but quantitative estimates are available only for the emissions to the atmosphere.

Rapid industrialization and urbanization has dramatically increased China's mercury emissions to the atmosphere in recent decades. Atmospheric emissions in 2007 were estimated to be 643 tonnes[①]. As reported previously[②], such estimates remain subject to significant margins of error but will improve as more rigorous pollutant release reporting comes into use. While there is some debate about the fate of these emissions, mercury's ability to stay in the atmosphere over long periods of time assures that significant amounts travel downwind from China and are thus a concern for other nations[③].

Despite the numerous ways that mercury finds its way into the air, coal combustion in industrial boilers and power plants remains the largest source of atmospheric mercury emissions in China, accounting for more than 50% of the total (see Figure 4)[④], with substantial additional contributions from non-ferrous metals smelting and cement production.

<u>Atmospheric Emissions</u>

Approximately half of the mercury released to the air falls out locally. The other half of the mercury travels, and while doing so, changes its chemical and physical form. Most local deposition occurs as dry particles, while global deposition occurs mainly with rain and snow.

① Source: SPS Mercury Team 2011.

② Wu Y, Wang SX, Streets DG et al. Trends in anthropogenic mercury emissions in China from 1995 to 2003. Environmental Science &Technology, 2006, 40, 5312-5318.

③ Adapted from: Mason R.P. and Sheu G.R. 2002. Role of the ocean in the global mercury cycle. Global Bio- Chem Cycles. 16(4): 1093.

④ Source: SPS Mercury Team 2011.

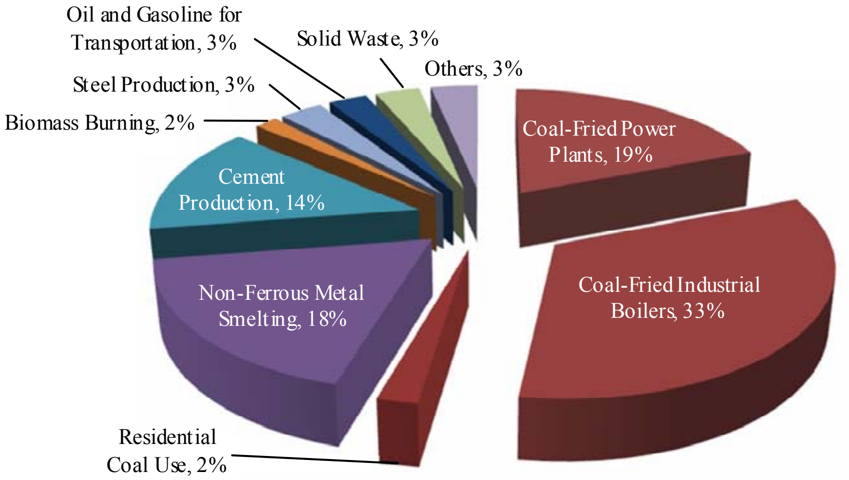


Figure 4 Atmospheric Mercury Emissions from Major Sectors in China in 2007①

China has serious problems with local mercury pollution, particularly in areas near abandoned mercury mines and old, highly polluting smelting and non-ferrous metal plants. In addition, the industries where mercury is released to the atmosphere as an unintentional by-product (e.g. coal burning, non-ferrous metal production) contribute to the mercury loading of the environment locally as well as regionally and globally.

2.2 Health impacts from mercury pollution

Mercury exposure of the general population most often involves dietary intake of methyl mercury. Globally the greatest concern is the uptake of methyl mercury through fish and marine mammals. In China, however, different dietary habits in different parts of the population will mean differences in mercury exposure. In the coastal populations, fish and seafood are important sources; for people living inland, rice consumption may be more important②.

Mercury exposure of the general Chinese population appears comparable to levels found among human populations elsewhere that have low fish consumption. There are, however, small groups of people who may be exposed to dangerously high levels of mercury. These include people living close to mercury-contaminated sites and dependent on locally grown food, fishermen and their families having particularly high fish and seafood

① Ibid.

② Zhang H, Feng XB, Larssen T, et al. Bioaccumulation of methyl mercury versus inorganic mercury in rice (Oryzasativa L.) Grain. Environmental Science & Technology 2010; 44: 4499-4504.

consumption, and workers with occupational exposure in the mining, smelting and PVC industries. It is also important to note that there exist large uncertainties regarding the risks of mercury exposure through rice consumption; the uncertainty is due to the lack of data for dose-response analysis of rice consumption.

There is a paucity of data on human mercury exposure in China, but several studies have been carried out in Guizhou Province. Here, the mercury intake levels estimated for the general population were low, but with important exceptions in heavily contaminated mining areas. Since mercury pollution exists at many contaminated sites where rice is also grown, further investigation is critical to assess exposure and to correlate it with human bio-monitoring (especially for pregnant women) and with potential health effects. It is uncertain whether the advisory limits for human intake, which are based on fish consumption, provide adequate protection for a population with rice-based exposure; rice lacks the micronutrients found in fish that might partly offset neurotoxicity. Data on health impacts are not available.

Blood, hair, urine and milk have been used to assess human exposure to mercury. Hair is a particularly attractive human sample as it is easy and relatively non-intrusive to obtain, and as it gives information of exposure over time (typically one cm of hair records one month of dietary exposure). Some data exist on the mercury content of human hair from assessments of mercury exposure in China: a survey[①] of the general population (659 individuals) in coastal areas found a geometric mean concentration of 0.83 μg/g and values ranging from 0.03 to 8.7 μg/g. Fifty-seven percent of the samples had concentrations below the reference dose value set by the US-EPA[②] and 13% above the tolerable daily intake value set by WHO[③].

There are large differences in the distribution of mercury concentration in hair in different parts of the Chinese population due to very different food consumption patterns. An identified high exposure population is found on the Island of Zhoushan, off the coast of Zhejiang province, where many of the inhabitants are fishermen and their families, with a large portion of wild-caught fish in their diet. The mean mercury concentrations in their hair samples were higher than the corresponding concentration of the WHO provisional tolerable

① Liu XJ, Cheng JP, Song YL, et al. Mercury concentration in hair samples from Chinese people in coastal cities. Journal of Environmental Sciences-China 2008; 20: 1258-1262.

② A hair concentration of 1 μg/g corresponds to US-EPA's Reference Dose for MeHg exposure. Mercury study report to congress. EPA-452/R-97. US Environmental Protection Agency, 1997.

③ The FAO/WHO Expert Committee on Food Additives value for provisional tolerable weekly intake is 1.6 μg/kg body weight/week, corresponding to 2.2 μg/g in the hair.

weekly intake①. These levels of mercury in hair were similar to what is reported in other populations with a fish-rich diet (including fishermen in Malaysia, Kuwait and Colombia, sport fishermen in Canada, and many Japanese communities②).

High mercury concentrations in hair were also reported for workers living in the mercury mining areas in Guizhou province③,④. These workers have both occupational exposure to gaseous mercury and exposure from contaminated rice in their diet.

Also, workers in other industries have occupational exposure to mercury, together with other toxic substances in the forms of gases and dust. Higher-risk industries include mining and smelting in general, and industries intentionally using mercury in the process or as a part of the final product. Workers in the VCM/PVC industry are one example of a situation of particular concern where there is exposure to numerous toxic compounds.

2.3 Mercury pollution prevention and control in China by sector

2.3.1 Coal fired power plants and industrial boilers

China is the largest consumer of coal in the world, with coal accounting for almost 75% of its energy production. The coal-fired industry includes coal-fired power plants and industrial boilers. Of these two, the power plants sector is the largest consumer of coal, but the industrial boiler sector is a larger source of atmospheric mercury emissions due to less air pollution control in this sector. Typical mercury content in the coal being burnt is 0.15～0.20 μg/g, but there are large variations between regions and coal qualities.

(1) Power plants

Coal-fired power plants in China consumed 1.33 billion tonnes of coal in 2007, accounting for 42% of national coal consumption. The coal demand by power plants is predicted to double by 2020, and, without further pollution control measures, such an increase would also double the mercury emissions. However, there are considerable co-benefits in terms of reduced mercury emissions from control measures for other pollutants ((SO_2, NO_x, PM) (see Table 1.)).

① Hair concentrations were 5.7 and 3.8 μg/g, respectively, for men, 2.3 and 1.8 μg/g for women, and 2.2 and 1.7 μg/g for children; Cheng JP, Gao LL, Zhao WC, et al. Mercury levels in fisherman. and their household members in Zhoushan, China: Impact of public health. Science of the Total Environment 2009; 407: 2625-2630.

② Comparison between available data from Chinese populations and other countries provided in a background document from Prof. Thorjørn Larssen and Yan Lin.Thorjorn.larssen@niva.no (June 2011)

③ Li YF, Chen CY, Xing L, et. al. Concentrations and XAFS speciation in situ of mercury in hair from populations in Wanshan mercury mine area, Guizhou Province. Nuclear Techniques, 2004, 27: 899-903.

④ Li P, Feng X, Qiu G, et. al. Mercury exposure in the population from Wuchuan mercury mining area, Guizhou, China. Science of the Total Environment, 2008, 395: 72-79.

Table 1 Co-Benefit of Mercury Removal by Various Air Pollution Control Devices

Control methods	Intentional pollutant to be controlled	Hg removal efficiency (%)
Coal washing	Particulate matter and SO_2	30
ESP	Particulate matter	29
ESP+WFGD	Particulate matter and SO_2	62
ESP+WFGD+SCR	Particulate matter, SO_2 and NO_x	66
FF	Particulate matter	67
WSCRB	Particulate matter	6.5
CYC	Particulate matter	0.1

ESP: electrostatic precipitator; WFGD: wet flue gas desulfurization; SCR: selective catalytic reduction; FF: fabric filter; WSCRB: water scrubber; CYC: cyclone dust collector.

Because of the stricter control of SO_2 during the "11th Five-Year Plan" period (2005-2010), the installation of flue gas desulfurization (FGD) has become mandatory for coal-fired power plants. In 2005 only 10% of the power plants had FGD installed; by 2009, 71% had the technology. As a result, despite a large increase in energy consumption and coal use over that period, there was a slight reduction in the SO_2 emissions and a slight reduction in mercury emissions from the power plants. An example of the co-benefit of SO_2 emission abatement and mercury emissions abatement in the power plant sector is illustrated in Figure 5.

During the "12th Five-Year Plan" period (2010—2015), NO_x emission control is given priority and equipment to reduce NO_x (Selective Catalytic Reduction – SCR) is to be installed at coal-fired power plants. SCR installations can further reduce mercury emissions from power plants (see Table 1).

As mercury is removed from the flue gas by the air pollution control devices (APCDs), the mercury enters the solid waste streams from the power plant. The mercury trapped by the particle control devices ends up in the fly ash and that trapped by the FGD system ends up in the gypsum. Both the fly ash and gypsum are resources that can be used in other industrial processes, for instance in the cement industry. Proper handling of the mercury-containing solid wastes thus becomes increasingly important as these control methods take effect.

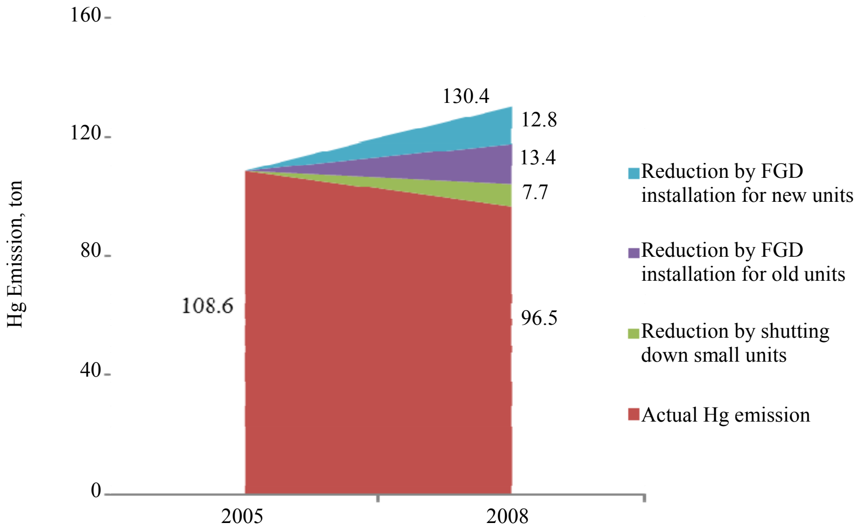


Figure 5 Illustration of the Co-benefit of Mercury Removal by SO_2 Control Measures During 2005—2008

If no measures for SO_2 control were taken, the mercury emissions in 2008 would have been 130.4 tonnes. The four different types of control measures that have been undertaken have brought that total down to an actual emission of 96.5 tonnes[①].

The total mercury emission from power plants was estimated to be 123.3 tonnes in 2007, with Jiangsu, Inner Mongolia, Shandong, Henan and Guangdong the provinces having the highest emissions (12.4, 11.8, 10.8, 9.9, and 7.5 tonnes, respectively).

(2) Industrial boilers

There are nearly 550,000 industrial boilers in China. The total coal consumption associated with these was 960 million tonnes in 2007, accounting for 30% of the total coal consumption in China (38% if coke consumption is included).

The application of APCDs on industrial boilers is not widespread and usually involves only simple equipment for particle removal that only removes a small fraction of the mercury. Due to limited capture of mercury by APCD, mercury emissions from industrial boilers are higher than from power plants. Total emissions were about 213.5 tonnes, with Shandong, Henan, Shanxi, Hebei and Guizhou as the top five emitters (22.6, 20.1, 19.4, 16.1, and 15.7 tonnes).

① Source: SPS Mercury Team 2011.

In summary, total mercury emission from coal combustion in China in 2007 was 368.5 tonnes. Of the total, power plants contributed 33%, industrial boilers 58%, residential use 5%, and other 4%. It bears repeating that even though power plants burn far more coal, mercury emission from power plants was lower than that from industrial boilers because modern APCDs were applied.

2.3.2 Non-ferrous metals smelting

The non-ferrous metal smelting industry includes zinc smelting, lead smelting, copper smelting and gold smelting (and other metals not discussed here). Current production of zinc, lead and copper is shown in Table 2.

Mercury is found in ores used by the sector. It is released during the smelting process, after which it can variously be: collected and used as a resource; released as a pollutant in other by-products (e.g. sulphuric acid); released into wastewater, solid waste or the atmosphere.

Table 2 Zinc, Lead and Copper Production in China in 2010①

Metals	Production (10^6 tonnes)
Zinc	5.16
Lead	4.20
Copper	4.57

Non-ferrous metal smelting in China still involves a large number of small- and medium-sized plants. Many use out-dated technology and hence have large mercury releases to the environment. These mercury emissions are a great challenge; the sector is developing rapidly while pollution-prevention techniques remain out-dated. The total mercury emission from non-ferrous metal smelting in China in 2007 was 116 tonnes. Emission from zinc smelting was the highest, estimated at 50 tonnes.

(1) Zinc smelting

China has been the biggest zinc producer in the world since 2002.

The out-dated small- and medium-sized smelters usually allow a very high fraction of the mercury in the ore to be emitted to the atmosphere. More modern and larger smelters typically use the sulphur in the ore to produce sulphuric acid as a by-product. At these plants about 99% of the mercury will be absorbed in the sulphuric acid rather than being emitted to the

① CNIA (China Nonferrous Metals Industry Association), http://www.chinania.org.cn/web/website/index_1010030397983910000.htm.

atmosphere. The most modern plants also have mercury removal and reclamation equipment, which may reduce the atmospheric mercury emissions further and reclaim mercury from the sulphuric acid. Removal of mercury from the sulphuric acid is important if the acid is to be sold for other uses, and in particular for fertilizer used to grow food crops. The mercury removal efficiency of each process of the zinc industry is shown in Table 3.

Table 3　Mercury Removal Efficiency (%) for Different Technologies

	Mercury Removal +Acid Plant	Acid Plant	Without Acid Plant	Artisanal Process
Efficiency	99.3	98.9	15.2	0

The mercury content of zinc concentrate (refined ore) is a very important parameter for emission estimation and varies greatly with the source of the ore. Especially for out-dated smelters, where mercury is not captured, the concentration of mercury in the zinc concentrate is determinative for the emissions. In modern plants that are able to capture and reclaim, this is obviously of less importance.

Table 4　Example of Zinc Production, Mercury Content in Zinc Concentrate and the Mercury Emission from the Zinc Smelting in Two Provinces

Province	Zinc Production (Tonnes)	Mercury Content in Concentrate (ppm)	Mercury Emissions
A	230 000	500	22
B	780 000	5	1.4

For example, Province ‘A’ had 500 ppm of mercury in their concentrate, while Province ‘B’ had less than 5 ppm. ‘A’ produces 230,000 tonnes of zinc while ‘B’ produces 780,000 tonnes. Despite having more than three times higher production of zinc in ‘B’, the mercury emissions were much lower (1.4 tonnes in ‘B’ vs. 22 tonnes in ‘A’) due to the differences in the mercury content of the raw material and the more out-dated equipment in ‘A’.

The total mercury emission from zinc smelting was estimated to be 50 tonnes, with 14% from large smelters, and 86% from small smelters. In contrast, the zinc production is 87% by large smelters and 13% from small ones. Enlarging the scale is necessary for applying modern technology and reducing mercury emission.

(2) Copper smelting

Mercury emissions from copper smelting were estimated to be 10.2 tonnes in 2007. Among the provinces, mercury emissions were highest in Inner Mongolia, Yunan and Hubei. High mercury content in copper concentrate and out-dated processes may be the reason for high mercury emissions in Inner Mongolia despite a relatively low copper production. In contrast, although high copper production and high mercury content in copper concentrate occur in Jiangxi province, mercury emissions are not high because of the low-emission process applied.

(3) Lead smelting

It is estimated that the mercury emission from lead smelting in China was 21.0 tonnes in 2007. The most important provinces were Henan, Hubei and Anhui.

(4) Gold smelting

In 2007, gold production was 236.5 tonnes. The mercury emission from gold smelting was estimated to be 37.2 tonnes, with 5.0 tonnes coming from large smelters and 32.2 tonnes from small smelters.

2.3.3 Cement production

There are about 4,000 cement producers in China currently, but this is expected to drop to between 500 and 1,000 through industry restructuring in the next five years①. Close to half of the world's cement is produced in China②. Mercury is a trace element in the raw feedstock materials, and in the fuels (mostly coal), making the cement industry a major mercury pollution source. In 2005, just over one billion tonnes of cement were produced in China③, while 1.68 billion tonnes were produced in 2009. Cement demand will keep growing in the near future as development goals continue to be pursued.

2.3.4 VCM/PVC industry

PVC is a type of plastic that is used for everything from water and sewer pipes to plastic toys and clothing. Most manufacturing of PVC around the world uses natural gas or petroleum as the raw material from which the plastic is manufactured. However, most PVC manufacturing in China uses a different process (the calcium carbide process) that starts with coal as the feedstock to produce VCM (from which PVC is made). In that coal-based process, mercury is a catalyst to spark the chemical reaction among the ingredients.

In PVC production through the calcium carbide process, low-mercury catalyst has been used to some extent in several VCM plants. However the industry has indicated that the use of this catalyst requires careful attention to process conditions (temperature less than

① Quote of Lei Qianzhi, President, China Cement Association – China Daily, page 17, September 21/2011.

② http://www.cembureau.be/sites/default/files/Activity_Report_2010.pdf.

③ Opportunities for improving energy and environmental performance of China's cement kilns. Lawrence Berkeley National Laboratory Report (LBNL-60638).

150 centigrade and controlled acetylene flow rates)[①]. This may be difficult for smaller and less advanced plants as significant capital investments are required.

Currently there are no mercury-free catalysts available for commercial use but there are ongoing efforts by Chinese institutions[②] to develop a mercury free catalyst for VCM production using coal. Recently a UK-Dutch consortium reported promising results from a pilot scale test of a catalyst that may be affordable[③]. If this catalyst proves to be effective and affordable under commercial operating conditions, optimistic estimates are that the technology could be available for initial commercial use as early as 2013. The mercury free catalyst is based on a noble metal, which will require care in catalyst transport and recycling.

As a result, large amounts of waste mercury catalysts, mercury-containing active coal, mercury-containing HCl, and mercury-containing alkaline agents are generated during production and, with the exception of the used catalyst, these are rarely recycled for technical and economic reasons. Each type of material poses serious environmental risks.

Handling of the used catalyst causes an additional problem, as workers are exposed to high levels of extremely reactive chemicals, including the mercury.

In 2009, the coal-based process was used at 94 of China's 104 VCM/PVC plants. The VCM/PVC industry has used between 570 and 940 tonnes of mercury annually in recent years (see Figure 6). It is predicted that by 2012, China's VCM/PVC industry will reach 10 million tonnes of production and exceed 1,000 tonnes of mercury consumption. China's VCM/PVC manufacturing industry is among the most significant users of mercury in the world today.

In China, three different ministries (NDRC, MIIT and MEP) carried out a series of programs to initiate reduction of the mercury consumption by this sector. They have established the following goals:

(1) By 2012: achieve 50% of the VCM industry using low-mercury catalyst, which is expected to reduce mercury use by 208 tonnes annually;

(2) By 2015: only use low-mercury catalyst (mercury use per tonne of PVC produced to

① R&D and Application of the technology for the replacement with low-mercury in PVC Industry. Xin Jiang Tian Ye Co. Ltd. UNEP Workshop on Feasibility of China's Mercury-Free Catalyst Research and Development in the VCM Industry. Beijing September 19, 2011.

② The study development of Chinese mercury-free catalyst. China Petroleum and Chemical Industry Federation and China Chlor Alkali Industry Association. UNEP Workshop on Feasibility of China's Mercury-Free Catalyst Research and Development in the VCM Industry. Beijing September 19, 2011.

③ Mercury Free VCM Catalyst. Presentation by Johnson-Matthey and Jacobs (copyright). UNEP Workshop on Feasibility of China's Mercury-Free Catalyst Research and Development in the VCM Industry. Beijing September 19, 2011.

drop 50%) and full recycling of the used low-mercury catalyst①; and

(3) By 2020: promote mercury-free catalyst and gradually become mercury-free across the VCM/PVC industry②.

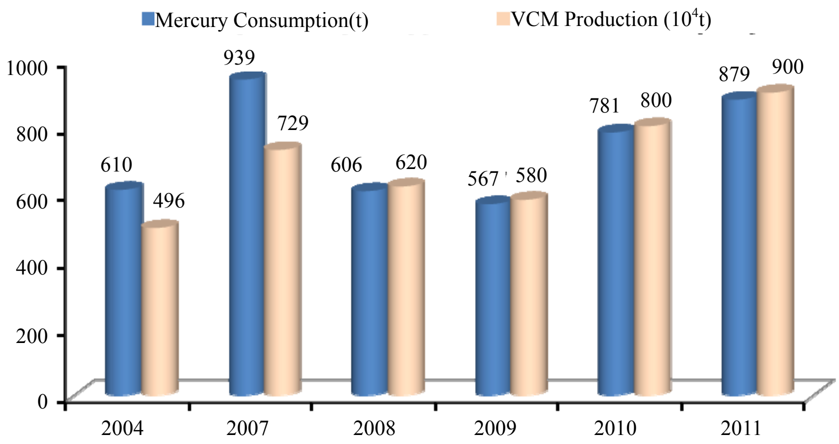


Figure 6 VCM Production and Mercury Consumption in VCM Industry③

With the VCM/PVC sector forecast to grow significantly in the near-term, experts suggest that the industry should actively seek opportunities to shift from the coal-based acetylene process to the ethylene process and to encourage facilities using the acetylene process to further invest in the transformation to lower-mercury and eventually to mercury-free methods.

2.3.5 Mercury-added products

In the production of mercury-added products such as medical devices, dental amalgam, fluorescent lamps, and batteries, the major problems are the management and disposal of wastes. Currently in China, most mercury-added products are sent to landfills along with

① Cleaner production technologies program in the PVC industry, MIIT (Ministry of Industry and Information Technology of the People's Republic of China), 2010. http://www.dhp.gov.cn/upload/2011/3/2412262376.pdf.
Mercury prevention and control in respect to industries related to PVC produced by calcium carbide method program, MIIT (Ministry of Industry and Information Technology of the People's Republic of China), 2010. http://baike.baidu.com/view/3717369.html.

② Mercury prevention and control planning in the VCM industry. CPCIF (China Petroleum and Chemical Industry Federation), CCAIA (China Chlor-Alkali Industry Association). http://wenku.baidu.com/view/ 4188021ba8114431b90 dd883. html.

③ Data compiled from these sources, LIU Dong-sheng, Fan Hong-bo. Strengthen mercury contamination prevention and treatments promote calcium carbide process PVC industry health sustainable development. China Chlor-Alkali. 2011, 4: 1-3.
JIAN Xiao-dong, SHENYing-wa, YAOWei, et al. Status Analysis and Reduction Countermeasures of China's Mercury Supply and Demand. Research of Environmental Sciences. 2009, 22 (7): 788-792.

municipal solid waste. The absence of an effective recycling system and proper hazardous waste handling process therefore poses a risk of mercury pollution to the environment.

(1) Medical products

China's current suite of mercury-added medical products include thermometers and blood pressure monitors. Annual thermometer production was 107 million units with about 50% being exported; blood pressure monitors production was 2.6 million units with about 20% being exported.

Table 5 Mercury Consumption for Medical Devices (Tonnes)

Industry	Product	1995①	2000②	2004③	2007④	2008⑤
Medical Devices	Thermometer	40.4	100	179	210-233	109
	Blood Pressure Monitor	15.7	50-60	95	86-98	118
Dental Material	Amalgam	6	5-6	6	5-6	Not Known
Total		62.1	155-166	280	301-337	227

(2) Compact Fluorescent Lamps

Mercury-containing bulbs remain the standard for energy-efficient compact fluorescent lamps (CFL). Ongoing industry efforts to reduce the amount of mercury in each lamp are countered, to some extent, by the ever-increasing number of energy-efficient lamps purchased and installed around the world. There is no doubt that mercury-free alternatives such as light-emitting diodes (LEDs) will increasingly become available, and technological developments have led to marketing of comparable mercury-free alternatives to the CFLs. Nevertheless, at present, for most lighting applications, the alternatives are very limited and/or quite expensive.

China is the world's largest producer of compact fluorescent lamps, with approximately 500—600 fluorescent lamp-producing enterprises. From 2000 to 2010, the industry's output increased from about 1 billion to about 6.7 billion lamps (see Figure 7), accounting for 80% of global production⑥. Of those 6.7 billion units, 55% were exported. The latest available information indicates that the sector used 78.2 tonnes of mercury in the

① SEPA (Now MEP). The Study of environmental protection register and important environmental management in the 21st Century (M). Beijing: China Environmental Science Press, 2001, 229.

② The investigated results of five key mercury related industries.

③ JIAN Xiao-dong, SHEN Ying-wa, YAO Wei, et al. Status analysis and reduction countermeasures of China s mercury mercury supply and demand (J). Research of Environmental Sciences, 2009, 22(7): 788-792.

④ Ibid.

⑤ China Association for Medical Devices Industry (CAMDI). http://www.camdi.org/.

⑥ Source: SPS Mercury Team 2011.

production of 4.8 billion lamps in 2008[①].

CFLs in China are produced using three processes:

1) Small-scale processing uses manual pipetting to deposit the mercury. The pipetting drops can range from 20—60 mg per lamp.

2) State of the art factories with automatic dosing of the mercury. The range of mercury dosing is 10—20 mg per lamp.

3) Best available technology where the dosing technology is via mercury-amalgam glass capsules plus special glass preparation. The range of mercury dosing is 3.5—5 mg per lamp.

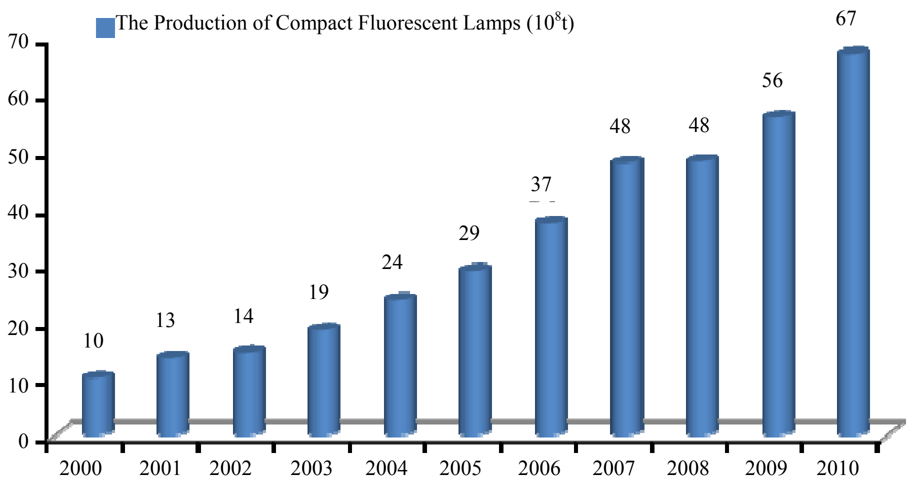


Figure 7 Compact Fluorescent Lamp Production in China

In recent times the government has been working with the industry association to have producers work towards limiting the mercury content of CFLs to 5 mg, but MEP officials advised that that this goal may not be reached until about 2013. With such a reduction the mercury consumption of the industry would decrease by about 35 tonnes. Additionally, China produces a large number of regular fluorescent lamps for use in residential, commercial, and industrial settings. For these, MEP officials advised that the government, in collaboration with industry, has established an anticipated limit of 10 mg per bulb. Unfortunately the production levels and mercury consumption of this sub-sector are not well understood at the moment. Anecdotal information points to an annual production of about 2.9 billion of these regular fluorescent lamps in 2010.

① Mercury related industries inventory report, 2008, MEP/CRC.

(3) Batteries

The use of mercury in batteries, while still considerable, continues to decline as many nations have implemented policies to deal with the problems related to mercury pollution from batteries.

While mercury use in Chinese batteries was confirmed to have been high before 2000, most Chinese manufacturers have reportedly now shifted to lower-mercury technologies, following both domestic and international legislative trends and customer demands. However, there are still vast quantities (tens of billions) of batteries with relatively low mercury content produced in China, and lesser quantities in other countries as well. From statistics, the current mercury consumption is reported by CRC/MEP to be 200 tonnes per year (2008)① however it is reported by MIIT to be 140 tonnes (2009)②. Over this same period, annual battery production was 39 billion units with 56% being exported③.

The MIIT Heavy Metal Pollution Comprehensive Prevention Plan④ released for consultation in November 2010 sought agreement with the battery industry to phase out production by 2013 of alkali manganese button batteries having more than 5ppm mercury⑤. The plan also calls for the Chinese battery industry to reduce its use of mercury by 80% by 2015.

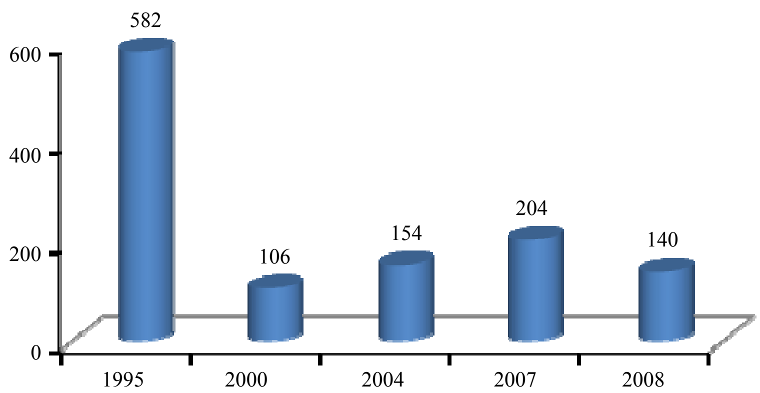


Figure 8 Mercury Consumption of the Battery Industry in China in tonnes⑥

① CRC/MEP, 2010. JIAN Xiao-dong, SHEN Ying-wa, CAO Guoqing. Investigation of mercury usage in the battery production and recommended reduced countermeasures (J). Environmental Science and Management, 2008, 33(10): 10-16.

② http://www.miit.gov.cn/n11293472/n11293832/n11293907/n11368223/13505234.html(Chinese only accessed Sept 21, 2011).

③ CRC/MEP. Mercury related Industries Inventory Report, 2008.

④ http://www.miit.gov.cn/n11293472/n11293832/n11293907/n11368223/13505234.html(Chinese only accessed Sept 21, 2011).

⑤ 5 ppm is considered the natural background of mercury therefore when 5 ppm is mentioned as a target it means 'no added mercury'.

⑥ Source: SPS Mercury Team 2011.

2.3.6 Mercury mining industry

China is one of only two countries in the world that still produces primary mercury (i.e., from mining). Most of China's mercury production is probably used domestically, though data on the domestic trade, imports, and exports of mercury are not available. The mercury used in industry in China is supplied by several sources: mining, imports, and recycling. In fact, China continues to import several hundred tonnes of mercury each year to meet domestic demand. Although mercury mining decreased temporarily about a decade ago, domestic mercury production has since increased steadily each year to meet the domestic demand.

In China there is currently only one active, large scale — and legal — mercury-mining operation, located at Xunyang, Shaanxi Province. This mine is reportedly close to being fully depleted, and is expected to produce for only a few more years. The possible depletion of domestic resources is of potential concern for China's mercury-using industry, though less mining may increase recycling efforts and may promote efforts to find alternatives. On the other hand, it may also put pressure on the authorities to relax import restrictions, and also encourage illegal imports.

Either way, a legacy of closed mines is a major problem for China; there are dangers for local populations not just from mercury pollution but also from mine tailing pond collapses, several of which have occurred in China recently[①].

2.4 Mercury pollution prevention and control in China

2.4.1 Regulatory system for mercury pollution prevention and control

In recent years China has strengthened its efforts to prevent and control pollution by mercury and other heavy metals through a number of laws, guidance documents and other domestic measures including a mercury pollution monitoring system. However, concerns have been identified about their scope, stringency, implementation and enforcement. The MEP develops and updates technical policies, BAT guidelines and standards related to the prevention and control of heavy metal pollution. There are about 20 mercury-related environmental standards, including a number of mandatory pollution control standards. Approximately 20 industrial standards address mercury production, consumption and disposal for activities such as the manufacture of batteries and lamps.

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① http://www.wise-uranium.org/mdaf.html.
http://www.chinadaily.com.cn/bizchina/2011-02/18/content_12040016.html.

In February 2011 the State Council approved The Heavy Metal Pollution Prevention and Control Plan (2011—2015) which focuses on mercury, lead, cadmium, arsenic and chromium. The Plan stipulates that "by the end of 2015, a few prominent problems that endanger public health and the ecological environment should be settled; a complete heavy metal pollution prevention and control system, emergency handling system and environmental and health risks assessment system should be established to solve prominent problems that impair public health; the heavy metal-related industrial structure should be further optimized and the frequent occurrence of contingent heavy metal pollution should be suppressed." MEP has provided Guidelines for the Formulation of Local Plan of Heavy Metal Pollution Prevention and Control to local governments[①]. As one of the most important heavy metals, mercury is included therein.

Although policies, regulations and standards to control mercury pollution have been established in China, compared with developed countries China's mercury management is still in the initial stages of development. It will be essential to establish efficient and effective mercury pollution prevention and control systems drawing upon lessons and experience from developed countries.

2.4.2 Responsible authorities for mercury pollution prevention and control

(1) National level

The Environmental and Resources Protection Committee (ERPC) of the NPC is responsible for developing, reviewing and enacting environmental laws.

Under the State Council, the MEP, the highest administrative body for environmental protection, is responsible for developing environmental policies and programmes. MEP deals with policy and regulatory matters from standards setting to enforcement, environmental impact assessments, and international conventions. As a cabinet-level ministry, MEP has the authority to co-ordinate other cabinet-level ministries to address environmental problems. Other ministries and agencies involved in environmental management are the State Development and Reform Commission, the Ministry of Health, the Ministry of Industry and Information Technology, the State Oceanic Administration, and the State Food and Drug Administration. An environmental protection management system spanning the relevant departments is gradually being established, but needs further development. Approaches to engage the broader society in mercury management still need to be developed.

① http://hbj.huaian.gov.cn/filedown? (accessed: Sept 8/2011).

(2) Local levels

The MEP supervises Environmental Protection Bureaus (EPBs) at the provincial, refectoral and county levels. As part of the provincial Governors' Offices, EPBs implement national and provincial environmental protection laws, regulations and standards and monitor pollution. Since the MEP became a cabinet-level Ministry in 2008, Directors of the EPBs will all eventually report directly to the MEP rather than the Governors' Offices. This change is being phased in with some Directors still operating under a co-management arrangement.

Various other sub-national administrative units also play important roles in environmental protection: Mayors' Offices; Planning Commissions; Industrial Bureaus; Finance Bureaus, and Urban Construction Bureaus. As at the national level, local levels are establishing coordination mechanisms under which EPBs take the leading role and are supported by other departments.

(3) Industrial associations

There are several industrial associations that can help to improve mercury management in China, for example: China National Coal Association, China Non-Ferrous Metals Industrial Association, China Battery Industrial Association, China Association of Light Industry, China Petroleum and Chemistry Federation, China Medical Devices Association, and so on. A more efficient and effective process is needed to engage all of the relevant industries.

3. International experiences on mercury pollution management

Developed countries have demonstrated that significant reductions can be made in mercury emissions from human activities without damaging their economies. They have used a wide range of strategies and approaches adapted to the particular circumstances of different industries that release or consume mercury.

3.1 Management strategies with clear emission reduction objectives

The United States, for example, developed emission reduction objectives for different industries (see Box 1). With implementation of its most recent rule, the power plant industry will achieve a mercury emission reduction of 78% between the baseline year of 2005 and the target year of 2015[①,②].

① http://epa.gov/mercury/pdfs/FINAL-Mercury-Roadmap-6-29.pdf. (Accessed: Sept.7/2011).

② http://www.federalregister.gov/articles/2011/05/03/2011-7237/national-emission-standards-for-hazardous-air-pollutants-from- coal--and-oil-fired-electric-utility. (Accessed Sept. 7/2011).

Box 1 US Management of Mercury Polluting Industries
The United States has introduced a series of control measures to address mercury emissions. Mercury is managed primarily under the Clean Air Act, which regulates hazardous air pollutants through a series of regulations and standards, including National Emission Standards for Hazardous Air Pollutants (NESHAP) Rules. Between 1990 and 2005, the US promoted mercury emission reductions through the control of large mercury emission sources, such as domestic garbage, hazardous waste, medical waste and chlor-alkali production. For the subsequent 10 years, the US will focus on smaller sources and industrial uses that collectively contributed over 20% of the nation's mercury air releases in 199936. Through such efforts, mercury emissions in the US decreased from 220 tons in 1990 to 113 tons in 1999 – a 45% reduction. The recently proposed Power Plant Air Toxics (NESHAP) Rule listed in the Federal Register in May 2011 expects mercury emissions to be further reduced from the 2005 baseline of 53 tons to about 11 tons by 2015 – a 78% reduction.

From 1970 to 2010 Canada reduced its mercury emissions by 90% using a mixture of mandatory and other instruments[①]: ① plant closures, ② regulations, ③ national emission standards adopted by the federal government and all Provinces and Territories (Canada-Wide Standards), ④ guidelines, ⑤ a voluntary 'Accelerated Reduction/Elimination of Toxics Program'[②], ⑥ environmental codes of practice, ⑦ mandatory pollution prevention plans, and ⑧ the creation of the National Pollution Release Inventory[③].

From a co-benefit perspective, the Government of Canada is currently moving forward with the development of regulations to reduce greenhouse gas (GHG) emissions from coal-fired electricity generation in Canada, to take effect July 1st, 2015[④]. These regulations are expected to reduce mercury emissions from the electrical power generation sector by about 40% by 2020 and 65% by 2030 compared with 2005 levels, and could reduce mercury emissions by up to 96% by 2050.

Norway's efforts to minimize harm caused by hazardous substances include mercury. The national target is for releases and use of mercury and other substances that pose a serious threat to health or the environment to be continuously reduced with a view to

① Risk management strategy for mercury. Environment Canada and Health Canada. October 2010.http://www.ec.gc.ca/doc/mercure-mercury/1241/index_e.htm (Accessed August 30, 2011).

② http://www.ec.gc.ca/Publications/default.asp?lang=En&xml=A2A7F1B4-599A-47C3-BF0E-F075B8211D91 (Accessed: Sept. 7/2011).

③ http://www.ec.gc.ca/inrp-npri/default.asp?lang=En&n=4A577BB9-1. (Accessed: Sept 7/2011).

④ Risk management strategy for mercury. Environment Canada and Health Canada. October 2010 http://www.ec.gc.ca/doc/mercure-mercury/1241/index_e.htm (Accessed August 30, 2011).

eliminating them completely by 2020.

In 2008, Norway introduced a general ban on the use of mercury in new products, with only a few time-limited exceptions. The ban applies to the production, import, export and placing on the market of products containing mercury. The decision to introduce the ban was based on an overall evaluation of risks to people and the environment, and assessments of the availability of alternative products that do not contain mercury. The ban also applies to any new areas of use for mercury that may arise in the future. Norway was the first country to ban the use of mercury dental amalgam fillings. A summary of Norway's efforts in reducing and eliminating mercury pollution is available in English[①] and Chinese[②].

In 2005, the European Union launched a mercury strategy[③] containing 20 measures to reduce mercury emissions, cut supply and demand and protect against exposure, especially to methyl mercury found in fish. This strategy sits atop many specific EU regulations and directives established since 1990 to reduce the use and emissions of mercury to air and water. The strategy has resulted in restrictions on the sale of measuring devices containing mercury and a ban that came into force in 2011, on exports of mercury from the EU. New rules on safe storage will follow shortly. The EU's mercury strategy is a comprehensive plan addressing mercury pollution both in the EU and globally.

The EU reduced its mercury emissions by 67% between 1990 and 2009[④]. In 2009 the EU-27[⑤] had total mercury air emissions of 73 tonnes. The member states that contributed the most to these emissions were Poland, Spain, Italy, and the UK respectively, representing a total of 38 tonnes.

3.2 Collaborative horizontal and vertical management

Due to the complexity and diversity of mercury pollution sources and impacts, prevention and control actions require collaboration amongst many institutions and interested parties. Multiple government agencies need to be engaged through several levels of jurisdiction, and several industry sectors have key roles to play in preventing and controlling mercury pollution. Citizens need to be engaged at the level of the general public but also as communities that may be at risk due to their location, occupation or

① http://www.klif.no/no/Publikasjoner/Publikasjoner/2010/Juni/Reducing-and-eliminating-mercury-pollution-in-Norway- The-mercury-problem.

② http://www.klif.no/no/Publikasjoner/Publikasjoner/2011/Februar/Reducing-and-eliminating-mercury-pollution-in-Norway- pa-kinesisk.

③ EU community strategy concerning mercury. 28.01.2005. COM (2005) 20 Final. SEC (2005) 101. (Reviewed: Sept. 20/2011).

④ EU emission inventory report 1990 - 2009. EEA Technical Report No. 9/2011. (Reviewed: Sept. 20/2011).

⑤ Twenty-seven member countries.

susceptibility.

Effective inter-agency collaboration requires the clear definition of roles and responsibilities and the coordinated planning of operations and management. In most countries a lead Department assumes overall responsibility for environmental protection, while other departments contribute in accordance with their particular mandates (see Box 2①).

Box 2 Division of Responsibilities Among US Federal Departments
The US Environmental Protection Agency develops standards related to air, water and soil pollution and controls mercury emissions from pollution to reduce the environmental risks caused by mercury; the US Food and Drug Administration is mainly responsible for the management of mercury in cosmetics, food and dental products; the Occupational Safety and Health Administration is mainly responsible for the management of mercury exposure in the workplace.

In large countries and federations such as China, particular attention is required to ensure coherence and coordination of efforts by the central and regional levels of governments. Consistent application and enforcement of national standards is often a challenge in such cases. In the case of Canada, both the federal and Provincial/Territorial governments have jurisdiction over environmental protection and thus there are both federal and provincial or territorial organizations that develop policies and provide inspection and enforcement services in their respective jurisdictions. Coordination of efforts is done both at operational levels and policy levels through the joint development of Canada-Wide Standards. Several Canada-Wide Standards played a role in the reduction of Canada's mercury emissions②.

3.3 Effective legislation and innovative regulatory approaches

In managing mercury pollution, developed countries generally use broad empowering legislation for environmental protection under which regulations are developed to control mercury emissions and releases and to limit mercury uses and exposure to mercury.

These countries use a standard regulatory life cycle of the kind depicted in Figure 9. The early stages of the cycle include issue identification and analyses that draw upon environmental risk assessments, cost-benefit analyses, and other techniques for regulatory

① Note: All three accessed on Sept 7/2011. http://www.fda.gov/food/foodsafety/product-specificinformation/seafood/foodbornepathogenscontaminants/ methylmercury/ucm115644.html.
http://www.epa.gov/hg/.
http://www.osha.gov/SLTC/mercury/index.html.

② Risk management strategy for mercury. Environment Canada and Health Canada. October 2010 http://www.ec.gc.ca/doc/mercure-mercury/1241/index_e.htm. (Accessed August 30, 2011).

impact assessments to support decision making that balances social, environmental and economic values.

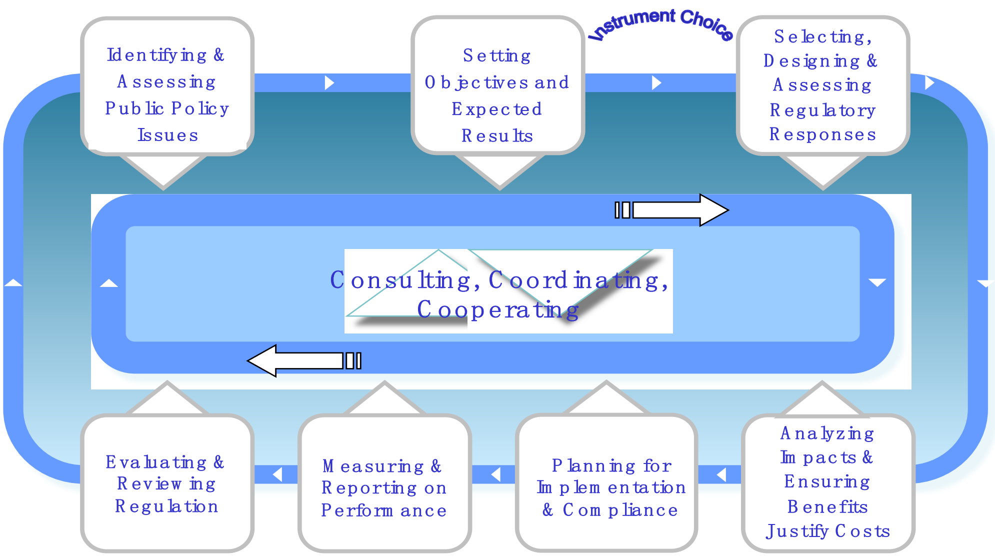

Figure 9 Lifecycle Approach to Laws and Regulations①

Box 3 describes important work by US-EPA on the early stages of this cycle②.

Box 3 Mercury Study Report to Congress: Overview 1997
A Mercury Study Report to Congress was prepared by the US-EPA. The Report provided a mix of strategies for the effective control of mercury emissions. The four major types of control techniques reviewed included: Pollution prevention measures, including product substitution, process modification and materials separation; Coal cleaning; Alternative approaches; and Flue gas treatment technologies. Additionally, the EPA provided the associated costs, the regulatory issues, and the financial impacts for a number of potentially affected industries if the proposal was to be successful.

Instruments ranging from mandatory to "voluntary", including market forces and information, may be used to change the behaviour of industries and consumers (Figure 10). Choosing amongst the many possible approaches requires collaboration amongst technical experts (who are familiar with the risks and measures that might be taken) and economists or policy experts who can assist with the assessment of the social and economic

① Figure 9 courtesy of Treasury Board of Canada Secretariat.
② http://www.epa.gov/hg/report.htm (Accessed: Sept. 7/2011).

implications of possible actions[①].

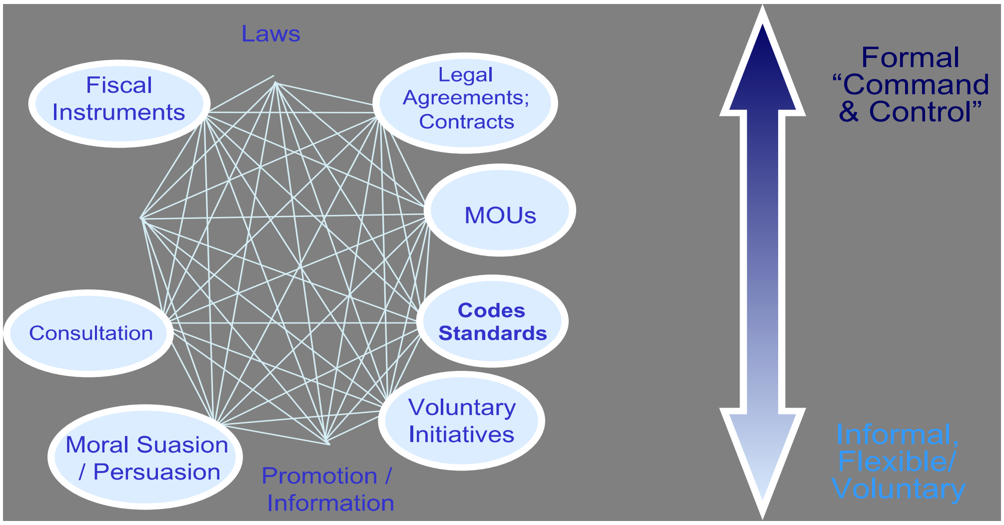

Figure 10 Innovative Approaches to Regulation Using Different Instruments[②]

With an expanded arsenal of tools many innovative approaches can be taken. Consider for example the use of mandatory, publicly accessible, facility-based inventories of pollutant releases[③, ④]. These have a powerful regulatory effect[⑤] in the context of an open economy where public disclosure becomes an important environmental management tool. Rigorous mandatory reporting of mercury releases would provide China with credible data to support its national management decisions (e.g. to determine how much reduction is needed, or whether measures taken are having an impact) and for international negotiations. A system established initially for mercury could be extended eventually to include other heavy metals and other priority pollutants.

In terms of economic instruments, a cap-and-trade (CAP) system was proposed to

① Environment Canada uses an internal guidance document (Instrument Choice Framework for Risk Management under the Canadian Environmental Protection Act (1999) – March 2009) based on a document published by the Treasury Board of Canada Secretariat on "Assessing, Selecting and Implementing Instruments for Government Action (http://www.tbs-sct.gc.ca/ri-qr/documents/gl-ld/asses-eval/asses-eval00-eng.asp). Accessed: Sept.14/2011.

② Figure 10 courtesy of Treasury Board of Canada Secretariat.

③ Pollutant release and transfer registers as a reporting mechanism for mercury release and transfers. UNEP (DTIE)/ HG/INC.2/INF/6 12 January, 2011 accessed November 19, 2011 at: http://www.unep.org/ hazardoussubstances/ Portals/9/Mercury/Documents/INC2/INC2_INF6_PRTR.pdf

④ http://acts.oecd.org/Instruments/ShowInstrumentView.aspx?InstrumentID=44&InstrumentPID=41&Lang=en&Book=False. (Accessed: Sept 7/2011).

⑤ Archon Fung and Dara O'Rourke. Reinventing environmental regulation from the grassroots up: explaining and expanding the success of the toxics release inventory. Environmental Management Vol. 25, No. 2, pp. 115–127.

reduce mercury emissions from coal-fired power plants in the USA[①]. Under this system, those manufacturers who could not meet the new requirements would have had the opportunity to purchase emission rights for their excess emissions from the manufacturers who had met and surpassed the emission standards by improving and upgrading their equipment.

While this initiative was not successful for legal reasons[②], a cap-and-trade regime may nevertheless be a viable approach for mercury and the US-EPA did considerable work to design such a system. However it is a controversial approach that can be opposed by opponents as ‘trading in toxics’. If caps are sufficiently stringent they could lower emissions overall, but would do so at variable levels in different locations (less reductions from plants that would buy credits from those making the most reductions) – and it would of course be hard to explain to residents in the less-favoured locations why it is acceptable for their exposure to be higher than in other locations.

Industry-led mercury management initiatives driven by societal and market pressures can also be effective. During a mission to Canada in July 2011, SPS Team Members heard from leaders of the Canadian chemical, mining and forestry industry associations. The global chemical industry’s ‘Responsible Care Program’ was launched in 1985 as a response to the Bhopal, India crisis and other events that had eroded public confidence in the industry to the point of threatening their ‘social license’ to operate. Under Responsible Care each facility operated by member companies is required to develop environmental and safety programs that are shared with local communities and subject to third party reviews[③].

Following reports of significant environmental damage inside and outside of Canada, the Canadian Mining Association created a similar program to protect their ‘social license’ to operate. Member companies establish targets above and beyond regulatory requirements, recognizing that the public wants to see transparent management and that local communities near mines and processing plants want to be informed and involved.

Members of the Canadian Forestry Products Association, not wanting to wait to be regulated by Governments or attacked in the marketplace where their brand can be seriously damaged, chose to get ahead of these threats by making the changes themselves. A leading example of this is the recently signed Canadian Boreal Forest Agreement under which the industry has committed to adopting good stewardship standards and to protecting

① http://www.epa.gov/air/mercuryrule/ (Accessed: Sept 7/2011).

② http://www.cadc.uscourts.gov/internet/opinions.nsf/68822E72677ACBCD8525744000470736/$file/05-1097a.pdf Accessed: Sept 7/2011.

③ http://www.ccpa.ca/ResponsibleCareHome.aspx. http://www.icca-chem.org/en/Home/Responsible-care.

a significant proportion of the forest from logging. In return environmental organizations agreed to cease media and market campaigns that were hurting the industry in the marketplace①.

Evolving trade rules are also a major instrument to drive industries and governments to strengthen their management of environmental issues such as mercury pollution. There are newly emerging restrictions on the trade in mercury and mercury-containing products②. At the level of the WTO a dialogue continues to develop at the trade and environment committee on proposals to establish "border tax adjustments — to address competitiveness and leakage issues that may develop" as some countries, for example, fail to take sufficiently stringent measures to deal with green house gas emissions③. It is reasonable to think that mercury pollution could be the subject of similar discussions in the future given calls for global action, including, most recently, by the Arctic Council in its report on Arctic Pollution 2011④.

As new regulations move their way through the development and approval stages it is often the case that a Regulatory Impact Analysis Statement (RIAS) be prepared so as to clearly outline the anticipated business and consumer impacts and the domestic and international governance impacts of the proposed regulation. An important part of the RIAS process is the cost-benefit analysis (CBA) statement wherein the social, economic, and environmental costs of the proposed regulation are discussed. In the case of pollution prevention regulations, the CBA will, in most cases, outline the environmental release reductions expected. In Canada⑤, the USA⑥, and the EU these RIAS and CBA procedures are open to public scrutiny. It is essential that evidence on implementation, impacts, and compliance be gathered to support these analyses. In the case of pollution regulations, the EC National Pollution Release Inventory⑦ is built to provide essential information on impacts.

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① For more information see: http://canadianborealforestagreement.com. http://www.canadiangeographic.ca/boreal. (Accessed: August 15 2011).

② Mr. Kees den Herder, an SPS Member from the Netherlands, presented the SPS Team with a large number of WTO restriction notices (for example) by the EU, Korea, and China alerting that those nations/regions were imposing border tariffs and/or import bans on certain mercury-added devices. Sept.4/2011.

③ Climate change takes centre stage at WTO Environment Committee. Bridges Trade BioRes. Volume 11 Number 13, 11 July 2011. International Centre for Trade and Sustainable Development. http://ictsd.org/downloads/biores/biores11-14.pdf (Accessed: August 30, 2011).

④ AMAP, 2011. Arctic Pollution 2011. Arctic Monitoring and Assessment Program (AMAP), Oslo. Vi + 38pp ISBN-13 978-82-7971-066-0 (full report available from http://www.amap.no/) (Accessed: August 30, 2011).

⑤ http://www.gazette.gc.ca/rp-pr/p1/2011/2011-02-26/html/reg4-eng.html (Accessed: Sept 7/2011).

⑥ http://www.epa.gov/ttn/ecas/regdata/RIAs/ToxicsRuleRIA.pdf (Accessed: Sept. 7/2011).

⑦ http://www.ec.gc.ca/inrp-npri/default.asp?lang=En&n=4A577BB9-1 (Accessed: Sept. 7/2011).

3.4 Upgrading of industrial structures and making a shift to a green economy

There are many sectors that use or produce mercury, and thus the matter is complicated. Japan, the US, Canada, Norway and the EU have adopted practical and feasible measures to stop or restrict mercury use in many sectors. Their experience is that these changes require adjustments to the industrial structure, often with significant capital investments for technological upgrading. Supporting policy measures that favour such investments, for example tax relief to encourage capital investments for cleaner production can facilitate these.

4 Strategy and action plan for mercury management in China

China announced a program to address heavy metal pollution in its 12th Five-Year Plan and is actively involved in multilateral negotiations on a proposed international mercury convention.

Both initiatives will require the improved management of mercury through a well-coordinated national strategy and action plan. This chapter describes what the strategy and action plan should include and examines the required supporting elements.

4.1 Nation-wide mercury management strategy and action plan for China

The goal of this management strategy and action plan would be to protect human health and the environment from the dangers of mercury pollution and to reduce China's contribution to global mercury releases. Key features of this strategy and action plan would include:

(1) *Short and long-term goals to reduce mercury releases* consistent with the current 12th Five-Year Plan for heavy metals for the period 2011—2015 and beyond;

(2) Strengthened measures to *protect the health of the Chinese population and the environment* from exposure to mercury;

(3) A compulsory *National Pollution Release and Transfer Inventory* information platform to support decision making;

(4) *Improved environmental performance in key mercury-dependent industry sectors and communities* consistent with national strategies for clean production and greening of the economy;

(5) *Strengthened regulatory policies and instruments* for the management of mercury;

(6) A *comprehensive management system* based on a continuous improvement approach with effective and consistent implementation throughout China;

(7) *Market-based mechanisms* gradually introduced as a supplement to enforceable command and control measures;

(8) Targeted *science and technology improvements* to provide the evidence base to support decision making for mercury risk management and control; and

(9) *Increased enforcement capacity* for the consistent national implementation of the action plan.

The following sections set out approaches and actions required to support such a robust Strategy and Action Plan.

4.2 A Sound mercury information base to identify and manage risks

The National Action Plan will need more timely and reliable information on the production, distribution, use, release, recycling, disposal and the resulting flows of mercury in China. Generating such information will require compulsory monitoring and reporting of mercury releases from key pollution sources. The ability to display this data by sectors, key regions, air sheds and water basins will allow managers and scientists to document the distribution and flows of mercury. It will further allow them to establish industrial emission factors that are appropriate for use by regulators in China and to identify, assess and reduce risks to the health of the Chinese population.

Environmental risk and early warning systems need to be established along with industry-specific risk profiles.

Finally, adequate data are needed to support assessments of the social and economic impacts of mercury reduction measures.

To improve the evidence base for the cradle-to-grave management of mercury and the related risks in China, and to support China in its international mercury activities, key features of an information collection and analysis base need to include:

(1) A transparent, compulsory, nationally coordinated, facility-based, and regularly updated mercury release and transfer reporting system – designed to adopt the best practices from UNEP's inventory of tools and the pollutant release and transfer registry systems described by UNEP① and currently recommended by the OECD for implementation by its member states②;

(2) An inventory of mercury movements into air, water, land, and waste streams to

① Pollutant release and transfer registers as a reporting mechanism for mercury release and transfers. UNEP (DTIE)/HG/INC.2/INF/6 12 January, 2011 accessed November 19, 2011 at: http://www.unep.org/ hazardoussubstances/ Portals/9/Mercury/Documents/INC2/INC2_INF6_PRTR.pdf.

② http://acts.oecd.org/Instruments/ShowInstrumentView.aspx?InstrumentID=44&InstrumentPID=41&Lang=en&Book=False.

support the identification of human health and environmental risks to determine the priorities for control interventions; and

(3) An environmental risk information and early warning system to prevent environmental risks and to promote early identification and response to emergencies.

Note: The infrastructure and procedures used in a system of this kind for mercury could also be used to address other heavy metals, persistent organic pollutants and other pollutants of national concern.

4.3 Information and actions to reduce risks to public health

There is a high degree of uncertainty in the estimates of China's mercury emissions and releases and consequently the distribution and fate of large amounts of the mercury released in China, is not clear. Therefore, studies on the speciation, molecular transformation and transport of mercury are needed along with a strengthening of monitoring and evaluation to support the assessments of risk to human health. This work would provide the key information needed for scientific evidence-based assessments of potential risks.

To reduce the impacts of both new and historic mercury pollution on human health it will be necessary to establish appropriate public advisories, and occupational health measures. Steps to address these needs should include:

(1) Strengthening monitoring for mercury in the environment, in foods, and in humans;

(2) Re-evaluating consumption standard limits for rice (and other crops), fish, cosmetics, etc. to provide guidance for cases where the levels are elevated;

(3) Developing appropriate communications messages particularly for populations in contaminated areas and in areas where food products are found to have elevated mercury, and for other vulnerable populations (e.g. pregnant women and young children); and

(4) Strengthening occupational health and safety monitoring and protection programs for persons in high-risk occupations (e.g. mining, smelting, PVC production, etc.).

4.4 Strengthened risk-based management of contaminated sites

Contaminated soils expose local populations to variable levels of mercury for extended periods through the consumption of mercury-contaminated crops. This differs from the situation in many countries where fish consumption is the major pathway for human exposure to mercury. In China, the foods most often contaminated by mercury are crops, such as rice, wheat and corn. Recent research found that methyl mercury could be highly accumulated in rice, thus posing a health risk to consumers①.

A risk-based approach should be adopted for the management of contaminated sites②. Key actions required to do this are:

(1) Establishing a transparent National Public Registry of mercury-related contaminated sites to support the identification, assessment and categorization of such sites so that priorities can be set and decisions made concerning their remediation and future use;

(2) Establishing a government-wide legislative structure to clearly outline the division of responsibility and to determine the adequacy of laws for the management of both current and legacy sites contaminated by mercury, including financial mechanisms to support the decommissioning and remediation of priority sites;

(3) Remediating sites giving priority to those posing the greatest risks to human health and the environment;

(4) Supporting the creation/emergence of a domestic industrial sector capable of providing the various remediation requirements including supporting demonstration projects; and

(5) Establishing a long term monitoring system at mercury-contaminated sites to protect (local) public health and the environment.

4.5 Promote green transformations of industries and communities

China's technical capacity needs to be strengthened with further acquisition, development and application of cost-effective mercury pollution control techniques and alternatives to the use of mercury.

China's commitment to reduce GHGs by 40% per unit of GDP③ will require industry sectors to adopt cleaner production methods. These will assist in reducing mercury use and releases. Such improved environmental performance will protect the health of the Chinese workforce and local communities, aid in securing community acceptance, and protect global competitiveness.

Additional strategies will be needed to provide support for the economic diversification of communities faced with the closure of small plants, and faced with the end of practices such as small-scale mining and smelting and dangerous waste management practices.

Key features of these transformations would be:

① Hua Zhang, Xinbin Feng, Thorjorn Larssen et al. In Inland China, rice, rather than fish is the major pathway for methyl mercury exposure. Environmental Health Perspectives 118:1183 – 1188.

② Informed by the CCICED special policy study on soil environmental protection in China, 2010. http://www.sfu.ca/international-development/cciced/pdf/2010_ReportofSoil.pdf.

③ State Council announcement of 2020 commitments for reduced CO_2. 26th November 2009. http:// finance. people.com.cn/GB/10461522.html [Chinese only].

(1) Promoting structural adjustment by industries that release or consume mercury, taking appropriate account of urban, rural and regional factors;

(2) Supporting the introduction and commercialization of mercury pollution-prevention technologies including the promotion of clean production process technologies, and the demonstration of best available and best achievable techniques and technologies (BAT[①]/BEP/MACT[②]) projects;

(3) Supporting industry to reduce the use of mercury in processes and products by using a range of financial incentives, and by compulsory and voluntary measures to encourage industry modernization and reform;

(4) Promoting alternate consumption choices and improving waste management and recycling; and

(5) Developing 'Green' economic diversification strategies for communities affected by the elimination of mercury-based industries[③, ④].

4.6 Strengthen China's management and regulatory regimes for mercury

China needs to systematically strengthen the management of its mercury pollution prevention and control activities at all stages of the regulatory lifecycle (see Figure 10).

Policy advice needs to be founded on greater capacity for risk assessment and analysis of management options to prevent and control mercury pollution in key sectors. Enhanced capacity is needed to select and apply appropriate technologies and clean production mechanisms and to monitor releases and oversee facility operations for key sectors and regions. Many of China's existing standards and specifications lag behind modern requirements for pollution control and management. Consistent national application of mercury pollution prevention and control measures is needed at a time of Township

① In EU BAT is defines as best available techniques and hence includes BEP (best environmental practice. For a specific sector a BAT reference document (BREF) gives detailed information on available and emerging techniques in the sector. BREFS are available at: http://eippcb.jrc.es/reference.

② MACT is a US-EPA standard. "When developing a MACT standard for a particular source category, the EPA looks at the current level of emissions achieved by best-performing similar sources through clean processes, control devices, work practices, or other methods. These emissions levels set a baseline, often referred to as the "MACT floor" for the new standard. At a minimum, a MACT standard must achieve, throughout the industry, a level of emissions control that is at least equivalent to the MACT floor. The EPA can establish a more stringent standard when it makes economic, environmental, and public health sense to do so. http://www.cdphe.state.co.us/ap/mact.html accessed September 10, 2011.

③ A helpful example is the small scale economic development work of UNDP in Kyrgyzstan found at the following link (accessed September 22, 2011) .
http://www.unep.org/hazardoussubstances/Mercury/InterimActivities/Partnerships/SupplyandStorage/PrimaryMercurySupplyProject/tabid/3547/language/en-US/Default.aspx.

④ The UNIDO office in China is developing a project proposal with MEP/FECO to seek GEF funding, focusing on the zinc smelting industry (UNIDO Representative, personal communication). This project could provide an opportunity to explore ways to support the adaptation of communities affected by the closure of small smelters

Industrialization to avoid risks of an East-to-West transfer of polluting industries.

Despite important high-level economic policies to support environmental protection in China, economic instruments do not yet play a significant role in the control and prevention of mercury pollution. Measures could include tax provisions to promote environmental protection beyond basic compliance with the laws, as well as supportive investment and financing mechanisms. The funding of mercury pollution prevention, control or remediation activities have yet to be fully explored.

Not least amongst the challenges for the regulatory system are the governance issues identified in OECD reports on China's environmental performance[①] and on regulatory governance in China[②]. With regard to policy, opportunities were identified to improve regulatory impact assessments and the integration of environmental and economic policies. An operational priority for the management of mercury and other heavy metals is the need to increase national consistency in the implementation of standards and regulations through provincial and local levels of government.

In order to strengthen its capacity for effective and efficient regulation of industries which release or use mercury, and the pollution resulting from past practices, China will need to:

(1) Strengthen all aspects of the regulatory life cycle as described in Chapter 3 (see Figure 10);

(2) Improve Regulatory Impact Analysis in line with the recommendations of the OECD Review[③] and use the OECD checklist[④];

(3) Strengthen the chain of command from National to Local levels to ensure consistent implementation, compliance, and enforcement of regulations and the application of other measures. This can be advanced by completing a transition now underway for Provincial Environmental Protection Bureau Directors to report directly to MEP Headquarters;

(4) Ensure that adequate operational capacity exists for inspection, enforcement and management of emergency responses;

(5) Promote voluntary initiatives by industrial sectors, for example, adoption of the international industry-led 'Responsible Care' program by the chemical industry; and

(6) Enforce national standards in rural regions and Western China to prevent the

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① OECD Environmental Performance Reviews: CHINA. OECD 2007. http://www.oecd.org/ document/24/ 0,3343,en_2649_201185_38952984_1_1_1_1,00.html (accessed August 30).

② OECD Reviews of Regulatory Reform. China. Defining The boundary between the market and the state. OECD 2009. http://www.oecd.org/document/36/0,3746,en_2649_37421_42222884_1_1_1_37421,00.html (accessed August 30, 2011).

③ OECD Reviews of Regulatory Reform. China. Defining the boundary between the market and the state. OECD 2009. http://www.oecd.org/document/36/0,3746,en_2649_37421_42222884_1_1_1_37421,00.html (accessed August 30, 2011).

④ The OECD reference checklist for regulatory decision making. OECD 1995. http://www.oecd.org/dataoecd/20/10/35220214.pdf (accessed August 30, 2011).

migration of polluting industries from more developed regions.

4.7 Develop and apply knowledge to reduce mercury use, releases and impacts on public health and the environment

Public information, awareness and education are needed on practical measures to reduce exposure to mercury and on the release of mercury, especially for those vulnerable populations, such as indigenous people, women, children, and workers living close to industrial and mining activities. Thus it is important to improve the current knowledge base and to begin reducing the knowledge gaps in environmental impact assessment processes, environmental management tools, and the scientific advice available to government, industry and the public.

To reduce knowledge gaps and the levels of uncertainty in the technical and scientific advice available to government, industry, and the Chinese people, actions should include:

(1) A thorough national review of the current status and knowledge of mercury similar to those completed or underway in other nations and regions[①];

(2) Improved monitoring and reporting of the various species of mercury in the environment, foods and humans, recognizing the differences between China and other regions of the world where such research has been carried-out;

(3) Establishing and refining dose response relationships for human health impacts, as current data are based on locations that may not be reflective of the Chinese situation[②];

(4) Improving the understanding of the fate and effects of mercury emissions and their biogeochemical cycles;

(5) Confirming that the methylation of mercury following the flooding of lands for the creation of hydro-reservoirs in China does not represent a problem, given the experience of other countries;

(6) Developing and importing innovative emission-reduction technologies;

(7) Improving communications that promote mercury product recycling and the use of alternate products and devices; and

(8) Strengthening occupational safety training for persons (including management, technologists and operators) in mercury-dependent industries.

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① For example: AMAP, 2011. Arctic Pollution 2011 (Mercury in the Arctic). Arctic Monitoring and Assessment Programme (AMAP), Oslo, Norway. vi+38 pp. http://amap.no/documents/ The US-EPA mercury risk Assessment http://yosemite.epa.gov/sab/sabproduct.nsf/fedrgstr_activites/A&N%20Hg%20Risk%20Assessment%20TSD!OpenDocument &TableRow=2.2 Canadian Mercury Science Assessment http://www.ec.gc.ca/scitech/default.asp?lang=En&n=1890C965&xsl= articlesservices,viewfull&po=3CEEE8E1#9.

② The Seychelles and the Faroe Islands.

4.8 Strengthen international cooperation and actively support the global campaign to eliminate mercury pollution

As China develops its capacity for mercury management, a strengthening of international cooperation will secure support for improved mercury management in China. Such cooperation will also increase the introduction of capital and technology, develop personal and technological collaboration, and strengthen overall international cooperation for environmental protection. There is great reputational value in strengthening China's international image through the promotion of a global campaign to prevent mercury pollution. As China is in the midst of negotiations on a global mercury convention, strengthened international cooperation will assist the formulation of practical provisions for the mercury convention and will guide China's mercury management policies in the future.

Key features of this task should include actions to:

(1) Establish policy dialogues and information exchanges with key international partners to promote the global strategic campaign on mercury;

(2) Promote cooperation and communications with developing countries and countries with economies in transition;

(3) Strengthen bilateral communications and cooperation on management, technology, international trade, capital investments, human resource capacities and governance of the mercury problem;

(4) Promote the introduction of best available and best achievable techniques and technologies for mercury pollution and control from other countries, and spur the development of domestic technologies to improve mercury management; and

(5) Monitor and contribute actively to discussions on trade and environment at the WTO as it may relate to mercury in the future.

4.9 Improve the environmental performance of industries that use or release large quantities of mercury –sector specific strategies

Regulation of each of the major sectors, which are described in detail in Section 2.3, will require strategies that take account of technical options, economic and social factors, trade strategies, international norms and the interplay with broader national policies, for example, on energy. Mercury reduction strategies will be needed with short-term strategies focused on early returns – i.e., the most mercury reduction at the lowest cost, and long-term strategies focused on more complex and costly reductions that will require time for careful investments.

Such approaches require discussions and collaboration amongst leaders from the industry sectors, academia, energy and industry ministries and central policy agencies to ensure that opportunity for innovation, future energy supply, and economic, industrial and social strategies and impacts, are fully considered in such key decisions. It will also be necessary to engage the provinces and local governments to the extent that their support will be needed for effective implementation and enforcement.

There will be requirements for command-and-control types of mercury emission regulations that progressively implement more demanding standards. Standards to be set in China should take account of international examples and factors ranging from the protection of the environment and human health in China to assuring the continuing access of Chinese products to international markets that are currently, and may become, sensitive to environmental performance.

The industries targeted for priority attention based on their impact on human health and the environment can be divided into two categories: those that release mercury, and those that use mercury in their processes or produce mercury-containing products.

The Key Sources of Mercury Releases

(1) Coal-Fired Power Plants and Industrial Boilers

(2) Non-Ferrous Metal Smelting

(3) Cement Production

The Key Mercury Users/Producers

(1) VCM/PVC Production (using the Calcium Carbide Process)

(2) Mercury Mining and Smelting

(3) Recycling and disposal of Mercury-Containing Wastes

(4) Mercury-Added Products

a. Battery Producers

b. Compact and Fluorescent Lamp Producers

c. Medical Devices Producers

Proposals for actions in these industries are set out in the following sector-specific strategies. These should form the basis for comprehensive consultations with the industries concerned and with other Ministries and stakeholders as regulatory impact assessments are prepared, leading to appropriate 'Made in China' management and regulatory measures. A summary of the anticipated benefits from actions in these sectors is set out in Table 6.

As part of its ongoing work the MEP should assign a national team leader to each of the key sectors to lead the building of the required sector-specific strategies and plans.

4.9.1 Coal-fired power plants and industrial boilers

China's resource and energy strategies dictate that coal will continue to be an important energy source, even in the long-term. Mercury emissions from the use of coal will be reduced as China improves its energy efficiency and increases its use of renewable and alternate energy sources. On the other hand, while desulfurization and de-dusting facilities have been installed in most coal combustion industries in China, techniques dedicated to the removal of mercury remain absent.

In order to reduce mercury emissions from these sources the following steps are required:

(1) Promote cleaner production such as advanced coal processing techniques and the use of low-mercury coal①;

(2) Reduce mercury emissions by measures to control other air pollutants (SO_2, NO_x, PM) through timely national implementation of the new standards released on September 21/2011 to take affect on January 1/2012②, and by improving the stability and availability of existing devices. Simultaneously, it is necessary to promote the development and the demonstration of approaches to establish best available and best achievable techniques and technologies (MACT, BAT/BEP)③;

Box 4　Possible Emissions Reductions from Coal-fired Power Plants and Boilers
Estimates are that emissions from coal-fired power plants in China can be significantly reduced from 2005 levels by 2020 using BAT. The SPS Team suggest that a target of <5 μg/m³ is doable by 2015 and <3 μg/m³ could be doable by 2020. Estimates are that emissions from industrial boilers in China can be significantly reduced from 2005 levels by 2020 using BAT. The SPS Team suggest that small inefficient boilers of less than 14 mega-watt capacities should be discontinued. Boilers up to 75 mega-watts capacities should have an emission target of <10 μg/m³ and boilers larger than 75 mega-watts should have an emission target of <3 μg/m³ by 2020.

① Which can be further aided by utilizing coal washing techniques, low-order coal extraction, and CWS preparation.
② Statement by Wu Xiaoqing, Deputy Environment Minister [MEP]; China Daily, page 1, September 22/2011. Relates to new more stringent standards targeting SO_2, NO_x, Mercury, and soot discharged from coal-fired power plants.
③ Activated carbon injection, addition of bromine or bromides before combustion, in flue gas additives, or at points in the generation process, and others.

(3) Establish mercury pollution controls for the coal-combustion industries, including an industry-wide regulatory regime, appropriate emission standards① (Box 4) and some necessary economic incentives;

(4) Improve the plan of action and the enforcement of mercury pollution regulations to ensure mercury emissions standards are met;

(5) Discontinue small high-polluting industrial boilers or shift to natural gas where available; and

(6) Improve the management flow of mercury-containing waste products such as fly ash, FGD gypsum, and wastewater.

4.9.2 Non-ferrous metal smelting②

There are many medium- and small-sized enterprises operating at different technical levels in the non-ferrous metal smelting industry in China. In order to reduce mercury releases, the following measures should be adopted:

(1) Phase in binding production-based emission limits based on BAT from international sources (Box 5) to improve the environmental performance of this industry sector while encouraging further research and development of domestic technologies;

(2) Strengthen research and the introduction of relevant core technologies for mercury pollution control within the industry;

(3) Promote the application of mercury removal technologies to enable enterprises to collect, process or release mercury for further use or resale;

(4) Reduce from the current 10 ppm③ to 1 ppm the upper limit for mercury in sulphuric acid as it may be used as a raw material for the production of other materials including fertilizers, which could then re-introduce mercury into the crop food chain;

(5) Close small inefficient and highly polluting plants. Current regulations banning the operation of small-scale facilities need to be better enforced. Structural change in the non-ferrous industry will require government support for adaptation by the communities affected; and

(6) Improve requirements to track and control mercury entering the sulphuric acid streams of these plants and other reclaimed mercury wastes.

① For example: the currently proposed emission standard of 30 μg/m^3 is considered far too high. A new standard should be set taking into consideration levels being targeted by the USA [1.5 μg/m^3] and the EU [3 μg/m^3].

② In particular: zinc, lead and copper.

③ Sulphuric Acid for Industrial Use – Standards Press of China GB/T 534. 2002-09-24.

Box 5 BAT Emission Limits
Emission limits may initially be set in line with Canadian legislation, i.e. 0.2 gram of mercury per ton of finished zinc, nickel, or lead, or 1 gram of mercury per ton of finished copper. More stringent emission limits should be phased in on new installations. The current BAT for instance suggests that less than 0.01 gram per ton of zinc is realistic and doable.

4.9.3 Cement production

The mercury emissions from cement production are highly dependent on the mercury content of the raw material used and also the mercury content of the coal. Currently very little information is available on the mercury content of this raw material. Mercury emissions from cement production should be reduced by actions to:

(1) Seek co-benefits from other pollution control measures, including energy saving and air pollution control[①] and from strengthening mercury control technologies in this area;

(2) Establish binding emission limits[②] and mercury management[③,④];

(3) Phase in improved requirements to track and control waste mercury entering the cement industry from gypsum and fly ash (as outputs from the coal combustion industry), and other waste streams;

(4) Improve the availability of information on the content of mercury in the raw material in order to help guide the selection of low-mercury feedstock.

4.9.4 VCM/PVC production

In China, the acetylene production process — using a mercury catalyst — still dominates the VCM/PVC industry, accounting for more than 70% of the total, which leads currently to a huge demand for mercury. The following steps should be taken to accelerate mercury reduction in the VCM/PVC sector:

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① Including changing particle emission control from ESP to FF.

② By applying BAT, a limit of mercury emission of < 0.05 mg/m^3 is achievable. [http:// www. environment-agency.gov.uk/static/documents/Business/How_to_Comply_-_Cement_EPR3_01a.pdf]. There is also a new US production standard of: 55lbs/million tons clinker for existing sources and 21lbs/million tons clinker for new sources: www.epa.gov/ttn/atw/pcem/pcempg.html - Table 1 of the final rule [page 55052]. The emission standard is 10 μg/m^3 for existing sources and 4 μg/m^3 for new sources.

③ Management measures are described in the Reference Document on BAT in the cement, lime and magnesium oxide manufacturing industries, European Commission, May 2010. (ftp://ftp.jrc.es/pub/eippcb/doc/clm_bref_0510.pdf).

④ The replacing materials are added as powder after milling of the clinker in a cold mixing process with other additives such as gypsum.

Acetylene Process
It takes 1.2 kilograms of mercury in the catalyst to produce each metric ton of VCM

(1) Priority must be assigned to achieving mercury-free PVC production processes. Recalling the 2007 guidance provided by the NDRC, the industry should actively seek opportunities to shift from the coal-based acetylene process to the ethylene process, which is more energy efficient;

(2) Facilities using the acetylene process should be encouraged to further invest in the transformation to lower-mercury processes and eventually to mercury-free methods of production. Binding regulations and improved enforcement measures should be phased-in to track and control mercury entering the waste streams and by-products;

(3) Research on mercury-free technologies and processes should be strengthened[①];

(4) Explore the extent to which a shift away from the acetylene method will provide co-benefits in reduced GHG emissions[②] and thereby reduce pressure on other industrial sectors that share a GHG cap with the VCM/PVC industry; and

(5) Work should be done to strengthen the control and management of the whole process, establishing economic incentives to reduce the use of mercury, and to promote the recycling of low mercury catalyst. Authorities should also explore ‘cap and trade’ systems or fees for mercury use.

4.9.5 Mercury-added products

The following recommendations should be considered to reduce mercury in the mercury-added products sectors:

(1) Promote the development and use of mercury-free or low mercury-added products as alternatives to the current mercury-added products;

(2) Establish mercury content limits on production, import, export and consumption of mercury-added products;

(3) Develop an action plan to reduce the use of mercury-added products including the industrial structural adjustments required;

(4) Encourage, through regulatory measures, the gradual transition of mercury-added

① Such as: new molecular sieve fixed-mercury catalysts and integrated large-scale chloride fluidized bed reactors.

② The production of one metric ton of PVC by the acetylene process produces twice the CO_2 emissions than the ethylene process used in Europe and North America.

products at the poorest level of mercury content to meet the same limits of products at the best level of mercury content;

(5) Improve the development, introduction and promotion of recycling technologies for existing mercury-added products industries; and

(6) Adopt a production license system that favours extended producer responsibility measures, cleaner production, circular economy initiatives, and voluntary industry sector measures to reduce the mercury-added content of their products.

4.9.6 Recycling and disposal of mercury wastes

There is a wide range of mercury-containing wastes that need special attention, such as batteries, mercury-added lamps, medical devices, dental amalgam, VCM mercury catalysts, gas cleaning sludge, and smelting wastes. Currently, in China most used mercury-containing products are sent to landfills along with municipal solid waste. The absence of an effective recycling system and proper hazardous waste handling therefore poses a high risk of mercury pollution to the environment. It will therefore be important to properly enforce China's hazardous waste management regulations. The following steps should be taken to improve recycling, handling and disposal of mercury-containing waste:

(1) Strengthen the introduction and development of mercury wastes recycling and disposal technologies;

(2) Strengthen collection, storage, recycling and disposal systems for mercury-containing waste;

(3) Establish strict recovery efficiency and pollutant discharge standards for the mercury waste handling industries; and establish evaluation methods and indicators;

(4) Promote the use of cost-benefit analyses to determine whether it is more efficient and effective to promote the use of mercury-free products or the recycling of mercury-added products;

(5) Establish market-based incentives for recycling of mercury-containing wastes; and

(6) Enhance consumer awareness and set up special recycling sites at convenient locations in the community. Engage government, manufacturers, recycling professionals and communities in the development and operation of an effective recycling system for waste mercury-containing products.

Note: Dental amalgam can easily and cheaply be removed from dental wastewater. Action might be initiated through a national dental association as a prelude to eventual binding regulations to remove dental amalgam from waste streams.

4.9.7 Mercury mining and smelting

Mercury mines and smelting facilities release mercury to the environment through a number of pathways. The long-term legacy of these mines and smelters is an accumulation of mercury in humans, animals and plants in the surrounding environments. The risk of mine tailing collapses poses an additional risk. The following recommendations should be considered to reduce mercury pollution from both the operating and legacy mines and smelters:

(1) Strengthen national government oversight of this industry for the approval, control and reporting of production;

(2) Undertake risk-based management based on human health impacts and impacts to the environment for contaminated sites resulting from closed mines, smelters, and their waste sites;

(3) Strengthen enforcement and emergency response capacity and establish financial mechanisms to support the identification, decommissioning and remediation of both legal and illegal mines and mercury processing plants; and

(4) In order to optimize the use of funds for remediation and protect the environment, food supply and public health, collaboration should be strengthened among authorities responsible for the general security, safety and emergency response capacity (e.g. related to risks of mine tailing collapse).

4.10 Overview of the effects of mercury pollution controls on pollution from other heavy metals

Many measures to reduce mercury releases will directly or indirectly reduce pollution from other heavy metals.

Combustion processes that release mercury also emit other heavy metals such as lead, cadmium, thallium and zinc. Hence measures by coal-burning sectors targeting mercury and conventional air pollutants, especially particulate matter, will also reduce those other heavy metal emissions. Similarly, proper treatment of the waste streams in these sectors will not only reduce mercury releases but also the releases of other heavy metals.

In the non-ferrous metals sector, several heavy metals other than the metal being produced are commonly also present in the ore. Pollution control measures will thus reduce the release of mercury and other heavy metals. The closing of small, inefficient and highly polluting non-ferrous metal smelters will be particularly efficient in preventing pollution by mercury and other heavy metals, both to air and water.

Furthermore, the management regime and regulatory capacity established to prevent and control mercury pollution will support the development and implementation of measures required to reduce and prevent pollution from other heavy metals. Table 6 indicates qualitatively some of the benefits and co-benefits one could expect following the implementation of improved mercury pollution prevention measures across the sectors previously discussed.

Table 6 Qualitative View of Anticipated Benefits from Actions by the Various Sectors

Sector	Quantity of Mercury Involved[①]	Opportunities for Early Actions	Benefits for Health and the Environment		Co-Benefits for other Heavy Metals
			China	Global	
Coal Fired Power Plants	++				
Coal Fired Boilers	+++				
Non-Ferrous Smelters	++				
Cement Production	++				
VCM/PVC Production	++++				Zero
Battery Production	++				
Thermometers	++				Zero
Blood Pressure Monitors	+				Zero
Compact & Fluorescent Lamps	+				Zero
Dental Amalgam	+				Zero
Mercury Mining	++++				

Good	Better	Best

① Qualitative scale of 'Use' of mercury or the 'Release' of mercury. += Not Much ++= Medium Amount +++= Large Amount ++++= Very Large Amount.

5. Recommendations for Priority Actions

Europe and then North America were for centuries the major sources of anthropogenic mercury releases. Following substantial reductions of mercury releases from these two regions over the past three decades, Asia is now by far the largest source, and China the largest national producer, user, and releaser of mercury. Indeed, China now accounts for more than 50% of global use.

China's economic development efforts over the past 30 years have spurred significant industrial growth. During this period, as described in previous chapters, China's connection to mercury has grown on three fronts: (1) With the expansion of its heavy industries such as non-ferrous metals smelting, cement production, coal-fired power generation, and industries relying on coal-fired industrial boilers, mercury emissions from smelting and coal combustion have made China the biggest emitter of mercury to the atmosphere. (2) For the production of PVC in China, coal rather than oil or natural gas is used as a feedstock in a process that demands a significant amount of mercury as a catalyst for the chemical reaction, making this the biggest mercury-use industrial sector in the world. (3) The growth in production of batteries, fluorescent lights, and mercury-added medical instruments has been such that China now produces most of the global supply, thereby contributing significantly to waste streams around the world created as these products reach the end of their useful life.

China now has an opportunity to address these problems through innovation and modernization of its industrial base. As a world leader in international trade and economic growth, and consistent with its green development strategy, it is in China's interest to significantly reduce its use and production of mercury and releases to the environment while strengthening recycling and waste management systems. Now is the time to act as the world is focused on international cooperation to control mercury pollution.

Based on the opportunities set out in Chapter 4 of this report and in particular the sector-specific analyses (section 4.9), recommendations are made for early and longer-term actions consistent with the "12^{th} Five-Year Plan" for heavy metals for the period 2011-2015 and beyond. In addition to the specific priority recommendations that follow, this report identifies several other actions that can usefully be taken by China in the near and long term to reduce mercury pollution and its impacts. Table 7 provides an overview of the estimated reductions in mercury emissions and mercury demand that China could expect to achieve if the recommendations provided in this report are implemented over the next decade.

The overall approaches that we recommend are to: ① strengthen the management and regulatory systems to control the use mercury and other heavy metals, including measures to protect the health of the Chinese population; ② establish ambitious but feasible targets for reduced use of mercury and reduced releases of mercury to the environment, drawing upon experiences of other countries; and ③ foster the development of closed-loop systems for the management of mercury as a resource to reduce and eventually eliminate the demand for new mercury in China.

While this report has focused on mercury, many of the proposed actions will contribute directly or indirectly to the control of pollution from other heavy metals. For example measures to reduce mercury pollution from non-ferrous metal smelters, mining, coal-fired boilers and cement production will also reduce pollution from other heavy metals such as lead and cadmium. Furthermore, the regulatory systems and capacity established for mercury pollution control will support the development and implementation of measures required to reduce and prevent pollution from other heavy metals. A similar CCICED Special Policy Study would be helpful to develop appropriate strategies and action plans for these other pollutants.

In its "12th Five-Year Plan" China has made clear commitments to address pollution by mercury and other heavy metals and is moving forward with early actions. This will require dedication and continued effort that should start immediately and accelerate over the next decade.

Table 7 Overview of Estimated Possible Reductions by 2020 (Tonnes)①

Sector	Baseline Emissions	Anticipated Emission Reduction	Baseline Use	Anticipated Use Reduction
Coal-Fired Power Plants	123 [2007]	12+37= 49 (40%)		
Coal Fired Boilers	213 [2007]	85 (40%)		
Non-Ferrous Smelters	116 [2007]	111 (96%)		
Cement Production	90 [2007]	23+27=50 (55%)		
VCM/PVC Production			780 [2010]	208+286+286= 780 (100%)
Battery Production			140 [2009]	112 (80%)
Thermometers			109 [2008]	54 (50%)
Blood Pressure Monitors			118 [2008]	40 (34%)
Compact Fluorescent Lamps			68 [2010]	35+12=47 (70%)
Fluorescent Lamps			130 [2010]	101 (78%)
Total②	542	295 (55%)	1345	1134 (84%)

① See Sections that follow and the Final Report for calculations and methods used.

② Be mindful that there is rounding of numbers for display purposes.

5.1 Take early actions that offer public health and environmental benefits

There are a number of actions that can be taken quickly to protect human health and the environment from mercury.

5.1.1 Non-ferrous smelters

Governments, and in particular Environmental Protection officials, should take immediate steps to close the remaining small, inefficient and highly polluting non-ferrous metal smelters by strengthening and ensuring the implementation and enforcement of regulations banning the operation of such facilities.

These measures will serve not only to protect the health of workers and nearby communities, but will provide a substantial portion of the emission reductions from this sector with limited impact on productivity. Taking the zinc industry as an example, over 80% of the mercury emissions come from these small smelters that produce less than 20% of the zinc.

These actions will also reduce pollution from other heavy metals such as lead and cadmium. Structural change in the non-ferrous industry will require government support for economic diversification and adaptation by the communities affected.

5.1.2 Coal combustion

To reduce mercury emissions from the coal combustion sectors China should:

(1) Promote implementation of best available techniques for mercury-specific controls (e.g. activated carbon injection, addition of bromine or bromide) with support for early uptake through training and financial incentives;

(2) Reduce demand for coal combustion through continued efforts to improve energy efficiency and to increase the use of renewable and alternate energy sources; and

(3) Further strengthen requirements for action by the coal combustion sectors to control other air pollutants and thereby increase the co-benefits of reduced mercury emissions, an approach that in recent years has contributed to decreased mercury emissions despite an increase in coal consumption by this sector.

5.1.3 Protecting citizens

Health, Labour, Environmental, Safety and Emergency Authorities should collaborate on measures to:

(1) Protect citizens at risk from exposure to mercury as a result of their occupations,

food or place of residence (e.g. near contaminated sites). Measures needed include: ① food consumption advisories based on monitoring and standards appropriate to China, ② effective occupational health and safety programs, and ③ information, advice and support to people living in proximity to contaminated sites;

(2) Ensure secure management of hotspots near abandoned mercury mines and mercury mine tailings to prevent further water, soil and air-pollution and to prevent possible mine tailing collapses; and

(3) Strengthen inspection and enforcement to ensure that illegal activities such as artisanal small-scale gold mining or illegal waste disposal are prevented.

5.2 Make major reductions in mercury emissions and releases to protect public health and the environment in China and reduce China's contribution to global emissions

Major reductions in mercury emissions can be achieved in the following sectors through capital investments over the next decade.

5.2.1 Coal combustion sectors

(1) Industrial boilers should shift to natural gas where available and feasible. Where coal must be used, advanced coal processing techniques and the use of low mercury coal should be encouraged. Small and inefficient coal-burning boilers of less than 14 mega-watt capacities should be discontinued. Taking account of international practices, boilers above 75 mega-watts capacities could have an emission target of 10 $\mu g/m^3$ by 2020 thereby reducing their emissions by about 40%.

(2) Emissions from coal-fired power plants in China can be significantly reduced from 2010 levels by 2020 using modern technologies. A target of less tham 5 $\mu g/m^3$ seems feasible by 2015 and less than 3 $\mu g/m^3$ could be achieved by 2020. Even assuming a 10% annual growth in coal consumption by these plants, these targets would reduce mercury emissions in 2015 by about 10% and in 2020 by a further 30% from 2007 levels.

5.2.2 Non-ferrous smelter sector

The sector should be required to phase in binding emission limits taking account of technologies available from international sources while encouraging further research and development of domestic technologies. For example, an achievable emission limit of 0.2 grams of mercury per ton of finished zinc or lead, or 1 gram of mercury per ton of finished copper could be implemented. These limits, along with the closure of the small highly polluting smelters, would reduce non-ferrous smelter emissions from 116 tons [2007] to about 5 tonnes, a reduction of 96%. More stringent emission limits should be phased in for new smelters since, with the current best available technology, emissions of less than 0.01 grams per ton of zinc are already realistically achievable.

A regulation limiting the maximum mercury content in sulphuric acid produced as a by-product from this sector should be strengthened by reducing the maximum limit from the current 10 ppm to 1 ppm and actively enforced especially where this by-product may be used to produce fertilizers for food crops.

5.2.3 Cement sector

Binding emission limits should be phased in for the cement sector based on best available technologies and management measures used in North America and Europe. A standard of 10 $\mu g/m^3$ could reduce emissions in 2015 by about 25% and in 2020 a standard of 4 $\mu g/m^3$ could reduce emissions by a further 30% from 2007 levels. Co-benefits can be achieved from other pollution control measures, including energy saving initiatives and air pollution control.

5.3 Reduce mercury use and demand and recycle waste mercury in a closed loop

China can reduce and eventually eliminate the demand for new mercury for its manufacturing sectors by fostering the development of closed-loop systems that manage mercury as a valuable resource, and by reducing the requirement for mercury in manufacturing processes and products.

5.3.1 VCM/PVC sector

Priority must be assigned to achieving cost-effective mercury-free PVC production processes.

Recalling the 2007 guidance provided by the National Development and Reform Commission for the Chlor-alkali (caustic soda, PVC) Industry[①], the sector should actively seek opportunities to shift from the coal-based to oil- or gas-based processes, that use no mercury and are more energy efficient.

Every effort should be made to achieve the government's announced goals for this sector, which are as follows:

(1) By 2012 achieve 50% of the sector adopting the low-mercury catalyst process to

① NDRC [2007]74. The web site is: http://www.sdpc.gov.cn/zcfb/zcfbgg/2007gonggao/t20071106_170922.html. [Accessed by Sep. 26th/2011].

reduce mercury use by an estimated 208 tonnes annually;

(2) By 2015 achieve 100% of the sector adopting the low-mercury catalyst process (mercury use per metric ton of PVC produced to drop by 50% or an estimated reduction of 286 tonnes) and implement the full recycling of the spent low-mercury catalyst;

(3) By 2020 promote mercury-free catalyst use and gradually achieve mercury-free production across the PVC industry.

Facilities that continue using the coal-based process should invest in the transformation to lower-mercury and eventually to mercury-free methods. Additionally, binding regulations and improved enforcement measures should be phased in to track and control mercury entering the VCM/PVC sector's waste streams and by-products.

If a promising new mercury-free catalyst now undergoing commercial trials should prove effective, steps should be taken to encourage its uptake by early adopters while continuing efforts to develop competing methods. There is an urgent need for significant investments in research on mercury-free technologies and processes for PVC production.

The government should foster these technologies by instituting financial mechanisms to assist the sector's transformation to mercury-free processes.

Considering industry forecasts that the sole mercury mine in China could be exhausted within 5 years, and given the need to drive innovation and adaptation in the sector, a policy of preventing fresh mercury from entering China's industrial system as early as 2015 would be an important step toward achieving mercury-free production across the PVC industry.

5.3.2 Closed-loop systems for mercury consuming industries

Develop closed-loop systems that capture and recycle mercury to eliminate the need for inputs of new mercury, thus fostering resource conservation and reducing waste. This approach can be applied broadly to capture and reuse mercury from many sources ranging from non-ferrous smelters to medical products.

This will require development of an effective mercury recycling system and proper hazardous waste handling regimes. This will require the strengthening and proper implementation and enforcement of China's hazardous waste management regulations.

China should consider establishing a cap on the available supply of mercury by 2015 to accelerate reduced dependence on the mining of mercury and to promote innovation and adaptation by the PVC sector and other mercury-consuming industries.

5.3.3 Improved standards for mercury-added products

Encourage producers of mercury-containing products to use less — or zero — mercury by:

a) Developing and implementing regulations to gradually require producers of high mercury-added products (e.g. lamps) to meet the same standards as products with the lowest mercury content available internationally;

b) Developing and using mercury-free or low-mercury-added products and by encouraging their use in place of current mercury-added products (e.g. through free exchange programs for medical devices);

c) Adopting a production licensing system that favours extended producer responsibility, cleaner production, circular economy initiatives, and voluntary industry measures to reduce the mercury-added content of their products; and

d) Improving recycling technologies and promoting the creation of the necessary industries.

China should promote, develop and implement the Heavy Metal Pollution Comprehensive Prevention Plan for the battery industry issued for comment by the Ministry of Industry and Information Technology on November 25, 2010. The Plan proposes to phase out alkali manganese button batteries with mercury exceeding 5 ppm by 2013. By 2015 mercury consumption by the battery industry in China would be reduced by 80% from a baseline of 140 tonnes.

As the producer of 80% of the world's compact fluorescent lamps, China has an opportunity to lead the development of a global standard for the mercury content in these lamps. The government working with the industry association has established a limit of 5 mg that it expects to achieve by 2013; this will decrease the industry's mercury demand by about 35 metric tons from 2010 levels. Further reductions of an estimated 12 tons could be made by moving to a limit of 2.5 mg in lamps less than 30 watts and a limit of 3.5 mg in lamps more than 30 watts.

Additionally, China produces a large number of regular fluorescent lamps for use in residential, commercial, and industrial settings. In 2010 this fluorescent lamp sector used about 130 tonnes of mercury. For these products, the government is considering a standard limit of 10 mg. This standard would reduce the total mercury used by the fluorescent lamp sector to about 29 tonnes.

5.4 Build strong foundations for a mercury–free green economy

Key foundations are required for successful actions to reduce pollution from mercury and other heavy metals. One is an effective national system for regulation and management of these pollutants. Another is a base of knowledge needed to protect public health and the environment and to foster innovation in green technologies to eliminate or significantly reduce pollution.

5.4.1 Regulation and management

(1) Establish a mandatory, transparent, facility-based and quality-controlled national inventory of mercury transfers and releases to support evidence-based cradle-to-grave management of mercury and the related risks in China;

(2) Strengthen regulatory capacity at all stages of the life cycle from issue identification and regulatory impact assessments to implementation, enforcement and evaluation, and increase the range of "instruments" used, including market-based and industry-led approaches. Accomplishing these ends will require building specialized capacity for example in the use of alternate instruments, cost-benefit analysis and regulatory impact assessment;

(3) Strengthen understanding and oversight of the key sectors for continuous mercury reduction. This will require dedicated staff to lead this work at the Ministry of Environmental Protection; and

(4) Strengthen management and regulatory systems for mercury and other heavy metals, including increased capacity for timely and effective emergency responses and for consistent application and enforcement of national standards and regulations throughout the country to prevent development of pollution havens in remote and developing regions and to prevent mercury from entering the food supply and other routes of exposure that put the population at risk.

5.4.2 Knowledge and innovation

(1) Improve monitoring for mercury in foods, humans, and the environment to support risk assessment and management measures;

(2) Foster new technologies suited for use in China (e.g. a mercury-free catalyst for the PVC acetylene industry, addition of bromine or bromide for coal-burning power plants, and small and clean industrial boilers). Support such efforts through a technology evaluation and verification system;

(3) Promote education and increased awareness amongst the public, government, industry, and medical personnel, including senior leaders, and build capacity for action in these areas.

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The front cover photo-ribbon includes a photograph of a cooling tower and men carting bags of spent mercury catalyst courtesy of Prof. Uwe Lahl of the SPS Team; a photograph of a young child playing with a container of mercury courtesy of Prof. Thorjorn Larssen of the SPS Team; and a public domain photograph of a small stone smelter. The Abstract page includes a public domain photograph of mercury droplets.

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