Economics of mercury control

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Abstract

With mercury legislation now in place in Canada and under revision in the USA, and action being considered on a global scale, there is a flood of new technologies into the market place – from treatments for enhancing existing control technologies to completely new, mercury-specific, systems. Since there is currently no universal 'best available technique' for mercury removal, the approach at each plant is being determined on a case-by-case basis.

This report summarises the regulatory situation regarding mercury emissions in different countries, the status of mercury control technology development, and the costs of emission reduction. Where possible, the economic evaluation includes any increased costs due to changes in waste disposal options for coal combustion by-products. The report also considers mercury control options during coal processing and preparation.

Acknowledgement

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Acronyms and abbreviations

ACI	activated carbon injection
ALAPCO	Association of Local Air Pollution Control Officials, USA
BAT	best available technique or technology
BEP	best environmental practice
CAIR	Clean Air Interstate Rule. USA
CAMR	Clean Air Mercury Rule, USA
CCC	Clean Coal Centre
CEM	continuous emissions monitor
CESP	cold-side electrostatic precipitator
CFBC	circulating fluidised bed combustion
CSI	Clear Skies Initiative, USA
CURS	Center for Urban and Regional Studies, USA
CWS	Canada-Wide Standards
EC	European Commission
ECO	electro catalytic oxidation
EIP	Environmental Integrity Project, USA
ESP	electrostatic precipitator(s)
EU	European Union
FBC	fluidised bed combustion
FF	fabric filter (baghouse)
FGD	flue gas desulphurisation
FPP	Fayette Power Project, USA
GEF	Global Environment Fund
HELCOM	Helsinki Commission
HESP	hot-side electrostatic precipitator
ICAC	Institute of Clean Air Companies, USA
ICR	Information Collection Request, USA
IGCC	integrated gasification combined cycle
IQ	intelligence quota
IPPC	Integrated Pollution Prevention and Control, EU
	European Union
LCPD	Large Combustion Plant Directive, EU
LRTAP	long-range transboundary air pollution
LSFO	limestone forced oxidation
MACT	maximum achievable control technology
Macf	million actual cubic feet
Macm	million actual cubic metres
MEA	multilateral environmental agreements
MEPOP	political initiative on mercury and persistent organic pollutants
mill	$^{1}/_{10}$ US cent
MW	megawatts
MWe	megawatts (electric)
NARAP	North American Regional Action Plan
NDRC	National Development and Reform Commission, China
NETL	National Energy Technology Centre
NPI	National Pollution Inventory, Australia
NRDC	National Resources Defence Council, USA
NSPS	New Source Performance Standards, USA
NWF	National Wildlife Federation, USA
OEWG	open-ended working group (UNEP)
OSPAR	Oslo and Paris Commission
PAC	powdered activated carbon
PCO	photo chemical oxidation
PEESP™	plasma enhanced electrostatic precipitator
POPs	persistent organic pollutants
PRB	Powder River Basin
PRTR	Pollutant Release and Transfer Register, EC
ROM	rough order-of-magnitude
SAICM	Strategic Approach to International Chemicals Management
SCR	selective catalytic reduction
SDA	spray dry absorber
SIP	state implementation plan, USA
SNCR	selective non-catalytic reduction
STAPPA	State and Territorial Air Pollution Program Administrators, USA
UN	United Nations
UNECE	UN Economic Commission for Europe
UNEP	UN Environment Programme
UN FCC	UN Framework Convention on Climate Change
US DOE	US Department of Energy
US EPA	US Environmental Protection Agency
USGS	United States Geological Survey
UV	ultra-violet

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1 Introduction

Mercury is released into the environment through natural processes (such as volcanic activity and weathering of rocks). However, human activities (mining, fuel use, products and processes such as chlor-alkali production) are now assumed to be the main source of mercury release into the environment. Total emissions globally have been estimated at 5000 t/y (US DOE, 2008). Mercury is still used in many products such as batteries, switches, thermometers, pressure gauges, dental amalgam and even face-whitening creams. Mercury use in small-scale gold mining is growing at an alarming rate with potentially over 50 million people worldwide involved in this activity. Alternatives to mercury exist in most industrial and product applications.

Mercury is released to the atmosphere from natural sources and human activities where it can drift for a year or more, spreading with air currents over vast regions of the globe. Mercury circulates between air, water and soil, until it comes to rest in sediments or landfills. On average, about three times more mercury is deposited from the atmosphere now than before the Industrial Revolution 200 years ago. For the last 30 s years, emissions from developing countries and economies in transition have increased, offsetting decreased emissions from developed countries.

Mercury pollution, mostly in the form of methylmercury, has caused severe health effects in several chemical incidents, most notably the incident in Minamata Bay, Japan, which caused severe neurological damage to over 2200 victims. Most exposure to methylmercury in the environment does not occur at anywhere near these levels. Governmental bodies have set daily mercury intake levels that are considered safe. The risk from diet mainly depends on how much contaminated fish is eaten: moderate consumption of fish with low levels of mercury is not a major cause for concern. However, there is sufficient evidence showing the effects of methylmercury on foetal development to justify warning children and women of child-bearing age to be careful about the species of fish they eat. Methylmercury also poses a health threat to predator fish, fish-eating birds and mammals, such as bald eagles, loons, otters, polar bears and seals.

Coal combustion can be a significant source of mercury to the atmosphere in some countries. However, on a global scale the contribution from coal combustion in most developed nations is relatively minor – mercury emissions from human activities in the USA are estimated to account for only around 3% of the global total and only 1% is from US coal-fired power plants. The USA recently promulgated several new pieces of legislation including the Clean Air Mercury Rule (CAMR) and the Energy Policy Act, along with the Global Climate Change and Clear Skies Initiatives (CSI). However, CAMR was overturned in early 2008 and is currently being rewritten. Many individual states within the USA have set their own more stringent regulations and targets most of which still apply, despite the vacation of CAMR. The US Department of Energy (US DOE) has invested heavily in the development of low-cost efficient energy techniques with a target of 90% mercury emissions capture efficiency by 2010 and continues to spend billions of dollars on clean coal technologies. All these regulations and targets mean that there is an unprecedented amount of activity in the development of mercury control technologies in the USA. In Canada, the Canada-Wide Standard (CWS) is also causing rapid movement towards the deployment of new mercury control options.

Although other countries in Europe and Asia are also actively developing mercury control systems, they are doing so without the urgency incurred by national and regional binding legislation and specific mercury reduction targets such as those that apply in North America at the moment. As a result the majority of research and development on new mercury control techniques is taking place in North America.

The United Nations Environment Programme (UNEP) Governing Council is likely to take a decision in February 2009 to further strengthen international action on mercury. The form this action is likely to take, whether a legally binding mechanism or a more flexible voluntary approach, is as yet undecided. A framework is established for voluntary initiatives under the UNEP Global Mercury Partnership; any additional measures initiated by the UNEP Governing Council in 2009 would complement and strengthen the existing, ongoing activity under the Partnership.

The tightening of legislation and the instigation of action plans are likely to result in the further reduction of mercury emissions from developed countries. However, the rapid increase in coal use in countries such as those in Asia may override reductions elsewhere. It is therefore essential that mercury control strategies are made both technically and economically viable in developing countries to ensure that the current upward trend in global mercury emissions is controlled effectively.

This report reviews the economics of mercury control options, from the legislative approaches through to the control technologies themselves. Chapter 2 reviews the legislation and action plans in place around the world that aim to reduce the global mercury burden. International, regional, multilateral, national and state legislation are summarised and discussed, highlighting, where possible, why different strategies are in place in different places. Chapter 3 then discusses the economics of the legislation, the cost benefits and the changes in the cost of mercury control with market factors. Chapter 4 concentrates on evaluating the potential for mercury control as a co-benefit effect due to the installation of control technologies for other pollutants such as SO_2 and NOx. Chapter 5 looks more closely at mercury-specific control technologies for large coal-fired plants. Finally, Chapter 6 looks at how the selection of the most appropriate mercury control strategy in developing countries will be determined by both plant specific factors and greater legal and economic issues.

2 Legislation and action plans

As discussed in a previous IEA CCC report (Sloss, 2003) legislation on emissions is commonly set in response to a recognised environmental problem. Mercury pollution has been reported in lakes in Northern Europe (especially in Sweden) and in North America. It is these countries that have taken the most remedial action with respect to the mercury problem. There may be significant mercury pollution in other emerging economies. However, pollution monitoring and reporting is not as stringent in these areas and therefore the problem is not being recognised and/or dealt with as efficiently.

Countries such as the USA, Canada and most of Europe arguably have relatively accurate information on mercury emissions. However, the data from Asia, Africa, South America, and Indonesia are sparse. Unfortunately, the lack of data on total coal use, plant type, control technologies and so on, mean that even a best estimate/guess based on generalised emission factors is likely to give an inaccurate result. In order for reduction strategies to be successful, there has to be some means to identify major sources, to determine baseline emissions, and to estimate the potential or observed reductions in emissions due to proposed or applied approaches. In a recent UN Environment Programme meeting concerning global mercury emissions (UNEP ad hoc open-ended working group on mercury, Bangkok 2007), one of the priorities listed was the requirement for more detailed and accurate emission inventories. A guidance document has been produced by UNEP which gives simple and concise instructions on how to prepare a best estimate for a mercury emission inventory (UNEP, 2005). A new study updating the previous global emission inventory for mercury will be available by the end of 2008 and will be presented to the UNEP Governing Council at its 25th session in February 2009.

Further work is also needed on the nature of mercury cycling in the environment, including a better understanding of the environmental effects of this complex element and more accurate information on the cause and effect of the different biological and neurological problems that may occur with increasing concentrations of mercury in the environment. A greater understanding of the true nature of problem will lead to more suitable and applicable solutions. These problems are outside the scope of this report but are the primary concern of the UNEP Global Mercury Partnership (*see below*).

As would be expected, the majority of the legislation and action on mercury control discussed in this Chapter applies in the developed world. The sections to follow briefly review the current and impending legislation on mercury both internationally and nationally.

2.1 International

Agreements between countries to work together to reduce emissions and concentrations of mercury are summarised in the sections to follow.

2.1.1 Multinational and binational agreements

There are a number of international agreements and action plans to co-ordinate action to reduce mercury emissions. These include (Sloss, 2003):

UNECE: The United Nations Economic Commission for Europe (UNECE) has a convention on long-range trans-boundary air pollution (LRTAP). This convention was published in 1998 and covers heavy metals including mercury. The protocol has been signed by Canada, Europe, Russia and the USA. Although the protocol calls for the installation of BAT (best available technique or technology) at new stationary sources, it does not go so far as to define BAT for coal-fired plants nor to specify any reduction strategies.

OSPAR: Oslo and Paris Commission's programme on reduction of land-based pollutants transported to the North Sea.

HELCOM: The Helsinki Commission programme covering the North Sea.

Barcelona Convention: A programme similar to OSPAR and HELCOM covering the Mediterranean Sea.

MEPOP: A EUREKA European political initiative studying the atmospheric cycling of mercury and persistent organic pollutants.

Nordic: Project between Denmark, Finland, Norway and Sweden to reduce mercury emissions.

Arctic: The Arctic Council's Environmental Protection Strategy includes mercury.

NARAP: North American Regional Action Plan between Canada, the United Mexican States and the USA to reduce mercury fluxes.

Binational Toxics: Canada and the USA have a project for cleaning up substances, including mercury, in the Great Lakes Basin Area.

None of these agreements or programmes include guidelines on how the proposed reductions in emissions or concentrations should be achieved other than by recommending 'best practices'. The agreements rely on the individual governments of each signatory country to produce a successful strategy to reduce mercury emissions. They therefore do not necessarily guarantee results. Action is rarely, if ever, taken against countries that are not as successful as others in reducing emissions.

2.1.2 UNEP Mercury Programme

In 2007, within Decision 24/3, the UNEP Governing Council recognised that *current efforts to reduce risks for mercury are not sufficient to address the global challenges posed by mercury*' and concluded that '*further long-term international action is required to reduce risks to human health and the environment...* For this reason, an ad hoc open-ended working group (OEWG) of Governments, regional economic integration organisations and stakeholder representatives was established that would review and assess options for enhanced voluntary measures and new or existing legal instruments in order to make progress in addressing the issue of mercury.

To facilitate the work of the OEWG, UNEP have prepared a study (UNEP 2007b) on options for a global initiative for the reduction of global mercury emissions which considered the different approaches, both legal and voluntary, that could be used to reduce global mercury emissions. Options for enhanced voluntary measures were discussed within the study. The study also outlined how voluntary approaches could include bilateral and multilateral cooperation as well as co-operation on a global scale. The approach could be a comprehensive, over-arching instrument or a number of narrower, discrete interventions which could concentrate on individual source types such as mercury containing products or mercury from coal combustion.

The study noted that voluntary approaches, lacking strong enforcement mechanisms, may be less likely to achieve as much mercury reduction as a legally binding approach. The report then reviewed existing international legal instruments to determine which, if any, could provide a template for a new legally binding mechanism for mercury, such as:

- the control of mercury wastes under the Basel Convention;
- expanding the scope of the Stockholm Convention (POPs – persistent organic pollutants);
- restriction of international trade in mercury under the Rotterdam convention;
- inclusion of mercury in the 'right to know' under the Aarhus Convention's Kiev PRTR (Pollutant Release and Transfer Register) Protocol;
- potential synergies with the UN Framework Convention on Climate Change (UN FCCC) (co-benefits through greenhouse gas mitigation).

There were also two options for new international legal instruments presented:

- mercury control under the Stockholm Convention – a new protocol for a legal instrument that addresses mercury directly;
- free-standing mercury convention – an independent freestanding protocol agreed on by signatory governments.

The effectiveness of an international agreement, voluntary or legally binding, is closely linked to the availability of financial and technical assistance to aid implementation. This is discussed in more detail in Chapter 3.

It was acknowledged that any new, legally binding, global instrument of mercury would not enter into force until 2012 at the earliest. The working group will prepare a final report representing options and any consensus recommendations to the Governing Council at its 25th session in February 2009. Although the options and consensus recommendations were not available as this report went to press, there is an emerging acknowledgement that a mixture of voluntary and legally binding measures are required to address to mercury issue at the international level. As part of Decision 24/3, UNEP was also tasked with strengthening ongoing voluntary mercury partnership activity, including the development of an over-arching framework for a UNEP Global Mercury Partnership, uniting governments and stakeholders around the world to work together. Partnership activity was initiated in 2005 and has been divided into five partnership areas, as follows:

- coal combustion;
- small-scale gold mining;
- chlor-alkali production;
- mercury in products;
- mercury fate and air transport research.

With international discussions on the delivery mechanism(s) for mercury reductions still in an early stage, it appears that the available response measures specific to reducing mercury emissions from coal combustion include:

- the establishment of mercury emission reduction targets and timetables;
- the establishment of mercury emission limits (end of pipe controls);
- improvements in energy efficiency in products and processes for lessen demand from electricity and the need to combust coal in electricity generation;
- improvements in energy conversion efficiency to reduce coal combustion (housekeeping, maintenance, boiler optimisation);
- transition to other energy sources (such as renewables) to reduce coal combustion;
- the pre-treatment of coal prior to combustion (coal washing);
- the use of higher ranking (lower mercury) coals;
- the establishment of mercury-specific BAT (best available technique or technology) standards for emissions control devices to capture mercury in flue gases;
- the use of air pollution control technologies for other criteria pollutants to capture mercury in flue gas;
- promotion of the development and use of mercury specific and cost-effective control techniques;
- promotion of the development and use of cost-effective multi-pollutants (so called 'zero or low emission' control techniques);
- establishment of monitoring and reporting programmes.

The first objective of the coal partnership is to produce a guidance document on BAT/BEP (best available technique/best environmental practice). This document, to be produced in conjunction with the IEA Clean Coal Centre (IEA CCC) would provide a simple summary of various mercury control options at coal-fired plant to allow developing nations to select measures which would be most appropriate and economic for their situation. It is proposed that this document would be completed by the end of 2008.

2.2 Regional

As discussed in a previous IEA CCC report (Sloss, 2003), existing legislation in Europe, especially the Large Combustion Plant Directive (LCPD) for particulates, SO_2 and NOx, has meant that most plants are fitting technologies such as low-NOx burners, SCR (selective catalytic reduction) and FGD (flue gas desulphurisation). This has meant that mercury emissions have also been reduced due to co-benefit effects. Co-benefit effects are those whereby mercury emissions are reduced as a result of the installations of control technologies for other pollutants and these are discussed in more detail in Chapter 4.

Richie and others (2005) have estimated the reduction in mercury emissions from coal-fired plants in Europe as a result of current and impending legislation, as shown in Table 1. Mercury emissions are predicted to decrease significantly between now and 2020, even with the arrival of new accession countries into the EU. As these new countries join they must adopt, within a prescribed timescale, the relevant EU legislation and therefore the co-benefit effects of SO_2 and NOx control within the LCPD are evident.

The European Commission (EC) recognises the significant reduction that has already been achieved in mercury emissions from coal combustion and also that this reduction is likely to increase with the tightening requirements already specified under the LCPD. It is therefore likely that the 'wait and see' approach to reducing mercury emissions could continue for a few more years. However, it is also likely that mercury monitoring could become a requirement on larger plants to obtain more accurate mercury inventory data. BAT for mercury may become a requirement in the future, but this will not be made binding until there is a better understanding of what BAT for mercury would actually comprise.

The new IPPC (Integrated Pollution Prevention and Control) permit scheme will make it easier for the EC to monitor individual plant operation and emissions. The new scheme will provide the regulators with a large amount of plant performance characteristics and data as well as more accurate emission inventories. This information will be useful in determining if mercury specific limits or controls are required means of mercury reduction at each plant. Data from the IPPC will be available at the end of 2008 and any decisions would be made after that. IPPC applies only to plants >50 MW. However, the EU is already considering the possibility of extending the scheme to include smaller plants.

2.3 National

Emission inventories and country specific action plans and legislation were discussed in more detail in previous reports from the IEA CCC (Sloss, 2002, 2003). The sections below focus on legislation and action being taken specifically to reduce emissions of mercury from the coal sector. Where possible, an explanation is given as to why the selected approach to mercury reduction was taken. The countries are ranked in order of those with the most legislation specific to mercury control.

2.3.1 USA

The electricity sector in the USA contributes around 40% of the total national emissions of mercury (Palmer and others, 2007). However, the US EPA believe that only 8% (11 of 144 t) of the mercury deposited from the atmosphere in the USA is actually from electric power plants in the USA, the remainder being from trans-boundary air pollution (McManus and others, 2005).

Mercury emissions in the USA dropped from 199 t/y in 1990 to 101 t/y in 1999, as shown in Figure 1 (US EPA, 2008). During that time, emissions from utility coal boilers only