



**UNITED NATIONS  
ENVIRONMENT PROGRAMME**

**Chemicals Branch, DTIE**



# **The Global Atmospheric Mercury Assessment: Sources, Emissions and Transport**



**Geneva, Switzerland  
December, 2008**

The Governing Council, by its decision 24/3 IV, paragraphs 24 (a) and (b), requested the Executive Director to prepare a report on atmospheric emissions of mercury. UNEP cooperated with the Arctic Council's Arctic Monitoring and Assessment Programme to develop a report responding to this request. The AMAP Secretariat was engaged to coordinate the work process.

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## Cover photos

Top-left: Mercury Thermometer Manufacturing: Without Occupational Safety gear. Source: Toxics Link.

Top middle: Mercury flask found in a gold mining village in the Philippines, originating from Almaden, Spain. Source: Lars Hyllander

Top right: Boy covering face to avoid fumes (ineffective) while burning amalgam to evaporate mercury and produce gold.  
Source: Kevin Telmer

Bottom left: Coal fired power plant. Source: [www.shutterstock.com](http://www.shutterstock.com)

Bottom middle: Workers in a cement factory. Source: [www.shutterstock.com](http://www.shutterstock.com)

Bottom right: Red hot slag from the Norilsk (Russia) nickel foundry, glowing at dusk. Source: Bryan & Cherry Alexander Photography

# Executive Summary

## Introduction

In 2007, the Governing Council (GC) of the United Nations Environment Programme (UNEP) through its Decision 24/3 requested the Executive Director of UNEP:

*to prepare a report, drawing on, among other things, ongoing work in other forums addressing:*

### *Atmospheric emission*

*(a) Best available data on mercury atmospheric emissions and trends including where possible an analysis by country, region and sector, including a consideration of factors driving such trends and applicable regulatory mechanisms;*

*(b) Current results from modelling on a global scale and from other information sources on the contribution of regional emissions to deposition which may result in adverse effects and the potential benefits from reducing such emissions, taking into account the efforts of the Fate and Transport partnership established under the United Nations Environment Programme mercury programme.*

Mercury and compounds containing mercury are toxic for humans and for the environment. As a naturally occurring element, mercury has always been present in the environment. Human activity, particularly since the start of the industrial age, has mobilized mercury in addition to that already in circulation naturally. Mercury is easily transported by air and water. In its gaseous elemental form, mercury has a long atmospheric lifetime (6-18 months) which means it can be transported around the globe, hence its characterization as a 'global pollutant'. Atmospheric mercury is deposited in various ways to the ground and water. After deposition, some of the mercury can be transformed, primarily by microbial action, into methylmercury. Methylmercury bio-accumulates and bio-magnifies in food webs, resulting in increased concentrations in organisms higher in the food web. For these reasons, mercury remains

an important subject of global pollution control efforts.

UNEP's 2002 *Global Mercury Assessment* examined the reasons for concern about mercury, its toxicology for humans and the environment, sources and levels of environmental mercury, and the prospects for policy actions. It relied on the best available information at that time, which were primarily data from 1995 and before.

In response to the 2007 UNEP GC request, this report *Global Atmospheric Mercury Assessment: Sources, Emissions and Transport* and the related *Technical Background Report to the Global Atmospheric Mercury Assessment* address atmospheric emissions (focusing on anthropogenic emissions), emissions trends, and results from modelling.

The new reports update these components of UNEP's 2002 *Global Mercury Assessment*. Specifically, they provide improved emissions estimates, including estimates for product-related emissions; new information on trends in emissions; scenarios that explore future emissions and the prospects for reductions; and the results of recent research on atmospheric transport, modelling, and deposition of mercury.

The new inventory of anthropogenic emissions represents the most up-to-date, state-of-the-art global inventory of anthropogenic emissions of mercury to the atmosphere currently available. The 2005 inventory incorporates new national reporting. In cases where national data are still lacking, improved estimates of emissions have been prepared based on better information from more countries and more accurate statistics and emission factors. The inclusion of emissions associated with product-use and disposal and artisanal/small-scale gold mining represent further significant improvements over previous inventories.

The Arctic Monitoring and Assessment Programme (AMAP) Secretariat was engaged to coordinate the process of developing the reports. This

arrangement ensured efficient mutual cooperation between the work on the UNEP reports and that on the ongoing AMAP mercury assessment. The reports have been subject to national and expert review. The detailed information that provides the basis for the statements made in this report is presented in the fully-referenced technical background report. The reports have also drawn on the work of the UNEP Global Mercury partnership (Mercury Air Transport and Fate Research partnership area) and AMAP.

## Key Findings

### Sources

Mercury is released from a variety of natural sources, including volcanoes and geothermal activity, wildfires and weathering of rocks and soils, and from various human activities. This report focuses on releases from human activities. Mercury is released to the atmosphere during burning of fossil fuels, processing ores from mining, and several industrial processes including the chlor-alkali industry. It is also found in various commercial and consumer products, and is released when waste containing those products is incinerated. The report also recognizes that mercury that has been deposited from the atmosphere can be repeatedly emitted again in various ways.

### Emissions

Global atmospheric emissions of mercury from human activity in 2005 were estimated to be approximately 1930 (range 1230–2890) tonnes. This number is in the same range as estimates of natural emissions from oceans (400–1300 tonnes per year) plus emissions from land (500–1000 tonnes per year). Re-emissions add a further contribution, with natural emissions plus re-emissions estimated to be around 1800–4800 tonnes per year, depending on the source of information and the estimation method. Although it is not possible to distinguish the anthropogenic and natural com-

ponents of re-emissions, the relative proportions are likely to mirror those of the original emissions. Thus, about half of re-emissions can reasonably be considered anthropogenic.

Burning of fossil fuels (primarily coal) is the largest single source of emissions from human sources, accounting for about 45% of the total anthropogenic emissions. Artisanal/small-scale gold mining was responsible for about 18%, with industrial gold production accounting for an additional 5–6% of global emissions from human activities. Other mining and metal production activities are responsible for about 10% of global anthropogenic releases to the atmosphere. Cement production releases a similar amount. Emissions from waste incineration and product-use sources are more difficult to estimate. These emissions could be considerably higher than the generally conservative estimates of 150 tonnes included in the 1930 tonnes global estimate.

Power plants are the largest single source in most countries with high mercury emissions, although in Brazil, Indonesia, Columbia, and some other countries (in South America, Asia and Africa in particular) artisanal/small-scale gold mining is the largest single source.

Geographically, about two-thirds of global anthropogenic releases of mercury to the atmosphere appear to come from Asian sources, with China as the largest contributor worldwide. The United States of America and India are the second and third largest emitters, but their combined total emissions are only about one-third of China's.

The uncertainties associated with estimates of mercury emissions are largely related to the application of various assumptions that are required to make up for a lack of actual measurement data. The figures for anthropogenic emissions are based on governmental emission data where available, combined with estimates for countries that did not provide such data. Some countries that are

Global anthropogenic emissions to air in 2005 from different regions.

Continent	2005 emission, tonnes	% of 2005 emission	Low-end estimate	High-end estimate
Africa	95	5.0	55	140
Asia	1281	66.5	835	1760
Europe	150	7.8	90	310
North America	153	7.9	90	305
Oceania	39	2.0	25	50
Russia	74	3.9	45	130
South America	133	6.9	80	195
Total	1930	100	1220	2900

major mercury emitters did not provide national emissions reports. Other countries, such as South Africa and Japan, provided updated information and more accurate emissions estimates than were available in the past. Measurements made at major point sources such as power plants are few, but where available they have been used as the basis for some emission estimates. The reliability of industrial activity statistics and other statistics used for the purposes of estimating emissions, and the accuracy of various assumptions about specific practices and technologies as they relate to mercury emissions are additional sources of uncertainty. Despite the uncertainties involved, the 2005 emissions inventory and its underlying data are considered to represent a robust inventory of contemporary global anthropogenic emissions of mercury to air, provide a picture of regional and national patterns and give insight into global trends.

### Temporal Trends in Emissions

In 1990, global anthropogenic mercury releases to the atmosphere from sources associated with incidental pollutant emissions, and the intentional use of mercury in the chlor-alkali industry were estimated at about 1910 tonnes. In 1995, estimated emissions rose to about 2050 tonnes, but fell by 2000 to about 1930 tonnes. The greatest decreases were in Europe, with substantial declines also in North America, reflecting the introduction and wider use of emissions control technologies. Emissions in Asia, South America, Africa and Oceania increased modestly over this period, attributed to economic expansion in some countries, with the largest increases seen in Asia.

Comparison of the earlier global inventories with the new 2005 figures is complicated by changes in methods, assumptions, and the addition of new sectors of activity. Using data for only those sectors included in both the 2000 and 2005 global emissions inventories, estimated total emissions from these sectors fell by about 450 tonnes. Some of this decrease is real, whereas some is likely due to improved quality of information, data and estimates. European emissions continued to decline through 2005. In Asia, increases in emissions from China and India were partly offset by declines in emissions from several other countries including Japan.

Scenarios of future emissions have been prepared to help explore the prospects for reducing mercury emissions and the implications of not

taking any action in this regard. These scenarios suggest that, if current trends in industrial development and resource use were to continue, mercury emissions in key selected sectors (those where mercury is an incidental pollutant and also the chlor-alkali industry) are likely to rise from about 1480 tonnes in 2005 to about 1850 tonnes by 2020. However, if emissions controls currently in place or planned in Europe were to be extended worldwide, mercury emissions from these sectors could drop to about 850 tonnes by 2020. Under a scenario of maximum technologically feasible reduction measures, emissions could drop to about 670 tonnes by 2020. Emissions from product use and artisanal/small-scale gold mining were not included in these scenarios. Projecting figures for these sectors is difficult, and the preliminary estimates produced were considered too speculative to introduce into the current scenario evaluation. However, both of these sectors have the potential for significant reductions in mercury emissions.

### Atmospheric Transport and Processes

Gaseous elemental mercury spreads around the world, with regional atmospheric concentrations varying from 1.1 nanograms per cubic meter in remote locations in the Southern Hemisphere to 4 nanograms per cubic meter in East Asia.

Although better information continues to become available as a result of new research, a more complete understanding of the processes that determine mercury transport in the atmosphere is needed to better connect anthropogenic sources to the eventual deposition of mercury and its uptake into food webs. The chemical reactions that mercury undergoes in the atmosphere and in the surface prior to uptake or re-emission are not understood adequately enough to determine exactly what factors promote or inhibit deposition and re-emission.

### Concentrations and Deposition

Atmospheric mercury reaches biota and humans after it has been deposited onto land or water bodies. Studies of sediments, peat, and ice cores provide a long timeline of mercury deposition. Sediments, for example, typically contain about three times as much mercury today as they did in pre-industrial times.

More recent trends are apparent from measurements conducted by several mercury monitoring networks, primarily in the Northern

Hemisphere. Data from air monitoring networks in Europe and North America show a decrease in wet deposition of mercury in the last decade, due to a decline in local or regional emissions. Measurements of mercury air concentrations at remote sites in North America and in Europe tend to show little change in the long-term average. At such locations the levels reflect global atmospheric background concentrations rather than the effect of local and/or regional emissions. On shorter time-scales, however, mercury concentrations in air at remote sites can vary significantly, a prime example being the strong variation at high latitude sites due to atmospheric mercury depletion events at certain times of the year.

### **Modelling**

Modelling can extend the information gained through observations of atmospheric mercury at individual monitoring sites by examining

the ways that mercury moves throughout the atmosphere and the environment. Modelling results indicating episodic long-range hemispheric transport of mercury are consistent with observations.

One application of models is to explore the regional and global effects of reducing mercury emissions. For example, mercury deposition in Europe has decreased by nearly half since the 1990s. Modelling studies demonstrate that this is likely the result of emissions reductions within the region itself. Despite similar emissions reductions in North America, however, deposition in the region has not declined as much. Models show that this can be partly explained by the changes in Asian emissions. Future emissions reductions in various major source regions can be expected to reduce deposition both within the source region and, to a lesser extent, in other parts of the world.

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