The US Mercury Emission Inventory for the Arctic Council Action Plan

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The Arctic Council, having agreed to act to reduce exposures to a number of priority pollutants in the Arctic region, has initiated a mercury project via the Arctic Council Action Plan (ACAP). The project is led by the Danish EPA with a Steering Group from all eight Arctic countries– Canada, Denmark, Finland, Iceland, Norway, Russia, Sweden, and United States. The overall project objective is to contribute to a decrease of mercury releases from Arctic countries. This will be accomplished partly by contributing to the development of a common regional framework for an action plan or strategy for the decrease of mercury emissions, and partly by evaluating and selecting one or a few specific point sources for implementation of control measures. It is felt that the decrease of mercury releases from key sources should serve as a demonstration of existing possibilities, giving inspiration to other control measures in the region.

One of the first steps in the action plan is the development of an inventory of mercury releases to the land, air, and water. Characterization of mercury usage and its disposition will provide the framework for an action plan and strategy for decreasing the amount of mercury in the environment. A detailed questionnaire was developed to collect consistent data from the involved countries, including key information on modeling parameters (e.g., latitude/longitude, stack parameters, chemical composition, and emissions control technology).

EPA completed the U.S. portion of the questionnaire to provide data and information to the project. All data sources are publicly available and most are from EPA inventories, e.g., National Emissions Inventory (NEI) for air emissions and Toxics Release Inventory (TRI) for solid waste disposal and water discharges. The results characterize the mobilization of mercury in the US to the land, air, and water. The overwhelming mobilization action is land disposal associated with gold mining. The most significant air source category is coal combustion. Other sources of air emissions include gold mining, chlor-alkali plants, municipal waste combustors, medical waste incinerators, and industrial boilers. There were minimal discharges to water bodies noted from the data available.

The ACAP project should result in availability of data to enable assessment of mercury issues in the Arctic and is expected to be a model for international data exchange on mercury and other pollutants. The overall project is intended to identify research opportunities for engineering demonstrations that provide scientific information on mercury control options in the Arctic and around the world.

Introduction

Reductions of exposures to a number if priority pollutants, including mercury, have been the focus of many organizations like the Arctic Council. Comprised of representatives from eight countries – Canada, Denmark, Finland, Iceland, Norway, Russia, Sweden, and United States, a mercury project has been initiated through the Arctic Council Action Plan (ACAP). It is the goal of this project to reduce the mercury emissions from the Arctic countries by the development of a regional action plan.

Mercury is a metal that can be found in three main forms – elemental gaseous, gaseous divalent, and particulate divalent. It is known that mercury enters the environment after being mobilized and released from various sources such as utility coal boilers and municipal waste combustors/incinerators. Because mercury cycles, it can be carried over long distances away from its initial source location. Mercury is deposited into the aquatic environments through precipitation and generally is found in its organic form known as methylmercury. Methylmercury has many health issues associated with it, including tremors and neurological damage. Also, methylmercury bio-accumulates, or increases in intensity as it is carried up the food chain. Because most of the Arctic region is dependant on aquatic environments for food, the accumulation of mercury in larger Arctic species is quite high. The concern about mercury levels found in species such as polar bears and fish within the Arctic region spurred urgency in developing a plan to reduce emissions for countries that may greatly affect the region.

The objective of the ACAP mercury project is to contribute to a decrease in mercury releases from Arctic countries. To accomplish this, a regional action plan will be developed and specific sources will be evaluated for the implementation of control measures. It is the hope of the Arctic Council that this project will serve as a lead to other regions in developing similar regional plans.

In order to properly identify the current emissions for each country, a regional questionnaire was developed by the Denmark EPA. The questionnaire, in the form of an Excel workbook, was distributed to and completed by all eight participating countries. This questionnaire serves to characterize mercury usage and disposition within each country, which will provide the basis for an action plan. By including data for land, air, and water mercury releases and key information on modeling parameters (e.g., latitude/longitude, stack parameters, chemical composition, and emissions control technology), the questionnaire provides a concise inventory of mercury releases for the Arctic countries. The first step in developing the regional action plan is the completion of the questionnaire by each country.

US Data Sources for Questionnaire

The questionnaire is comprised of 33 individual worksheets concentrating on release trends, trade statistics, source categories, and point sources. The sheets are designed so that emissions are categorized by industry type. US EPA data sources used in completing these sheets are listed below:

- Release trends - Global Mercury Assessment Report, UNEP[1].
- Trade statistics - US Geological Survey, Mineral Yearbook[2].
- Source categories - 1999 National Emissions Inventory for HAPs (NEI)[3] and 2001 Toxic Release Inventory (TRI)[4].
- Point sources - 1999 National Emissions Inventory for HAPs (NEI).

- TRI data can be found at the following website: http://www.epa.gov/tri/tridata/tri01/data/index.htm
- NEI data can be found at the following website: http://www.epa.gov/ttn/chief/net/1999inventory.html#final3haps

Toxics Release Inventory (TRI) -

The Toxics Release Inventory (TRI) is a Community Right-to-Know Inventory. Facilities meeting certain criteria are required to report annually. These include facilities that manufacture or process 25,000 pounds or more of listed substances or use 10,000 pounds or more of listed substances, that are in the manufacturing sector (Standard Industrial Classification (SIC) codes 20-39), electric utility sector, mining sector, solvent recovery sector, petroleum bulk storage sector, chemical wholesale sector and the treatment, storage and disposal sector, and that have 10 or more full-time employees. (Beginning in reporting year 2000, certain persistent, bio-accumulative toxic chemicals are subject to lower reporting thresholds).

Under TRI, for each chemical that meets the threshold, a facility reports the quantity that is released to the air, water, land, or managed as waste on-site or off-site (disposal, treatment, energy recovery, recycling). There are over 640 chemicals and chemical categories on the TRI list. The TRI facilities use the best available information to make their estimates, including monitoring data, emission factors, mass balance and engineering calculations.

While TRI provides information on point sources, it does not address many other important sources of toxics emissions, including mobile sources, combustion sources such as certain incinerators, and agricultural sources. TRI is not a modeling inventory and does not contain individual stack emissions for facilities nor stack parameters necessary for modeling. TRI is not comprehensive for all point sources in the US.

The 1999 National Emissions Inventory (NEI) -

The 1999 National Emissions Inventory (NEI) is a comprehensive inventory covering criteria pollutants and hazardous air pollutants (HAPs). The EPA's Emission Factor and Inventory Group (EFIG) in Research Triangle Park, North Carolina created the NEI. This database contains information on stationary and mobile sources that emit hazardous air pollutants (HAPs). The

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[1] United Nations Environment Programme *Chemicals*. Global Mercury Assessment. UNEP Chemicals, Geneva, Switzerland. December 2002.
[2] United States Geological Survey. Minerals Yearbook. Mercury 1994-2001.
[3] 1999 National Emission Inventory for HAPs, Final version, U.S. EPA, Office of Air Quality Planning & Standards. RTP, NC. July 21, 2003.
[4] 2001 Toxic Release Inventory, U.S. EPA, Office of Environmental Information. Washington, DC. June 16, 2003.

database includes estimates of annual emissions, by source, of air pollutants in each area of the country, on an annual basis. The NEI includes emission estimates for all 50 States, the District of Columbia, Puerto Rico, and the Virgin Islands. Included are emission estimates for individual point sources (facilities), as well as county level estimates for nonpoint, mobile and other sources.

Point sources in the NEI are sources for which the specific location is known; they may be either major or area sources. Major sources are defined in the Clean Air Act (CAA) as stationary sources that:

- Have the potential to emit 10 tons per year (tpy) or more of one HAP; or
- Have the potential to emit 25 tpy or more of any combination of HAPs.

Smaller point sources with annual emissions below these thresholds are defined as area sources.

Nonpoint sources in the NEI include area sources that are not identified as point sources because their specific locations are not known. Nonpoint sources also include other sources such as wildfires and prescribed burning whose emissions are estimated at the county level.

Data from the NEI are used for air dispersion modeling, regional strategy development, regulation setting; air toxics risk assessment, and tracking trends in emissions over time. The NEI is a modeling inventory and thus contains emissions, stack parameters, control device information, and location data for individual stacks. The NEI does not have any reporting thresholds for point sources.

The NEI is compiled from the following sources of data: state and local agencies, tribes, EPA Maximum Achievable Control Technology (MACT) and EPA "residual risk" data collected during regulatory development, industry data, TRI, mobile source data generated using EPA mobile source onroad and nonroad models, and EPA generated data for approximately 30 nonpoint source categories. NEI mercury estimates are of high quality for the most reported sources. Utility coal boilers, municipal waste combustors, medical waste incinerators, and hazardous waste incinerators emissions are based on source testing at all facilities.

Methodology

Crosswalk of the Questionnaire with NEI and TRI Data

Because of the large amount of data available from both the TRI and NEI databases, proper classification was essential for use in the questionnaire. In order to properly group the data provided by both databases into the source categories provided by the Danes, several assumptions and crosswalks were performed.

For the TRI data crosswalk with the ACAP categories, the primary identifier for source categories was the SIC codes. Each SIC code present in the TRI data was defined and then grouped with one of the ACAP source categories.

For the NEI data crosswalk with the ACAP categories, several identifiers were used for each: MACT, SIC codes, and SCC codes. (SCC codes are specific EPA codes that are assigned to

describe stationary and mobile processes having associated air emissions.) Most data were classified by MACT code if available because MACT codes were more descriptive and provided a more accurate grouping determination.

After the NEI and TRI were grouped into the ACAP source categories, the emissions values were categorized based on six classifications for releases and transfers. The classifications and corresponding inventory used are listed below:

- Atmospheric releases of Hg - NEI
- Direct releases of Hg to aquatic environments - TRI
- Direct releases of Hg to soil environments (including via diffusely lost waste) - TRI
- Hg to public/municipal waste water systems - TRI
- Hg to municipal/general waste treatment - TRI
- Hg to waste collected and treated as hazardous/medical waste - TRI

The TRI data had to be further grouped to fit into the above release and transfer classifications. The table below shows the TRI categories and how they were classified into the ACAP release and transfer categories.

ACAP Release/Waste Transfer Category	**TRI Category***
Direct releases of Hg to aquatic environments	Total surface water discharge
Direct releases of Hg to soil environments (including via diffusely lost waste)	Total underground injections Other landfills Total land treatment Surface impoundment Other disposal
Hg to municipal/public waste water systems	Publicly Owned Treatment Works (POTWs) Waste Water Treatment
Hg to municipal/general waste treatment	Transfers to other off-site locations Transfers for disposal
Hg to waste collected and treated as hazardous/medical waste	Resource Conservation and Recovery Act (RCRA) subtitle C landfills

**Some of the SIC codes used in the TRI program contain some ambiguities. For example, for SIC codes 30XX, 31XX, 34XX, 35XX and 36XX contain mercury releases from coal but also contain mercury releases from non-coal activities.*

Point Sources

Another crosswalk of the data had to be performed on the NEI for specific point source information. The same process stated above for the source categories was used for point sources. Because the questionnaire asked for point sources based on facility and not individual stacks, a

site latitude/longitude value was assigned to facilities with multiple stacks reported. In general, this site latitude/longitude value was based closely on the highest emitting stack at the facility.

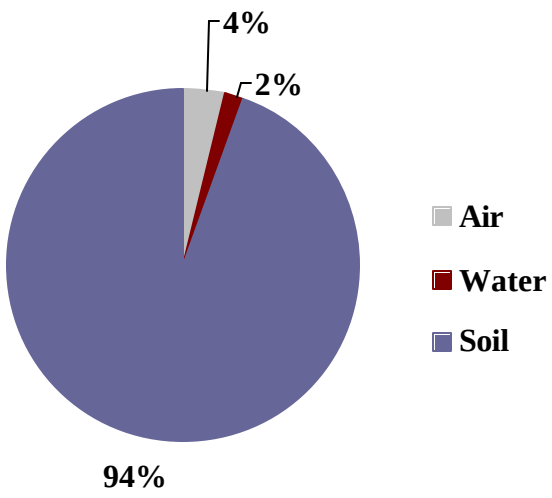
Only the top 10 emitting facilities for each ACAP source category were entered into the questionnaire, except for utility coal facilities that required the top 20 facilities. For each point source provided as a top 10 emitter, the site name, latitude/longitude, stack height (m), total mercury air emissions (kg/yr), and mercury speciation were provided. The mercury speciation was provided by various EPA sources, including Clear Skies percentages for all source categories except utility coal and chlor-alkali sources. Utility coal sources were already separated by chemical composition in the NEI inventory and chlor-alkali sources were classified using a more recent percentage value of 95/5. In March 2004, EPA's Emissions Factor and Inventory Group (EFIG) updated default mercury speciation profiles.

Data Results

Mercury is released to the atmosphere, water environments, and soil environments. There are interactions between these environments, causing fluxes in mercury concentrations within each media. Understanding the global mercury cycle helps illustrate this interaction between media. All mercury releases contribute to the global pool of mercury in the biosphere. Mercury has the ability to be continuously mobilized, deposited on land and water, and then re-mobilized.

The highest reported releases of mercury in the US are to the soil environments (94%), with air and water environments making up a small percentage of the total releases reported.

Figure 1: Mercury Releases to Individual Media (Percentage)



To better understand the total releases, the ACAP mercury questionnaire examined individual source categories for mercury releases. The highest reported releases, directly affecting the soil release percentage, were from gold mining operations. If gold mining releases were not taken into consideration, the percentages would reflect a more balanced distribution (62% soil, 27%

air, and 11% water). Table 2 provides the reported mercury releases by the ACAP defined source categories for releases to air, water, and soil.

Table 2: Mercury Releases to Individual Media (metric tpy)

ACAP Category	Air	Water	Soil
Co-production of non-ferrous metals	0.05	0	6.00
Dental amalgam fillings	0	0	0
Mercury from cement production	2.31	0	1.16
Mercury in batteries	0.01	0	0
Mercury in chlor-alkali production	5.93	0.05	0.44
Mercury in landfills/deposits	0.17	--	--
Mercury in manometers, blood pressure gauges and in education	0.78	--	--
Mercury mobilized by coal usage - large combustion plants	43.46	0.17	33.06
Mercury mobilized by coal usage - other coal uses	9.10	0.01	0.03
Mercury mobilized by extraction and use of oil, gas and biofuels	7.80	0.05	0.15
Mercury mobilized by other primary extraction/production of materials	3.41	0.33	81.11
Mercury mobilized by primary extraction and processing of copper	0.03	0	49.55
Mercury mobilized by primary extraction and processing of gold	10.45	45	2407.26
Mercury mobilized by primary extraction and processing of lead	0	0	7.78
Mercury mobilized by primary extraction and processing of other metals	1.42	0.06	33.33
Mercury outputs from incineration/combustion of hazardous/medical waste	8.63	--	--
Mercury outputs from incineration/combustion of municipal/general waste	4.62	0	26.60
Mercury outputs from other waste treatment	2.33	--	--
Mercury outputs from waste water systems	0.82	--	--
Mercury releases from recycling of other metals and materials	0.98	0	0.05
Mercury switches, relays and contacts	0	0	0
Mercury thermometers	0	0	0
Mercury use in other products and processes	3.61	0.10	11.71
Mercury used in light sources	0.97	0	0
Other	2.30	--	--
TOTAL EMISSIONS (tpy)	**109.2**	**46**	**2658.2**

Releases to Soil Environments

As shown in Figure 1, the highest reported amounts of mercury releases are to soil environments. The total reported emissions to the soil are 2232.8 metric tpy. The classification of these emissions in the ACAP questionnaire creates fewer details about the specific industries. By looking at the TRI source categories by SIC codes, a more detailed description of the releases is provided. Table 2 below provides a listing to the top 10 categories by SIC code for releases to soil environments. As observed in the ACAP categories, gold mining is at the top of the list with over 2000 metric tpy of reported mercury releases to the soil environment. Of the top 10, 4 are related to metal mining.

Mercury is found in most metal ores. During gold mining, a cyanide solution is used to extract gold from ores, but also has been found to extract mercury during the process. Once the mercury has been extracted from the ore, it is found in sediments left at the mining site. This mercury is

then remobilized each year during the winter and spring high flows and gets redistributed in water or in the soil.

Table 3: Top 10 Soil Emissions by SIC

SIC	Description	tpy
1041	Gold Ores	2082.4
3274	Lime	41.6
1021	Copper Ores	35.5
1044	Silver Ores	26.9
4911	Electric Services	18.1
1031	Lead and Zinc Ores	8.5
2816	Inorganic Pigments	3.5
3339	Primary Smelting and Refining of Nonferrous Metals, Except Copper and Aluminum	3.3
3331	Primary Smelting and Refining of Copper	3.3
XXXX	All other SIC codes	9.6

Other mining operations also allow for mercury extraction but have stricter controls and regulations to guard against excessive releases. In the smelting and refining processes, mercury can be extracted with other metal impurities and be collected as a sludge, which contributes to the releases to the soil.

Releases to the Atmosphere

The second highest reported mercury emissions are to the atmosphere. The total reported releases to the atmosphere are 117.8 tpy. Table 4 shows the top 10 source categories of mercury releases to the atmosphere. The highest reported emissions are from sources using utility coal boilers (47.9 tpy). These sources, along with municipal waste combustors and hazardous waste incinerators have traditionally been found to be the largest source emissions of mercury to the atmosphere. Because of the implementation of maximum achievable control technology (MACT) standards, both municipal waste combustors and hazardous waste incinerators have been able to reduce their emissions considerably.

The second highest amount of mercury releases to the atmosphere comes from gold mines. As stated in the section above, mercury is extracted when cyanide solutions are used to extract gold from ores. Gold mining by-products have been shown to be the only large mining-related source of mercury air emissions. Because of voluntary initiatives with Nevada gold mines, pollution prevention strategies have been implemented in hopes of reducing mercury releases from these sources.

Chlorine production ranks third for mercury emissions to the atmosphere. Mercury cells are commonly used at chlor-alkali plants, causing mercury to be released to the atmosphere. Recently, a MACT standard for these facilities has been promulgated to help reduce their contribution of mercury.

More information regarding air emissions from specific industries can be found on the AP-42 website: http://www.epa.gov/ttn/chief/ap42/index.html.

Table 4: Top 10 Air Emissions by Source Category

Source Category	tpy
Utility Boilers: Coal	47.9
Industrial/Commercial/ Institutional Boilers & Process Heaters	12.0
Gold Ores	11.5
Chlorine Production	6.5
Municipal Waste Combustors	5.1
Medical Waste Incinerators	2.8
Stationary Reciprocal Internal Combustion Engines	2.5
Commercial Hazardous Waste Incinerators	2.5
On-Site Hazardous Waste Incinerators	2.4
All other Source Categories	24.0

Releases to Aquatic Environments

The lowest mercury releases are reported to the water. These releases make up about 2% of the total mercury releases in the U.S. Most of these releases occur as a result of runoff or mercury contained in wastewater.

Table 5: Top 10 Water Emissions by SIC

SIC	Description	tpy
2631	Paperboard Mills	0.26
4911	Electric Services	0.19
1221	Bituminous Coal and Lignite Surface Mining	0.09
2816	Inorganic Pigments	0.07
3312	Steel Works, Blast Furnaces (Including Coke Ovens), and Rolling Mills	0.06
2812	Alkalies and Chlorine	0.05
2911	Petroleum Refining	0.05
2869	Industrial Organic Chemicals, NEC	0.02
2819	Industrial Inorganic Chemicals, NEC	0.01
XXXX	All other SIC codes	0.05

Conclusions

Benefits of Participation

By participating in this project with the Artic Council, EPA has been able to achieve several benefits. First, EPA has been able to demonstrate leadership in both policy and research/assessment. As an agency, EPA has been able to provide guidance and assistance to other countries in developing their own emission inventories and rule-making strategies.

Through taking a national emissions inventory, EPA has identified the facilities that contribute the most to mercury emissions. Since the questionnaire that was compiled examined all release media (soil, air, and water), EPA now has a complete modeling inventory to allow for determination of how the U.S. mercury emissions affect the Artic region. Table 6 below shows

the results of the ACAP project by listing total atmospheric mercury emissions reported from each country.

Table 6: Breakdown of Atmospheric Mercury Releases From the Arctic Countries (metric tpy)*

Country	tpy
Canada	8
Denmark	1.4
Finland	0.5
Iceland	NA
Norway	0.6
Russian Federation	39
Sweden	0.6
USA	107
Total	**10.5**

*Note: Results taken from DRAFT Report, "Reduction of atmospheric mercury emissions from Arctic countries – Regional mercury inventory.

Conclusion

Through EPA's participation in the ACAP Mercury Project, the U.S. has a complete multimedia modeling inventory, a result not previously obtained. By using the modeling inventory, the fate and transport of mercury can be determined. The process used in this inventory can be used in the future to develop multimedia inventories for other pollutants as well.

By examining the trends in mercury air emissions, it has been found that mercury air emissions has decreased as a result of the implementation of MACT standards. With several MACT standards having promulgated after this project's completion, it is EPA's hope that this decreasing trend will continue.

Gold mining operations were identified as an industry sector needing further attention to determine if controls are needed to reduce their emissions. This industry contributes the highest releases to soil environments, and second highest to the atmosphere.

Finally, this project and EPA's participation, can serve as a model to other countries and regions. By developing complete regional emission inventories, protecting the whole environment can be accomplished.