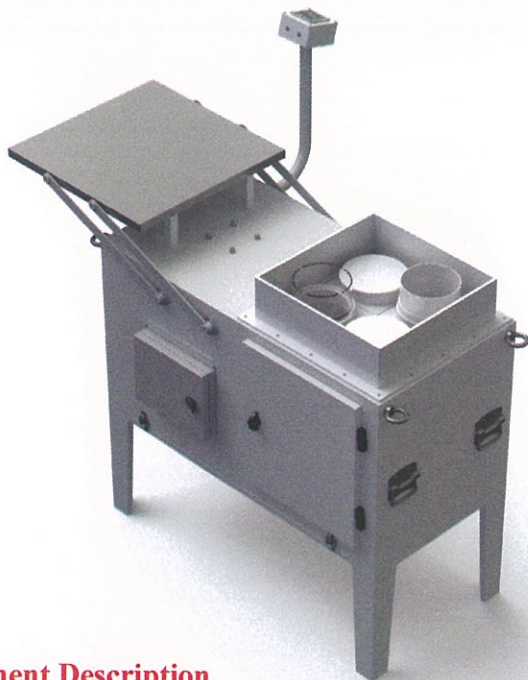


Mercury Deposition Sampler

Model:MDS-01



Equipment Description

1. Sampling description : a top cover automatically shields the trace mercury collection device so as to prevent falling dust from polluting the collection device in the non-rainfall period; in the rainfall period, the top cover automatically opens and wet deposition is collected when a wet deposition sensor senses the rainfall.
2. The present equipment can continuously sample, and collects rainwater mercury through the trace mercury collection device.
3. The ON/OFF time of the most appropriate sensor can be adjusted according to the field sampling environment, so that the sampling readiness is improved.

Trace mercury collection device

A glass funnel is adopted to collect mercury deposition, and a mercury deposition sample is collected through a Teflon collection tank; the sample can be prevented from being polluted by utilization of a pure collection device, and the mercury deposition sample is prevented from being volatilized by utilization of a glass water-sealed check valve.

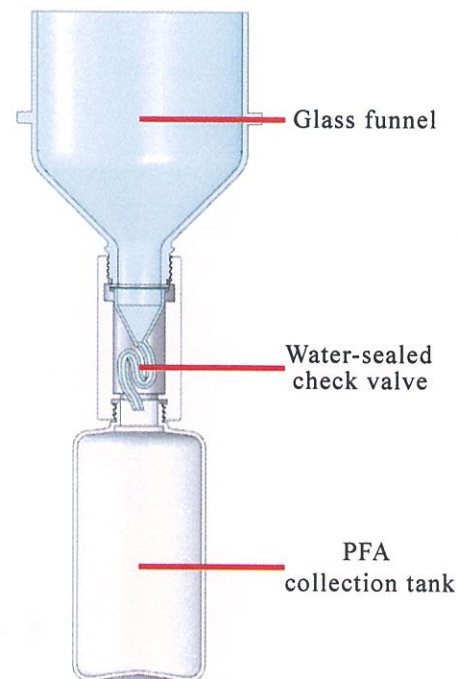
Heavy metal collection device

A funnel and a collection tank which are both made of PE are adopted to collect heavy metal, and no metal components are contained in the material, so that the sample can be ensured not to be polluted.

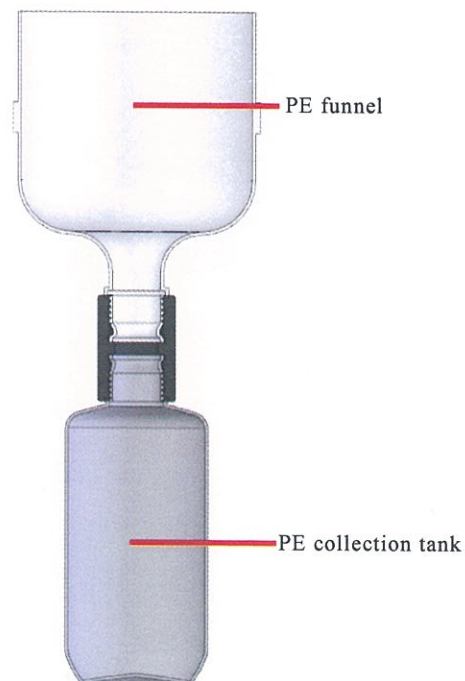
Main body Material : stainless steel, outdoor paint Weight: about 55kg

Control box

Control mode: microcomputer programmable controller and industrial touch screen
Control characteristics: delay time of starting and finishing wet deposition can be randomly adjusted according to the field sampling environment, so that the sampling degree of accuracy is greatly improved.
Material: stainless steel
Display control mode: industrial touch screen



Trace mercury collection device



Heavy metal collection device

Machine Shop

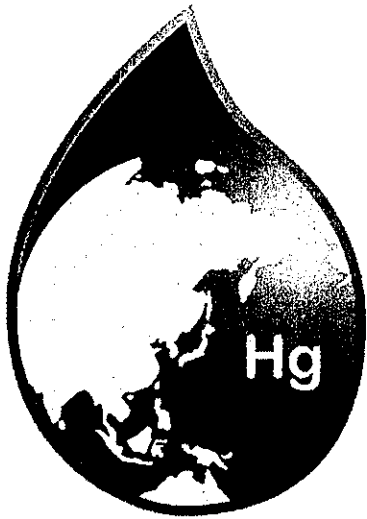
FORTELICE INTERNATIONAL CO.; LTD.

<http://www.machine-shop.com.tw>

TEL : +886-2-8252-1656

FAX : +886-2-8252-1657

E-Mail : sale@machine-shop.com.tw



Asia Pacific Mercury Monitoring Network

Asia Pacific Mercury Monitoring Network Site Information Worksheet

Document Change History

Version	Description	Effective Date
1.0	Initial document	Dec 2015

Introduction

New sites that wish to join a Asia Pacific Mercury Monitoring Network (APMMN) must complete this form, the Site Information Worksheet (SIW). The completed SIW, site sketch, and site photos should be submitted to the address listed below. Alternatively, documentation may be submitted via email at apmmn@apmmn.org.

apmmn@apmmn.org
apmmn@apmmn.org
apmmn@apmmn.org
apmmn@apmmn.org
apmmn@apmmn.org

Sites that are proposing to move more than 30m from their original, approved location must submit a new SIW, site sketch, and site photos as well.

Questions regarding the SIW should be directed to apmmn@apmmn.org. He may be contacted at [1234567890](tel:1234567890), or via email at apmmn@apmmn.org.

Attach additional pages as needed.

Check one, this SIW is for a: New Site Site Relocation

Site Identification

Parameter	Value
Site Name	
Site ID*	
County	
State/Province/other	
Latitude of the collector/sampler (e.g., 40.0528 degrees N, 40 degrees 3.168 minutes N, or 40 degrees 3 minutes 10 seconds N)	
Longitude of the collector/sampler (e.g., 88.3719 degrees W, 88 degrees 22.314 minutes W, or 88 degrees 22 minutes 19 seconds W)	
Altitude of the collector/sampler (meters)	
Sponsoring Agency	
Operating Agency	
Site Owner	

* Value assigned by the APPMN Program Office.

Site Personnel

Parameter	Site Operator	Backup Operator	Site Supervisor
name			
phone number			
fax number			
E-mail address			
mailing address			
shipping address (for any site supplies)			

Site Logistics

How will the site be secured against vandalism?

How will the site be accessed in summer (e.g., auto/truck, ATV, foot)?

How will the site be accessed in winter (e.g., auto/truck, ATV, foot)?

Site Instrumentation

Parameter	Description
power* (e.g., AC, Solar, Battery)	
collector/sampler, manufacturer and model number	
precipitation gage, manufacturer and model number	
backup precipitation gage, if available**	
wind direction instrument (if one onsite), manufacturer and model	
wind speed instrument (if one onsite),, manufacturer and model number	
Temperature instrument (if one onsite), manufacturer and model number	
relative humidity instrument (if one onsite), manufacturer and model number	
barometric pressure instrument (if one onsite), manufacturer and model number	
solar radiation instrument (if one onsite), manufacturer and model	

* If AC powered, include the voltage and service amperage. If solar powered, include the output wattage and angle of the panel. If battery powered, include the type (e.g., lead-acid, gel cell) and capacity of the battery.

** Include the type (e.g., stickgage, tipping bucket, Belfort gage) and network associated with the backup precipitation gage.

Other Monitoring Networks

Indicate whether any of the following networks are located within 500m of the proposed site.

Aerosol and Gas Measurements		
Network	Distance from Proposed Site (m)	Direction from Proposed Site (degrees)
EANET		
Other		
Other		
Other		

Meteorological Measurements		
Network	Distance from Proposed Site (m)	Direction from Proposed Site (degrees)
WMO		
EANET		
Other		
Other		
Other		

Site Description

Ground Cover within 30m of collector/sampler		
Type	Percent Coverage	Notes
Exposed dirt		
Rock		
Mown grass		
Dense vegetation		
Trees		
Water		
Other		
Other		
Other		
Other		

Land use within 500m of collector/sampler		
Type	Percent Coverage	Notes
Pasture		
Cultivated fields		
Desert		
Forest		
Open water		
Residential development		
Commercial development		
Other		
Other		
Other		
Other		

Do animals graze near the site? If yes, describe (i.e., type of animal, approximate number, portion of year, proximity to the site).

Is there any treated lumber within 5m of the collector/sampler? If yes, describe (i.e., amount, and location relative to the instrument).

Is there any galvanized metal within 5m of the collector/sampler? If yes, describe (i.e., amount, and location relative to the instrument).

Are there any overhead wires or tower guy wires within 5m (laterally) of the collector/sampler? If yes, describe.

Assume magnetic north is zero degrees, rotate clockwise from the proposed location of the collector/sampler when completing the tables below.

Transportation Related Sources*, 0 - 100m from the collector/sampler					
Description	Surface Material (e.g., asphalt, concrete, dirt, gravel, sand, mix)	vehicles/day		Distance from Proposed Site (m)	Direction from Proposed Site (degrees)
		Summer	Winter		
e.g., parking lot	gravel	10	10	40	120
e.g., airport taxiway	tarmac	20	20	100	10

* Transportation related sources include: maintenance yards, parking lots, private access roads, streets, highways, waterways, marinas, and airports.

Storage Areas*, 30 - 100 m from the collector/sampler			
Object	Amount	Distance from Proposed Site (m)	Direction from Proposed Site (degrees)
e.g., fuel for tractors	500 gallons	30	150

* Storage areas for road salt, agricultural chemicals, fuels, waste, etc.

Large Emission Sources*, 100m – 20km from the collector

Description	Size (e.g., MW, kg/yr, number)	Distance from Proposed Site (km)	Direction from Proposed Site (degrees)
e.g., electric utility	30 MW	5	330
e.g., poultry farm	20,000 chickens	0.75	110

* Large emission sources include: feedlots, stationary combustion sources, mining operations, incinerators, abattoirs, and chemical manufacturers.

Objects include other monitoring equipment, bushes, trees, fences posts, fences, towers, instrument shelters, sheds, buildings, etc that are greater than 1m tall (as measured from the base of the collector/sampler) and greater than 5cm in projected dimension (e.g., width, depth).

Instrument: Precipitation Collector

Objects, 0 – 30 m from the				
Object	Object Dimensions		Distance from Proposed Site (m)	Direction from Proposed Site (degrees)
	Height (m)	Width or Depth (m)		
e.g., wood fence post	1.2	0.2	4.9	90
e.g., tree	2.3	2.8	8	130

Laboratory Facilities

Parameter	Value
lab space (e.g., none, good, fair, poor)	
distance between lab and site (km)	
balance, manufacturer	
balance, model number	
type of low conductivity water (e.g., de-ionized, distilled, milli-Q, bottled)	
Tekran 2537, serial number	
Tekran 1130, serial number	
Tekran 1135, serial number	
Tekran 1102A, serial number	

Worksheet Documentation

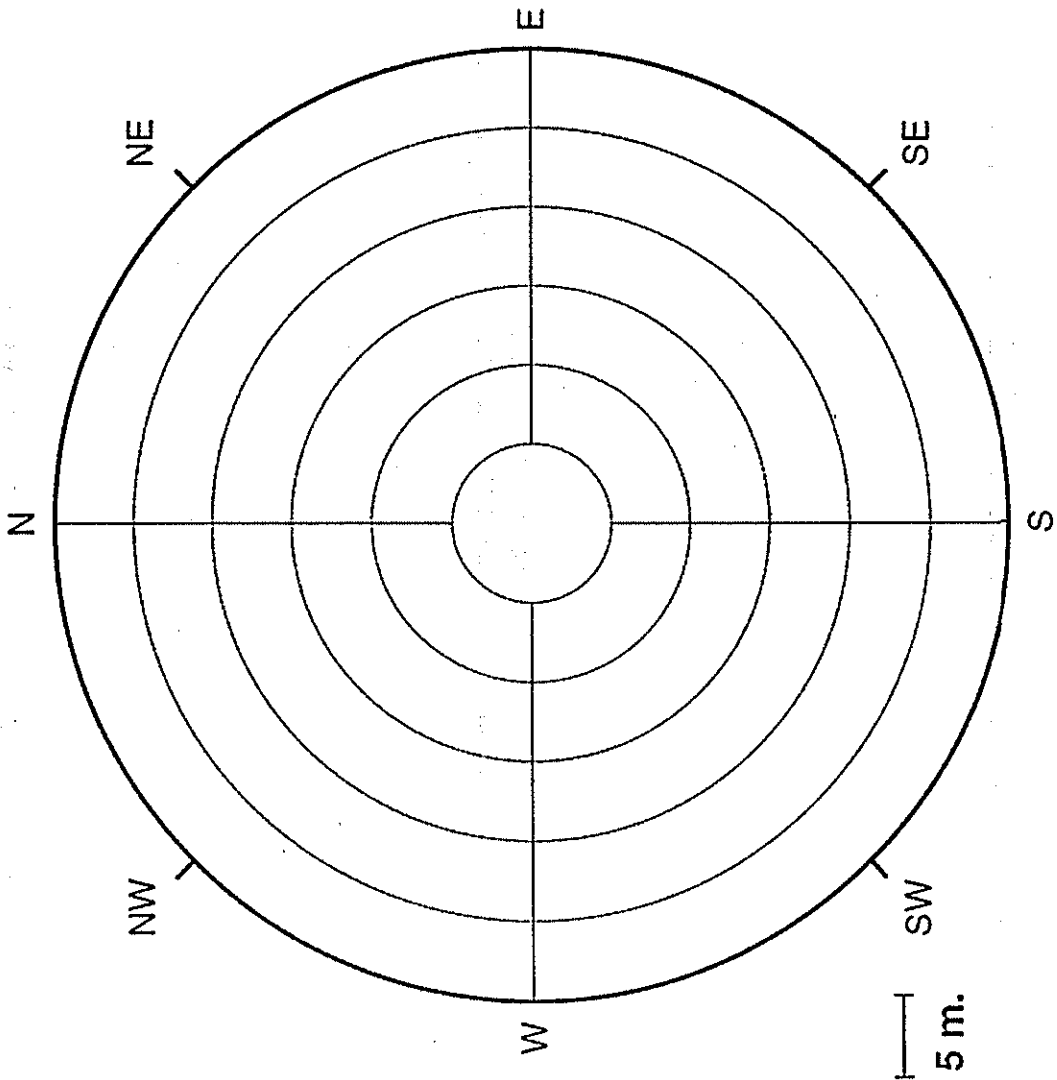
Parameter	Value
name of person who completed SIW	
title	
phone number	
fax number	
E-mail address	
mailing address	
date prepared	

Remember to include the following documentation when submitting the completed Worksheet:

Site sketch (using the template provided)

Photos of the proposed location in 8 directions (N, NE, E, SE, S, SW, W, and NW)

NADP 30m Site Sketch Template



5 m.

	Collector
	Raiagage
	Raiagage Shield
	Buildings
	Air Quality Shelter
	Fence
	Non-APMMN Instrument
	Platform
	Post
	Power Line
	Solar Panel
	Stick Gage
	Tower

GROUND COVER

	Trees
	Shrubs
	Dense Vegetation
	Mown Grass
	Bare Ground
	Sparse Vegetation
	Rock
	Water
	Shrub In Violation
	Tree In Violation

Site Name:

Date:

(Provisional Translation)

An Excerpt from "Manual of Measurement Method of Hazardous Air Pollutants" (March 2011, Air Environment Division, Environment Management Bureau of Water & Air Environment Fields, MOEJ)

Measurement method for mercury in the ambient air

Gold amalgamation trap, thermal desorption and cold vapor-atomic absorption spectrometry

1 Overview of the measurement method

Mercury in the atmosphere is collected at a constant flow rate by using a collection tube filled with collection particles. The particles are composed of diatomaceous earth particles with gold baked on their surfaces. Mercury in the atmosphere is collected as gold amalgam. During sampling, the surfaces of the collection particles may adsorb interfering gas and measured values could be compromised. In order to eliminate the influence of interfering gas, re-collect the mercury vapor generated by the collection tube attached to the thermal desorption device in the collection tube that is controlled to maintain the appropriate temperature.

The collection tube used to re-collect mercury is heated at high temperature, and desorbed atomic mercury is led to the absorption detector cell of the atomic absorption spectrometer to determine the quantity of mercury by measuring the atomic absorption at a wavelength of 253.7 nm.

With this method, analysis and collection of gaseous elemental mercury suspended in the ambient air is possible. Measurement accuracy and sampling efficiency of the other chemical forms of mercury is partly uncertain. However, because the majority exists as gaseous elemental mercury, the measured value determined by this method is considered as measured value for mercury concentration in the ambient air.

It is necessary to implement measurement quality control in order to ensure the reliability of the measured value determined by the measurement of mercury as described in this manual.

2 Reagent

(1) Standard material

Elemental mercury: more than 99% purity with assay.

(2) Diatomaceous earth particles

Thermostable diatomaceous earth particles of 500-600 μm in diameter.

(3) Gold chloride acid

Gold chloride (III) acid tetrahydrate $\text{HAuCl}_4 \cdot 4\text{H}_2\text{O}$, CASRN 1303-50-0

(4) Collection particles

Collect 3 g of diatomaceous earth particles in a beaker (50-100 mL). Then, add a solution prepared by dissolving 1 g of gold chloride (III) acid (HAuCl_4) to 20-30 mL of water and stir uniformly. After heating to approximately 80°C and drying by occasionally shaking, place the collection particles in a tubular furnace and heat for 30 minutes at about 800°C with air flow. (See Note 1)

3 Apparatus and equipment

(1) Sampling device

The sampling device is as shown in Figure 1. A collection tube, a flow control device, a pump, and a flow measuring device are connected.

It is desirable to collect samples directly within the collection tube. When, for unavoidable reasons, a conduit is used, use equipment made of clean glass or tetrafluoroethylene and/or material of equal or better property as it is less likely for mercury gas to adhere. Equipment for the sampling device should be washed thoroughly, to avoid contamination. In addition, after assembling the device prior to sampling, it should be confirmed that there are no leaks.

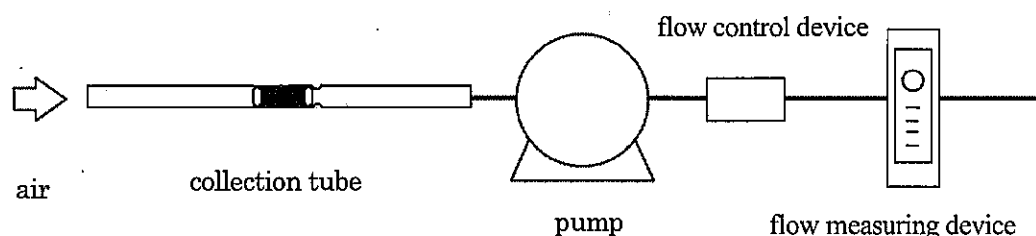


Figure 1 Overview of mercury sampling device

a) Collection tube

As illustrated in Figure 2, a quartz glass tube with a circular recess is filled in the order of quartz wool, approximately 80 mg of collection particles, and quartz wool. (See Note 1)

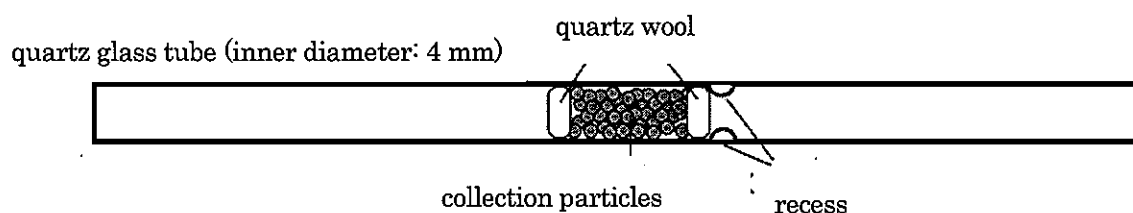


Figure 2 Example of a mercury collection tube

b) Collection tube sealed container

The container should be a glass test tube that can be hermetically sealed and stored free from mercury contamination.

c) Pump

The sealed pump, such as diaphragm type, should have a controllable gas flow rate within the range of 0.1-1.0 L/min, or be a pump of equivalent or higher performance.

d) Flow control device

The flow control device should have a controllable gas flow rate within the range of 0.1-1.0 L/min, control accuracy within $\pm 10\%$ of the configuration; or, be a device of equivalent or higher performance.

e) Flow measuring device

The flow measuring device should be able to measure to 3 decimal places of 0.001 L/min with wet gas meter, dry gas meter, float shaped area flow meter, and mass flow meter, and must be operated with high accuracy within the control range of the flow control device. A unit allowing integrated flow rate measurement is desirable, or a unit of equivalent or higher performance.

(2) Sample introduction device

a) Thermal desorption device

As illustrated in Figure 3, the used collection tube with the air sample is attached to the thermal desorption device, and the heating furnace (first) is heated to 600-700°C with a flow of mercury free air. After the vaporized gas within the mercury is washed and moisture is eliminated by introducing through a gas scrubbing bottle (see Note 2), the samples are re-collected in a collection tube (refining collection tube) attached to an atomic absorption spectrometer set to 150°C. The gas passed through the collection tube is released to the open air. Under this condition, only mercury is trapped into the collection tube and the adsorption of other interfering gas to the collection particles is suppressed. Thus, interfering substances in the mercury analysis is eliminated.

Next, after the re-collection procedure, the valve is switched to the absorption detector cell side, and the atomic mercury released by a heating of second furnace is led to the absorption detector cell of the atomic absorption spectrophotometer.

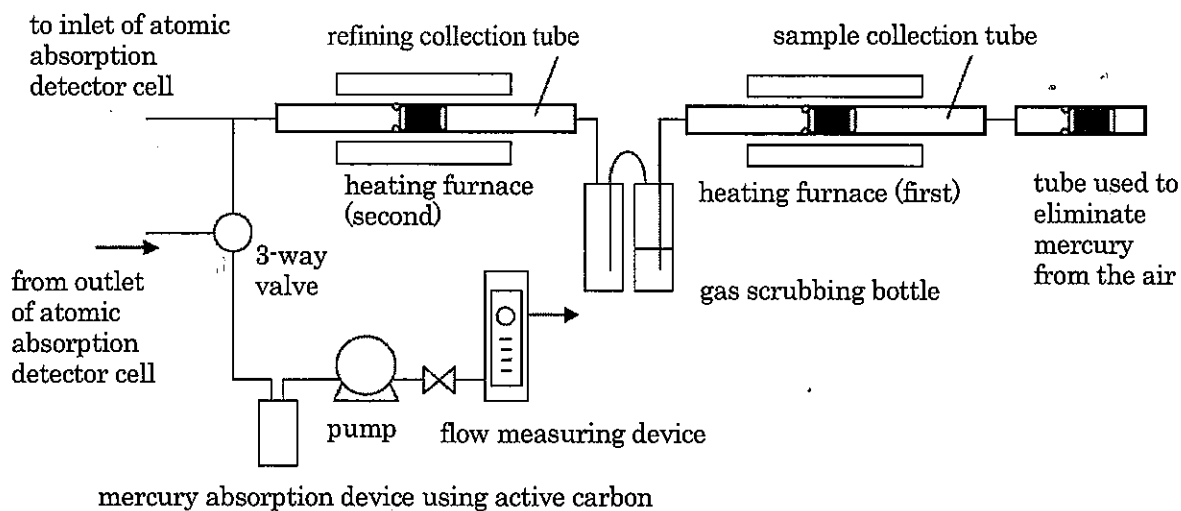


Figure 3 Example of thermal desorption device for mercury analysis

(3) Atomic absorption spectrometer

An atomic absorption spectrometer for mercury analysis or an atomic absorption spectrometer is used. This device is composed of a light source unit, an absorption detector cell unit, a wavelength selection unit, and a photometry unit.

a) Light source unit

The light source unit is a low-pressure mercury lamp or a mercurial hollow cathode lamp.

b) Absorption detector cell unit

The absorption detector cell is a plastic or glass tube (that does not absorb mercury) of 100-300 mm length with quartz glass windows at both ends.

c) Wavelength selection unit

The wavelength selection unit for the atomic absorption spectrometer for mercury analysis is normally non-dispersive type. However, a spectrometer with a diffraction grating may also be used.

d) Photometry unit

The detector of the photometry unit is a phototube, a semiconductor detector, or a photomultiplier tube.

e) Carrier gas

The carrier gas is air, nitrogen, etc. that is mercury free.

(4) Mercury standard gas

A mercury vapor saturated gas preparation device as shown in Figure 4 is used. The device should have a structure that can be sealed after putting a few grams of elemental mercury in a glass container with thermal insulation. Also, it must be equipped with a control pressure hole for balancing the pressure within the glass vessel with the external atmospheric pressure (gas tight syringe insertion hole) and a thermometer that can measure the temperature in the glass vessel measurable to $1/10^{\circ}\text{C}$. The amount of mercury contained in a unit volume of mercury vapor saturated gas in the preparation device is shown in Table 1. (See Note 3) (See Note 4)

(5) Gas-tight syringe

Capacity of $10\ \mu\text{L}$ - $1\ \text{mL}$.

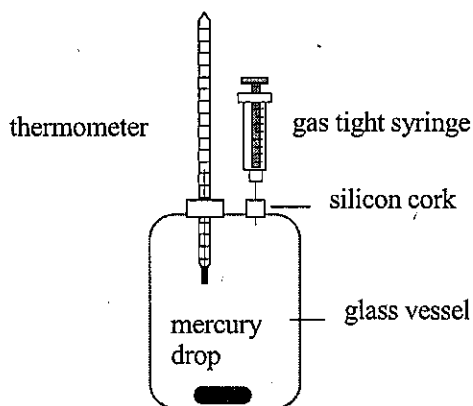


Figure 4 Overview of mercury vapor saturated gas preparation device

Table 1 Unit volume weight of mercury contained in mercury vapor saturated gas

Unit: ng/mL

t °C	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
0.0	2.179	2.202	2.225	2.248	2.271	2.295	2.319	2.343	2.368	2.392
1.0	2.417	2.441	2.465	2.489	2.514	2.539	2.564	2.589	2.614	2.640
2.0	2.666	2.691	2.716	2.741	2.766	2.792	2.818	2.844	2.871	2.897
3.0	2.924	2.951	2.978	3.005	3.033	3.061	3.089	3.117	3.146	3.175
4.0	3.204	3.234	3.264	3.295	3.325	3.356	3.388	3.419	3.451	3.483
5.0	3.516	3.549	3.583	3.616	3.650	3.685	3.719	3.754	3.789	3.825
6.0	3.861	3.897	3.933	3.970	4.007	4.045	4.083	4.121	4.159	4.198
7.0	4.237	4.276	4.316	4.356	4.396	4.437	4.478	4.519	4.561	4.603
8.0	4.645	4.688	4.731	4.774	4.817	4.861	4.905	4.949	4.994	5.039
9.0	5.085	5.131	5.178	5.225	5.273	5.321	5.369	5.418	5.467	5.517
10.0	5.567	5.616	5.666	5.716	5.767	5.818	5.870	5.921	5.974	6.026
11.0	6.079	6.133	6.187	6.241	6.296	6.351	6.407	6.463	6.519	6.576
12.0	6.633	6.692	6.751	6.810	6.870	6.931	6.992	7.053	7.115	7.177
13.0	7.240	7.304	7.369	7.435	7.501	7.568	7.635	7.703	7.771	7.840
14.0	7.909	7.979	8.049	8.119	8.191	8.262	8.335	8.408	8.481	8.555
15.0	8.630	8.705	8.781	8.858	8.935	9.013	9.092	9.171	9.251	9.331
16.0	9.412	9.493	9.575	9.658	9.742	9.826	9.910	9.995	10.081	10.168
17.0	10.255	10.342	10.429	10.516	10.604	10.693	10.783	10.873	10.964	11.056
18.0	11.148	11.242	11.337	11.433	11.529	11.626	11.724	11.823	11.922	12.022
19.0	12.123	12.225	12.328	12.432	12.536	12.641	12.747	12.854	12.961	13.070
20.0	13.179	13.289	13.400	13.511	13.623	13.737	13.851	13.965	14.081	14.198
21.0	14.315	14.434	14.553	14.674	14.795	14.917	15.040	15.164	15.289	15.415
22.0	15.542	15.670	15.800	15.930	16.061	16.193	16.326	16.461	16.596	16.732
23.0	16.869	17.008	17.148	17.289	17.431	17.574	17.718	17.864	18.010	18.158
24.0	18.306	18.456	18.606	18.758	18.911	19.065	19.220	19.376	19.534	19.693
25.0	19.852	20.012	20.174	20.336	20.500	20.664	20.830	20.998	21.166	21.336
26.0	21.506	21.679	21.853	22.028	22.204	22.382	22.560	22.741	22.922	23.105
27.0	23.289	23.474	23.660	23.847	24.036	24.227	24.418	24.611	24.805	25.001
28.0	25.198	25.397	25.598	25.800	26.003	26.208	26.415	26.622	26.832	27.042
29.0	27.255	27.469	27.685	27.902	28.121	28.342	28.564	28.787	29.012	29.239
30.0	29.467	29.697	29.928	30.160	30.395	30.631	30.868	31.107	31.348	31.591
31.0	31.835	32.081	32.329	32.579	32.830	33.084	33.339	33.595	33.854	34.114
32.0	34.376	34.641	34.908	35.177	35.448	35.720	35.995	36.271	36.549	36.829
33.0	37.111	37.395	37.681	37.969	38.258	38.550	38.843	39.139	39.437	39.736
34.0	40.038	40.341	40.647	40.954	41.264	41.575	41.889	42.205	42.523	42.843
35.0	43.165	43.491	43.819	44.148	44.481	44.815	45.152	45.491	45.832	46.176
36.0	46.522	46.870	47.221	47.575	47.930	48.289	48.649	49.012	49.378	49.745
37.0	50.116	50.488	50.863	51.241	51.621	52.004	52.389	52.777	53.167	53.560
38.0	53.955	54.354	54.755	55.158	55.565	55.974	56.385	56.800	57.217	57.637

4 Sampling

(1) Baking collection tube

With the mercury free gas at a flow rate of 0.2-0.5 L/min, heat the collection tube at 800°C for 5 minutes. After the heating, the collection tube is cooled under flowing gas and placed in a sealed container to prevent contamination. This procedure is preferably performed immediately before use. (See Note 5)

When baking multiple numbers of collection tubes all at once, the blank value should be measured from the same baking lot at a rate of at least 10% or more of the samples with the designated method. The blank value converted to atmospheric concentration should be below the target minimum determination limit. If the blank value exceeds the target minimum determination limit, all collection tubes of the same lot, including the measured tube, should be re-baked, and the blank value checked again.

(2) Sampling

Take out the collection tube from the sealed container, and attach the side with dents (circular recess) to the sampling device (as shown in Figure 1). After confirming that there are no leaks in the entire path of the sampling, operate the pump for 24 hours with an aspiration at a flow rate of approximately 0.1-0.5 L/min.

After the sampling is over, seal the collection tube and place it in a sealed container until analysis.

Store the collection tube for the travel blank test in a sealed container, carry it in the same manner as the collection tube for the samples, except for the sampling procedure. In other words, open the plug of the travel blank collection tube during sample preparation (from when the plug of collection tube for sampling is opened until the start of sampling). Seal the collection tube for the travel blank again, and place it besides the collection tube for sampling during the sampling. After the sampling is completed, open the plug and seal it once again together with the collection tube for samplings, and store it until analysis. This travel blank test must be performed whenever contamination is suspected during transportation of the collected samples from the sampling site. Otherwise, it is not necessary to perform this procedure every time as long as it is confirmed that the prevention measures for contamination are carried out. However, in order to ensure the reliability of the sampling, the travel blank test should be thoroughly verified in advance and should be prepared to present the data when necessary. This procedure must be conducted on more than three samples that are approximately 10% of the total number of a set of samples from the same study area, period, transportation, or distance. (See Note 6)

More than two collection tubes are sampled for the duplicate analysis under the same conditions. The number of samplings for the duplicate analysis is approximately 10% of the total number of a series of samples.

5 Test procedure

(1) Setting analytical conditions of the sample introduction device, the atomic absorption spectrometer, and adjusting the equipment

Analytical conditions of the sample introduction device and the atomic absorption spectrometer are set following the example shown below.

Sample introduction device

Heating duration: 2 minutes

Carrier gas: air passing through the mercury collection tube 0.5 L/min

Washing solution: diluted neutral phosphate pH standard solution (1 + 1)
Atomic absorption spectrometer
Light source: mercury discharge tube
Wavelength: 253.7 nm
Detection method: non-dispersive two-beam-type cold atomic absorption method

(2) Sample measurement

The thermal desorption apparatus illustrated in Figure 3 is operated as follows.

Take the collection tube with the sample out from the sealed container and attach it to the first heating furnace. Attach the purification collection tube of exclusive use, of which the blank was sufficiently reduced in advance, to the second heating furnace and keep the temperature of the furnace at 150°C. Switch the three-way valve to suction pump, then, heat the first heating furnace at 600-800°C to vaporize the mercury while the mercury free gas flows at a constant flow rate of 0.2-0.5 L/min and re-collect mercury into the collection tube (as shown in Figure 3, the refining collection tube in the second heating furnace). Next, switch the three-way valve to absorption detector cell, guide the mercury vapor which vaporized by heating at 500-800°C in the second heating furnace to the absorption detector cell. Mercury is measured by an atomic absorption at spectrum analysis wavelength of 253.7 nm and weight of mercury (A_s ; ng) is obtained from peak height or peak area based on the calibration curve prepared in advance in (3).

(3) Creating a calibration curve

Take an appropriate amount of standard gas of mercury (0.1-10 ng of mercury) stepwise using the gas-tight syringe from the mercury vapor saturated gas preparation device, inject the gas into the collection tube of the thermal desorption-atomic absorption spectrometer (the collection tube in the first heating furnace in Figure 3), create a calibration curve based on the relationship between the absorbance obtained in (2) and the amount of mercury injected. The calibration curve is created by 5 or more different mercury injection volumes (including zero). The calibration curve is created just before the measurement. (See Note 7, Note 8)

(4) Operation blank test

For the blank test use the same baked lot tube as the sample collection tube. The operation blank value is obtained following the procedure (2). (See Note 9)

(5) Travel blank test

The weight of the mercury is measured by procedure (2) for the collection tube used for the travel blank test described in 4-(2). More than three samples are measured, and the average is considered a travel blank value (A_t ; ng). (See Note 10)

(6) Sensitivity test of atomic absorption spectrometer

Standard gas is injected into the first collection tube so that the weight is close to the mid-position of the calibration curve and the sensitivity fluctuation is confirmed by carrying out procedure (2). This confirmation should be done at least once every 10 samples. When it is confirmed that the sensitivity fluctuation of the device is stable, the frequency of the sensitivity tests may be reduced within this range. However, there are risks in conducting sensitivity tests at longer intervals. Because the relationship between the cause of

abnormal values or dual measured values exceeding the standard value and the sensitivity fluctuation cannot be confirmed, all samples in the period may be re-measured or treated as missing values. In addition, when the sensitivity fluctuation exceeds 20%, all samples measured previously should be re-measured. Thus, the frequency of the sensitivity test should be set within a practical range such that re-measurement is possible, taking these risks and sample storability into account. Prior to reducing the frequency of the sensitivity test, it should be discussed sufficiently about the test in order to ensure the reliability so that a drastic sensitivity fluctuation does not occur and that the sensitivity is kept stable during a long temporal interval. Documents or data should be prepared for presentation when necessary. (See Note 11)

(7) Duplicate analysis

The mercury amount for collection tubes for the dual measurement described in 4-(2) is measured by the procedure explained in (2). (See Note 12)

6 Measurement of detection limit and minimum determination limit

Inject the standard gas which is equivalent to the lowest concentration for creating the calibration curve (near the minimum determination limit) into the baked collection tube, and obtain a measured value by conducting procedure 5-(2) (A: ng). Then, value A is substituted to (As – At) of formula (3) to calculate the atmospheric concentration. The detection limit and minimum determination limit of mercury are calculated from the standard deviation (sigma) obtained from measuring results of more than 5 samples, by using formulas (1) and (2). However, if the operation blank value exists, the operation blank value must be measured, and the calculation must be conducted by using a larger standard deviation within those of a standard gas and an operation blank value. (See Note 13)

This measurement should be carried out more than once if analytical conditions of the instruments are configured

Detection limit = 3 sigma (ng/m³) formula (1)

Minimum determination limit = 10 sigma (ng/m³) formula (2)

7 Calculating the atmospheric mercury concentration

The atmospheric mercury concentration is calculated using formula (3) based on the results obtained in 5-(2).

$$C = (A_s - A_t) / (V \times 293 / (273 + t) \times P / 101.3) \dots \dots \dots \text{ formula (3)}$$

- C: mercury concentration in the atmosphere at 20°C (ng/m³)
- As: mercury amount of the sample (ng)
- At: travel blank value (ng)
 Operation blank value will be used if it is regarded as being equivalent to the travel blank value.
- V: collected volume measured by the flow meter (m³)
- t: average temperature at the time of sample collection (°C) (See Note 14)
- P: average air pressure at the time of sample collection (kPa) (See Note 14)

If a wet-type integrating flow meter is used, relative humidity correction is made after calculating dry gas

volume using the average water temperature ($^{\circ}\text{C}$) of integrating flow meter as “t” and (P-Pw) as “P”. Here, Pw is a saturated water vapor pressure (kPa) at average temperature “t” at the time of the sample collection.

(Note 1) Commercial collection particles or collection tubes filled with these collection particles are readily available.

(Note 2) Water is used as washing solution. However, if acidic substance exists within the trapping material and the pH of the washing solution drops, a small amount of mercury may be dissolved into the washing solution. In such a case, it is preferable to use neutral phosphate pH standard solution diluted with water, instead of using water as the washing solution. Use after having confirmed that there is no mercury contamination in the washing solution.

(Note 3) Commercial mercury saturated gas preparation equipment is commercially available.

(Note 4) Mercury standard solution can be used. Method for preparing mercury standard solution in this case is as follows.

(1) Mercury diluted solution: take 10 mg of L-cysteine into a volumetric flask (1000 mL), add water and dissolve by shaking, add 2 mL of nitric acid, then, add water to the mark line. Prepare the dilution when it is used.

(2) Mercury standard stock solution (100 $\mu\text{g Hg/mL}$): take 67.7 mg of mercury chloride (II) (HgCl_2) into a volumetric flask (500 mL), dissolve in mercury diluted solution, and add additional mercury diluted solution to the mark line to make a standard stock solution. Store it in a refrigerator.

(3) Standard mercury solution (0.001-0.1 $\mu\text{g Hg/mL}$): obtain by adjusting the standard stock solution to a predetermined concentration. Dilute with mercury dilution solution when it is used.

(Note 5) The collection tube may be heated for more than 30 minutes at approximately 800°C to reduce the blank, cooled in an atmosphere free of mercury contamination, then stored in the collection tube sealed container.

(Note 6) The travel blank value must be measured for at least three samples within a series of measurements. However, if a large variation exists in measurement results of the three samples, and may cause a large error in the measurement results by subtracting these travel blank values from the measured values, it is suggested that the travel blank test should be conducted for a necessary number of times which is deemed to be statistically meaningful.

(Note 7) If a reducing vaporization device is used, attach the collection tube to the outlet of the reduced vaporizer. The mercury standard solution is reduced, vaporized mercury is collected, and a calibration curve is made. If there is a heating furnace between the first heating furnace and the gas scrubbing bottle as shown in Figure 3, a calibration curve can be also made using a mercury standard solution. The substantial steps are as follows.

Make a standard concentration series of mercury standard solution (0.001- 0.1 $\mu\text{gHg/mL}$). Inject 100 μL of the solution into the magnetic boat or collection tube. Place it in the first heating furnace. Following procedure 5-(2), make a calibration curve based on the relationship between the mercury injection volume and the absorbance. It should be noted that contamination from the magnetic boat or collection tube should be avoided.

The calibration curve is made for standard concentration series with 5 or more stages, including zero. The calibration curve is made when a measurement is conducted.

(Note 8) The range of concentrations of the calibration curve must be changed according to the concentration level of mercury in the ambient air.

(Note 9) This operation should be performed prior to sample measurement, and the concentration in the air converted from the operation blank value is compared with the target minimum determination limit. In order to make the actual atmospheric concentration of mercury measurable, the operation blank value should be reduced as much as possible.

(Note 10) If the travel blank values of the mercury are less than or equivalent to the operation blank values, contamination during transport can be disregarded and concentration can be calculated by subtracting the operation blank value from the measured value of the sample. However, in such a case where there is contamination during transportation, the minimum determination limit (10 s: converted to the atmospheric concentration) determined from the standard deviation of the travel blank values of more than 3 samples is smaller than the target minimum determination limit, moreover, the minimum determination limit obtained from the travel blank value is larger than the target minimum determination limit, the concentration can be calculated by subtracting the travel blank value from the measured value of the sample, if only the value calculated by subtracting the travel blank value from that measured in 5-(2) is larger than the minimum determination limit drawn from travel blank value.

However, if there is contamination during transportation, the minimum determination limit drawn from the travel blank value is larger than the target minimum determination limit, and the value of subtracting the travel blank value from the value measured is smaller than the minimum determination limit drawn from travel blank value, the values are generally treated as missing data. In such case, sampling must be conducted again after eliminating the cause of contamination.

(Note 11) Differences of absorbance of making the calibration curve and sensitivity testing should be ensured to be within $\pm 20\%$, where, in fact, the range of $\pm 10\%$ is preferable. If the sensitivity fluctuation exceeds $\pm 20\%$, the analytical instrument and measurement method must be adjusted, calibration curve must be made again, and the samples must be re-measured.

(Note 12) Check if the difference between the two measurements is under 30% when the concentrations are above the minimum determination limit (i.e., check if the difference between every measurement and the average is within the range of $\pm 15\%$). If the difference is large, the values are generally treated as missing data, and the sampling is carried out again after investigating the cause.

(Note 13) If the minimum determination limit is larger than target minimum determination limit, equipment and instruments should be checked and adjusted, so that it is below the target minimum determination limit.

(See Note 9).

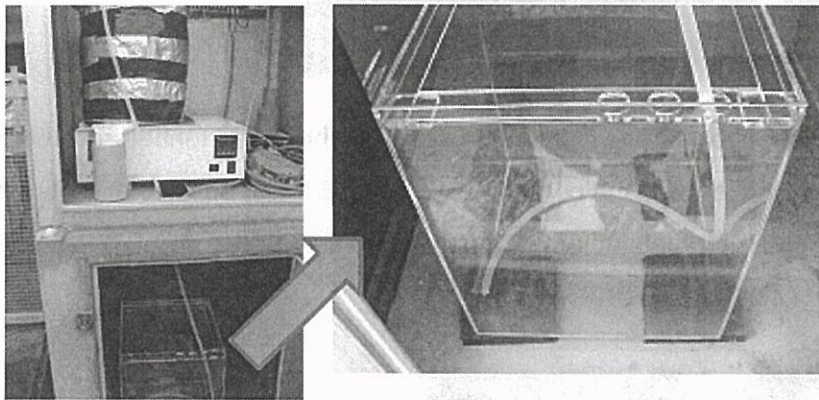
(Note 14) Data of the nearest meteorological stations or other appropriate observation agencies could be used.

Sampling manual for air and wet depositions (For Hg analysis)

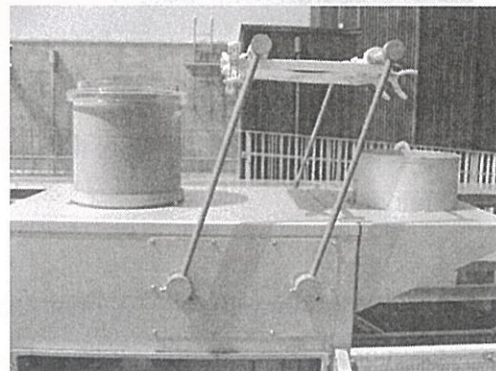
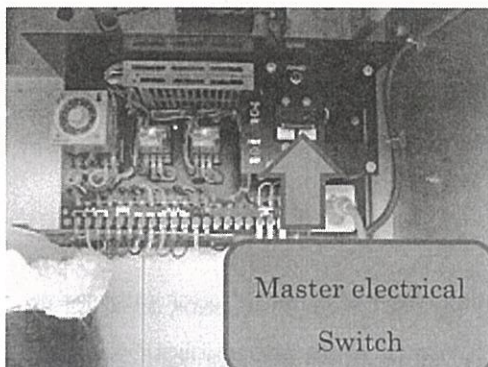
National Institute for Minamata Disease

English version

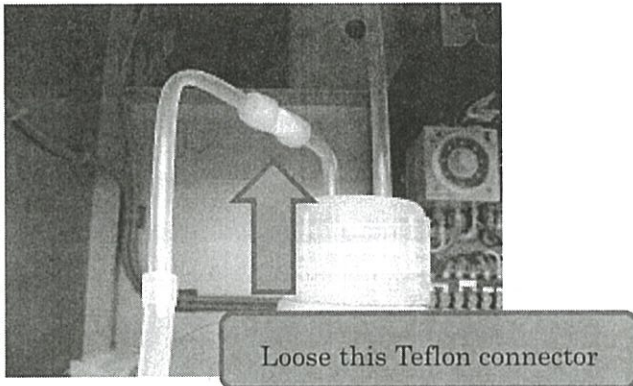
1. Check the normal working of an air pump, a ball flow meter, wet-only rain sampler (US-330S; Ogasawara Co, Ltd or Y12; Komatsu Co Ltd). If these instruments are not working correctly, record it to the field note.
2. Turn off the air pump and HV sampler and record the integrated air volume. If the rain sample is overflowed and stored in the drainage box, measure the height (cm) from the bottom of the box to water surface using a ruler and record it to the field note. After that, discard the stored water in the box.



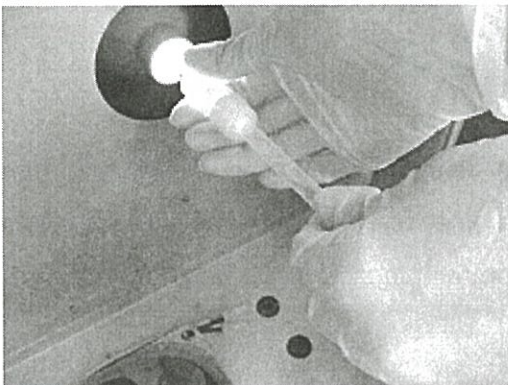
3. Turn off the cooler system in the wet-only sampler. In the case of US-330S, Turn off the main power supply of the wet-only sampler when the lid of the sampler moves at the center of the sampler by touching the rain sensor. In the case of Y12, turn the switch for washing mode on.



4. Confirm the all replacement equipment for air and rain sampling.
5. Wear clean polyethylene gloves.
6. Remove a drainage tube from a L-type Teflon tube attached on the cap of the sample bottle.



7. Unfasten the screw of the connector between the glass funnel and the long PFA tube and push the tube and connector into the 5L PFA bottle. After that, remove the 5L PFA bottle with an aluminum jacket from the sampler.



8. Remove the long PFA tube, the connector and the L-type PFA tube from the sampling bottle. Put them in the zippered polyethylene bag and store it in the container.
9. Cover the bottle with a PTFE inner cap and screw the outer lid back on it tightly.
* Caution! ; Prevent the retrieved sample bottle from the sunlight exposure as possible. Put the bottle into the zippered polyethylene bag after removal of the

aluminum jacket and put the bottle into the storage box.

10. Detach the glass funnel and the catch basin from the sampler and put them in the zippered polyethylene bag. In addition, remove the PTFE plate behind the lid of the sampler and put it in the zippered polyethylene bag. After that, store them in the container.



11. Retrieve the filter holder and put it in the zippered polyethylene bag which the sample ID is indicated.

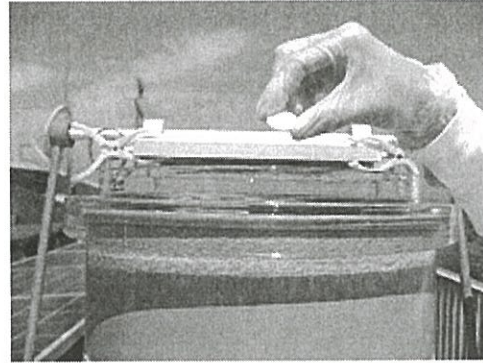


12. Wipe up the rain sampler and the plate of the cooling system using wet towel. In addition, wash the rain sensor using 200 ml of DDW.



13. Wear new clean polyethylene gloves.

14. Attach the new clean glass funnel and the catch basin on the sampler.



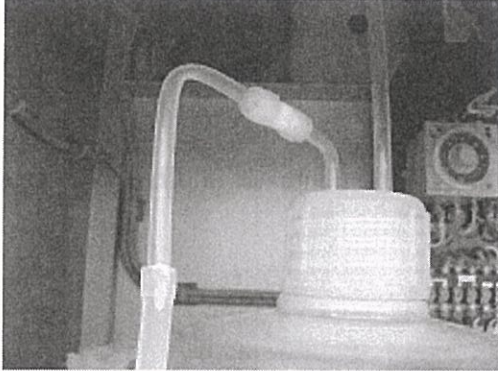
15. Pick up the new and clean 5L PFA bottle with the L-type PFA tube and the clean long PFA tube with the Teflon connector from the zippered polyethylene bag. Then, replace them into the aluminum jacket and put them on the cooler system in the sampler.



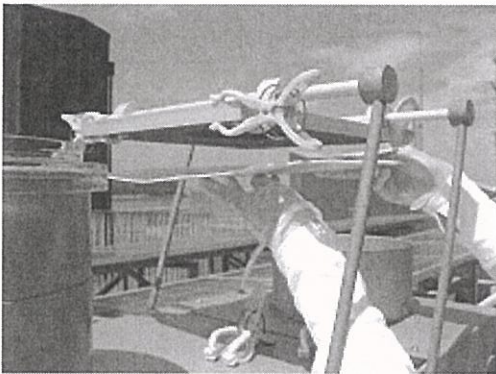
16. Connect the long tube to the glass funnel.



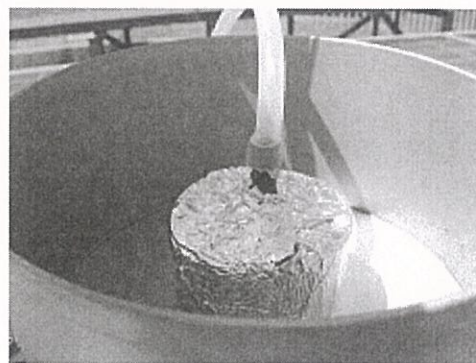
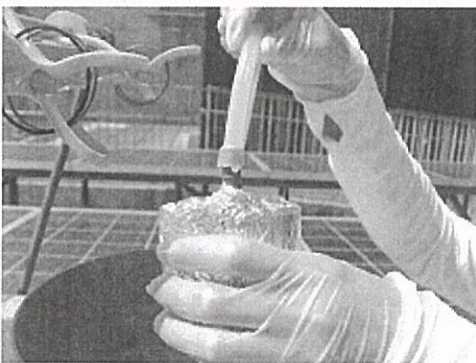
17. Connect the drainage tube to the L-type Teflon tube attached on the cap of the sample bottle.



18. Attach the PTFE plate behind the lid of the sampler using four clips.



19. Cover the new filter holder with aluminum foil and put it in place.



20. Reconfirm that the all equipment is correctly attached. Turn on the main power supply of the rain sampler and the cooler system. In the case of Y12, turn the switch for washing mode off. After that, close the front page of the rain sampler.

21. Turn on the air pump and adjust the air flow rate to 4 L/min. Record the starting time of the sampling to the field note.

22. Confirm that the lid of the rain sampler automatically works well.

23. Confirm the all retrieved equipment is stored in the container and bring the storage box to the analytical laboratory.

大気・降水試料の採取記録

v20140224

観測地点	熊本県水俣市
試料名	20 年 月 第 週
試料採取期間	20 年 月 日 時 分 (天候:) ~ 20 年 月 日 時 分 (天候:)

大気試料

	機器	流速 (L/min)	積算流量
水銀用フィルター	ポンプ-流量計-積算流量計		(採取前) 2 (採取後) m3
大気浮遊粒子フィルター	ハイボリュームエアサンプラー(HVS)	300	m3
化学成分用フィルター	SHIBATA製ミニポンプ		
ポンプ用サンプラー	パッシブサンプラー		

大気浮遊粒子フィルター(石英繊維ろ紙)	採取前重量	採取後重量	試料重量
	g	g	g

処理状況	試料の有無	保存状態	前処理	分析	結果
粒子状水銀		冷蔵 冷凍			
ガス状水銀化合物		冷蔵 冷凍			
ガス状金属水銀		冷蔵 冷凍			
粒子状水銀(HVS)		冷蔵 冷凍			
金属成分(HVS)					
イオン成分(HVS)		冷蔵 冷凍			

降水試料

ルート No.	
試料採取瓶重量 (g)	採取前 採取後 試料重量
オーバーフロー	有り 無し
オーバーフローした量	ml * 有りの場合のみ記入

処理状況	試料の有無	保存状態	前処理	分析	結果
総水銀用		冷蔵 冷凍			THg: MeHg:
微量金属用		冷蔵 冷凍			
pH・イオン		冷蔵 冷凍			
		冷蔵 冷凍			
保存用		冷蔵 冷凍			

備考

(観測地点周辺の状況など気づいたことを書いてください。)

大気・降水試料の採取記録

v20140224

観測地点	熊本県水俣市
試料名	20 年 月 第 週
試料採取期間	20 年 月 日 時 分 (天候:) ~ 20 年 月 日 時 分 (天候:)

大気試料

	機器	流速 (L/min)	積算流量
水銀用フィルター	ポンプー流量計ー積算流量計		(採取前) 2 (採取後) m3
大気浮遊粒子フィルター	ハイボリュームエアサンプラー (HVS)	300	m3
化学成分用フィルター	SHIBATA製ミニポンプ		
ポンプ用サンプラー	パッシブサンプラー		

大気浮遊粒子フィルター(石英繊維ろ紙)	採取前重量	採取後重量	試料重量
	g	g	g

処理状況	試料の有無	保存状態	前処理	分析	結果
粒子状水銀		冷蔵 冷凍			
ガス状水銀化合物		冷蔵 冷凍			
ガス状金属水銀		冷蔵 冷凍			
粒子状水銀 (HVS)		冷蔵 冷凍			
金属成分 (HVS)					
イオン成分 (HVS)		冷蔵 冷凍			

降水試料

ルート No.	
試料採取瓶重量 (g)	採取前 採取後 試料重量
オーバーフロー	有り 無し
オーバーフローした量	ml * 有りの場合のみ記入

処理状況	試料の有無	保存状態	前処理	分析	結果
総水銀用		冷蔵 冷凍			THg, MeHg
微量金属用		冷蔵 冷凍			
pH・イオン		冷蔵 冷凍			
		冷蔵 冷凍			
保存用		冷蔵 冷凍			

備考

(観測地点周辺の状況など気づいたことを書いてください。)

ICMGP 2017: Integrating Research and Policy in a Changing World

Providence, Rhode Island USA



photo: David Amadio



International Conference on Mercury as a Global Pollutant 2017: Integrating Research and Policy in a Changing World

Plans are underway for the 13th International Conference on Mercury as a Global Pollutant (ICMGP) to be held in Providence, Rhode Island, USA 16-21 July 2017. The organizing committee includes: Charles Driscoll (co-chair, Syracuse University), Celia Chen (co-chair, Dartmouth College), Rob Mason (University of Connecticut), David Gay (National Atmospheric Deposition Program), Noelle Selin (MIT), Elizabeth Henry (Anchor QEA) and David Evers (Biodiversity Research Institute).

Mercury science and management are the focus of attention world-wide. The global treaty on mercury, the Minamata Convention, is now being ratified and requires that countries around the world control both new and existing sources and monitor the effectiveness of those controls. In the US, there are plans to implement the Mercury and Air Toxics Rule which will limit primary anthropogenic emissions. In many other countries, the use of mercury in artisanal gold mining is under investigation as the magnitude of associated mercury releases may have been underestimated. And globally, many local efforts are in progress to remediate mercury contaminated sites. While these initiatives are important steps to mitigate mercury contamination, the extent and rate of potential recovery is unclear because of uncertainties in our understanding of mercury cycling through the biosphere. Mercury is a complex, multifaceted contaminant especially given that methylmercury, the more toxic form, biomagnifies and drives most human health advisories and concerns for wildlife impacts. Moreover, mercury transport, transformations, bioaccumulation and exposure are affected by numerous interacting processes and phenomena (e.g., climate change, nutrient loading, land use/cover, food web dynamics, human behavior and decisions).

The theme of this conference will be ***understanding the multiple factors that accelerate and attenuate recovery of mercury contamination in response to environmental inputs on local to global scales.***

The 13th ICMGP will follow the tradition of previous successful conferences with synthesis, detailed sessions and presentations on mercury science, technology, management and human health. We will encourage a diverse community of conference participants, including industry, government, research institutions, NGOs, and academics. As New England is home to many colleges and universities, we will strongly promote and support student participation. We will foster wide ranging discussion among participants across issues spanning environmental media, biogeochemical processes, disciplines, types of mercury contamination and remediation, temporal and spatial scales, societal issues and outreach activities. Input from the mercury community will be solicited for special sessions. We envision a broadly based program that would include plenary, invited and contributed oral presentations; poster presentations; small group meetings; opportunities for student mentoring; demonstrations by instrument vendors, industry and research groups; and networking. We will craft a technical program that reflects the latest advances, highlights critical understanding and promotes active discussion of the science of mercury and innovative strategies for its management.

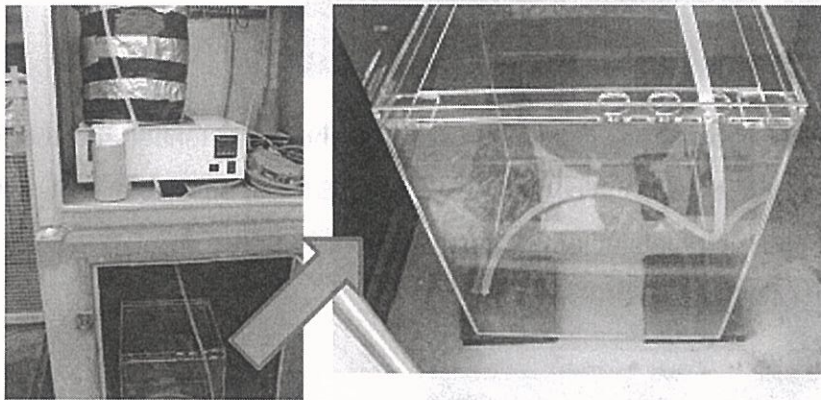
Providence will be an engaging venue for ICMGP 2017. One of the oldest cities in the US (est. 1636), Providence is easily accessed by major (New York, Boston) and regional (Providence, Manchester, Hartford) airports, and by rail from major Northeast U.S. cities (Boston, New York, Washington D.C.). The conference will be staged at the Providence Convention Center, which can easily accommodate the anticipated number of participants of ~1000. Providence is a medium sized city (population 175,000) with a charming historical downtown that is readily accessible to the conference center. This coastal community is home to intriguing restaurants, pubs and coffeehouses. Cultural and recreational opportunities abound, including *WaterFire*, an environmental art installation that consists of about 100 bonfires that blaze just above the surface of the three rivers that pass through downtown Providence. Providence is already gearing up to welcome the participants of the 2017 ICMGP.

Sampling manual for air and wet depositions (For Hg analysis)

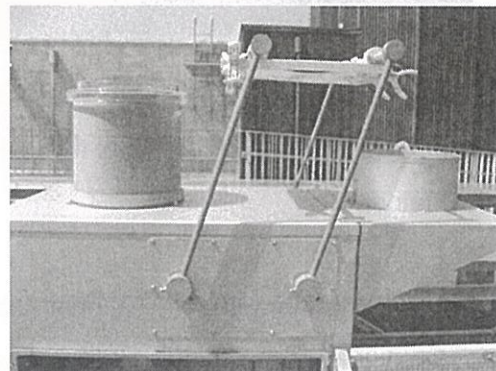
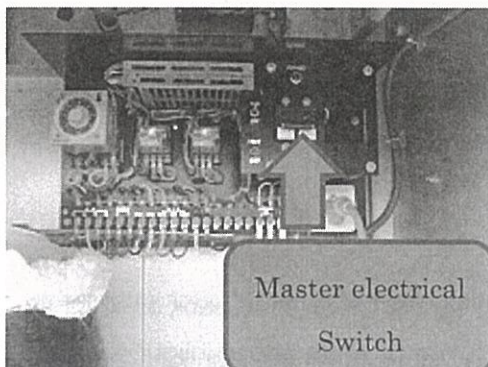
National Institute for Minamata Disease

English version

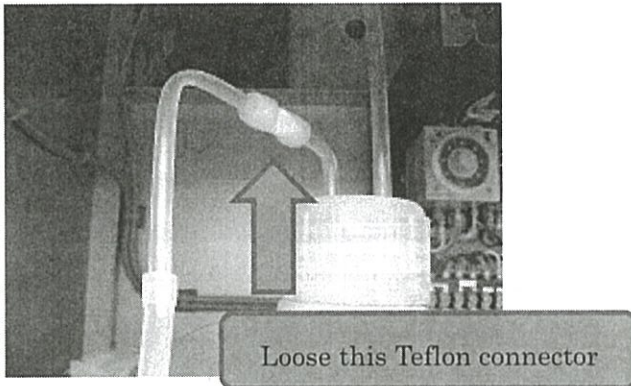
1. Check the normal working of an air pump, a ball flow meter, wet-only rain sampler (US-330S; Ogasawara Co, Ltd or Y12; Komatsu Co Ltd). If these instruments are not working correctly, record it to the field note.
2. Turn off the air pump and HV sampler and record the integrated air volume. If the rain sample is overflowed and stored in the drainage box, measure the height (cm) from the bottom of the box to water surface using a ruler and record it to the field note. After that, discard the stored water in the box.



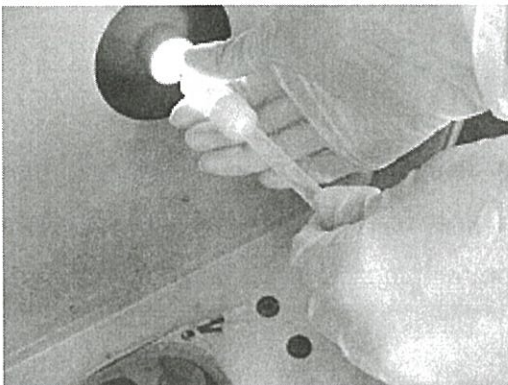
3. Turn off the cooler system in the wet-only sampler. In the case of US-330S, Turn off the main power supply of the wet-only sampler when the lid of the sampler moves at the center of the sampler by touching the rain sensor. In the case of Y12, turn the switch for washing mode on.



4. Confirm the all replacement equipment for air and rain sampling.
5. Wear clean polyethylene gloves.
6. Remove a drainage tube from a L-type Teflon tube attached on the cap of the sample bottle.



7. Unfasten the screw of the connector between the glass funnel and the long PFA tube and push the tube and connector into the 5L PFA bottle. After that, remove the 5L PFA bottle with an aluminum jacket from the sampler.



8. Remove the long PFA tube, the connector and the L-type PFA tube from the sampling bottle. Put them in the zippered polyethylene bag and store it in the container.
9. Cover the bottle with a PTFE inner cap and screw the outer lid back on it tightly.
* Caution! ; Prevent the retrieved sample bottle from the sunlight exposure as possible. Put the bottle into the zippered polyethylene bag after removal of the

aluminum jacket and put the bottle into the storage box.

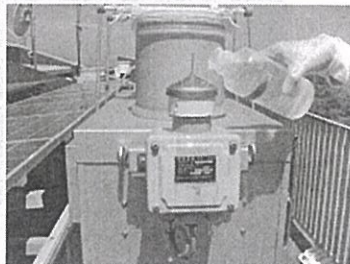
10. Detach the glass funnel and the catch basin from the sampler and put them in the zippered polyethylene bag. In addition, remove the PTFE plate behind the lid of the sampler and put it in the zippered polyethylene bag. After that, store them in the container.



11. Retrieve the filter holder and put it in the zippered polyethylene bag which the sample ID is indicated.

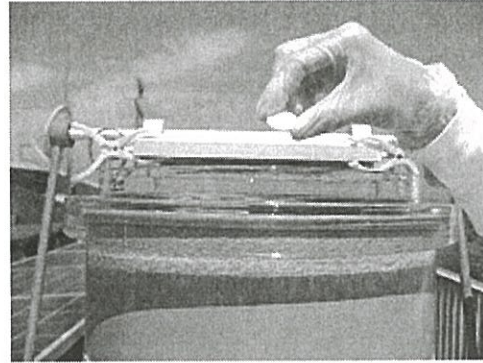


12. Wipe up the rain sampler and the plate of the cooling system using wet towel. In addition, wash the rain sensor using 200 ml of DDW.



13. Wear new clean polyethylene gloves.

14. Attach the new clean glass funnel and the catch basin on the sampler.



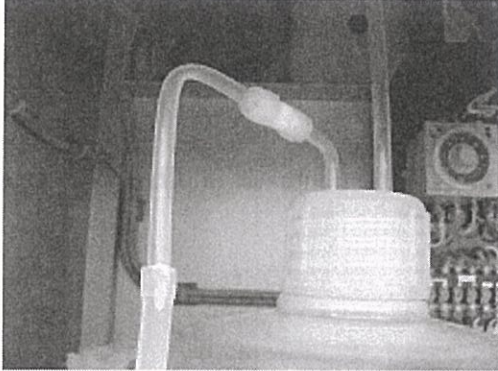
15. Pick up the new and clean 5L PFA bottle with the L-type PFA tube and the clean long PFA tube with the Teflon connector from the zippered polyethylene bag. Then, replace them into the aluminum jacket and put them on the cooler system in the sampler.



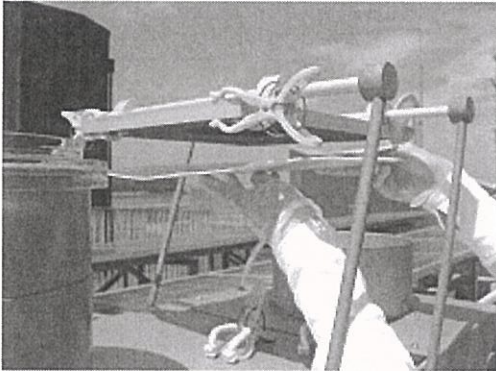
16. Connect the long tube to the glass funnel.



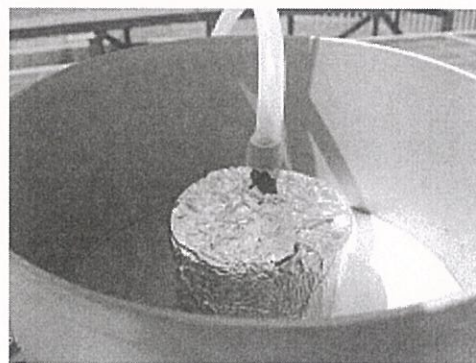
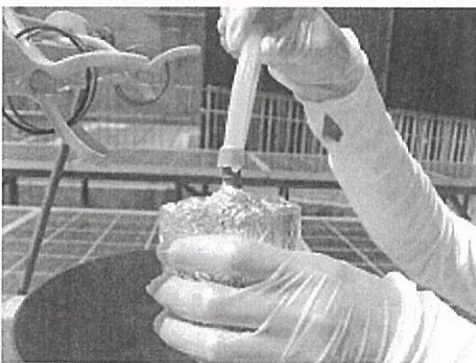
17. Connect the drainage tube to the L-type Teflon tube attached on the cap of the sample bottle.



18. Attach the PTFE plate behind the lid of the sampler using four clips.



19. Cover the new filter holder with aluminum foil and put it in place.



20. Reconfirm that the all equipment is correctly attached. Turn on the main power supply of the rain sampler and the cooler system. In the case of Y12, turn the switch for washing mode off. After that, close the front page of the rain sampler.

21. Turn on the air pump and adjust the air flow rate to 4 L/min. Record the starting time of the sampling to the field note.

22. Confirm that the lid of the rain sampler automatically works well.

23. Confirm the all retrieved equipment is stored in the container and bring the storage box to the analytical laboratory.

ศูนย์วิจัยและฝึกอบรมด้านสิ่งแวดล้อม

Environmental Research and Training Center

ERTC



ศูนย์วิจัยและฝึกอบรมด้านสิ่งแวดล้อม

ประสานความร่วมมือนักวิจัยด้านสิ่งแวดล้อม

และหน้าที่ความรับผิดชอบ

วิจัยและพัฒนาเชิงนโยบาย ยุทธศาสตร์และการบริหารจัดการสิ่งแวดล้อม รวมทั้ง
โลกการสร้างเครือข่ายนักวิจัยสิ่งแวดล้อม ทั้งในประเทศและระหว่างประเทศและ
ารข้อมูลงานวิจัยด้านสิ่งแวดล้อม

กลุ่มน้ำ และขยะ

ภารกิจและหน้าที่ความรับผิดชอบ

วิจัยและพัฒนาเทคโนโลยี ด้านการบำบัดน้ำเสีย การอนุรักษ์
น้ำผิวดินและน้ำใต้ดิน รวมถึงการอนุรักษ์และฟื้นฟูสิ่งแวดล้อมของ
แหล่งน้ำ การติดตามตรวจสอบคุณภาพน้ำ น้ำใต้ดิน น้ำผิวดิน
และเทคโนโลยีการบำบัดน้ำ วิจัยและพัฒนาเทคโนโลยีการใช้ประโยชน์
และเพิ่มมูลค่าของเสียและขยะการลดผลกระทบสิ่งแวดล้อมจาก
กระบวนการกำจัด

อากาศ เสียงและความสั่นสะเทือน

และหน้าที่ความรับผิดชอบ

วิจัยและพัฒนาเทคโนโลยีด้านสิ่งแวดล้อม ด้านอากาศ เสียง และ
สั่นสะเทือนเกี่ยวกับวิธีการติดตามตรวจสอบ ให้คำปรึกษาแนะนำ
การแก้ไขปัญหาที่เกิดจากผลกระทบด้านอากาศ เสียงและความสั่น



กลุ่มการเปลี่ยนแปลงภูมิอากาศ

ภารกิจและหน้าที่ความรับผิดชอบ

ศึกษา วิเคราะห์ วิจัย พัฒนา ประสาน เพื่อการ
บริหารจัดการสิ่งแวดล้อมเชิงรุกอย่างบูรณาการของประเทศ
ที่เกี่ยวกับการเปลี่ยนแปลงภูมิอากาศ



สารอันตราย

และหน้าที่ความรับผิดชอบ

ติดตามตรวจสอบและปฏิบัติการวิจัยที่เกี่ยวกับสารอันตราย สร้างองค์ความรู้ด้าน
าษาที่ วิจัยและการจัดการสารอันตรายและสารที่เกี่ยวข้องกับสารอันตราย ส่งเสริม
สนับสนุนความร่วมมืองานวิจัยและพัฒนาเทคโนโลยีการจัดการสารอันตรายและ
อันตรายกับหน่วยงานต่างๆ ทั้งในประเทศและต่างประเทศ เพื่อพัฒนาเทคโนโลยี
สมกับสภาพแวดล้อมของประเทศไทย

กลุ่มมาตรฐานและรับรองระบบ

ภารกิจและหน้าที่ความรับผิดชอบ

พัฒนาระบบคุณภาพของห้องปฏิบัติการให้เป็นไปตามมาตรฐาน
สากล การพัฒนาระบบตรวจสอบความเที่ยงตรงแม่นยำของข้อมูลของ
ห้องปฏิบัติการด้านสิ่งแวดล้อม และการพัฒนาห้องปฏิบัติการอ้างอิงด้าน
สิ่งแวดล้อม รวมทั้งการประสานความร่วมมือในการรับรองระบบคุณภาพ
ตามมาตรฐานสากล ตลอดจนให้คำปรึกษาแนะนำในด้านระบบคุณภาพ
และการรับรองระบบคุณภาพ



สถาบันไดออกซินแห่งชาติ

ภารกิจและหน้าที่ความรับผิดชอบ

ติดตามตรวจสอบและปฏิบัติการวิจัยที่เกี่ยวกับสารไดออกซิน สร้างองค์ความรู้
ด้านการวิเคราะห์ วิจัย และการจัดการสารไดออกซินและสารที่เกี่ยวข้องกับ
สารไดออกซิน ส่งเสริมและสนับสนุนความร่วมมืองานวิจัยและพัฒนาเทคโนโลยีการ
จัดการสารไดออกซินกับหน่วยงานต่างๆ ทั้งในประเทศและต่างประเทศ เพื่อพัฒนา
เทคโนโลยีที่เหมาะสมกับสภาพแวดล้อมของประเทศไทย ให้บริการตรวจวิเคราะห์
สารไดออกซินและสารที่เกี่ยวข้อง



โครงการวิจัยในระหว่าง ปี 2556 - 2558

ชื่อผลิตภัณฑ์ : กาแฟด้วยสารสกัด 100%
สูตร กาแฟดิบ 100% 1000g
ขนาดบรรจุ 200 กรัม



ประสานความร่วมมือนักวิจัยด้านสิ่งแวดล้อม

การวิจัยและส่งเสริมการผลิตและบริโภคสินค้าที่เป็นมิตรต่อสิ่งแวดล้อม

การศึกษามิปัญญาท้องถิ่นด้านการอนุรักษ์ทรัพยากรธรรมชาติและสิ่งแวดล้อม จังหวัดเพชรบุรี

การส่งเสริมกระบวนการเรียนรู้ของชุมชนเพื่อการแก้ไขปัญหาหมอกควันอย่างยั่งยืนในพื้นที่ดอยยาว ดอยผาหม่น วัตถุประสงค์ เชียงราย

การศึกษาการเปลี่ยนแปลงสภาพภูมิอากาศโลก และผลกระทบของภาวะมลพิษกับการเปลี่ยนแปลงประชากรจุลชีพในตะกอนและน้ำในรอบฤดูกาลของกลุ่มน้ำปิง

อากาศ เสียงและความสั่นสะเทือน

การศึกษาปัญหาคลื่นและสารพิษจากแหล่งทิ้งขยะชุมชน

ศึกษามลกระทบจากการแพร่กระจายของสารพิษในอากาศ

การเผาต่อซังข้าวโพดเลี้ยงสัตว์ในที่โล่ง

การติดตามตรวจสอบการตกสะสมของกรดในพื้นที่

ของประเทศไทย

การศึกษารูปแบบการใช้ที่ดินเพื่อลดผลกระทบต่อด้านเสียง

ทำอากาศยานสุวรรณภูมิ

การศึกษามลกระทบของระดับเสียงจากรถไฟฟ้ามหานครที่มีต่อชุมชน

การศึกษามลกระทบด้านเสียงจากวิธีปฏิบัติทางการบิน

ศึกษาทำอากาศยานสุวรรณภูมิและทำอากาศยานดอนเมือง

การศึกษามลกระทบของกรดในพื้นที่ป่าต้นน้ำของประเทศไทย

กลุ่มน้ำและขยะ

1. การศึกษาความเป็นไปได้ในการนำน้ำทิ้งชุมชนที่ผ่านการบำบัดแล้วมาใช้ประโยชน์ทางการเกษตรในพื้นที่เสี่ยงภัยแล้ง
2. การศึกษาประสิทธิภาพในการบำบัดน้ำเสียของผักตบชวาในคลองโรงเจ
3. การปนเปื้อนของสารกลุ่มผลิตภัณฑ์ยาและผลิตภัณฑ์ดูแลสุขภาพในแม่น้ำบางปะกง

กลุ่มสารอันตราย

1. การศึกษาพัฒนาแนวทางการลดใช้สารเคมีในการเกษตร ด้วยกระบวนการวิจัยแบบมีส่วนร่วม : กรณีศึกษาอำเภอแม่แตง จังหวัดเชียงใหม่
2. การศึกษาพัฒนาแนวทางการจัดการความเสี่ยงจากสารเคมีกำจัดศัตรูพืชกลุ่มออร์กาโนฟอสเฟตในพื้นที่ภาคเหนือตอนบน ด้วยกระบวนการวิจัยแบบมีส่วนร่วม

กลุ่มการเปลี่ยนแปลงภูมิอากาศ

1. โครงการพัฒนาเตาเผาขยะชีวมวลไร้ควันอย่างง่ายสำหรับชุมชน
2. โครงการศึกษาการจัดการปัญหาการเปลี่ยนแปลงสภาพภูมิอากาศโดยชุมชนในประเทศไทย
3. โครงการพัฒนาดัชนีความร้อนและการประยุกต์ใช้ศึกษาด้านความร้อนในประเทศไทย
4. โครงการพัฒนาโมเดลต้นแบบการจัดการขยะชุมชนด้านภัยโลกร้อนระดับจังหวัด
5. โครงการศึกษามลกระทบจากการเปลี่ยนแปลงสภาพภูมิอากาศต่อสภาพพาราในประเทศไทย
6. โครงการพัฒนาดัชนีความร้อนและการประยุกต์ใช้ศึกษาด้านความร้อนในประเทศไทย
7. โครงการบรรเทาการปลดปล่อยก๊าซเรือนกระจกจากภาคเกษตรด้วยสารยับยั้งไนตริฟิเคชัน กรณีศึกษาการผลิตข้าว ข้าวโพดและอ้อย
8. โครงการประเมินศักยภาพของธรรมชาติในการบำบัดพื้นฟูน้ำใต้ดินที่ปนเปื้อนสารอินทรีย์ระเหยในพื้นที่เขตควบคุมมลพิษ จังหวัดระยอง
9. การประเมินความเสี่ยงเชิงนิเวศจากการปนเปื้อนของดินและน้ำใต้ดิน ในพื้นที่เขตควบคุมมลพิษ จังหวัดระยอง

โครงการความร่วมมือระหว่างประเทศ

1. โครงการวิจัยร่วมไทย-ญี่ปุ่น เรื่อง การศึกษามลกระทบการตกสะสมของกรดในพื้นที่ป่าต้นน้ำของประเทศไทย
2. โครงการวิจัยและพัฒนาเทคโนโลยีการนำน้ำกลับมาใช้ใหม่ในภูมิภาคเขตร้อน
3. โครงการร่วมมือระหว่าง The United Nations University (UNU) กับกรมส่งเสริมคุณภาพสิ่งแวดล้อม ดำเนินการโดยสถาบันไดออกซินแห่งชาติ

บันไดออกซินแห่งชาติ

การศึกษาระยะการกระจายตัวของสารไดออกซินและพีวแรนในอากาศ

มีศึกษา พื้นที่กรุงเทพมหานครและปริมณฑล)

การติดตามตรวจสอบข้อมูลพื้นฐานการปนเปื้อนของ

ไดออกซินบริเวณรอบอาคารปฏิบัติการไดออกซิน



Environmental Research and Training Center

Collaboration of Environmental Researchers Group

and Responsibilities

Responsible for environmental research and technology development in terms of policy, strategy, and administration and development research network mechanism in both national and international level as well as providing services on environmental data.

Water and Waste Group

and Responsibilities

Water and Solid Wastes Group has responsible for research and development technology on wastewater treatment, surface water and groundwater conservation and rehabilitation including water quality monitoring in surface water and groundwater. Furthermore, research and development on added value of solid wastes and garbage, reduce environmental effects on solid wastes disposal, cooperative-support services with related agencies.



Air Noise and Vibration Group

Roles and Responsibilities

Air Noise and Vibration Group is responsible for conducting research to develop analytical methodologies and extend knowledge related to air pollution and noise and vibration problems in Thailand. The section also extend technical assistance to other agencies. It also provides scientific data to support the mission of the Department of Environmental Quality Promotion.

Hazardous Substance Group

and Responsibilities

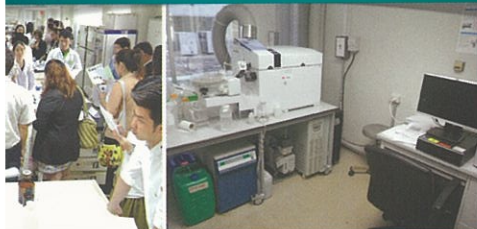
Research and monitoring of hazardous substances. Knowledge to the analysis method and management of hazardous substances or related to hazardous substances. Promote and encourage research and development, management of hazardous and harmful substances with related organizations, both domestic and international to promote the technology that suitable for the country. By working with or support the various agencies involved and fulfill duties as assigned.



Climate Change Group

Roles and Responsibilities

Research and development, and collaboration for integrated environmental administration related to climate change.



Standard and Accreditation Group

Roles and Responsibilities

To develop laboratory quality system in compliance with the international standards and develop environmental laboratory quality-check accuracy and precision as well as develop environmental reference laboratory and also to cooperate on international quality system certification standards and provide advices on the quality system and quality system certification.

National Institute of Dioxin

and Responsibilities

National Institute of Dioxin was established to monitor and research dioxin and dioxin-like compounds. The institute has a collaboration with domestic and international organizations to conduct research and develop technologies to decrease dioxin emissions from point sources. Furthermore the institute provides knowledge to the people and academic institutes on the analysis of dioxin and dioxin-like compounds as well as their environmental management and control. Generally, the National Institute of Dioxin (Thailand) provides laboratory services to support the government and private sector.



On-going Research Project during 2013 – 2015

The Collaboration of Environmental Researchers Group

1. Research and Promote Environmental Friendly Production and Consumption.
2. The Study of Local Wisdom for Environmental and Natural Resource Conservation : Case study at Petchaburi Province
3. The Development of Community Learning Process for Sustainable Solution of Haze Problem in Doi-yon Doi-Pha Mon Area, Chang Rai Province.
4. The Study of Climate Changes and the Impacts of Pollution to Microbial Population Dynamics in Sediment and Water of Ping Watershed along Three Seasons.

Water and Waste Group

Feasibility of Treated Municipal Wastewater Reuse in Agriculture in Water Scarce Areas.
Study on the Efficiency of Wastewater Treatment
Water Hyacinth in Rong Jae canal.
Pharmaceutical and Personal Care Products
Contamination in Bang Pakong River.



Air Noise and Vibration Group

1. Study on Odor and Toxic Compounds Emissions from Municipal Solid Waste.
2. Study on Impact of Distribution of Ambient Air Toxics from Open Burning of Corn Crop Residue.
3. Study of Acid Deposition in Thailand.
4. The Study of Land Use Compatibility Suvarnaphumi Airport.
5. The Study of the Impact on Noise Level Caused by Dual Tracks Trains and Effect to Communities.
6. The Study of the Impact on Noise Pollution Related to Flight Paths Activities; Case Studies of Suvarnaphumi and Donmuang Airport.
7. The Joint Research Project on Catchment Analysis in Thailand.



Hazardous Substance Group

1. Participatory Research on Chemical Reduction in Agricultural Practices: Case study-Mae Taeng District, Chiang Mai Province, Thailand.
2. Participatory Research on Organophosphate Pesticide Risk Management in the Upper Northern Part of Thailand.

National Institute of Dioxin

Study on Distribution of Dioxin/Furan in Ambient Air (Case study : Bangkok Metropolitan Region).
Dioxin Monitoring in Ambient Air Surrounding
Laboratory Area.



The International Cooperation Project

1. The Joint Research Project on Catchment Analysis in Thailand
2. Research and Development for Water Reuse Technology in Tropical Regions
3. International co-project: The United Nations University (UNU) and The Environmental Quality Promotion (DEQP) under Responsibility of National Institute of Dioxin (Thailand)



Climate Change Group

1. Development of Low Cost Smoke-free Biomass Reactor for Local Communities.
2. Community-based Management on Climate Change Problem in Thailand.
3. Heat Index Development and Its Application for Heat Wave Study in Thailand.
4. Development of Lower Greenhouse Gas Emission Model for Community Solid Waste Management at Provincial Level.
5. The Impact of Climate Change on Rubber in Thailand
6. Heat Index Development and Its Application for Heat Wave Study in Thailand.
7. Mitigation of Greenhouse Gas Emissions from Agricultural Sector by Nitrification Inhibitors: Case study of Rice, Sugarcane and Maize Production.
8. Assessment of Natural Attenuation of Groundwater Remediation in Pollution Control Area, Rayong Province.
9. Ecological Risk Assessment of Soil and Groundwater Contamination in Pollution Control Area Rayong Province.

วฟ. ศูนย์วิจัยและฝึกอบรมด้านสิ่งแวดล้อม



ความเป็นมา

ศูนย์วิจัยและฝึกอบรมด้านสิ่งแวดล้อม เป็นหน่วยงานในสังกัดกรมส่งเสริมคุณภาพสิ่งแวดล้อม ซึ่งอยู่ภายใต้กระทรวงทรัพยากรธรรมชาติและสิ่งแวดล้อม ก่อตั้งโดยความร่วมมือระหว่างรัฐบาลไทยและรัฐบาลญี่ปุ่น โดยมีจุดมุ่งหมายเพื่อส่งเสริมและดำเนินการวิจัยพัฒนาเทคโนโลยีที่เหมาะสมในการป้องกันและควบคุมมลพิษ รวมทั้งการอนุรักษ์และจัดการทรัพยากรธรรมชาติและสิ่งแวดล้อม ตลอดจนมีภารกิจด้านการถ่ายทอดเทคโนโลยี เพื่อการจัดการทรัพยากรธรรมชาติและสิ่งแวดล้อมแก่เจ้าหน้าที่ภาครัฐ เอกชน และองค์กรเอกชนทั้งในส่วนกลางและส่วนภูมิภาค และนับตั้งแต่ศูนย์วิจัยและฝึกอบรมด้านสิ่งแวดล้อม ก่อตั้งในปี พ.ศ. 2535 ศูนย์วิจัยและฝึกอบรมด้านสิ่งแวดล้อมมีบทบาทสำคัญในการสนับสนุนรัฐบาลไทยในการขับเคลื่อนประเทศพัฒนาที่ยั่งยืนและเพื่อคุณภาพชีวิตที่ดีขึ้นของประชาชน

วิสัยทัศน์

มุ่งสู่การเป็นศูนย์ที่มีความเป็นเลิศในด้านการวิจัยและพัฒนาเทคโนโลยีเพื่อการพัฒนาที่ยั่งยืนและคุณภาพชีวิตที่ดีประชาชน

จาก และหน้าที่ความรับผิดชอบ

วิจัยและพัฒนาเทคโนโลยีที่เหมาะสมกับการควบคุมมลพิษและการจัดการสิ่งแวดล้อม รวมทั้งการนำของเสียกลับมาใช้ประโยชน์ และทำการกำจัดหรือทำลายของเสียอย่างถูกวิธี

วิจัยและพัฒนาวิธีการติดตามและตรวจสอบคุณภาพสิ่งแวดล้อม

วิจัยและพัฒนาวิธีการวิเคราะห์ตัวอย่างสิ่งแวดล้อม และการผลิตตัวอย่างมาตรฐานสำหรับใช้อ้างอิง รวมทั้งประสานงานในการตรวจสอบความเที่ยงตรงของข้อมูลจากการวิเคราะห์ตัวอย่างสิ่งแวดล้อมระหว่างห้องปฏิบัติการด้านสิ่งแวดล้อม ตลอดจนให้บริการในการใช้เครื่องมือ และวิธีการวิเคราะห์ตัวอย่างสิ่งแวดล้อมแก่หน่วยงานที่เกี่ยวข้อง

ส่งเสริม สนับสนุนเครือข่ายความร่วมมือการวิจัย และพัฒนาเทคโนโลยีด้านสิ่งแวดล้อมระหว่างหน่วยงานที่เกี่ยวข้อง ทั้งภายในประเทศและต่างประเทศ



Introduction to ERTC

The Environmental Research and Training Centre (ERTC) is a division operating under the Department of Environmental Quality Promotion (DEQP) and under the overall jurisdiction of the Ministry of Natural Resources and Environment (MONRE). Its establishment was supported by the government between Thailand and Japan. The fundamental purpose of ERTC is to carry out research and to provide technical support in the implementation of natural resources and environmental policy and natural resources and environmental initiatives. ERTC also provides technology transfer on natural resources and environmental management and pollution control to staff from national and local government, international and local organizations, private sector and NGOs. Since its establishment in 1992, the Environmental Research and Training Centre has played a key role in efforts by the Royal Thai Government to ensure the country's sustainable development and quality of life of the people.

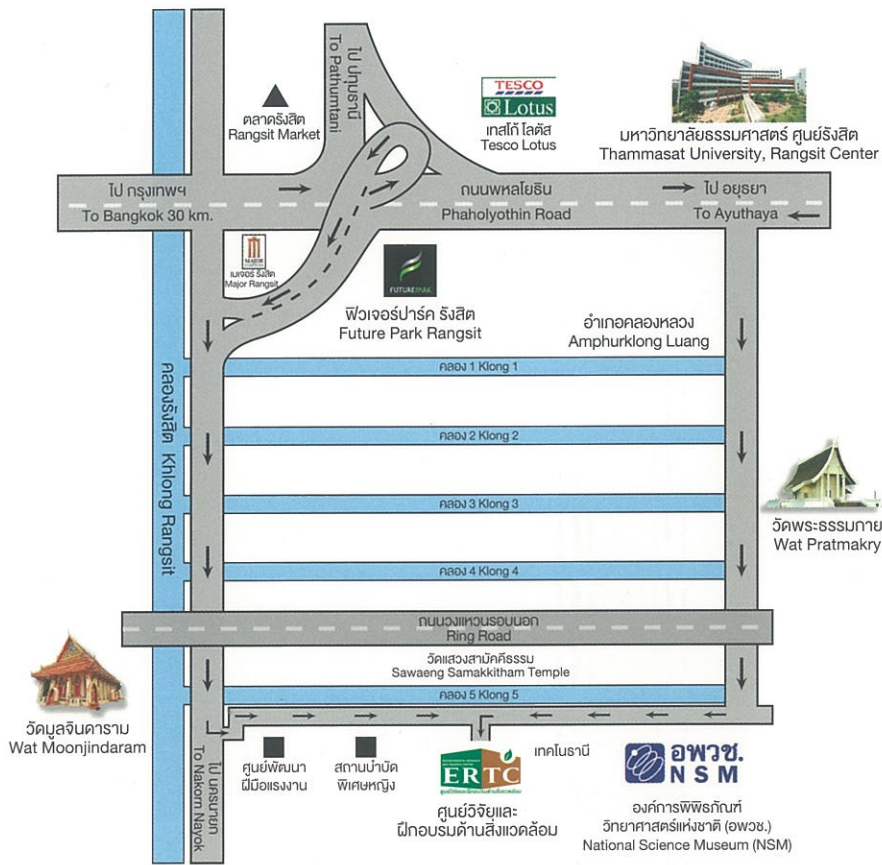
mission

The ERTC aims to be a center of excellence in the environmental research for sustainable development and better quality of life of the people.

Functions and Responsibility

- undertake research and develop appropriate technology for pollution control and environmental management as well as develop technology for waste recycling and proper eradication.
- undertake research and develop monitoring methods and environmental quality monitoring programmes.
- undertake research and methodology development in analysis of environmental samples and to provide standard reference materials as well as to coordinate in checking accuracy and precision of the data between environmental laboratory and also to advice on the use of scientific instruments and analysis of environmental samples for concerned agencies.
- promote and encourage cooperational network of research and technology development for environmental management with both national and international relevant agencies.

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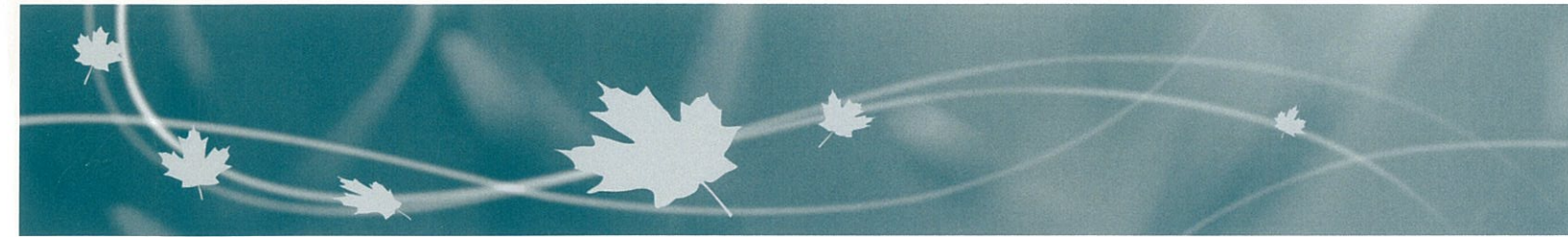
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Canadian Mercury Science Assessment **Summary of Key Results**

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*Canadian Mercury
Science Assessment*
**Summary of
Key Results**



The text has been changed “However, the combination of mining, eutrophication resulting from urbanization, and extensive logging on the watershed of small lakes may result in optimum conditions for methylating large amounts of mercury in surface sediments, and these conditions may last for several decades. Thus, while mining may not be a direct source of methylmercury, mine wastes with elevated levels of mercury should not be placed near lakes with a high potential for mercury methylation. Particular attention should be placed on lakes and rivers located near towns with a history of gold and mercury mining where local residents often fish.”

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INTRODUCTION

The Mercury Science Program, part of the Clean Air Regulatory Agenda (CARA), was developed in 2007 to establish the scientific knowledge base to support regulatory decision-making for mercury. The intent of the program was (1) to determine key indicators of environmental quality and human health that are relevant to atmospheric emissions of mercury, (2) to quantify current and past levels for these indicators, and (3) to develop the capacity to predict changes in these indicators associated with changes in levels of atmospheric emissions of mercury or the receiving environment.¹ The geographic focus of the CARA Mercury Science Program was south of the Arctic Circle (60°N latitude). CARA partnered with the Canadian Arctic Northern Contaminants Program (NCP), an Aboriginal Affairs and Northern Development Canada (AANDC) program that conducts scientific research to respond to concerns about human exposure to elevated levels of contaminants, such as mercury, in fish and wildlife species important to the traditional diets of northern Aboriginal people. In 2012, NCP published *Canadian Arctic Contaminants Report III: Mercury in Canada's North* to provide a comprehensive evaluation of the environmental fate of mercury in the Canadian Arctic. The Canadian Mercury Science Assessment is a comprehensive, peer-reviewed synthesis of the state of scientific knowledge on mercury in Canada that includes information from the NCP report, covering Canada south and north of the Arctic Circle. In addition, this assessment builds on the recently published regional environmental assessments of the Great Lakes Basin² and northeastern North America³ and is planned to feed into the North American Western Mercury Synthesis Report, being prepared as of 2013. The Canadian Mercury Science Assessment serves both the research and policy communities. For research, this assessment provides current information (up to 2012) about

mercury in Canadian ecosystems, knowledge gaps, and predictive capabilities to inform program management. For decision-making, this Summary of Key Results provides science-based responses to several policy-related questions, and recommends directions for mercury research in Canada.

In 2010, Environment Canada and Health Canada launched its *Risk Management Strategy for Mercury*, which provided a summary of the Government of Canada's progress to date and future activities to manage mercury. This strategy outlined current federal research, monitoring and assessment activities aimed at strengthening our understanding of mercury, and summaries of expected future outcomes of regulation and science.

Preparation of this assessment began in 2008 with a series of workshops involving scientists and policy-makers from the federal, provincial, and territorial governments and from universities. These workshops led to the development of 7 science questions and sub-questions that capture the information needs of the science and policy communities in Canada. Based on these questions, the goal of this assessment is to synthesize the current state of knowledge on environmental mercury pollution in Canada. Its purpose is to inform decision-making by policy-makers and research managers through: (1) presentation of science-based information in the context of the policy-related questions; (2) establishment of a baseline against which to measure future changes in mercury levels in the environment; (3) identification of priorities for future science needs; and, (4) information to national and international scientists on the state of Hg research in Canada.



- 1 Morrison, H.A., 2011. The Canadian Clean Air Regulatory Agenda Mercury Science Program. *Ecotoxicology* 20, 1512-1519. 10.1007/s10646-011-0714-1.
- 2 Evers, D.C., Wiener, J.G., Basu, N., Bodaly, R.A., Morrison, H.A., Williams, K.A., 2011. Mercury in the Great Lakes region: bioaccumulation, spatiotemporal patterns, ecological risks and policy. *Ecotoxicology* 20, 1487-1499. 10.1007/s10646-011-0784-0.
- 3 Evers, D.C., 2005. Mercury Connections: The extent and effects of mercury pollution in northeastern North America. BioDiversity Research Institute., Gorham, Maine, p. 28.

The policy-related questions are as follows:

1. Is mercury a risk to ecosystem and human health in Canada?
 - a. If so, where, how, and to what extent is mercury a risk to these assessment end points?
2. Are human activities contributing to observed mercury levels, and thus risk, in the Canadian environment?
 - a. If so, what are these activities?
 - b. Which activities are having the most significant impact on mercury levels in fish in Canada?
 - c. What are the current and forecasted trends in mercury emissions/releases from these activities?
 - d. From a long-range transport perspective, what are the major emission source regions contributing to Canada's mercury burden?
3. How are atmospheric emissions of mercury linked to methylmercury exposure and accumulation in terrestrial and aquatic biota and in humans?
 - a. Are Canadian ecosystems responding to recent reductions in domestic atmospheric emissions of mercury?
 - b. If so, what are the indicators of recovery, where is it occurring, and how quickly are ecosystems responding?
 - c. If not, what factors are confounding/masking the expectation of recovery?
 - d. Can predictions be made regarding the impact of future changes in atmospheric emissions on mercury levels in deposition and methylmercury levels in biota?
4. What are the linkages between other air pollutant emissions (e.g., acidifying emissions, greenhouse gases, etc.) and mercury accumulation in biota?
5. How might changes in other human activities (e.g., land-use practices) affect the distribution of mercury between environmental compartments, methylmercury formation, and the accumulation in biota?

6. In light of our current understanding of mercury in the Canadian environment, where, and to what extent, do we need to continue atmospheric and effects monitoring?
 - a. What are the most promising environmental indicators of reductions in anthropogenic emissions of mercury?
 - b. What are the most promising indicators of ecosystem recovery?
7. Where, and on what, should we focus future research efforts for mercury?

In addition to supporting Canada's domestic policy and science priorities, the assessment provides a scientific foundation to assess the effectiveness of efforts to reduce global mercury emissions resulting from the ratification and implementation of the Minamata Convention. The assessment also provides information to inform environmental decision-making outside of mercury mitigation through the assessment of the effects of land-use, eutrophication, acidification, and climate change on mercury transport and fate.

BACKGROUND ON MERCURY

Mercury is a natural element commonly known as *quicksilver*. It is the only metal that is liquid at room temperature; it is predominantly found in the Earth's crust in the form of cinnabar (mercuric sulphide). Mercury is emitted to the environment through natural and anthropogenic (human activity-induced) sources, and may be re-emitted from previously deposited mercury of both anthropogenic and natural origin.⁴ Natural sources of mercury include forest fires, volcanoes, ocean/aquatic emissions, and weathering of the Earth's surfaces. Mercury is released anthropogenically to the environment through processes such as coal burning, metals smelting, gold and silver mining, and chlor-alkali production using mercury or mercury compounds. It is also emitted from incinerators and areas flooded by dams, and through the production, breakage, and disposal of products containing mercury.

Once in the environment, mercury can be found in several forms. Each form of mercury has different chemical properties that govern how

soluble, reactive, and toxic the mercury is. The most important forms of mercury with respect to environmental transport, fate, and effects are elemental mercury, divalent mercury, and methylmercury. Elemental mercury is very volatile and is stable in the air, which enables it to travel long distances once emitted. Divalent mercury forms compounds that are more soluble in water or reactive in the air. Methylmercury is the most toxic form and is the predominant form in fish, wildlife, and humans.

Animals and humans tend to absorb and retain over time most of the methylmercury in the food they consume (bioaccumulation). At each step up in the food chain, predators accumulate mercury from their prey. As a result, over their lifetime, they have much higher mercury levels in their system than their prey (biomagnification). Predatory fish and wildlife at the top of aquatic food chains can have mercury levels in their tissues 1 000 000 times greater than the levels in the freshwater where they live. Figure 1 shows simple diagrams of the bioaccumulation and biomagnification processes.

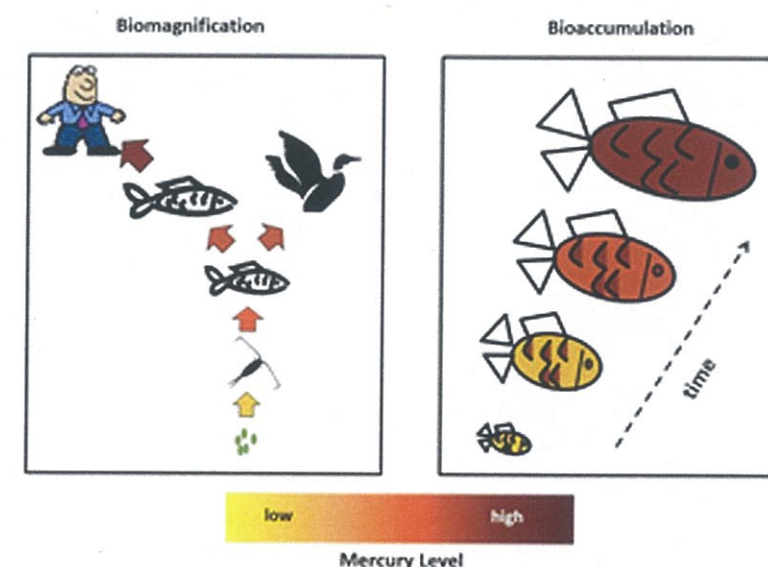


Figure 1: Simplified schematic of biomagnification (left) and bioaccumulation (right) processes of methylmercury in the ecosystem.

⁴ UNEP, AMAP, 2013. Technical background report for the global mercury assessment 2013. Arctic Monitoring and Assessment Programme/UNEP Chemicals Branch, Oslo/Geneva, p. 263 pp.

Environmental cycling of mercury is complex and involves many different processes and pathways. The predominant processes that mercury undergoes include emission, deposition, re-emission, transformation (methylation/ demethylation/ oxidation/ reduction), accumulation and magnification. Figure 2 is a simplified schematic showing environmental cycling of mercury in Canada. Each chapter in the assessment discusses a different contribution to the overall mercury cycle and is identified in the drawing. One chapter (9) uses the information on processes from most chapters to tie together cycling of mercury in the whole ecosystem.

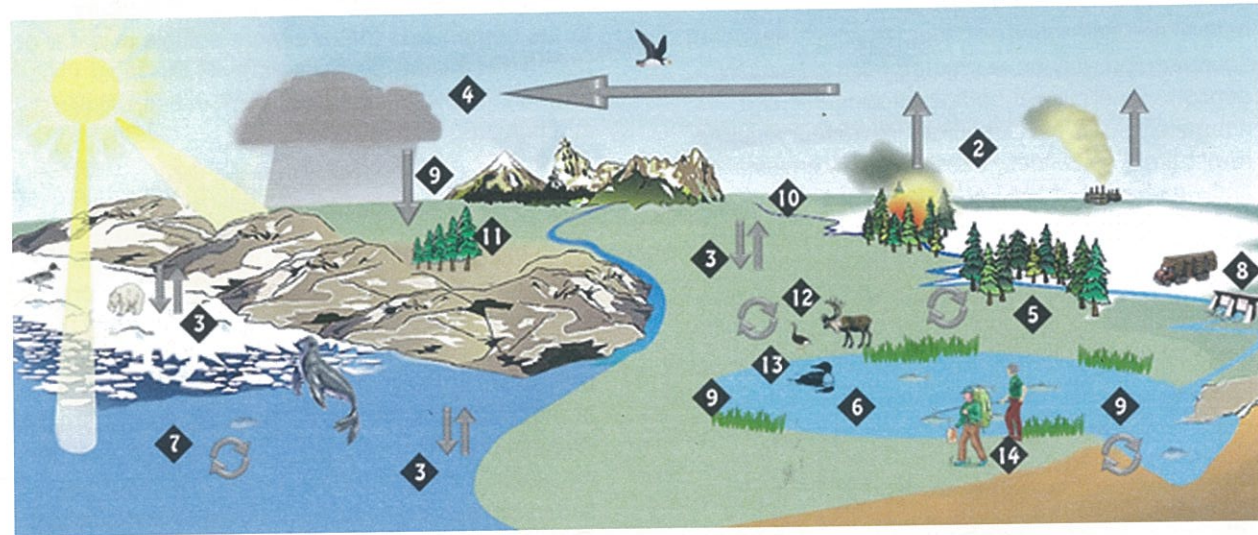


Figure 2: The main processes that mercury undergoes in the ecosystem. The numbers indicate the chapters in which each process is discussed in the assessment report.

Chapter 2: Releases of Mercury Into Air and Water From Anthropogenic Activities in Canada; **Chapter 3:** Surface Fluxes; **Chapter 4:** Atmospheric Processes, Transport, Levels, and Trends; **Chapter 5:** Mercury Fate and Methylation in Terrestrial Upland and Wetland Environments; **Chapter 6:** Mercury Fate and Methylation in Freshwater Aquatic Ecosystems; **Chapter 7:** Mercury in the Marine Environment: Processes and Levels; **Chapter 8:** Influences of Anthropogenic Activities on Mercury Transport, Methylation, and Bioaccumulation; **Chapter 9:** Mercury Cycling in Ecosystems and the Response to Changes in Anthropogenic Mercury Emissions; **Chapter 10:** Mercury in Terrestrial and Aquatic Biota Across Canada: Geographic Variation; **Chapter 11:** Mercury in Terrestrial and Aquatic Biota Across Canada: Temporal Variation; **Chapter 12:** Health Effects of Mercury in Fish and Wildlife in Canada; **Chapter 13:** Assessment of Current Mercury Risks to Piscivorous Fish and Wildlife in Canada; **Chapter 14:** Mercury and Human Health

POLICY-RELATED QUESTIONS

Question 1:

Is mercury a risk to ecosystem and human health in Canada?

Mercury remains a risk to Canadian ecosystems and human health



- a. If so, where, how and to what extent is mercury posing risks?

Ecosystem risks

In Canada, there are a substantial number of aquatic environments in which mercury levels in fish-eating (piscivorous) fish and wildlife are sufficiently high to be of concern. Methylmercury, the organic form of mercury, is of greatest concern for human and environmental health because of its high toxicity and its ability to accumulate in the tissues of living organisms and become more concentrated following transfer from prey to predators. As a result, predatory fish and wildlife at the top of aquatic food chains can have mercury concentrations in their tissues 1 000 000 times greater than the concentrations in the freshwater where they live.

The risks of mercury to piscivorous fish and wildlife across Canada have been assessed using indicator species known to have the potential for high exposure: walleye and northern pike are the indicator fish species, and common loons are the indicator bird species. Potential risks of exposure include threats to health, growth, breeding, and survival. Ecological risks of mercury increase from west to east across Canada, and mercury poses significant risks to the health and reproductive success of common loons (Figure 3) and predatory fish (Figure 4) in parts of southeastern Canada. Overall, risks of abnormal behaviour in common loons due to mercury exposure are found in 36% of the 677 Canadian lakes studied, and risks of impaired loon reproduction due to mercury, in 10% of 195 lakes studied. Similarly, mercury risks to reproduction in predatory fish are found in 82% of the 1 582 Canadian lakes studied, and mercury risks to fish health, in 73% of the 1 407 lakes studied. The higher mercury levels in eastern Canada also affect many other species of aquatic invertebrates, fish, birds, and mammals. Patterns of elevated mercury concentration levels in Arctic wildlife are different from those in wildlife in southern and central Canada. Several species of marine mammals, such as beluga whales, ringed seal, and polar bear, have higher mercury levels in the western and high Arctic (such as the Beaufort Sea) than in the eastern and southern Arctic.

In Canada, methylmercury concentrations tend to be greater in freshwater fish and wildlife in areas where the lakes and rivers are acidic. Similarly, methylmercury levels in lakes and rivers tend to be higher in areas where there are abundant wetlands in watersheds, where freshwaters are dark brown, and where there are recently flooded reservoirs. Geographic areas with bedrock and soils with poor buffering capacity (ability to neutralize additions of acid) or with high levels of acidic deposition from air pollution tend to have more acidic lakes and rivers and higher methylmercury concentrations in aquatic food webs. This combination of characteristics is more common in southeastern Canada, where methylmercury in piscivorous fish and wildlife tends to be highest.

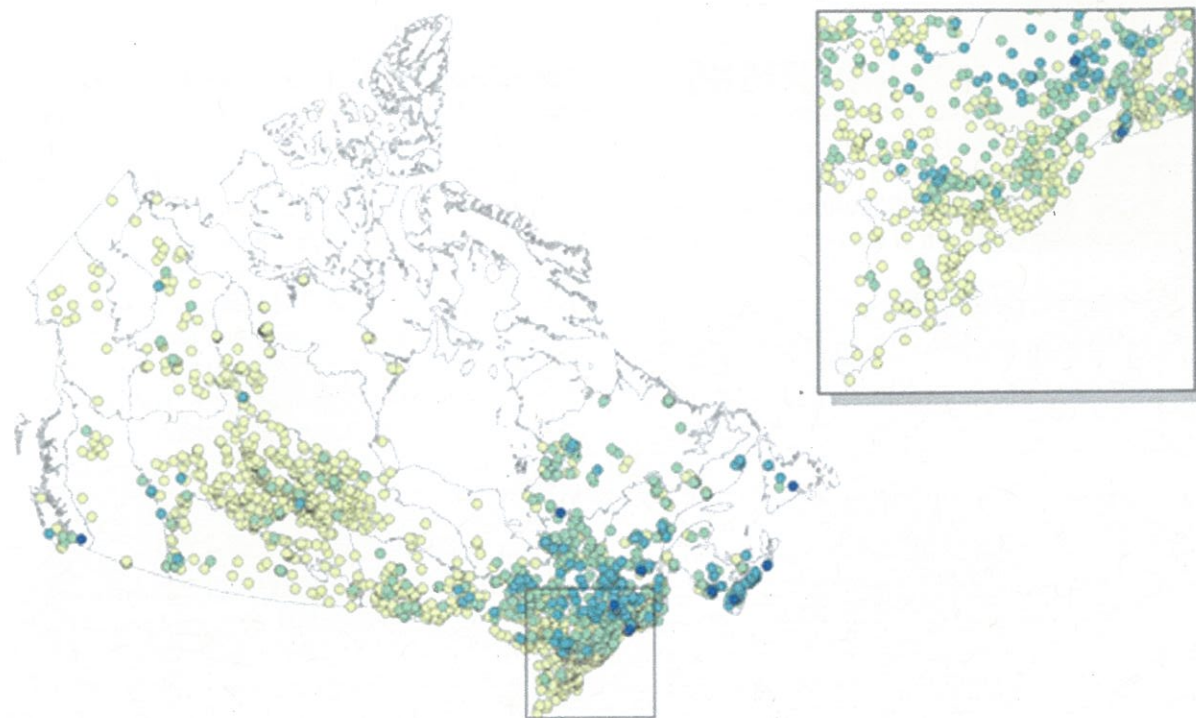


Figure 3: Map of freshwater locations in Canada, showing mercury risks to common loons.

Dark blue: Risk of failed productivity; **Teal:** Risk of impaired productivity; **Green:** Risk of impaired behaviour, and **Yellow:** Below all loon risk benchmarks

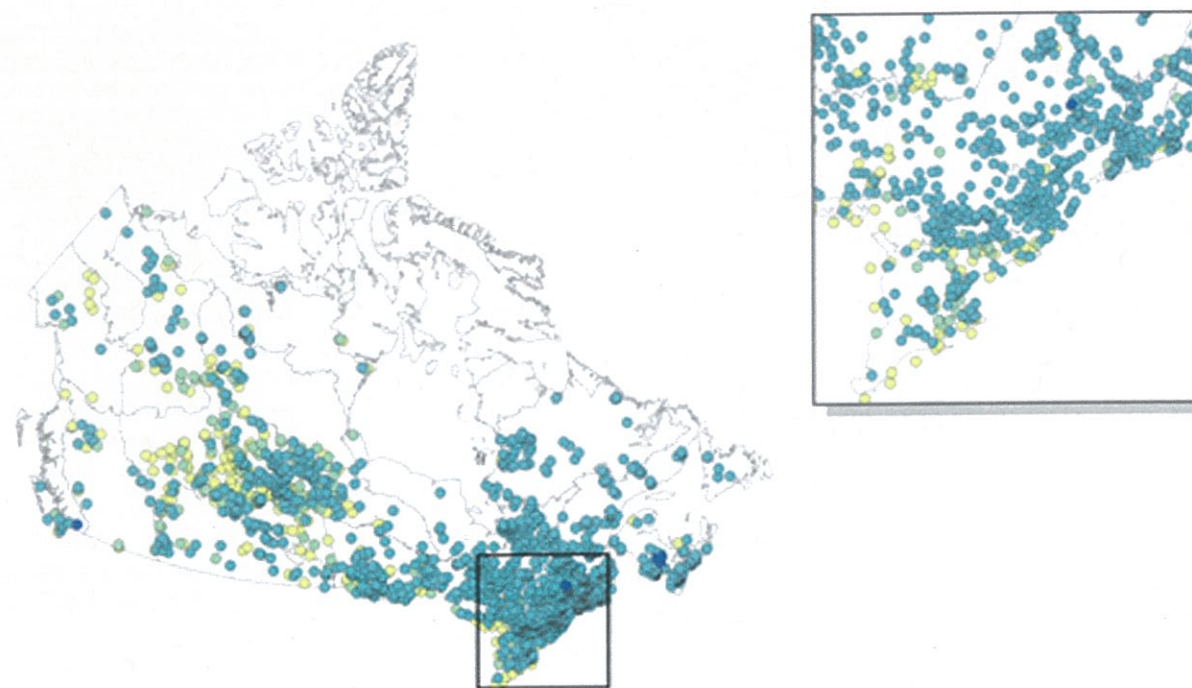


Figure 4: Map of freshwater locations within Canada showing mercury risks to piscivorous fish.

Dark blue: Risk of impaired behaviour; **Teal:** Risk of health impairment; **Green:** Risk of reproduction impairment and **Yellow:** Below all risk benchmarks

Human health risks

In Canada, methylmercury remains a potential public health issue for populations who rely on the consumption of large predatory fish and traditional wildlife items. People are exposed to methylmercury primarily through the consumption of fish and seafood. Elemental mercury exposure from dental amalgams does not pose a health impact for the general population. In Canada, mercury blood levels of $20 \mu\text{g L}^{-1}$ or lower are considered within an acceptable range. Individuals with levels between 20 and $100 \mu\text{g L}^{-1}$ are considered at increasing risk, and those with levels above $100 \mu\text{g L}^{-1}$ are considered at risk of health effects. However, for specific groups of people, including children (under 19 years of age), pregnant women, and women of childbearing age (younger than 50 years), a lower provisional mercury blood guidance value of $8 \mu\text{g L}^{-1}$ has been proposed by Health Canada in order to account for the increased susceptibility of neurological development of young children and fetuses. Some groups, such as Aboriginal peoples, sport fishers, and Asian Canadians, may be more likely to be exposed to methylmercury in higher concentrations than the general Canadian population because of a diet high in fish and seafood.

Biomonitoring

Several programs are in place to monitor exposure to methylmercury in biological samples (e.g., hair, urine, or blood sampling) for the general Canadian population, northern Aboriginal communities, First Nations communities, and prenatal exposure in infants and children. Other studies have evaluated methylmercury exposure in Asian Canadians and sport fishers. According to data from Cycle 1 of the Canadian Health Measures Survey (CHMS) (2007–2009), approximately 2.2% of females aged 16–49 (includes pregnant women) have blood mercury levels exceeding the guidance value of $8 \mu\text{g L}^{-1}$. When children are also considered, 1.6% of Canadian children and youth and women of childbearing age combined have blood mercury levels exceeding the guidance value of $8 \mu\text{g L}^{-1}$. This suggests that only a small percentage of these vulnerable populations may require follow-up testing, dietary advice, or other further action.

By contrast, Inuit in the eastern Canadian Arctic have shown the highest concentrations of mercury among northern populations, with levels exceeding $8 \mu\text{g L}^{-1}$ in over 50% of mothers examined during a small study in the Baffin region of Nunavut in 1997; however, more recent data suggest that northern levels have been decreasing in the last several decades. During a follow-up study in Nunavut in 2005–2007, only 20% of mothers had levels exceeding $8 \mu\text{g L}^{-1}$. Moreover, studies in the Nunavik region of northern Québec have also shown a downward trend for mercury levels in mothers from 1992 to 2007. These decreases may be due to a combination of public health interventions, dietary change, and heightened awareness among communities. Available data about mercury concentrations in people living in First Nations communities south of 60°N latitude suggest that mercury exposure is generally lower than for Arctic Inuit populations but still a concern in many isolated First Nation communities where fish is a diet staple.

Effects

Health effects, in particular neurological impairments, are associated with exposure to high levels of methylmercury. The developing nervous system is considered to be the most susceptible to the adverse health effects of methylmercury; thus, developing fetuses, infants, and young children are at a higher risk of developing adverse health effects. Recent studies suggest that neurological deficits (including decreased movement speed and dexterity, vision problems, and memory issues) in adults may also be attributable to methylmercury exposure. The level and duration of exposure to methylmercury influences the severity of adverse health outcomes. However, omega-3 fatty acids, found in high levels in some fish species, play a pivotal role in certain aspects of neurodevelopment, and may be capable of mitigating or negating some of the adverse effects of prenatal exposure to methylmercury through fish consumption. Recent studies suggest a possible link between methylmercury exposure and some adverse effects on the adult cardiovascular system, but more research is needed. Although for most populations, consuming fish carries a risk of exposure to methylmercury, the benefits of fish consumption are thought to generally outweigh these risks, depending on the levels of mercury in the fish, the frequency and amount of consumption.

Question 2:

Are human activities contributing to observed mercury levels, and thus risk, in the Canadian environment?

Human activities are contributing to observed mercury levels in Canada



a. If so, what are these activities?

Mercury is emitted to the atmosphere through natural sources, anthropogenic emissions, and re-emission of previously deposited mercury. Anthropogenic activities such as electricity generation, smelting, cement production/processing, waste incineration, and disposal of mercury-containing products release mercury into the environment. Canadian emissions in 2010 were 5 300 kg to air and 240 kg to water. In comparison with other major mercury-emitting countries, such as the United States and China, Canadian emissions are relatively small. Figure 5 shows the distribution of anthropogenic sources of the 2010 mercury emissions in Canada to air and water.

Until its closure in 2009, Canada's largest source of mercury to the atmosphere was the Hudson Bay Mining and Smelting operations in Flin Flon, Manitoba. Decreases in emissions from this smelter, due to decreases in the smelter operations and control technologies to reduce emissions of a variety of pollutants, accounted for the most significant Canadian decreases in Hg emissions from the early 1990s until 2010. Canadian mercury emissions have decreased over time and are expected to stabilize

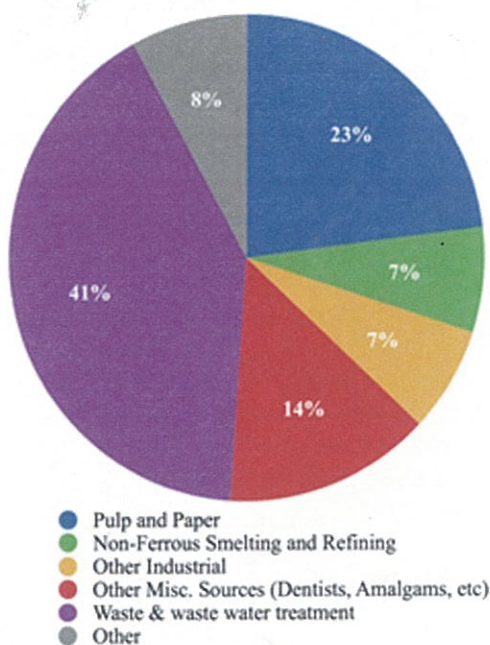
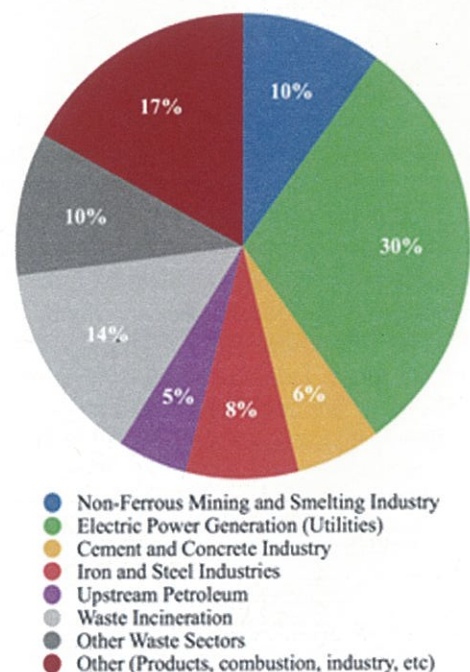


Figure 5: Distribution of the major contributing sectors of mercury emissions to air in Canada in 2010 (left) and sector contributions of mercury releases specifically to water in 2010 (right). In the category "other, combustion" includes residential fuel and wood combustion and "industry" includes emissions from industries such as pulp and paper and iron ore mining.

Table 1: Provincial and territorial total mercury emissions and percentage of total national total emissions for 1990, 2000, and 2010

Province	1990		2000		2010	
	kg	%	kg	%	kg	%
Alberta	1 184	3	1 062	16	1 175	22
British Columbia	3 668	10	1 139	6	549	10
Manitoba	20 169	57	1 231	13	366	7
New Brunswick	729	2	436	5	158	3
Newfoundland	253	1	184	2	122	2
Nova Scotia	384	1	261	5	139	3
Northwest Territories	79	0	4	0	13	0
Nunavut	2	0	2	0	2	0
Ontario	4 426	13	2 675	31	1 191	22
Prince Edward Island	35	0	27	0	16	0
Quebec	3 667	10	1 296	15	730	14
Saskatchewan	662	2	575	7	855	16
Yukon	4	0	2	0	1	0

in the future. In 2010, overall Canadian emissions of mercury were reported to have decreased by 85% in air and by about 50% in water since 1990.

Mercury emissions differ among provinces, and have decreased in most provinces between 1990 and 2010, with the exception of Alberta and Saskatchewan (Table 1). Alberta's levels have remained the same while Saskatchewan's levels have increased as a result of a doubling of emissions from coal-fired electricity generation and some small increases in the upstream and downstream petroleum sectors. In 2010, Alberta and Ontario equally shared nearly half of the national burden of mercury emissions. Saskatchewan and Quebec shared a third of the national burden, while the rest of the country made up the rest.

While many of the direct emissions have decreased, revolatilization of historically deposited mercury can contribute to the continued elevated levels of mercury in the air. For example, the highest levels of re-emitted mercury in air in Canada continue to be found in the area around the smelter in Flin Flon, although the smelter was shut down in 2009. As well, historical mine waste continues to be a significant source of mercury to the environment long after the cessation of mining and milling activities. In the case of some gold mines in Nova Scotia, mine waste continues to emit mercury 60 to 70 years later.

Other human activities contribute to high mercury levels observed in certain Canadian environments. For example, land-use changes, eutrophication⁵ and acidification of aquatic ecosystems, and climate change from anthropogenic activities contribute to elevated levels of mercury. The main land-use changes that affect mercury dynamics are logging activities and reservoir⁶ impoundments. As well, acidic emissions (such as sulphate and nitrate) can be subsequently deposited on land and water, where they can affect rivers and lakes. Acidification of rivers and lakes leads to transformation of elemental mercury to toxic methylmercury, which can then bioaccumulate in aquatic plants, fish, and piscivorous wildlife.

Human activities driving climate change are expected to have complex effects on mercury dynamics that are challenging to predict. Climate change impacts such as higher water temperatures and changes in the temperature layers of lakes are likely to alter methylmercury production. However,

⁵ Eutrophication is the process of enrichment of organic matter in an ecosystem. Eutrophication of waterways is caused by nitrogen and phosphorus, largely from agricultural fertilizer and manure, human sewage, and a variety of urban activities.

⁶ Reservoirs are bodies of water created by humans, including flooded areas, primarily for hydroelectric power generation and, to a lesser extent, flood protection, irrigation, water supply, and recreation. The new reservoirs result in large areas of terrestrial vegetation being flooded, which creates decomposition of the vegetation and stimulation of microbial activity, including bacteria that methylate Hg.

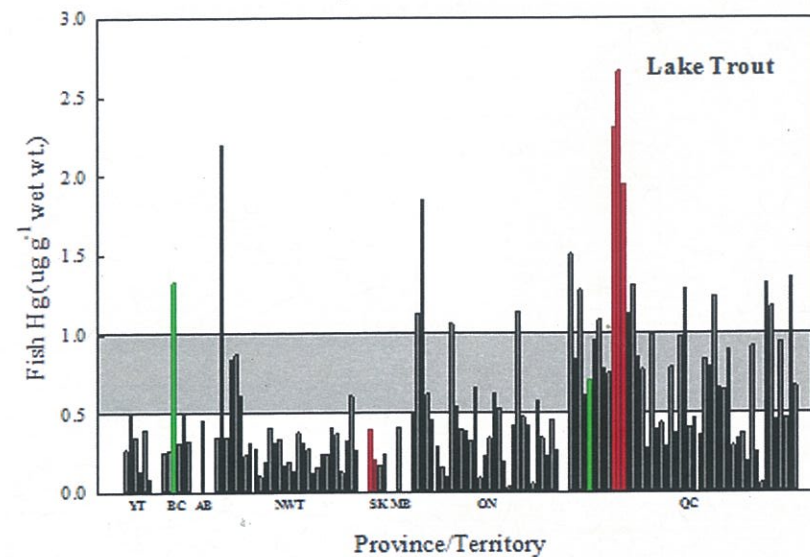


Figure 6: Example of mercury levels in lake trout muscle from various locations (lakes or reservoirs, not including any of the Great Lakes) from west to east across Canada. The shaded area represents the range of estimated lowest observed adverse effect level for fish toxicity. Green bars = “contaminated lakes” (lakes categorized as likely receiving some level of mercury pollution from nearby sources); red bars = reservoirs.

reduced seasonal ice cover in lakes may reduce the amount of methylmercury available. The largest changes in temperature are expected in northern Canada, where precipitation and moisture levels are expected to generally increase. Mercury cycling and bioaccumulation (especially in the Arctic) could be adversely influenced by climate change. For instance, current evidence shows that mercury levels are going up in some populations of Arctic biota but not necessarily in others, which suggests local or regional factors that may involve climate change. Mercury pollution from point sources such as smelters and mining is not currently a significant problem for marine regions in Canada; however, there have been significant local impacts on Canadian marine areas during the 20th century.

b. Which activities are having the most significant impact on mercury levels in fish in Canada?

Anthropogenic activities such as reservoir impoundment, mining, previous chlor-alkali production using mercury cells, coal burning, municipal waste incineration, cement production, and metals smelting are generally associated with mercury contamination of local and regional ecosystems. Fish mercury levels are generally higher in eastern Canada than in central and western

Canada; and Ontario, Quebec, and Nova Scotia have relatively high proportions of lakes where mean mercury concentrations in lake trout, northern pike, and walleye exceed an estimated lowest amount of mercury that causes an adverse effect⁷ on these fish.⁸ For example, Figure 6 shows the mercury levels in lake trout sampled from numerous lakes across Canada. Only 13% of lakes west of Ontario had trout with mean mercury concentrations that met or exceeded the lowest observed adverse effect level threshold range for fish, whereas 32% of Ontario lakes and 67% of Quebec lakes exceeded it. Furthermore, in Ontario 57% the lakes sampled for walleye and 49% of lakes sampled for northern pike reported mean mercury levels in these fish to be either within or greater than the concentration range for negative effects in fish. Some of the elevated mercury levels in fish in eastern Canada were attributable to reservoir impoundment, previous chlor-alkali emissions, and regional deposition of atmospheric emissions. However, most fish with elevated mercury concentrations were from semi-remote lakes and reservoirs characterized by nutrient-poor, low alkalinity, and low pH conditions, or by periodic flooding of wetlands.

⁷ The lowest level that produces effects on growth, health, reproduction, or behaviour, or causes death; expressed as the lowest observable adverse effect level range.

⁸ The lowest observable adverse effect level is a mercury concentration of 0.5–1.0 µg g⁻¹ wet weight of fish muscle.

Mercury levels in fish in the Great Lakes were higher in the past because of mercury deposited from industrial emissions in the region, including coal-fired power plants, metal production, waste incineration, and cement production. As these regional emissions decreased, starting in the 1970s, the mercury levels in fish in the Great Lakes declined as well. The highest mercury emissions in central Canada were from the base metal smelter in Flin Flon; however, mercury levels in fish (yellow perch) near Flin Flon were no higher than those in more distant reference lakes, and were not sufficiently high to affect the health of fish or of fish-eating wildlife. Similarly, lakes close to Alberta coal-fired power plants did not have fish with elevated mercury levels, compared with more distant lakes. By contrast, lakes contaminated by mercury mining activities, such as Pinchi Lake in central British Columbia, had high mercury levels in fish (trout).

Why are levels of mercury often high in fish, even in lakes far from point sources such as smelters, coal-fired power plants, and mines? To link anthropogenic inputs of mercury to fish mercury levels in lakes, key factors such as the chemical and physical properties of the lake and surrounding watershed must be considered. It has been shown that the acidity of the lake water is one of the most significant factors affecting mercury levels in fish. Thus, while there may be a significant mercury input to the lake from a given industry, if the pH/alkalinity of the lake is high, there may be relatively little mercury methylation and hence little accumulation of mercury by fish. For example, most of the lakes where Hg concentrations in yellow perch exceeded estimated toxicity thresholds for breeding common loons, that use these fish as a food source, were from lakes with higher acidity (pH<6.5). Conversely, lakes near the

base metal smelter at Flin Flon (pH 7-8.5) showed the greatest inputs of Hg, yet corresponding fish Hg levels were low.

Other activities such as changes in land use, eutrophication, and climate change likely affect levels of mercury in the Canadian environment, although the relative magnitude of ecosystem responses (including fish mercury concentrations) is not precisely known. These long-term environmental changes influence mercury methylation processes, which affect the transfer and accumulation of mercury in biota.

c. What are the current and forecasted trends in mercury emissions/releases from these activities?



Overall, atmospheric mercury emissions in Canada have declined 85% between 1990 and 2010, from approximately 35 to 5 tonnes (t) per year (Table 2). This large decline is primarily due to process changes in the non-ferrous metal mining and smelting sector (where emissions have declined

Table 2: Sectors emitting mercury to air in Canada

Sector	Total emissions yr ⁻¹ , t				
	1990	1995	2000	2005	2010
Non-ferrous metal mining and smelting	24.9	4.7	1.9	1.7	0.5
Electric power generation	2.3	2.0	4.0	2.1	1.6
Cement and concrete industry	0.5	0.4	0.4	0.2	0.3
Iron and steel industries	0.9	1.0	1.0	0.7	0.4
Waste sectors	3.8	4.3	2.1	1.4	1.3
Other	2.9	2.4	1.7	1.2	1.2
Total emissions	35.3	14.7	11.2	7.3	5.3
% per year decrease (over previous 5 years)		11.7	14.6	10.7	6.0

98%) as well as economic and regulatory impacts on the sector. The second largest decline in emissions is from waste sectors (where emissions have declined 76% over the same period of time). The smallest decline in the reported mercury emissions is from the electric power generation sector (30%). Currently, fossil fuel combustion for electric power generation is the largest single source of mercury emissions in Canada, accounting for 30% of the total emissions.

Canadian mercury emissions are forecasted to remain relatively constant in the future (Figure 7). After 2010, significant anticipated reductions in emissions from non-ferrous smelting and refining, pulp and paper, and electric power generation sectors are offset by anticipated increases from other miscellaneous sources and the waste sector. It is difficult to estimate any changes in releases of mercury from products and from changes in recycling, since regulations governing disposal of products have not yet been enforced and there is uncertainty associated with the current information (up to 50% for legacy emissions). The contributions of other minor sectors are expected to increase due to population growth and increased demand for materials.

d. From a long-range transport perspective, what are the major emission source regions contributing to Canada's mercury burden?



Based on results from Environment Canada's Global/Regional Atmospheric Heavy Metals (GRAHM) model, an estimated 95% of the anthropogenic mercury deposited in Canada comes from sources outside of the country. These contributions are approximately 40% from East Asia, 17% from the United States, 8% from Europe, and 6% from South Asia.

Mercury can remain in the air for a long time (6–12 months) and can be transported long distances from its source, termed long-range transport. Thus, it is important to identify primary source regions outside of the country that contribute to deposition in Canada to understand the full mercury burden within Canada.

Global mercury emissions are currently dominated by East Asia, followed by emissions from sub-Saharan Africa, South America, South Asia, Europe, and the United States. The relative contributions of emissions to net deposition in Canada from various source regions have been assessed for the year 2005 using the GRAHM model. As an example, the relative size of emission source contributions from 9 continental regions to deposition in 4 selected sub-regions in Canada is shown in Figure 8. In 2005, approximately 115 t of mercury was deposited to Canada; approximately 40% of the mercury deposited was from current global anthropogenic emissions and approximately 60% from other global terrestrial (approximately 35%) and oceanic (approximately 25%) emissions. These other emissions include both natural emissions and re-emissions of mercury deposited in the past.

East Asia and the United States are the predominant areas contributing to Canada's mercury burden. Europe, South Asia, Africa, South America, and Australia all contribute at similar levels to mercury deposition in Canada. Approximately two-thirds of all mercury deposited from East and Central Asian to all regions in Canada is of anthropogenic origin. Anthropogenic and terrestrial emissions from sources in Europe and South Asia contribute equally to deposition across Canada. In contrast, the relative contributions of anthropogenic and terrestrial emissions from the United States and Canadian sources to mercury deposition vary depending on the region of Canada receiving mercury. In northern and western Canada, the total contribution of anthropogenic and terrestrial emissions to annual deposition from East Asian (24 to 26%) is twice as high as the total contribution from the United States (7 to 12%). In comparison, in eastern Canada the total contribution of the same emissions from East Asia (20 to 23%) is comparable to the total contribution from the US (15 to 22%). European contributions to northern, western, and eastern regions in Canada are all comparable (5 to 7%).

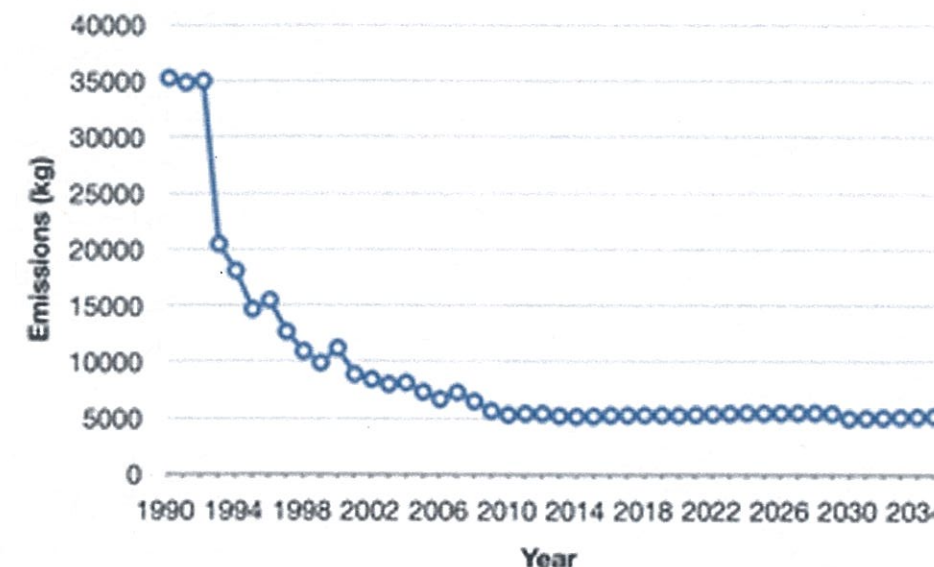


Figure 7: Historical and projected Canadian mercury emissions trends in air using the Energy, Emissions, and Economic Model for Canada (E3MC) model.

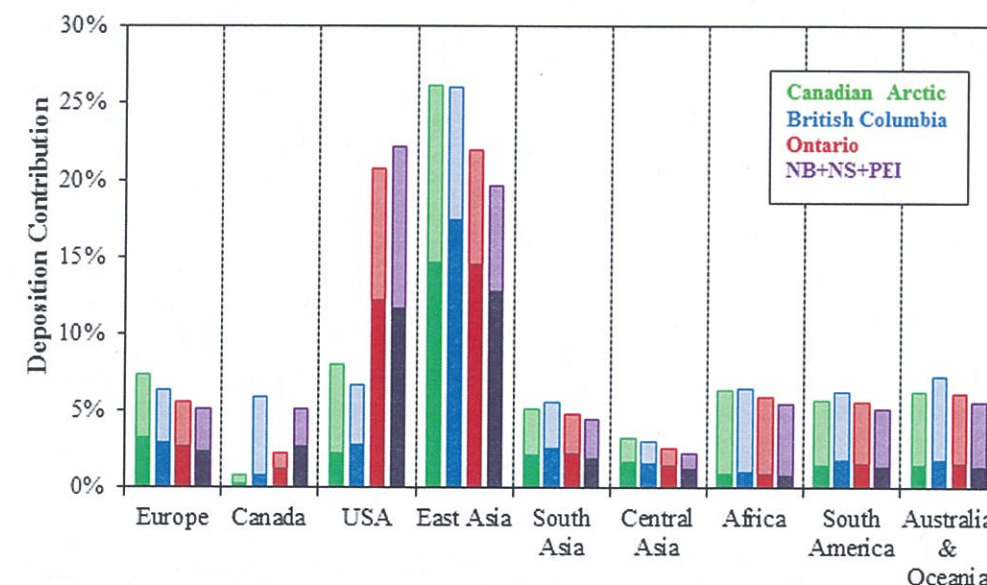


Figure 8: Relative contributions from emissions from individual source regions to net mercury deposition for the Canadian Arctic, British Columbia, Ontario and New Brunswick, Nova Scotia and Prince Edward Island combined for the year 2005 (as estimated by the Global/Regional Atmospheric Heavy Metals model). Contributions from each source region are divided into contributions from “anthropogenic” sources (shown as dark colours) and “other terrestrial” (including both natural and re-emission) sources (shown as light colours).

Question 3:

How are atmospheric emissions of mercury linked to methylmercury production, exposure, and bioaccumulation in terrestrial and aquatic biota and humans?

Atmospheric mercury emissions are linked to methylmercury exposure through a series of biogeochemical processes in the environment.



a. Are Canadian ecosystems responding to recent reductions in domestic atmospheric emissions of mercury?

The responses of Canadian ecosystems to decreases in domestic emissions vary among ecosystem compartments. In the past 15 years, the atmosphere has shown varying declines in mercury levels, likely in response to reductions in emissions. However, the response in fish and wildlife in Canada differs more significantly among regions and among species. Of the fish and wildlife populations studied, mercury levels had increased in 31%, decreased in 21%, and remained stable in 48%. Of all the populations that report increases, 83% are from the Arctic and the greatest increases have been seen in seabirds. Mercury levels in fish populations also vary: 50% of the populations that showed a decline were fish and seabirds from known areas of emission reductions (Great Lakes and Atlantic regions).

Whether ecosystems have responded to changing emissions is challenging to determine because mercury is transported through several compartments in the ecosystem between emissions and exposure; thus, it cannot be assessed as a simple cause-and-effect relationship. Further, the response depends on many factors affecting the ecosystem, which adds challenges to scaling information from specific ecosystems to all of Canada. Research into understanding ecosystem responses to emissions, both experimentally and through modelling, is discussed in this assessment.

Response in the atmosphere

In recent decades, inventories have reported a decline in mercury emissions domestically and, until most recently, globally, but not in all geographical regions. While measured total gaseous mercury levels have declined in Canada, there has been no significant decline in wet deposition of mercury (mercury reaching the ground through rain) reported. Canadian atmospheric mercury emissions have declined 85% from 1990 to 2010 (Table 2). Levels of mercury measured in ambient air have ranged between no decline and 26% total decline over various time periods and locations between 1995 and 2011. From 1995 to 2011 the total decline in the high Arctic was 15%; however, this is less than declines reported in temperate regions over the same time period (15-23% \pm 1-2 years). In the Great Lakes region declines are reported to range from 10 to 21% and are likely as a result of reductions in North American emissions. Interestingly, at a site close to a power plant in Genesee, Alberta there have been neither declining nor increasing trends reported in mercury levels over 7 years. Many point sources have reduced emissions over time, including the smelter in Flin Flon, Manitoba (which reduced emissions until its closure in 2009). While local mercury levels in the air near the smelter have declined 20% since the closure, they still remain approximately twice as high as those at any other monitoring site in Canada. This is likely a result of re-emissions of locally deposited mercury. As well, elevated levels of mercury in the sediments around Flin Flon have been attributed to atmospheric deposition from the smelter.

Overall, decreases in ambient mercury levels have not decreased by the same amount as Canadian mercury emissions over the past 2 decades.

This is likely because of incoming emissions from outside of Canada, as shown by model results, as well as naturally occurring and re-emitted mercury. Although Canadian, North American, and European anthropogenic emissions have declined in the past decades, recent inventories (2010) suggest that global emissions remained the same or were slightly higher than in 2005, reflecting greater emissions abroad, particularly from Asia.

In the northern hemisphere, ambient mercury levels peaked in the 1980s and then decreased to a plateau between 1996 and 2001. These trends were confirmed through simulations using the GRAHM model and primarily result from the decreases in global and regional emissions of mercury. However, more recent measurements up to 2010 show that the global mercury concentration levels have decreased more significantly than can be explained by changes in emissions alone, suggesting a shift in the biogeochemical cycling of mercury. In addition, mercury concentrations in precipitation have declined at most sites in Canada since the mid-1990s. However, the amount of wet deposition of mercury has not changed significantly, and this is influenced by trends in precipitation. Finally, mercury levels in the air are not entirely controlled by emission reductions, as they are also affected by natural emissions as well as re-emissions of anthropogenically released mercury.

Response in biota

Mercury levels in monitored fish, birds, and mammals in Canada have shown varying trends, with differences among species and geographical regions. In this report, the regions in Canada that have been most influenced by domestic emission changes are the Great Lakes and Atlantic Canada. The Great Lakes region has shown both the largest and most numerous declines in mercury levels in individual populations (40% of fish and seabird populations reported). However, more recently, studies show that some of these decreases are reversing in some species. In Lakes Superior, Huron, and Ontario, mercury levels in fish have declined an average 60% (in lake trout) and 67% (in walleye) from the 1970s to 2007. The same fish species from Lake Erie showed a similar decrease in mercury levels until the mid-1990s, when levels started to increase again. Levels of mercury in some wildlife around the Flin Flon area show no influences of local emissions. In Atlantic Canada, 63% of populations show no change, 12% have decreasing mercury levels, and 25% have increasing levels. Some of these populations are considered to be at risk from mercury exposure (Figures 3 and 4). Over the 40 years in Canada, mercury levels in wildlife and



Figure 9: Overall trends in mercury concentrations in Canadian terrestrial mammals, fish, polar bears, beluga whales, seals, seabirds, and mussels (1967–2012).

fish have shown increasing, stable, or decreasing trends, with variation among monitored species and regions (Figure 9). Overall, mercury levels have increased in 31% of the populations investigated in this report, decreased in 21%, and remained stable in 48% (note: over 50% of the populations reported on are from the Arctic region). Of all the populations that show an increasing trend, 83% are from the Arctic. While marine mammals and fish are similarly represented in this group, the greatest increases are seen in seabirds. The only Arctic population showing decreasing trends is fish, based on short-term data.

Other factors affecting mercury levels in ecosystems

The observed variation in mercury levels and trends in biota across Canada is partly due to many factors, aside from emissions, that affect mercury behaviour. These factors include physical, chemical, and biological conditions in the atmosphere, land, and aquatic systems. Mercury levels in the environment vary naturally and may change in response to multiple factors such as emissions, climate change, and acidification. Ultimately, the amount of methylmercury available for uptake drives mercury levels in biota. Land vegetation (terrestrial) systems receive mercury from the air and export a portion to rivers and lakes. In fact, mercury levels in terrestrial and aquatic systems may still be changing in response to emissions from the past century because of delayed response in the ecosystem. This delay complicates efforts to determine the response of ecosystems to changes in recent domestic mercury emissions. These effects have been investigated as part of a unique long-term mercury study, Mercury Experiment to Assess Atmospheric Loadings in Canada and the United States (METAALICUS), conducted at the Experimental Lakes Area⁹ (ELA) in Ontario. METAALICUS studied the response of a whole ecosystem when mercury loads were increased experimentally. Results confirm that reductions in mercury deposition from the air result in reductions in mercury in the fish. However, METAALICUS and other projects have also shown these reductions may be delayed because drainage

⁹ In April 2014, the Experimental Lakes Area was reopened under the name "International Institute for Sustainable Development - Experimental Lakes Area (IISD-ELA)". The work conducted for this assessment was undertaken prior to April 2014 and thus this research site is referred to as ELA in this report; future work will refer to IISD-ELA.

basins around lakes are sinks for mercury that is deposited from the air. These basins respond slowly to changes in mercury levels (over decades to centuries).

Modelling the impact of emissions on mercury in ecosystems

For this assessment, an integrated air/land/water computer model was developed to address the complexities of the relationship between mercury emissions, deposition, and, ultimately, levels in fish. The model looks at the impact on fish of changes in global and domestic mercury emissions. Changes in mercury levels in lakes are controlled by 5 factors: (1) how important the input of mercury to the lake from stream inflow is when compared with direct atmospheric deposition; (2) how long it takes for deposited mercury to go from the surrounding area into the lake; (3) how much mercury emissions have declined; (4) how close the surrounding lake area is to the changing emission sources; and (5) how important is the production of methylmercury in water column when compared to its production in sediments in the lake. Combinations of these factors dictate how fish mercury levels change over time in response to changes in emissions. Ecosystems closer to major domestic sources are more likely to show reductions in fish mercury levels in response to the reductions in domestic mercury emissions because of the greater influence of these emissions on deposition in these ecosystems.

b. If so, what are the indicators of recovery, where is it occurring, and how quickly are ecosystems responding?

Indicators such as the concentration of mercury, or other chemical elements, in teeth of Arctic marine mammals have been used to show historical changes in the environment from the onset of the industrial revolution. Analysis of teeth has shown that mercury levels in marine biota increased after the late 19th century, with the most substantial increases occurring in the mid-20th century. This is an indicator of an impact on the Arctic marine ecosystem of the several-fold increase in anthropogenic mercury emissions over that time.

Currently, the indicators that can be used to show declines in mercury levels include changes in

mercury levels in the air, aquatic, and terrestrial systems. These indicators can also show ecosystem recovery from exposure and uptake. In addition, mercury levels in species such as piscivorous fish, seabirds, and marine mammals can also be used as indicators of ecosystem recovery. How quickly fish mercury levels respond completely to changes in the ecosystem depends on terrestrial and direct atmospheric loads to the lake where the fish live, as well as on whether and where mercury concentrations in the aquatic system are transformed into methylmercury. Overall, lakes where mercury input is primarily from the air will take less time for fish mercury concentrations to respond than lakes where mercury loads from terrestrial sources are important.

In the air, mercury levels across Canada have declined as emissions have decreased, although this recovery varies among regions. Modelling results show that most of the atmospheric response to changes in domestic and global emissions takes place within 6 to 18 months, but it can take approximately 5 years for the atmosphere to equilibrate to these changes. The strongest recovery in the air is in areas close to emission sources such as in Flin Flon (Manitoba), Bratts Lake (Saskatchewan), Reifel Island (British Columbia), Point Petre (Ontario), and St. Andrews (New Brunswick), where mercury levels have declined up to 3.3%¹⁰ per year. At these sites, declines in mercury levels have occurred more quickly than at sites that are impacted mainly by regional and global emissions. For example, in the Canadian high Arctic, the rate of decrease is significantly slower (approximately half as fast) than in temperate regions. Another source of mercury in air is re-emission of mercury previously deposited on the land and oceans. Reductions in these re-emissions are expected over various time scales, depending on the surface.

One way to assess the recovery of aquatic systems is to measure changes of mercury levels in piscivorous fish and wildlife species. In particular, fish, seabirds, and common loons have been used as indicator species in Canadian ecosystems. Mercury levels in fish living in water systems that have historically received direct inputs of mercury from industrial activity have declined since the implementation of mercury emissions controls. For instance, mercury levels of fish and wildlife in the

¹⁰ Flin Flon was not included in this result

Great Lakes region in Canada have largely declined over the last 4 decades, reflecting decreased air emissions in the region. For fish not directly impacted by nearby anthropogenic inputs, the estimated rate of change in mercury levels in fish, including standard-length lake trout, walleye, and northern pike, vary considerably, ranging between -1.5 and +1.5% yr⁻¹.

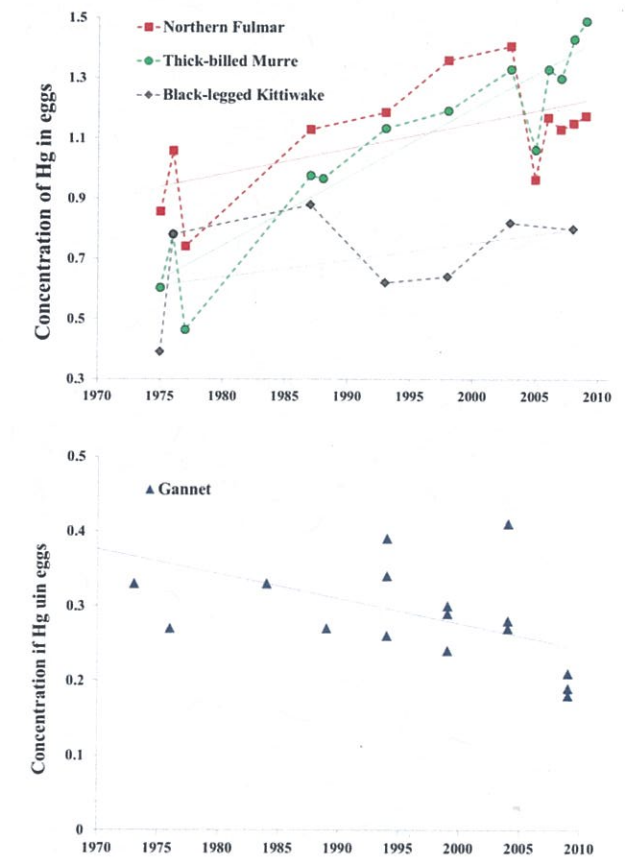


Figure 10: Change in mercury levels in eggs of 3 seabird species from Prince Leopold Island, Nunavut (left: concentration µg g⁻¹ (dry weight)), and in seabird eggs from the Gulf of St. Lawrence (right: concentration µg g⁻¹ (wet weight)). Solid lines are linear trends.

Mercury concentrations in indicator species such as seabirds in the Arctic suggest that levels are continuing to increase in the Arctic marine ecosystem; however, seabirds from other areas show decreases or stable levels, suggesting that those ecosystems are now less impacted by mercury. Dietary shifts in seabirds make the interpretation of trends more challenging. Figure 10 shows that mercury levels in Arctic seabirds have increased overall by 54% to 119% in the eggs of



black-legged kittiwakes, northern fulmars, and the thick-billed murre over 35 years. By contrast, it shows the decline in mercury levels in northern gannet eggs from the Gulf of St. Lawrence over 30 years.

In marine mammals, only beluga whales from the western Arctic show increases in mercury levels up to 2002 and declines since that time. Thus, this indicator species shows some signs of the recovery of this ecosystem over the past 10 years. However, for the most part, other marine mammal populations studied showed no signs of changes in mercury.

The integrated model developed for this assessment investigated the response time of fish mercury levels as an indicator of ecosystem recovery from changes in mercury emissions. Recovery depends on the response rates of many atmospheric, terrestrial, and aquatic processes. At the ELA, aquatic systems responded to decreases in mercury deposition by a decline in mercury levels over a long time scale. For terrestrial systems, there are no long-term records for observed mercury levels in streams, which are required to estimate their recovery time scale. The overall response time of an ecosystem is limited by those processes that respond most

slowly, and the terrestrial system is the slowest step in the overall response of freshwater fish mercury levels to changes in mercury emissions. As noted, in lakes where mercury loading is primarily from the air, fish mercury concentrations will fully balance back to lower levels more quickly than in lakes where terrestrial mercury loading is important. For example, the Great Lakes primarily receive mercury from direct deposition from the atmosphere; therefore, observed declines in mercury levels in Great Lakes biota in recent decades are likely a result of decline in mercury emissions in the region. Lakes with a mix of terrestrial and atmospheric mercury input exhibit multiphase responses, with a quick response on a scale of years and a slow second phase on a scale of decades and possibly centuries. In addition to mercury loading to a lake, mercury concentrations within the lake take time to respond. Inorganic mercury concentrations in sediments may require decades to fully equilibrate, whereas the water column can respond within months.

c. If not, what factors are confounding/masking the expectation of recovery?

Mercury levels in Canada are not driven solely by domestic emission of mercury. The mercury cycle is multifaceted; thus, there are many factors complicating our ability to directly link reductions in Canadian emissions of mercury to levels in the ecosystem and biota. The main factors are emission sources, acidification, land-use changes, urbanization, eutrophication, and climate change.

Global and US emissions are larger than Canadian emissions, which make distinguishing between domestic and foreign impacts a challenge. Input from external mercury emissions can mask the recovery of an ecosystem from changes in domestic emissions. Further, anthropogenic emissions other than mercury can cause acidification of terrestrial and aquatic systems. The resulting acidic deposition from these other emissions enhances methylation of mercury and may mask (or hide) the impact of mercury emission reduction efforts. Changes in land use also impact the amount of mercury available within the ecosystem. For instance, newly formed reservoirs release mercury from the flooded area and enable it to enter the new aquatic system, where it is methylated. As well, eutrophication driven by agriculture and aquaculture can cause nutrient enrichment and increase the methylation potential of a given ecosystem. By contrast, urbanization removes the natural landscapes that enable methylation processes.

The largest unknown is the impact of climate change on the cycling and methylation of mercury. A warming climate, as well as changes in sunlight, in the amount of organic matter, in precipitation patterns, and in the frequency and intensity of forest fires will change the dynamics of the ecosystem and food webs. These changes may have serious impacts on how mercury is methylated within the system and how it is taken up by biota. Some areas are projected to experience increased precipitation, runoff, and soil moisture levels, which would likely change the production rates and mercury loads to the system. Increased watershed nutrient loads and primary productivity in aquatic systems under warmer and wetter conditions could partially offset other factors that increase fish mercury levels. In regions such as the Arctic, changes in climate affect sea ice cover, which impacts how much mercury is transformed, deposited, and retained. Currently, it

is very difficult to make accurate statements about future national trends in mercury processes and levels in biota resulting from climate change.

d. Can predictions be made regarding the impact of future changes in atmospheric emissions on mercury levels in deposition and methylmercury levels in biota?

The impacts of changes in mercury emissions on deposition and methylmercury levels in fish are generally predicted through models. Using the GRAHM model, future changes in mercury levels in the air and in deposition have been predicted using various emission reduction scenarios from different regions such as Canada, the United States, Asia, and Europe, separately and in combination. The “best case scenario”¹¹ of worldwide controls on anthropogenic emissions resulted in predicted reductions in mercury deposition of 20%–50% among modelled ecosystems. Model scenarios involving reductions in Canadian anthropogenic emissions¹² resulted in minimal (1%) reduction in atmospheric deposition (mercury deposited from the air) in remote ecosystems, but up to 70% reductions for ecosystems close to major Canadian mercury emission sources.



A suite of process-based atmospheric, terrestrial, aquatic, and bioaccumulation models was integrated into a single framework for this assessment

¹¹ The “best case scenario” is the Maximum Feasible Technological Reduction (MFTR), which assumes that all available technological methods of reducing anthropogenic Hg emissions are implemented globally in all sectors.

¹² 90% capture rate of emissions from coal-fired facilities or 50% emission reduction for all sectors

to simulate the effects of different emission reduction scenarios on fish mercury levels in lakes. The integrated ecosystem model simulated the relationships among mercury emissions, atmospheric cycling and deposition, export to lakes from land, mercury cycling within lakes, and bioaccumulation in fish. The integrated model was applied to 5 lake ecosystems in different regions of Canada. Figure 11 shows an example of the application of the model to 2 lakes: Wabamun Lake, Alberta (a lake close to local mercury emissions from coal-fired facilities), and Lake 240, in the ELA in Ontario (a remote lake), using 2 emission scenarios: (1) the “best case” scenario of emission reductions and (2) “no additional emissions controls” scenario. The model predicted that, in the absence of

additional emissions controls above current levels, in the future fish mercury concentrations will rise above current levels in all the lakes modelled. Implementing any of the emissions controls scenarios resulted in lower future fish mercury levels compared to the “no additional emissions controls” scenario (up to 30% for the lakes investigated after 150 years for the “best case” scenario). While the models showed that emissions controls are beneficial compared with no action, even the best case mercury emissions controls would not lower fish mercury concentrations in all watersheds below current levels. If mercury deposition decreased modestly, fish mercury levels would decline in some ecosystems systems, remain stable in some ecosystems, or continue to rise and stabilize at higher levels in others. Therefore,

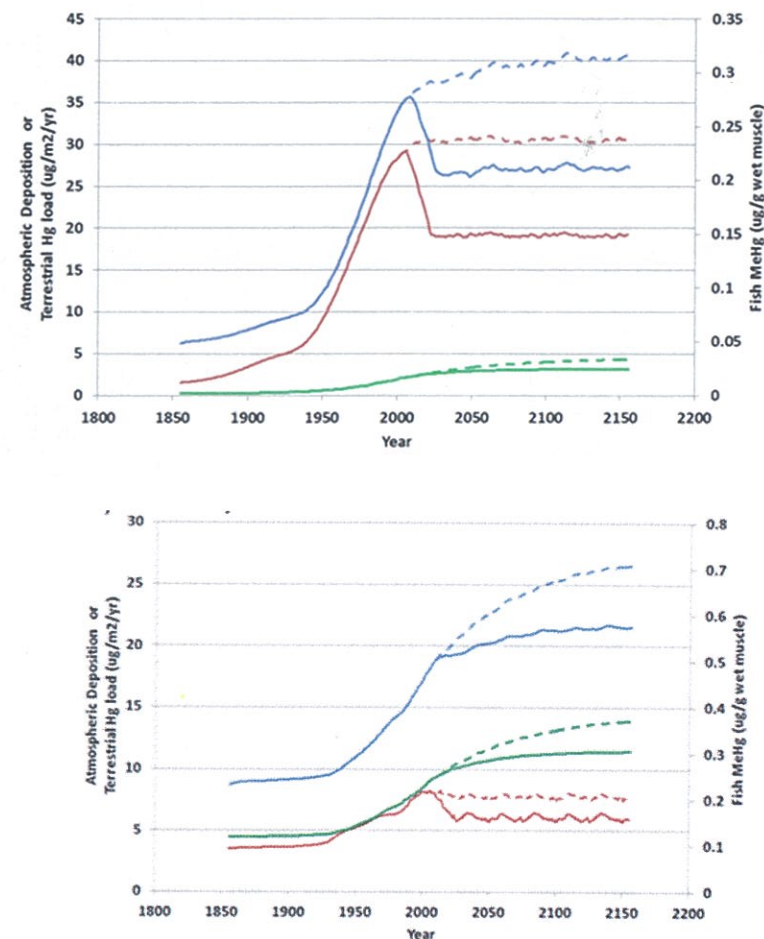


Figure 11: Predicted atmospheric mercury deposition (red), mercury levels in lake inflow streams (green), and fish mercury levels (blue) from the year 1840 to 2156 in 2 lakes investigated. Solid lines are associated with the “best case scenario” for emissions controls, applied starting in 2007, and the dashed lines are associated with the scenario in which no additional emissions controls are implemented. Top: Wabamun Lake, Alberta (close to mercury emissions from coal-fired power plants); bottom: Lake 240, Experimental Lakes Area, Ontario (remote lake).

significant global-scale reductions in mercury emissions would be required to broadly reduce fish mercury concentrations below current levels across Canada.

The ecosystem modelling conducted in this study and the results presented here consider only the impact of changes in anthropogenic emissions on mercury levels in the ecosystems. Other environmental changes, such as land use, climate, other air pollutant emissions and environmental chemistry or biology, can alter the biogeochemical transformations of mercury in the ecosystems and, therefore, influence mercury levels in Canadian ecosystems.

Question 4:
What are the linkages between other air pollutant emissions (e.g., acidifying emissions, greenhouse gases, etc.) and mercury accumulation in biota?

Atmospheric emissions of greenhouse gases and acid precursors can be linked, under some circumstances, to enhancement of methylmercury in aquatic ecosystems and subsequent accumulation of mercury in biota.



Mercury goes through a complex cycle in the ecosystem from emission to accumulation in biota. Many factors affect the multiple processes throughout the cycle. The main driver of Hg accumulation in biota is the formation and availability

of methylmercury in the ecosystem. The main environmental factors that affect methylation of mercury include temperature, pH, and sulphur, nitrate, and oxygen conditions, all of which are affected by industrial emissions.

Increases in greenhouse gas emissions have resulted in changes in the global climate, with temperatures predicted to increase across Canada in the 21st century. Climate change could act to either increase or decrease fish mercury levels, depending on the conditions of the ecosystem. Hence, it is impossible to make simple overarching statements about expected national trends in fish mercury levels as the climate changes. Regions that are projected to be warmer and experience increased precipitation, runoff, and soil moisture levels would likely experience increased mercury loading from the atmosphere and terrestrial systems. In turn, this may increase microbial activity and the rate of production of methylmercury. On the other hand, under warmer and wetter conditions, other factors (increased watershed nutrient loads, primary productivity, and faster growth rates of fish in aquatic systems) may offset the increases in fish mercury levels. Sensitive areas such as northern Canada are already witnessing effects of a warming climate, predominantly through changes in sea ice patterns, which may affect the deposition of mercury in the spring. Changes in temperature are expected to accelerate in the future, and precipitation and moisture levels are expected to increase. Hence, mercury cycling and bioaccumulation (especially in the Arctic) could be affected by increases in greenhouse gases and the resulting changes in global and regional climate.

Acidification of Canadian waters has contributed to the current high concentrations of mercury found in fish and other biota in some regions of the country. More acidic (lower pH) aquatic conditions generally lead to higher methylmercury levels in biota. Refining fossil fuels, burning coal, and metal smelting emit mercury and associated acid precursors, such as sulphur dioxide and nitrous oxides, to the air. Acid deposition from these sources leaches mercury from soils to aquatic systems and can cause an overall decrease in water pH. The lower pH and higher concentrations of metals found in acidic waters increase the uptake of toxic metals in biota, affecting the growth, survival, and reproduction of fish, invertebrates, and primary producers and pose a major threat to aquatic biodiversity. Further, bacteria

in lake sediments produce methylmercury when little to no oxygen is present (for example, because of eutrophication of lakes). Therefore, measures aiming to control acid precursor emissions will indirectly contribute to reducing mercury bioaccumulation in aquatic biota. The acidification of aquatic systems that lack properties to buffer acid is long-lasting and may continue for decades after acid emissions controls have been implemented. It is unclear how much of the recent decreases in mercury concentrations in fish in Canadian lakes can be attributed to decreased acid emissions or to other environmental factors. However, controlling acid emissions in Canada will limit atmospheric mercury emissions, which will ultimately lead to reduced mercury methylation in these aquatic systems.

Question 5:

How might changes in other human activities (e.g., land-use practices) affect the distribution of mercury between environmental compartments, methylmercury formation, and the accumulation in biota?

Human activities such as logging, reservoir impoundment, mining activities, and activities causing eutrophication can affect the transport of mercury, increase the methylation of mercury, and enhance mercury bioaccumulation in biota.

Human activities unrelated to mercury emissions can induce long-term environmental changes influencing mercury transport, methylation, and bioaccumulation in aquatic organisms. These activities include logging, mining, reservoir creation, agriculture, and urbanization (including sewage). These human factors may alter not only the bioavailability of recently released anthropogenic mercury but also that of natural mercury already present in the

environment, which would otherwise be unreactive if left undisturbed.

Logging activities have important consequences for mercury input to nearby small lakes, where increased levels of mercury in biota have been reported. Smaller lakes are more impacted than larger lakes by soil disturbance resulting from logging activities. In larger lakes, other environmental activities tend to offset these disturbances. Mining activities have been responsible for long-lasting mercury contamination of aquatic organisms in productive lakes. Mercury from mining is generally released in an insoluble inorganic form, and certain aquatic conditions are required for the mercury to be methylated. However, the combination of mining, eutrophication resulting from urbanization, and extensive logging on the watershed of small lakes may result in optimum conditions for methylating large amounts of mercury in surface sediments, and these conditions may last for several decades. Thus, while mining may not be a direct source of methylmercury, mining should be limited to areas far from lakes affected by additional conditions or activities that enhance methylation. In particular, attention should be placed on lakes and rivers located near past and present gold and mercury mining towns where local residents fish.

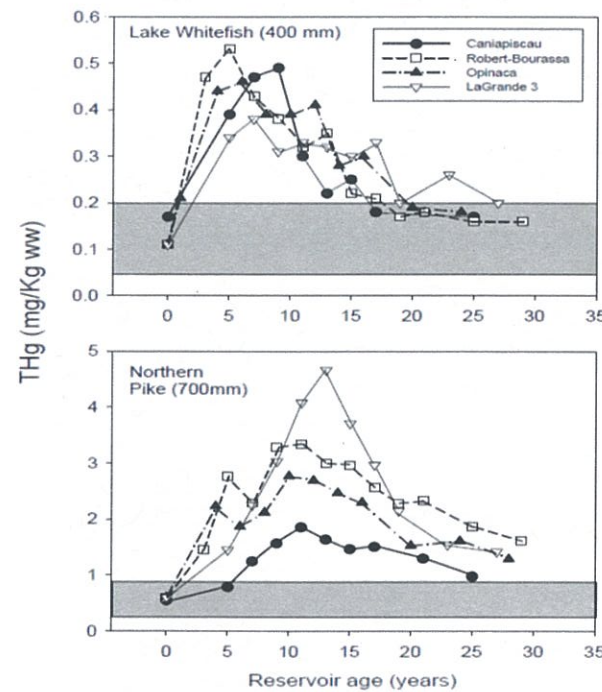


Figure 12: Mercury levels in fish from newly created reservoirs in northern Quebec.

The creation of reservoirs often increases concentrations of methylmercury in fish and other biota. New reservoirs result in large areas of terrestrial vegetation being flooded, leading to decomposition of the vegetation and stimulation of microbial activity, including bacteria that methylate mercury. The establishment of reservoir impoundments creates a sharp increase in methylmercury levels in predatory fish, which continues for several decades (20–30 yr), before levels start to decline to normal levels (Figure 12 as an example). Concentrations of methylmercury in fish populations within reservoirs often exceed consumption guidelines, and human exposure to this contaminant through fishing has caused concern in Canada, especially in northern communities. As well, levels of mercury in fish are frequently elevated in rivers and lakes downstream of new reservoirs. In whole-ecosystem experiments conducted at the ELA, the creation of small experimental reservoirs resulted in large increases in methylmercury.

Eutrophication is caused by inputs of nitrogen and phosphorus to waterways, largely from agricultural fertilizer and manure, human sewage, and a variety of urban activities. Eutrophication can stimulate productivity in aquatic systems, which leads to the enhancement of mercury methylation. The levels in organisms living in most highly eutrophic systems are low, but moderate eutrophic conditions are responsible for higher rates of mercury methylation and uptake by aquatic organisms that can last for several decades.

Overall, several land-use activities affect mercury bioaccumulation in aquatic organisms. Human vulnerability to the presence of mercury in Canadian aquatic systems is a real concern. In planning land uses that can increase mercury levels in waterways, special emphasis should be placed on the lakes and rivers most frequently used for fishing and hunting, including even occasional sport fishing, food sources for native communities, and subsistence hunting.

Question 6:

In light of our current understanding of mercury in the Canadian environment, where, and to what extent, do we need to continue atmospheric and effects monitoring?

Monitoring of mercury should continue in Canada.

Monitoring of air levels and atmospheric deposition needs to be increased.

Long-term monitoring of predatory fish and birds, as well as some terrestrial and marine mammals, needs to be increased.

Long-term monitoring is necessary to know whether changes in mercury emissions are having an impact on the mercury levels in Canadian ecosystems. To adequately respond to long-term impacts on the Canadian environment, it is recommended that: 1) current efforts to monitor mercury in the atmosphere, in deposition, in lake/marine environments, and in biota continue or increase; 2) selected research efforts for mercury in abiotic (non-living) and biotic (living) systems be initiated or increased to target areas and species that have been identified to be at risk and 3) new technologies for monitoring must be developed to increase spatial coverage and minimize, when possible, costs of monitoring. It should be taken into consideration that multidisciplinary research efforts and monitoring of trends and effects should be combined and undertaken at the same locations, where possible.

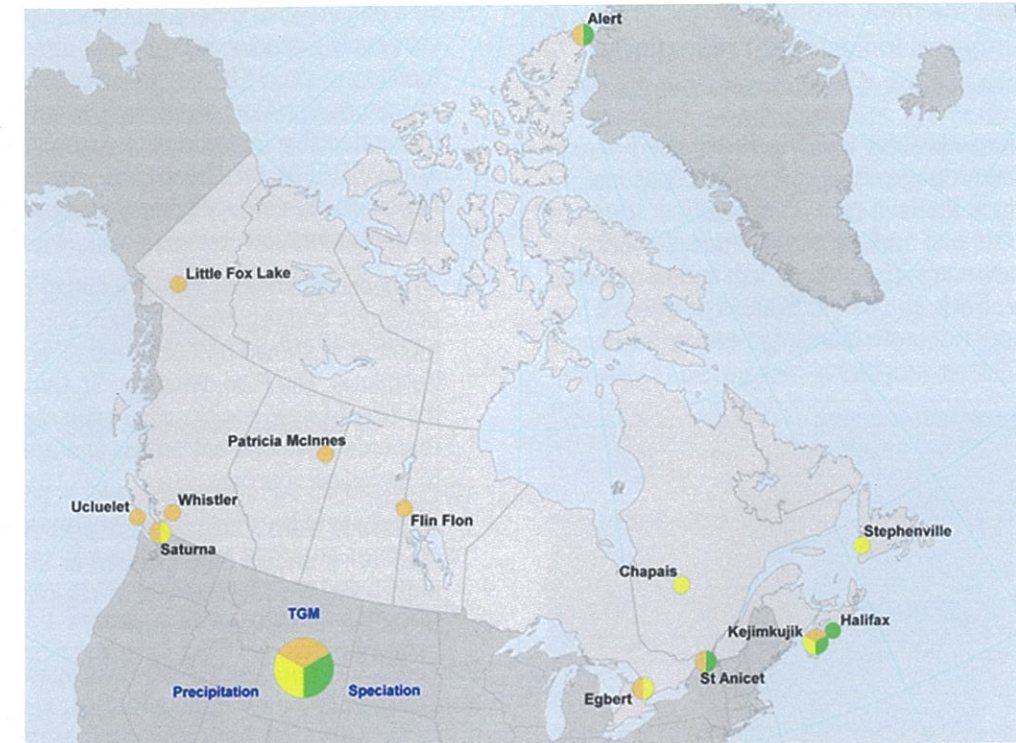


Figure 13a: Map of the 2014 atmospheric mercury monitoring and wet deposition (precipitation) sites in Canada.

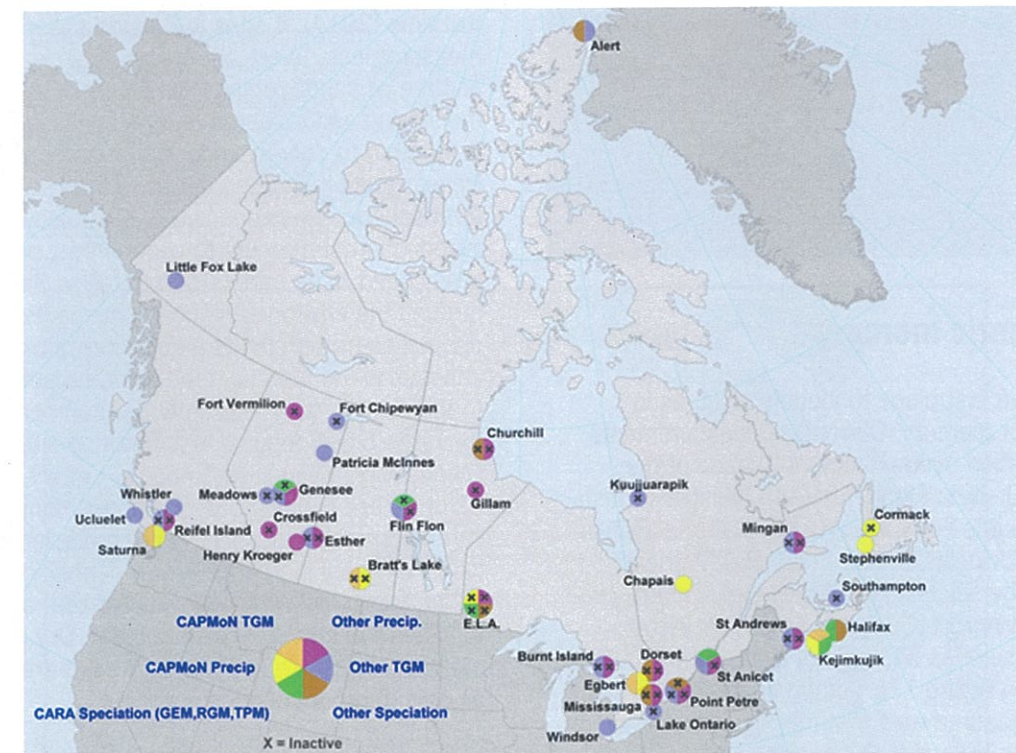


Figure 13b: All sites of atmospheric mercury monitoring in Canada from 1995 to 2014. A full list of the time coverage for each site can be found in the full science assessment Chapter 4: Section 4.3.

a. What are the most promising environmental indicators of reductions in anthropogenic emissions of mercury?

Environmental indicators that have been used to monitor anthropogenic mercury reductions in Canada include levels in air; wet deposition; lakes, rivers, and oceans; surface emissions; sediments; wetlands; mammals, piscivorous fish and birds; and insectivores. Each of these indicators provides a different aspect of understanding mercury issues in the Canadian environment.



Atmospheric mercury

The air is the first place to identify changes in emissions of mercury. Currently¹³, measurements are in operation by Environment Canada at the following 10 sites: Alert (Nunavut), Whistler (British Columbia), Little Fox Lake (Yukon), Saturna (British Columbia), Ucluelet (British Columbia), Patricia McInnes (Alberta), Flin Flon (Manitoba), Egbert (Ontario), St Anicet (Quebec), Kejimikujik (Nova Scotia); these sites and type of measurements made are shown in Figure 13a. A map of all atmospheric mercury measurements that have been collected in Canada over various time periods between 1995 and 2014 is shown in Figure 13b.

¹³ September 2014

- 1) To measure atmospheric input/deposition into vulnerable Canadian ecosystems atmospheric monitoring should be continued or enhanced at Kejimikujik, Flin Flon, Ucluelet, International Institute for Sustainable Development - Experimental Lakes Area (IISD-ELA), the Great Lakes region, the Arctic region, resource development areas, and areas close to emission sources.
- 2) To measure ambient levels resulting from domestic and regional emission sources monitoring should be continued or enhanced at Kejimikujik, Flin Flon, Windsor, St. Anicet, Saturna, the Great Lakes region, the Arctic region, resource development areas, and areas close to emission sources.
- 3) To assess transboundary transport of mercury monitoring should be continued or enhanced at Kejimikujik, Whistler, the Arctic region, and the Great Lakes region.

Mercury is neither created nor destroyed but is only transformed in the environment; thus, several forms of mercury (termed *speciated mercury*¹⁴) must be investigated. Current measurements of speciated atmospheric mercury provide some indication of the transformation and deposition of mercury. At this time (2014), 4 sites in Canada collect these measurements: Alert, St. Anicet, Kejimikujik, Halifax, and the oil sands region (See Figure 13a). More monitoring and research to identify these species is required to entirely understand atmospheric transformation and deposition of mercury. Atmospheric deposition is the main pathway for the introduction of mercury to watersheds, and thus air levels need to be understood to follow the pathways through the environmental compartments. Wet deposition of mercury is a good indicator of changes in the mercury load from the atmosphere to the environment. Currently, Environment Canada operates 5 wet-deposition monitoring sites: Stephenville, Kejimikujik, Chapais, Egbert, and Saturna (see Figure 13a). Additional monitoring is recommended in areas where modelled trends indicate recent increases in wet deposition, notably in the Arctic, the west coast of Canada, and areas of increased resource development. Dry deposition measurements are not yet routine but are included as part of recommended activities.

¹⁴ Currently, there is uncertainty in identifying which Hg compounds make up the various atmospheric Hg species; thus, they are defined operationally. There are also limitations in the current measurement methods.

New technologies are emerging to aid with monitoring and evaluating declines in mercury emissions. Passive samplers (samplers requiring no power) are being developed to increase spatial coverage in Canada to better assess mercury levels across the country. As well, new techniques employing the isotopic fractionation of mercury are being developed to assess source regions of atmospheric mercury. The research and development for these potential monitoring tools should be encouraged for future implementation.

Terrestrial and aquatic mercury

Mercury found in lake sediments, ice cores, forests, and peat bogs is a good indicator of changes over time. However, the information gathered from these samples does not allow differentiation between mercury that is produced through deposition or biogeochemical processes. Lichen and mosses are the only terrestrial vegetation that absorb and accumulate appreciable amounts of mercury, although their use as a good indicator for mercury is uncertain. Currently, there is a lack of programs, outside of the METALICUS program, investigating terrestrial system mercury deposition indicators in Canada. Further, there are few long-term measurements of mercury in lakes, rivers, and oceans in order to ascertain changes in deposition or inputs from watersheds. It is recommended that terrestrial and aquatic monitoring be initiated in conjunction with other measurements to allow integration of information from all systems.

Biota

Monitoring mercury in biota in Canada should reflect the following overall objectives: (1) monitoring the species that are most likely to show adverse health effects due to mercury exposure; (2) monitoring mercury in species that would reflect changes in atmospheric mercury deposition, and (3) monitoring mercury trends that are important in consumption and exposure. Further, the key species chosen for long-term monitoring should meet the following criteria: (1) be resident in Canada, (2) accumulate measurable concentrations of mercury, (3) be easily sampled, and (4) have a reasonably stable or small home range.

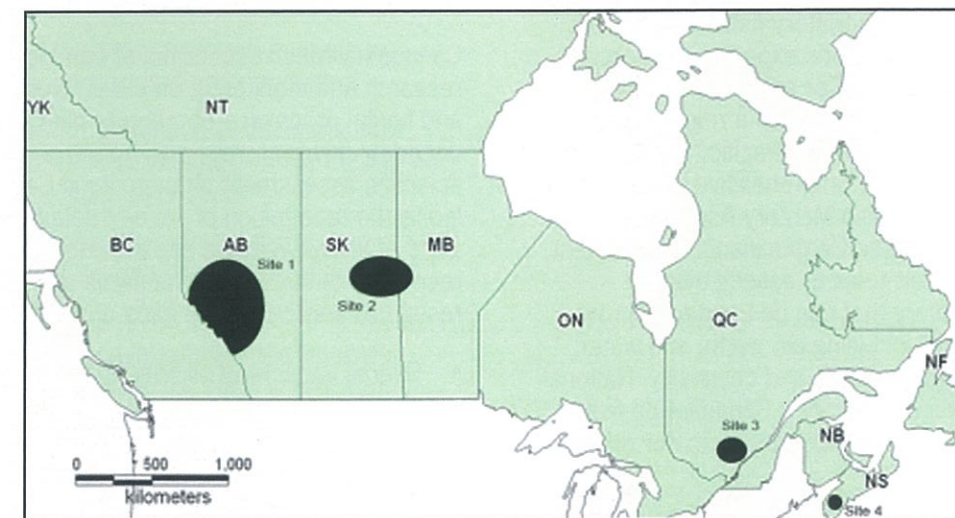


Figure 14: Locations of CARA fish and wildlife mercury study sites.

Bearing these considerations in mind, several animal species are recommended for long-term mercury monitoring in Canada, specifically for freshwater (mink, common loon, walleye, northern pike, lake trout, Arctic char), marine (seabirds, mussels; marine fish, seals, beluga whales, polar bears), and terrestrial (caribou, little brown bat) environments.

Piscivorous fish are good indicators of methylmercury exposure, in particular predatory fish such as lake trout, northern pike, and walleye. The common loon is perhaps the most studied avian species with respect to methylmercury toxicology in Canada. New mechanisms need to be developed throughout Canada to encourage monitoring of mercury concentrations using consistent methods in fish and wildlife. Such mechanisms should be coordinated among federal, provincial, territorial, and Aboriginal government agencies, universities, and non-governmental organizations.

For monitoring of aquatic ecosystems, multidisciplinary work at recommended sites should be undertaken. The first CARA Mercury Science Program conducted research on biota at the 4 sites shown in Figure 14. We recommend that enhanced measurements be undertaken at Flin Flon, IISD-ELA, Kejimikujik, sites in Ontario/Quebec and at the ELA.

b. What are the most promising indicators of ecosystem recovery?

Whole-system monitoring of mercury over time is a valuable method to assess the changes in ecosystems and their recovery from mercury exposure. Mammals, predatory fish and sea birds are good indicators of biotic exposure to mercury in aquatic environments. For example, sea birds are currently being monitored on a regular basis by Environment Canada in the Pacific, Atlantic and Arctic marine regions. Comprehensive studies such as the Great Lakes Basin Mercury Assessment and the Canadian Arctic Contaminants Assessment Report are excellent tools to assess overall ecosystem recovery that can be used to improve integrated models including air, earth, and water, as well as biology, geology, and chemistry. National-scale investigations, such as a Canada-wide fish survey for mercury are a valuable indicator of recovery.

An effective national mercury monitoring program could make use of existing programs for mercury monitoring and for sampling biota for other purposes (other contaminants, biological indices, and health monitoring). This type of national coordination would include only a few changes to existing protocols and could operate at minimal extra cost. Local hunters, trappers, fishers and provincial monitoring programs of sport fish also provide a valuable and cost-effective resource for sample collection; working with them has the added benefit of involving stakeholders in these monitoring programs. A strong, coordinated, national leadership that engages partners from all aspects of wildlife management, research, and use will be the key to the success of this initiative.

Question 7:

Where, and on what, should we focus future research efforts for mercury?

Future research efforts for mercury in Canada should build on currently successful programs and should emphasize the development of nationally led integrated programs that address priority gaps of knowledge

Canada has been successful at conducting research and monitoring on the environmental and health processes of mercury over the past decades; however, many unknowns remain. This scientific assessment on mercury in Canada has led to the recognition of several detailed priority gaps of knowledge and has provided scientific recommendations for focus areas and future research. Some of these gaps are as follows:

- Overall impacts of climate change and land-use changes on the mercury cycle remain uncertain
- There remains a lack of adequate, long term, coordinated, integrated and dedicated monitoring of mercury in Canada for air, water and biota.

- An increase in detailed information on reported emissions to the National Pollutant Release Inventory is required
- There is a shortage of knowledge on emissions of mercury from surfaces and the impact of these emissions and re-emissions on Canadian inventories
- There is a lack of understanding of the factors affecting methyl mercury production and promotion into aquatic food webs in Canadian ecosystems
- Mercury dynamics in the terrestrial ecosystem represent the highest uncertainty in Canadian ecosystems
- Characterization of atmospheric mercury species and their deposition remains unknown; this continues to limit predictive capabilities of current models.
- The number of exposure studies of mercury needs to be increased in infants and children less than 6 years of age, particularly for First Nations infants,
- There is a lack of information on the relationship between methyl mercury exposure and cardiovascular and renal diseases, and immunologic and carcinogenic effects

Several recommendations from this assessment report are as follows:

- An effective nationally coordinated mercury monitoring program for sampling key indicators should be initiated
- Integrated ecosystem research on mercury needs to be coordinated and conducted
- A more detailed evaluation of the impacts of climate and land-use changes on the cycling and uptake of mercury is required
- Detailed process research on deposition, terrestrial and ocean cycling, methylation and surface emissions should be prioritized
- A comprehensive evaluation of the mercury emissions reported to the NPRI is required
- Continued biomonitoring and follow-up studies to monitor trends of methyl mercury exposure is recommended, especially for vulnerable populations

- Emphasis on proper communication of the risks of mercury exposure and the nutritional and socioeconomic benefits of fish and traditional wildlife food consumption should be made

A detailed summary of the gaps of knowledge and recommendations for future research can be found in Chapter 15.



ASSESSING MERCURY IN CANADA

The Science Assessment is structured to follow mercury through the ecosystem from source to sink. It begins with anthropogenic emissions of mercury, followed by a discussion of the many processes that mercury undergoes, including surface exchange, atmospheric, aquatic, terrestrial, and marine processes. A discussion of how human activities impact mercury dynamics is followed by a description of the modelling work that depicts the ecosystems response to mercury inputs. Spatial and temporal trends of mercury levels in biota are presented and are followed by an analysis of the biological effects of mercury and the ecological risk of mercury to select species. The assessment concludes with an analysis of the human exposure to mercury, health effects and risk management measures in Canada.

Highlights of individual chapters

Chapter 2: Releases of Mercury Into Air and Water From Anthropogenic Activities in Canada

Coordinating author: Gregor Kos

In 2010, Canadian mercury emissions were reported to be 5 300 kg to air and 240 kg to water. Canadian air emissions are small in comparison with those from other major mercury-emitting countries (for example, approximately 35% of US levels in 2008 and 1% of levels in China in 2010). Releases to air and water in Canada have decreased from 1990 to 2010 by 85% for air and about 50% for water. While these numbers reflect significant decreases, there remains considerable uncertainty in these estimates (up to 50% uncertainty for legacy emissions). Control technologies that have been implemented in Canada to reduce emissions for a variety of pollutants have resulted in the lowering of mercury emissions. Canadian mercury emissions are expected to stabilize in the future.

Chapter 3: Surface Fluxes

3a: Factors Affecting Mercury Emissions from Canadian Soils

Coordinating author: Nelson J. O'Driscoll

Mercury is emitted naturally from soils to the air. These emissions are an important part of the global mercury cycle, contributing an estimated 700–2 000 Mg yr⁻¹ to the global atmosphere. Mercury emissions from Canadian soils depend on the make-up and mercury content of the underlying geology. Emissions range from -0.3 to 91.8 ng m⁻² h⁻¹. Currently, accurate national estimates of mercury emissions and re-emissions from soils to the air cannot be made because of a lack of empirical data; thus, estimates are based on mercury cycling models. Of the few soils studied in Canada, those in certain areas of Ontario and British Columbia have much higher emissions of mercury than study locations in the United States, Brazil, and Sweden. In fact, some mineralized soils and shale rock from Ontario and cinnabar from British Columbia have the highest mercury emissions measured from any soils in the world. By contrast, background and agricultural soils in Ontario and Nova Scotia have the lowest mercury emissions of soils that have been studied to date. Factors that affect the emission of mercury from soils include soil moisture and temperature, solar radiation, organic matter content, and microbes in the soil.

3b: Total Mercury Concentrations in Stream and Lake Sediments Across Canada

Coordinating author: Paul A. Arp

Mercury levels in stream and lake sediments vary across Canada by region and from one location to another. Mercury concentrations in sediments decrease from south to north, are low in barren and ice-covered landscapes, and are somewhat correlated with the modelled atmospheric mercury deposition patterns. Levels tend to be high in areas where substantial deposits of natural mercury erode into the surfaces and stream banks. Sediment mercury levels are highest downstream from current and past mining and smelting activities and lowest in the Arctic and high alpine areas. Mercury accumulations differ from stream to lake sediments, with the latter containing more organic matter, thus enabling Hg methylation and thereby stimulating MeHg uptake by biota.

3c: Mercury in Forest Soils and Vegetation, Including Mosses and Mushrooms – A Case Study

Coordinating author: Paul A. Arp

This chapter summarizes how mercury deposited from the air accumulates in undisturbed forested areas, using a recent case study. The accumulation of mercury gradually increases to areas such as canopy foliage, mosses, fungal mycelia, or soil substrates with increasing exposure time. While some fungi (such as boletes) are mercury hyper-accumulators, others (such as chanterelles) are not; the difference is due to increased mycelial longevity and extent. Mercury concentrations increase sharply within the accumulating forest litter, and mercury generally remains within the mineral soil for 1 000 or more. Local mercury sources from geological processes further add to the mercury loads in forest soils and vegetation. However, root uptake of mercury by forest vegetation and transfer of this mercury into wood is low. As a result, most of the mercury in forested catchments remains in the forest soil and litter.

Chapter 4: Atmospheric Processes, Transport, Levels, and Trends

Coordinating author: Alexandra Steffen

Considerable research, monitoring, and modelling have been conducted to understand atmospheric processes affecting mercury in Canada. Mercury undergoes several chemical and physical transformations in the air that lead to enhanced deposition. The Arctic is especially vulnerable to mercury deposition because of its unique chemistry, which results in precipitation of mercury from the air to the snow and ice during the spring. While measured levels of mercury have decreased since 1995 across Canada, the decreases are not the same in all regions. Greater decreases are found in regions that have experienced large decreases in anthropogenic emissions such as urban areas, Flin Flon, Manitoba, and the Great Lakes region. Levels of mercury in precipitation have also declined at most sites in Canada since the mid-1990s. Wet deposition amounts across Canada were simulated for 2006 and were fairly uniform across the country except for localized areas of high mercury deposition along the west coast and in coastal areas in the western Arctic and sub-Arctic. Using modelling, it is estimated that 40% of the deposition

in Canada comes from worldwide anthropogenic emissions and 60% from other terrestrial and oceanic emissions (including geogenic emissions/re-emissions of previously deposited mercury). From the model, it is estimated that over 95% of the anthropogenic mercury deposited in Canada comes from sources outside of the country (40% from East Asia, 17% from the United States, 8% from Europe, and 6% from South Asia). In northern and western Canada, the total contribution to annual deposition from anthropogenic and other terrestrial emissions from East Asia (24 to 26%) is twice as high as the total contribution from the United States (7 to 12%). In comparison, in eastern Canada the total contribution from anthropogenic and other terrestrial emissions from East Asia (20 to 23%) is comparable to the total contribution from the US (15 to 22%).

Chapter 5: Mercury Fate and Methylation in Terrestrial Upland and Wetland Environments

Coordinating Author: Vincent St. Louis

This chapter describes the current state of knowledge about the transport, transformation, and fate of mercury in undisturbed terrestrial ecosystems in Canada. The chapter highlights the complex array of factors that ultimately control methylmercury production and transport to water bodies. Mercury deposited from the air remains in vegetation until it enters upland and wetland soil pools, where it may be stored for long periods of time or methylated and transported downstream. This chapter also highlights the uniquely Canadian processes controlling mercury accumulation and release from snowpacks, as well as changes in soil mercury storage due to wildfire.

Chapter 6: Mercury Fate and Methylation in Freshwater Aquatic Ecosystems

Coordinating Author: Vincent St. Louis

In Canada, ponds, wetlands, and small shallow lakes tend to have higher methylmercury concentrations than larger, deeper lakes. Methylation (methylmercury production) is carried out primarily by micro-organisms such as sulphate-reducing bacteria, iron-reducing bacteria, and methanogenic archaea. Demethylation (methylmercury destruction) can be caused by photochemical or microbial processes and is important for reducing

methylmercury available to aquatic organisms. Methylation of mercury is determined by how much mercury is available to methylating micro-organisms and how efficiently the micro-organisms can convert mercury to methylmercury. Production of methylmercury in bottom sediments and the water column, as well as inputs of methylmercury from wetlands, are the primary sources of methylmercury in lakes. Inputs of methylmercury from upland terrestrial catchments and the atmosphere are less important. Photochemical destruction in lake waters and loss through outflows are the primary mechanisms for removing methylmercury from lakes, which helps to decrease exposure of aquatic organisms and foodwebs.

Chapter 7: Mercury in the Marine Environment: Processes and Levels

Coordinating author: John Chételat

Marine animals are important dietary items that expose many Canadians who rely on them as a major food source to methylmercury. Mercury from anthropogenic emissions and natural sources enters Canada's marine environments by long-range atmospheric transport, ocean currents, coastal erosion, and rivers. The relative importance of these pathways of mercury transport differs among marine ecosystems in Canada. Methylmercury production in the marine water column is likely important, and, in coastal regions, sediments are also production sites. Methylmercury is found in seawater at ultra-low levels; however, its biomagnification through long food chains in the marine environment can result in elevated concentrations in predatory fish, mammals, and seabirds.

Chapter 8: Influences of Anthropogenic Activities on Mercury Transport, Methylation, and Bioaccumulation

Coordinating author: Marc Lucotte

In addition to point-source releases of mercury and atmospheric deposition, several anthropogenic activities may also influence its transport, methylation, and bioaccumulation in aquatic organisms. These activities therefore contribute to mercury levels in terrestrial and aquatic environments in Canada. This chapter describes the effects of anthropogenic activities such as

land use and land-use changes, eutrophication, acidification, and climate change. These may affect the dynamics of recently released anthropogenic mercury and of natural mercury in the environment. Reservoir impoundments will continue to contribute to enhanced mercury levels in predatory fish for several decades. Mining activities are responsible for long-lasting mercury contamination of aquatic organisms, especially in nutrient-poor lakes). Eutrophication leads to enhanced growth rates in fish and higher mercury biodilution. It therefore does not lead to increased methylmercury levels in aquatic organisms except in newly, impounded reservoirs. Acid emissions and deposition can lead to acidification of lakes, which leads to increased methylmercury levels in aquatic systems and biota. The predicted influences of climate change on the mercury cycle could increase or decrease mercury levels in fish, depending on ecosystem conditions. The areas in Canada most vulnerable to the impact of climate change on mercury processes are the sub-Arctic and the Arctic.

Chapter 9: Mercury Cycling in Ecosystems and the Response to Changes in Anthropogenic Mercury Emissions

Coordinating author: Ashu Dastoor

A suite of computer models for atmospheric, terrestrial, aquatic, and bioaccumulation processes was integrated into a single framework and used to simulate the effect of different emission reduction scenarios on fish mercury levels in Canadian lakes. The size of change and the time required for fish mercury concentrations to fully respond to emission reductions varied among ecosystems. The model predicts that, without additional emissions controls, fish mercury levels will rise above current levels in all lakes investigated. Emissions controls will result in lower future fish mercury levels compared with no emissions controls in the lakes investigated. However, lakes will take years to centuries to fully respond to emissions reductions, depending on the characteristics of the catchment. The "best case scenario" of worldwide anthropogenic emissions controls (all available methods of mercury emission reduction) result in a 20–50% reduction in mercury deposition to ecosystems and will lower fish mercury levels up to 30% after 150 years when compared with the "no emission reductions" scenario. However while beneficial, the "best case scenario" would

not decrease fish mercury concentrations in all watersheds below current levels. Mercury levels will decline in some ecosystems systems, remain stable in some systems, and continue to rise and stabilize at higher levels in others. Greater global-scale reductions in mercury emissions are required to broadly reduce fish mercury concentrations below current levels across Canada.

Chapter 10: Mercury in Terrestrial and Aquatic Biota Across Canada: Geographic Variation

Coordinating author: Neil Burgess

Data on mercury concentrations in Canadian plants and animals have been collected for decades. More mercury data exists for animals than plants, and more data for aquatic animals than terrestrial animals. Predatory fish and wildlife at the top of freshwater and marine food webs generally have the highest mercury concentrations due to biomagnification. In the southern portion of Canada, mercury concentrations generally increase from west to east across the country. Mercury concentrations in common loon, bald eagle, great blue heron, osprey, lake trout, walleye, northern pike, whitefish, and yellow perch all tended to be highest in southeastern Canada. A different geographic pattern was observed in the Arctic. Mercury concentrations tended to be higher in the western and high Arctic for ringed seal, polar bear, and beluga whales (with a few exceptions).

Chapter 11: Mercury in Terrestrial and Aquatic Biota Across Canada: Temporal Variation

Coordinating Author: Mary Gamberg

This chapter presents the current knowledge of changes over time in mercury concentrations in biota in Canada. No overall consistent trends were seen, geographically or by trophic position. For example, mercury concentrations are increasing in seabirds in the high Arctic but not in marine mammals or predatory fish in that area, while mercury concentrations remain relatively constant in all but one colony of seabirds on the Atlantic coast. Mercury concentrations in wildlife may be affected by small-scale, local drivers (such as the introduction of zebra mussels into the Great Lakes),

large-scale climatic drivers (perhaps related to the Pacific Decadal, Atlantic or Arctic Oscillations) or complex interactions of both. Increasing mercury concentrations, seen in some populations, may be cause for concern (seabirds from Prince Leopold and Coats Island, burbot from Fort Good Hope, and burbot and lake trout from Great Slave Lake). Other populations that have shown decreasing or generally stable trends in mercury concentrations in the past have exhibited an increasing trend in recent years (such as porcupine caribou, lake trout from 2 lakes in Yukon, sea-run char from Cambridge Bay and Nain, beluga whales from Hudson Bay and the western Arctic, ringed seals from Arviat, and mussels from the Gulf of St. Lawrence).

Chapter 12: Health Effects of Mercury in Fish and Wildlife in Canada

Coordinating author: Anton M. Scheuhammer

In many aquatic environments in Canada, the average mercury levels in biota are high enough to be of concern. The species at greatest risk for elevated mercury exposure are large predatory fish and fish-eating mammalian and avian wildlife. Elevated mercury exposure in breeding common loons and the fish that they feed on is found mainly in semi-remote lakes and reservoirs in eastern Canada, including Ontario, Quebec, and Nova Scotia, with nutrient-poor, low alkalinity, low pH conditions, or periodic flooding of wetlands. Fish and wildlife populations that are at risk would likely benefit from further reductions in industrial mercury emissions, which would decrease the deposition of new mercury available for methylation and bioaccumulation. Reduction in environmental methylmercury production would eventually lower mercury exposure and accumulation in high-trophic-level fish and wildlife species associated with mercury-sensitive aquatic food webs.

Chapter 13: Assessment of Current Mercury Risks to Piscivorous Fish and Wildlife in Canada

Coordinating author: Neil Burgess

Risk of mercury exposure for common loons and predatory fish was calculated based on estimated mercury concentrations in the prey fish they consume in over 1 900 lakes across Canada.

The results indicated potential risk to common loon behaviour in 36% of the study lakes and to reproduction in 10%. Similarly, the findings indicated potential risks from mercury exposure to reproduction in predatory fish in 82% of the study lakes and to health in 73%. For both loons and fish, the risks were greatest in southeastern Canada in areas of extensive forest cover, elevated deposition of atmospheric mercury, and poorly buffered soils. There was greater uncertainty associated with the assessment of mercury risks to fish than to loons, because there are fewer high-quality research studies on the impacts of dietary mercury on the health and reproduction of wild fish species, compared with research in common loons.

Chapter 14: Mercury and Human Health

Coordinating author: Tara Leech

This chapter presents knowledge of mercury exposure of Canadians, studies of human health effects, and measures for risk management. In Canada, methylmercury remains a public health issue for populations who consume significant amounts of predatory fish and certain traditional wildlife food items (*country food*). Exposure to mercury varies depending on regional, social, and occupational differences. Some groups, such as Aboriginal peoples, sport fishers, and Asian Canadians, are more likely to be exposed to mercury than the general Canadian population because their diet tends to be rich in fish and seafood. Biomonitoring of pregnant women and women of childbearing age show that approximately 2% of these women in the general Canadian population exceed the proposed guidance value (8 µg L⁻¹), and therefore require follow-up testing, dietary advice, and/or other intervention. Inuit mothers in the eastern Arctic have some of the highest concentrations of mercury among northern populations, with 20% of mothers from a small study in 2005-2007 exceeding the 8 µg L⁻¹ guideline (down from 53% in 1997). Health effects such as neurological impairments have been associated with exposure to high levels of methylmercury. The developing nervous system (in fetuses, infants, and young children) is considered to be the most susceptible to the adverse health effects of methylmercury. In addition, methylmercury exposure has been linked to adverse effects on the adult cardiovascular system as well as neurobehavioural outcomes in children, but more research is needed.

REGULATING MERCURY IN CANADA

Because mercury contamination is considered a national and global environmental and health issue, steps to mitigate emissions and exposure have been taken by the Government of Canada and the United Nations.

Mercury and its compounds are identified as a toxic substance under the *Canadian Environmental Protection Act, 1999*. In 2010, Environment Canada and Health Canada developed a *Risk Management Strategy for Mercury* that provides a comprehensive and consolidated description of the Government of Canada's actions to manage risks associated with mercury. Annex A of the strategy tabulates numerous existing risk management initiatives for mercury including regulatory action, environmental codes of practice/guidelines, pollution prevention plans, and Canada-wide standards, which cover areas such as emissions from industrial sources, mercury-containing products, and total mercury in fish for consumption.

Further, the strategy recommended undertaking science in support of policy initiatives on mercury. The strategy recommended the following actions: (1) monitor mercury levels in the environment; (2) improve our understanding of processes that govern mercury transformation; (3) increase our ability to predict the fate and transport of mercury; and (4) assess and communicate the accumulated scientific knowledge in Canada to inform domestic and global policy initiatives on the reduction of mercury emissions.

In October 2013, the Minamata Convention on Mercury (led by the United Nations Environment Programme) was opened for signature and has since been signed by 100 governments, including Canada, with the primary goal to protect the human health and the environment from anthropogenic emissions and releases of mercury and mercury compounds. The provisions within the Convention address all aspects of the mercury lifecycle, and of particular interest to Canada, aims to control and reduce atmospheric emissions of mercury from listed industrial sources. The preamble of the Convention, which sets out the context in which the Convention's

obligations should be interpreted, includes several statements that directly affect Canadians, including (but not limited to):

“Recognizing that mercury is a chemical of global concern owing to its long-range atmospheric transport, its persistence in the environment once anthropogenically introduced, its ability to bioaccumulate in ecosystems and its significant negative effects on human health and the environment...

Noting the particular vulnerabilities of Arctic ecosystems and indigenous communities because of the biomagnification of mercury and contamination of traditional foods, and concerned about indigenous communities more generally with respect to the effects of mercury...”

This national assessment can serve to inform scientists, science managers, and policy-makers on the current status and baseline information of mercury in Canada. Further, this assessment provides recommendations for future research and monitoring needs on mercury both nationally and internationally.

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