The 5th Asia-Pacific Mercury Monitoring Network Workshop

APMMN

Mercury Wet Deposition Roundtable Discussion

Standard Operating Procedures for APMMN

Da-Wei Lin and Guey-Rong Sheu

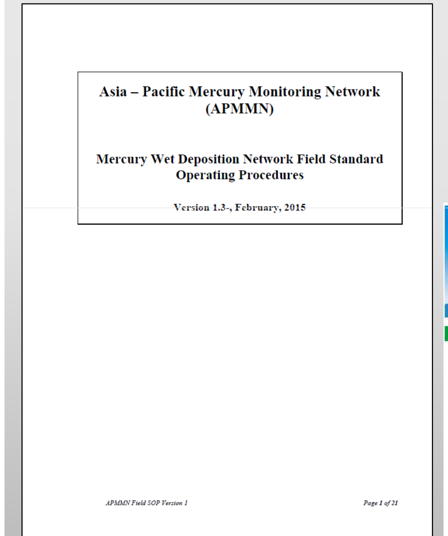
Department of Atmospheric Science, National Central University

July 27, 2016

Asia Pacific Mercury Monitoring Network

Center for Environmental Monitoring and Technology
National Central University

Current SOP


Asia – Pacific Mercury Monitoring Network (APMMN)

Mercury Wet Deposition Network Field Standard Operating Procedures

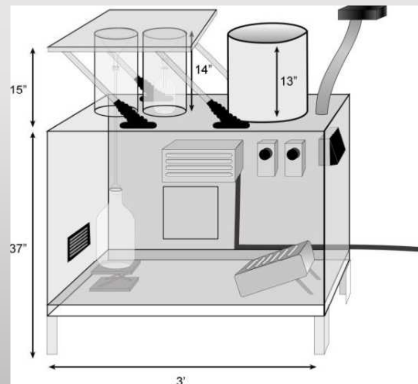
Version 1.3-, February, 2015

APMMN Field SOP Version 1 Page 1 of 21

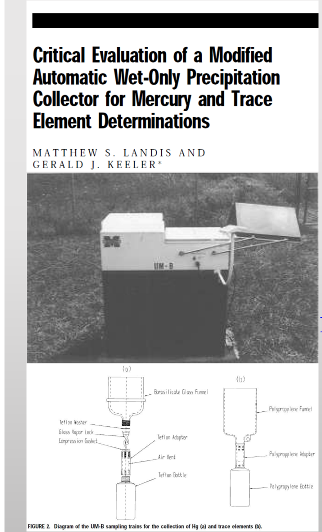
- Based on MDN/NADP SOP.
- Revised Ver. 1.3 by TEPA, USEPA, NADP, NCU, Vietnam and Thailand in 2015

Wet-only precipitation collector in current APMMN SOP

NADP-style Aerochem 301



Follow up...


Critical Evaluation of a Modified Automatic Wet-Only Precipitation Collector for Mercury and Trace Element Determinations

MATTHEW S. LANDIS AND GERALD J. KEELER*

Modified
Based on UM-B

Environ. Sci. Technol. **1997**, 31, 2610-2615

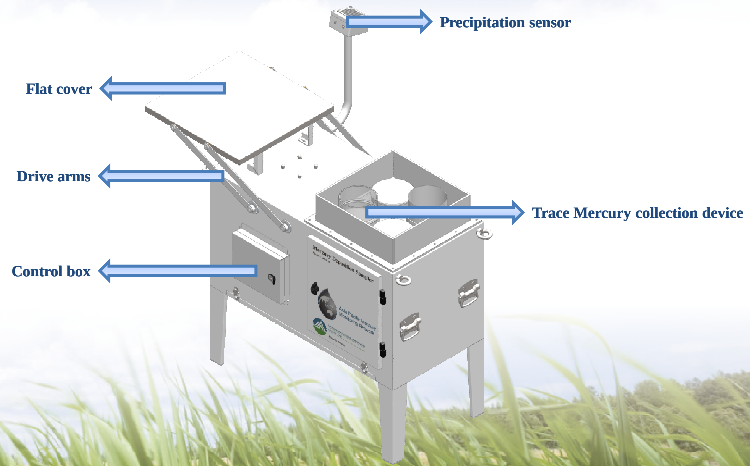
Machine Shop
章嘉企业有限公司

Mercury Deposition Sampler

General Manager
Cheng Jung Huang
E-mail：asir@machine-shop.com.tw

Machine Shop
章嘉企业有限公司

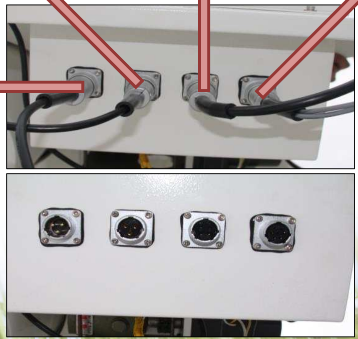
External item of the equipment



Machine Shop
章嘉企业有限公司

Flat cover

Internal item of the equipment

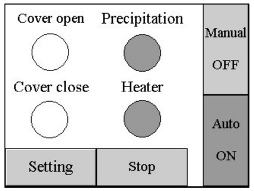


Internal item of the equipment

Description of Operation

When precipitation sensor detects precipitation.

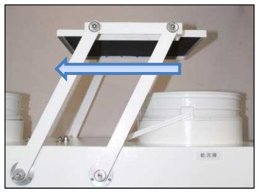
"Precipitation" light on controller monitor will be on. Then "Heater" will light on and shine followed by setting.



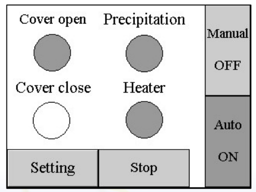
For example, set Heater ON to 10 seconds and Heater OFF to 5 seconds. "Heater" light will repeat shining 10 seconds and then going out 5 seconds until "Precipitation" light off.

Description of Operation

When "Precipitation" lights on, flat cover will open and start to collect mercury deposition



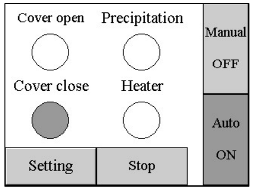
While the flat cover opening, Sensor positioning sheet will synchronously rotate with it until be detected by Flat cover opening positioning sensor with lighting on. Then flat cover will stop. "Cover open" on controller monitor will light on.



Description of Operation

When precipitation sensor doesn't detect precipitation.

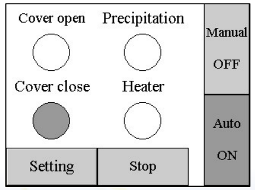
"Precipitation" light on controller monitor will be off. Then "Heater" will light of.



Description of Operation

When "Precipitation" lights off, flat cover will close.

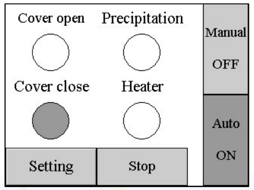
While the flat cover closing, Sensor positioning sheet will synchronously rotate with it until be detected by Flat cover closing positioning sensor with lighting on. Then flat cover will stop. "Cover close" on controller monitor will light on



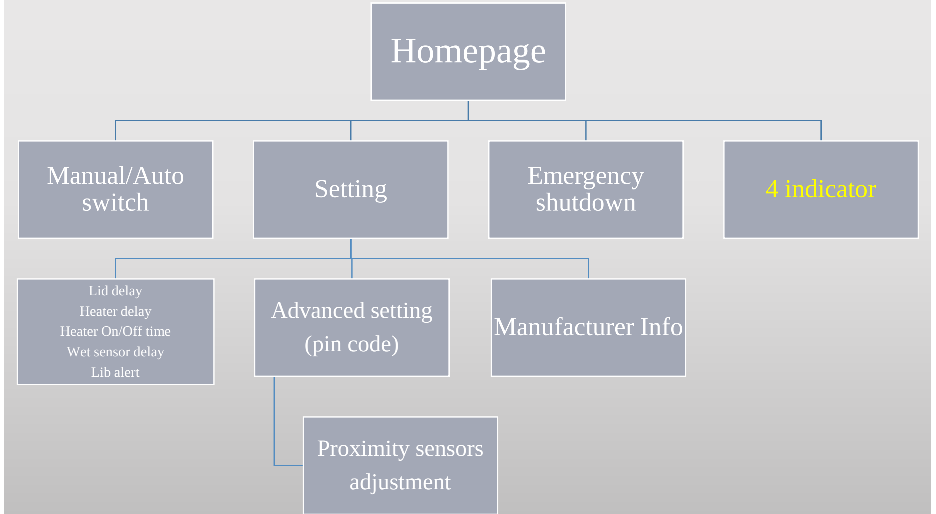
Description of Operation

When "Precipitation" lights off, flat cover will close.

While the flat cover closing, Sensor positioning sheet will synchronously rotate with it until be detected by Flat cover closing positioning sensor with lighting on. Then flat cover will stop. "Cover close" on controller monitor will light on

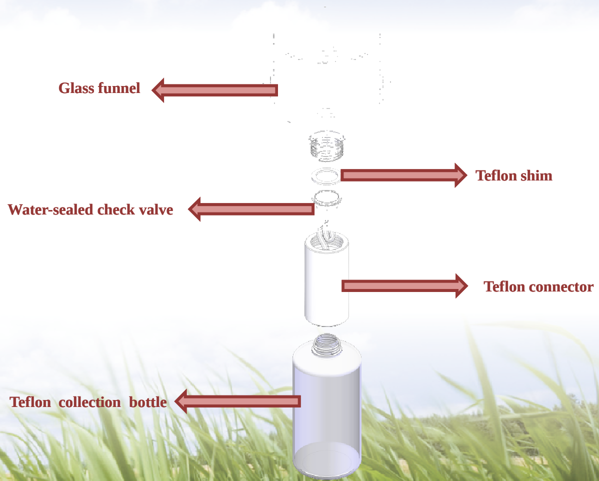


Control panel



Machine Shop
章嘉企业有限公司

Trace mercury collection device

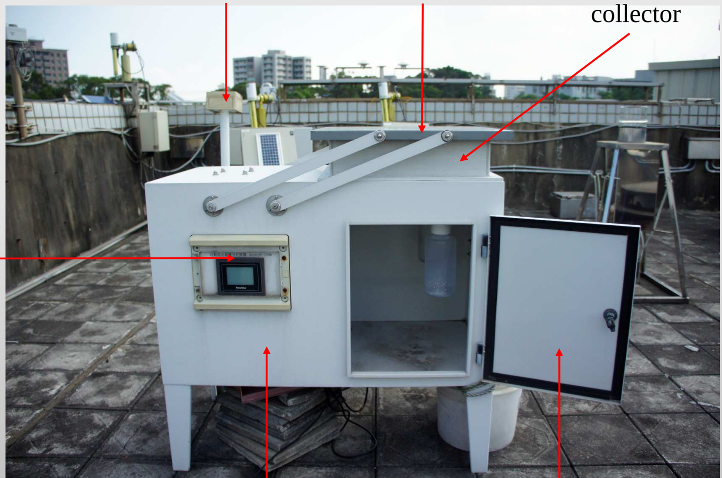


Machine Shop
章嘉企业有限公司

Trace mercury collection device

Wet-only precipitation collector-MIC type

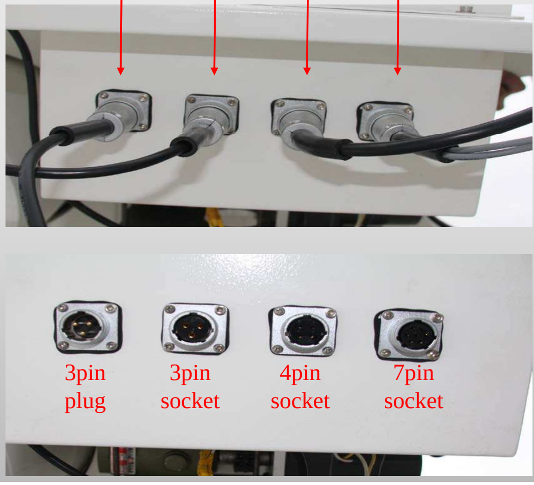
Front view



MIC type

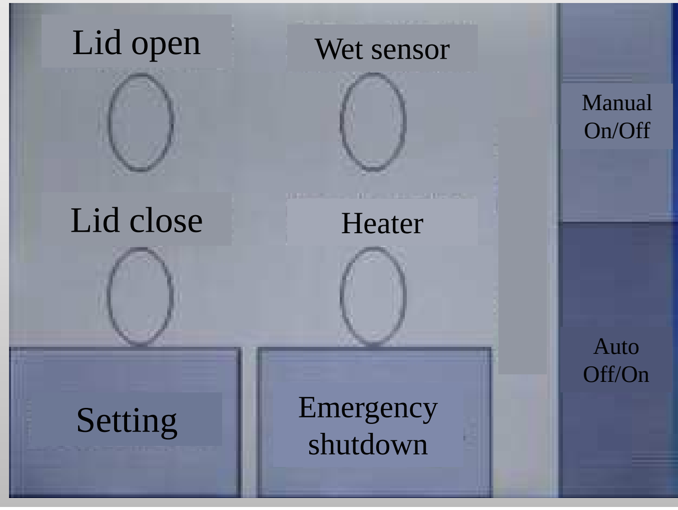
Top view

Power/Sensor adapter



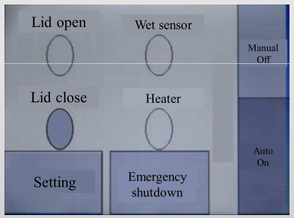
Control panel

Homepage

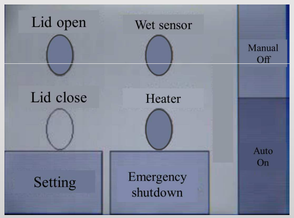


Control panel

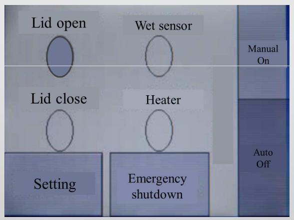
Non-rainy



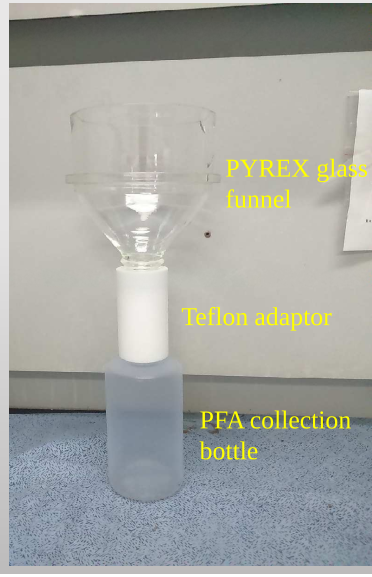
Rainy



Retrieve sample

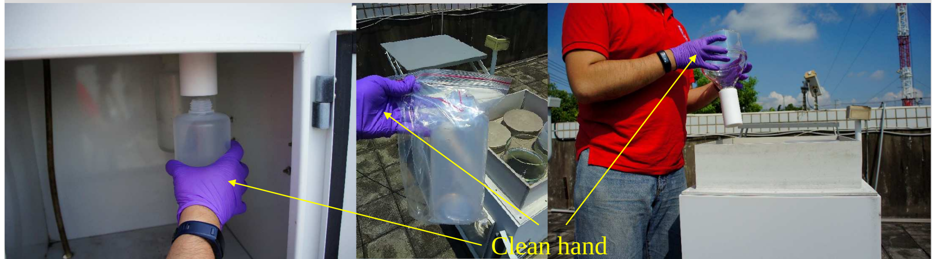


Mercury collection device

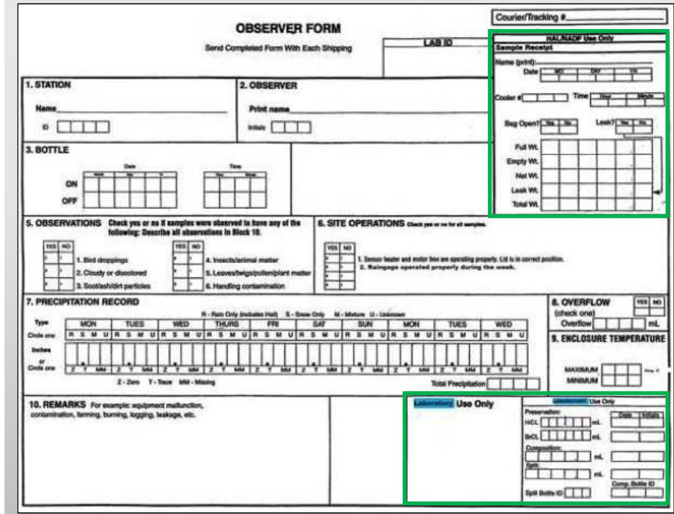


Retrieve your sample

- Changes on Tuesday morning between 8 to 10 AM local time.
- Approach collector facing into the wind
- Fill in the NOF



Network Observer Form (NOF)


OBSERVER FORM
Send Completed Form With Each Shipping
Courier/Tracking #
LAB ID
Sample Receipt
1. STATION
Name
ID
2. OBSERVER
Print name
Initials
3. BOTTLE
Date
Time
ON
OFF
5. OBSERVATIONS
1. Bird droppings
2. Cloudy or discolored
3. Soot/ash/dirt particles
4. Insects/animal matter
5. Leaves/twigs/pollen/plant matter
6. Handling contamination
6. SITE OPERATIONS
7. PRECIPITATION RECORD
MON TUES WED THURS FRI SAT SUN MON TUES WED
Total Precipitation
8. OVERFLOW
9. ENCLOSURE TEMPERATURE
MAXIMUM
MINIMUM
10. REMARKS
Laboratory Use Only

1. Station
2. Observer
3. Bottle
4. Observations
5. Site operations
6. Precip. record
7. Overflow
8. Enclosure Temp.
9. Remarks

MAL/APMMN use only

(APMMN Field SOP Ver 1.3, Page14)

Cleaning the collector

- Clean any surface have dirt with paper towel
- Clean any debris off sensor by brush or compressed air

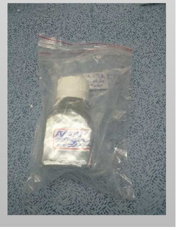
Deployment of new sample collector

- Use new gloves !
- Install new sample collector.
- Avoid to touch the inner wall of glass funnel
- Start the next week NOF
- Close the lid and enclosure door

Weigh, transfer and storage

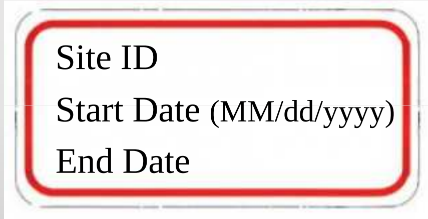
- Weigh the sample bottle and subtracting the pre-sample weight of bottle (recode it on the NOF)
- Transfer the sample from 1L to 150ml sample bottle
- Label the sample with sampling site ID, start/end date
- Place the sample into double sealable plastic bag
- Store the sample in a Hg-free and secure place (or refrigerator) if not shipping immediately.
- Capture rain gauge data
- Complete the NOF

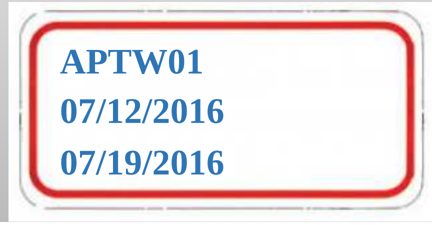


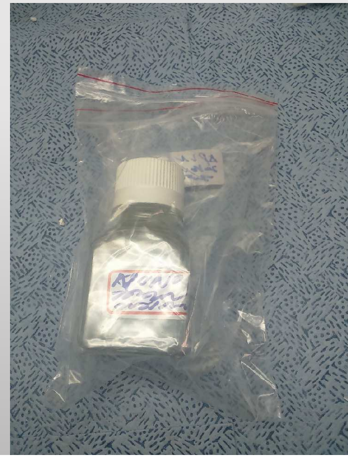


Sample label

- The most important part of taking sample







Shipping Info.

Ship samples at least **monthly** by int'l logistics service
Ex:

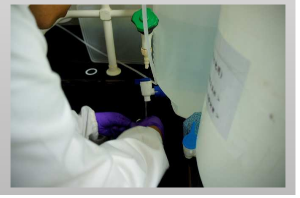
- Pack samples and NOFs singly or in bulk
- Cold shipping is unnecessary

Da-Wei Lin
Rm. ATM-101 (VHF antenna area)
No. 300, Chungda Rd., Chungli Dist., Taoyuan City 32001,Taiwan
Phone : 886-923-607952

Acid clean of used glassware

- Separate the collection device and soak within 10% reagent-grade hydrochloric acid for 72 hours (except O-ring)
- Rinse thoroughly each component with deionized water ($\rho \geqq 18.2$ MΩ) at least 3 times
- Air dry each component in the clean bench
- Cover each component with clean plastic bag and store
- Assemble each component before use





Problem occur in past year

Case 1:

No sealable plastic bag (double bags)

No lable on sample bottle

Problem occur in past year

Case 2:

Single sealable plastic bag only

Number of Sample bottle and NOF were unequal

Not use the suggest PETG bottle

Problem occur in past year

Case 3:

No label on the bottle

No NOF

THANK YOU

Da-Wei Lin

APMMN Site Liaison

dwlin@g.ncu.edu.tw

Asia Pacific Mercury Monitoring Network

Center for Environmental Monitoring and Technology National Central University

The 5th Asia-Pacific Mercury Monitoring Network Workshop

APMMN

Mercury Wet Deposition

Roundtable Discussion

Atmospheric mercury monitoring in Australia

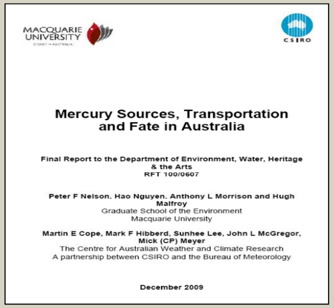
Professor Peter Nelson

MACQUARIE University

Sources, Transportation & Fate Study

MACQUARIE University

- Australian response required to UN initiative
  - Sources, transport & fate
  - Existing guidelines, standards, regulations
- In the face of:
  - Poor local emissions data
    - Anthropogenic
    - Natural (vegetation, water, soils, fires)
  - No local measurements of atmospheric concentrations or deposition
  - No capability to model transport and fate at continental scale
- Two reports to Australian Government


MACQUARIE UNIVERSITY
CSIRO

Mercury Sources, Transportation and Fate in Australia

Final Report to the Department of Environment, Water, Heritage & the Arts
RFT 100/0607

Peter F Nelson, Hao Nguyen, Anthony L Morrison and Hugh Malfroy
Graduate School of the Environment
Macquarie University

Martin E Cope, Mark F Hibberd, Sunhee Lee, John L McGregor, Mick (CP) Meyer
The Centre for Australian Weather and Climate Research
A partnership between CSIRO and the Bureau of Meteorology

December 2009

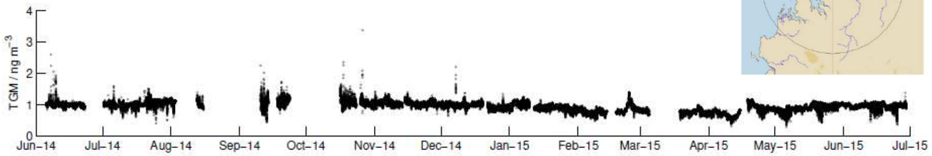
	Hg^0 (tonnes)	RGM (tonnes)	Hg^p (tonnes)	Total Hg (tonnes)	Range[1] (tonnes)	(%)
Anthropogenic						
Industrial	10.7	2.4	0.9	14	10-18	7
Commercial, Domestic + diffuse	0.8	0.1	0.1	1.0	0.5-1.5	0.4
Natural/ Re-emitted						
Vegetation	8	0	0	8	4-12	4
Canopy-soil	54	0	0	54	27-81	27
Bare soil	86	0	0	86	43-129	42
Fires	33	3	5	42	21-63	20

[1] Based on reported uncertainty estimates (AMAP/UNEP 2008; Friedli et al. 2009b; Mason 2009)

See: Nelson, P.F., Morrison, A.L., Malfroy, H.J., Cope, M., Lee, S., Hibberd, M.L., Meyer, C.P.(M.), McGregor, J., Atmospheric mercury emissions in Australia from anthropogenic, natural and recycled sources, Atmospheric Environment (2012), doi: 10.1016/j.atmosenv.2012.07.067.

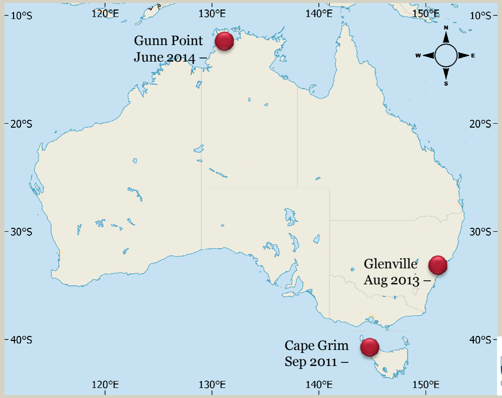
Mercury in Australia

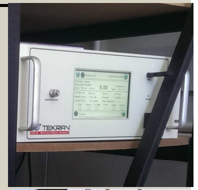
- *First Australian Power Station Measurements of mercury species*
- *Australian inventory from all sources- informing response to Minamata Convention*
- *First gas phase concentrations of mercury in Australia - Almost no SH data, providing constraints and tests of global mercury modelling and mercury atmospheric chemistry*
- *Invitation to join the Global Mercury Observing System (GMOS) led by EU*
- *First measurements of mercury in wet and dry deposition*
- *First mercury measured in fires in Australia; emission factors, and firefighter exposure*
- *Member UNEP Expert Group on Global Inventory (2010 Global Inventory, 2018 Assessment)*
- *Lead author (non ferrous smelting and roasting), UNEP Expert Group on Minamata Convention*
- *Long-term measurements and modelling in Sydney, Hunter Valley and Northern Australia - Included in Global Mercury Observing System*



Atmospheric Mercury

AUSTRALIAN LONG-TERM MONITORING SITES

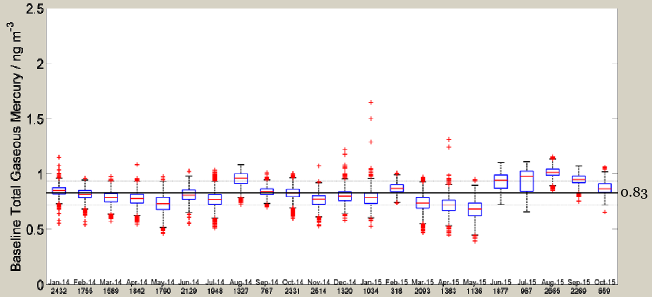




UNIVERSITY OF TORONTO

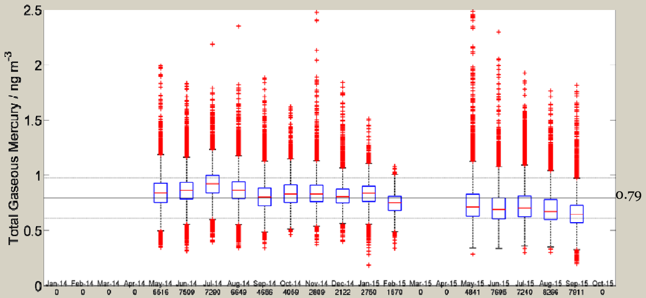
Seasonal Variation

CAPE GRIM, Tasmania (40.7° S, 144.7° E)



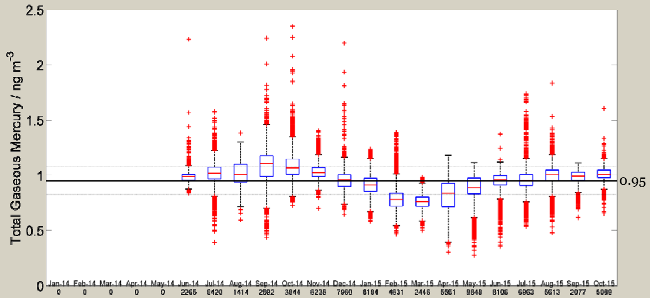
Seasonal Variation

GLENVILLE, NSW (32.4° S, 151.1° E)



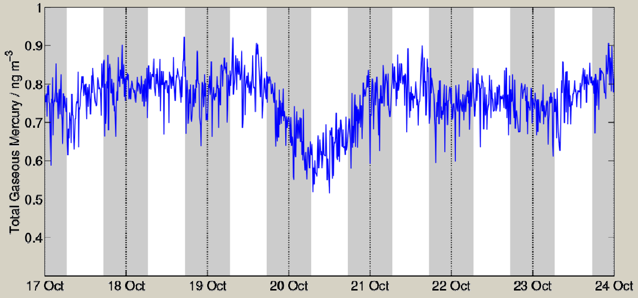
Seasonal Variation

GUNN POINT, Northern Territory (12.2° S, 131.0° E)



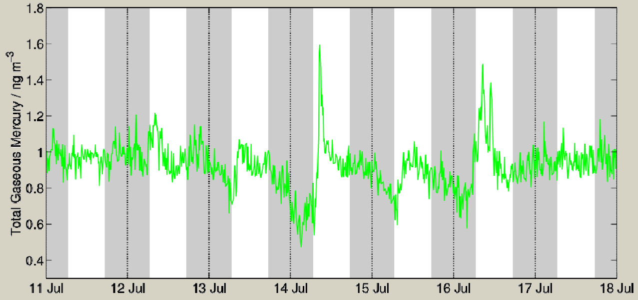
Daily Variation

CAPE GRIM, TAS



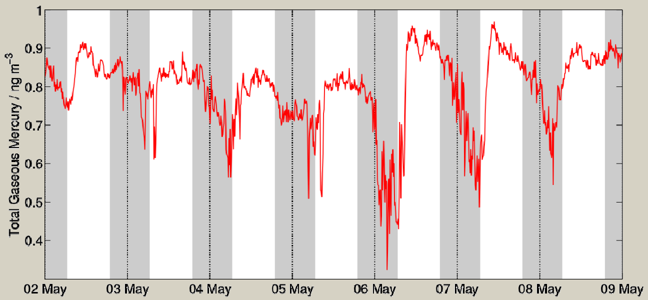
Daily Variation

GLENVILLE, NSW

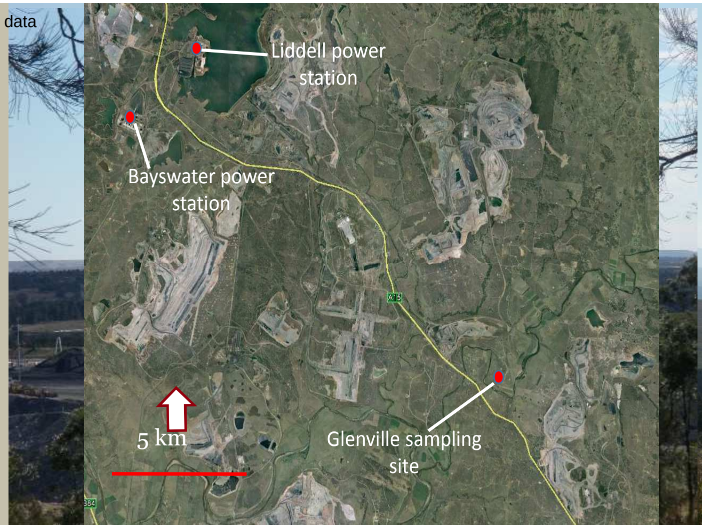


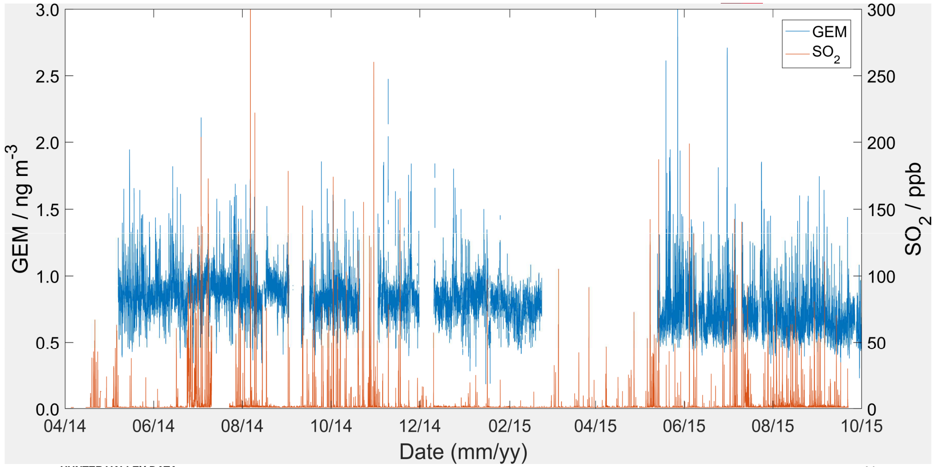
Daily Variation

GUNN POINT, NT

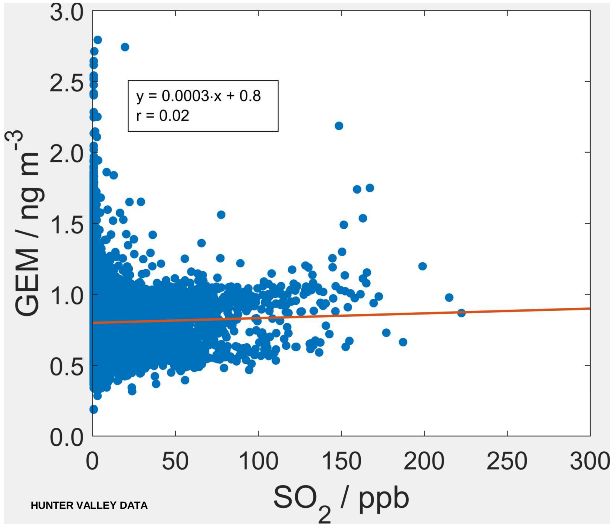


Hunter Valley data

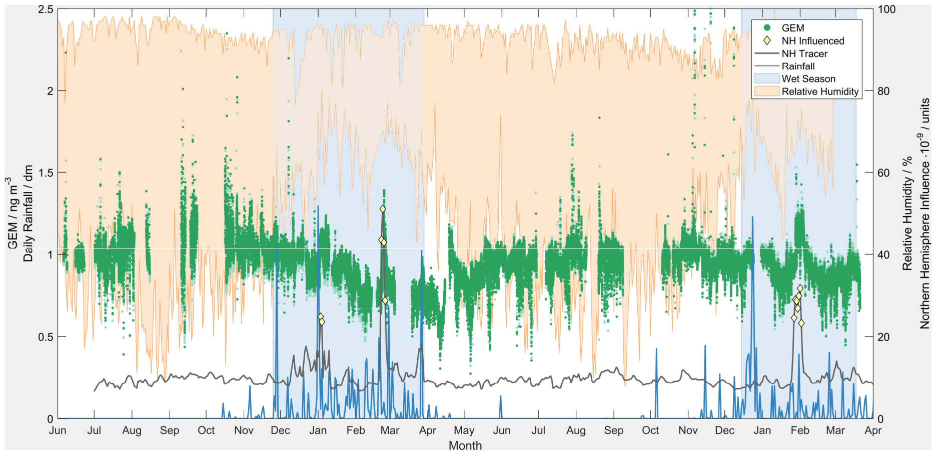




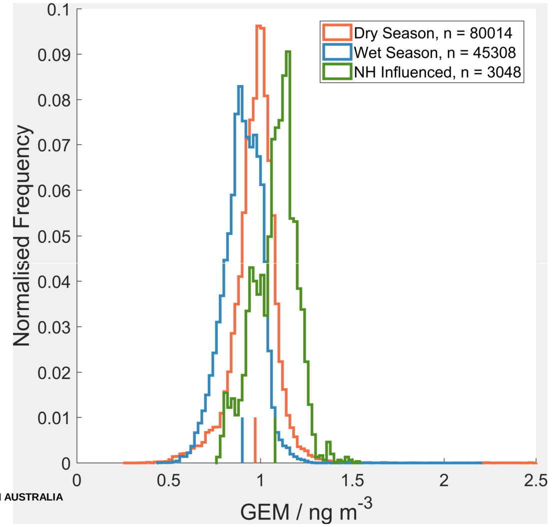
HUNTER VALLEY DATA



HUNTER VALLEY DATA

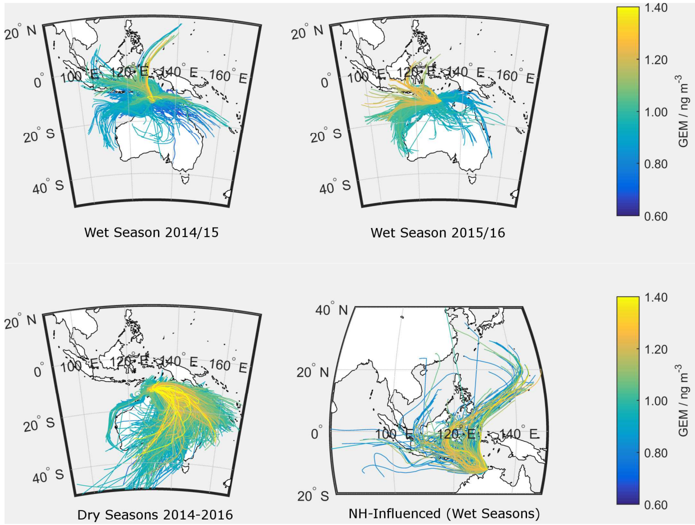


GUNN POINT, NORTHERN AUSTRALIA



GUNN POINT, NORTHERN AUSTRALIA

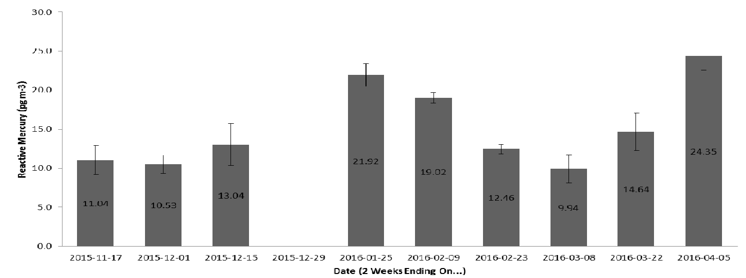
GUNN POINT, NORTHERN AUSTRALIA



University of Nevada, Reno

CSIRO

MACQUARIE University

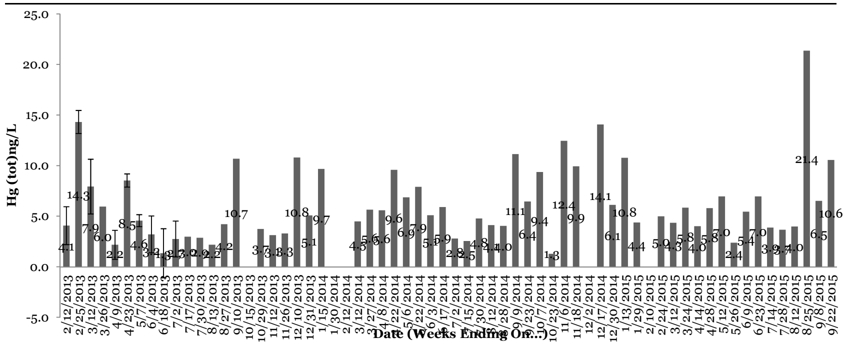


Continuous Gaseous Oxidized Mercury Measurements at Cape Grim using CEM filter Technology

Matthieu Miller, Grant Edwards, Mae Gustin

CSIRO ivl GMOS Global Mercury Observation System

MACQUARIE University



Cape Grim Wet Deposition

Ingvar Wangberg

Modelling

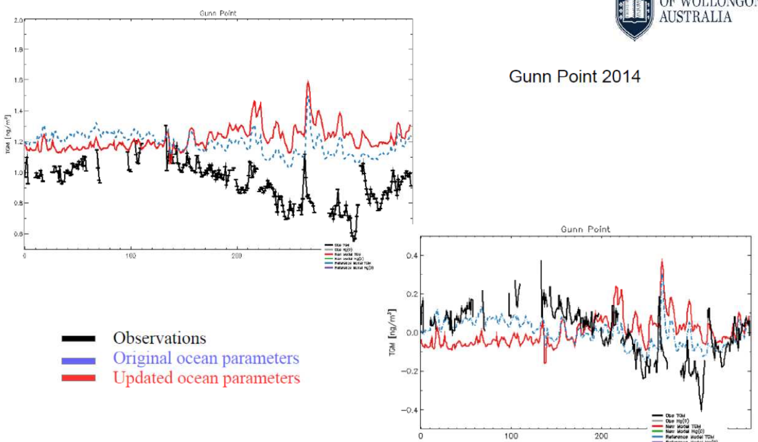
EARLY DEVELOPMENTS

MACQUARIE University

- GEOS-CHEM used for Gunn Point Data (with University of Wollongong)
  - Ocean parameters: updated and original
  - AMS data
  - Sensitivities
  - Annual Trends
  - Diurnal cycle and depletion events
  - Dry deposition velocity
- Sydney and Hunter Valley data (with CSIRO)
  - CSIRO-CTM
  - depletion events
  - Variable success

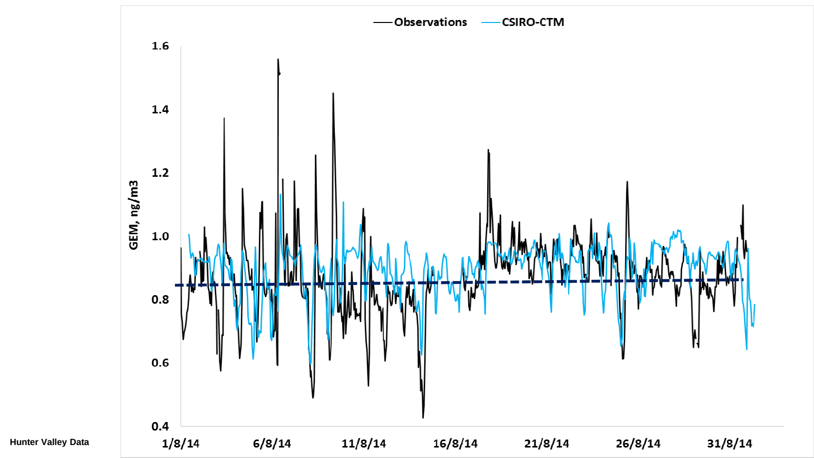
I- Ocean parameters : Updated and Original

Gunn Point 2014



I-Ocean ●●●●● II-Sensitivity III-Trends IV-Diurnal cycle V-Drydep 2

Glenville, Upper Hunter, August 2014



In Summary

SEASONAL VARIATION AND LONG-RANGE TRANSPORT

- Australia's emissions relatively low and dominated by industrial sources particularly non-ferrous sector
- Natural and re-emitted sources dominate over anthropogenic sources; fires significant particularly in northern Australia
- Atmospheric mercury measured at several sites since 2011
- Atmospheric mercury in temperate Australia may be relatively stable
  - Annual trends at Cape Grim similar to those shown in Slemr *et al.* (2015)
  - Similar mean concentration at Glenville, though with complicated sources
- Atmospheric mercury at Gunn Point shows significant annual variation
  - Higher median concentrations during dry season compared to wet
  - Maximum difference in monthly medians 0.35 ng m^{-3}
  - Northern hemisphere and fires contribute

In Summary

DAILY VARIATION AND DELIVERY TO ECOSYSTEMS

- Both Glenville and Gunn Point show intermittent periods of TGM *depletion*
  - Generally only under calm, stable, nocturnal conditions
  - Concentrations at Gunn Point generally return to pre-nocturnal levels
  - Large spikes at Glenville may be due to fumigation into overlying weak mixed layer, or advection from nearby sources
- Drops in atmospheric mercury concentrations at Cape Grim not as pronounced and don't appear to be locally driven
- Nocturnal depletion of elemental mercury suggests significant conversion (and deposition) of reactive forms
  - Consistent with a *multi-hop* model of atmospheric mercury transport
  - Changes to the long-term atmospheric mercury pool will ultimately have an effect on the delivery of mercury to ecosystems
  - Thus understanding of this delivery requires understanding and measurement of all atmospheric mercury species
- Initial progress with wet deposition and modelling efforts
  - Depletion events are very interesting and need more investigation
  - Ocean impacts

Acknowledgements

MACQUARIE
University

Dean Howard
Anthony Morrison
Peter Nelson
Grant Edwards
Upma Dutt
Matthieu Miller

CSIRO

Melita Keywood
Kathryn Emmerson
Martin Cope
Sunhee Lee
Mark Hibberd

UNIVERSITY OF WOLLONGONG AUSTRALIA

Jenny Fisher
Iris-Amata Dion

UNIVERSITY OF TORONTO

Australian Government
Bureau of Meteorology

University of Nevada, Reno

ivl

GMOS
Global Mercury Observation System

Introduction of Current Research on Mercury in Korea

JULY 27, 2016

Ministry of Environment

National Institute of Environmental Research

Rhokho Kim

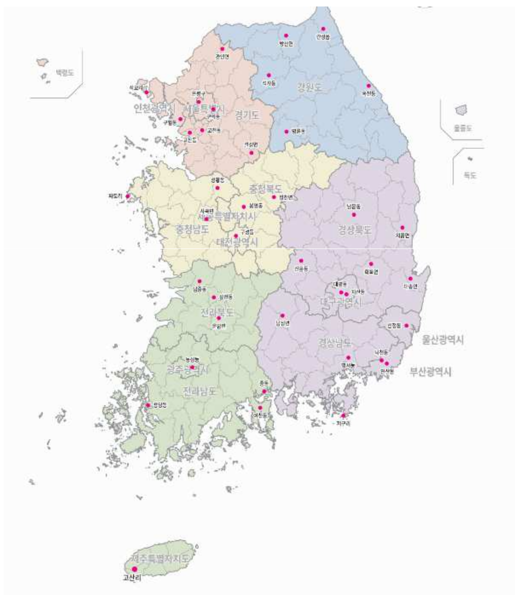
Acid precipitation monitoring network

- **Purpose**
  - To build basic data to understand the dry/wet deposition of acid air pollutants across the country and establish measures to minimize the damage they cause
  - To estimate domestic mercury air pollution based on which mercury management policy will be built (e.g., mercury risk assessment and transboundary mercury management)
- **Management**
  - As a member of the Acid Deposition Monitoring Network in East Asia (EANET), Korea operates monitoring stations that comply with EANET's QA/QC standards.

Acid precipitation monitoring network

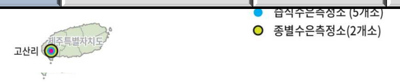
- **Siting criteria for monitoring stations**
  - The monitoring stations are included in the APMN to estimate the impact of mercury on the ecosystem by calculating the concentration and wet deposition of mercury.
  - The monitoring stations are installed in three area groups:
    - a) background areas to understand the long-range movement of mercury,
    - b) areas to calculate domestic mercury concentrations, and
    - c) lake/river areas where mercury is deposited as methylmercury.

Acid precipitation monitoring network in Korea (40 stations)

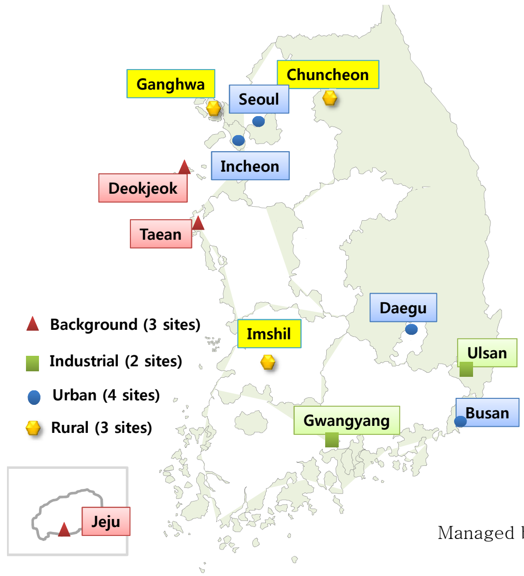


National Mercury Monitoring Stations in Korea (12 stations, 2016)

State		2009~2015	2016~2020		
			2016	2017	2018
Mercury Monitoring Stations	Total gaseous mercury	12 stations Deokjeok, Incheon, Seoul, Chuncheon, Taean, Daejeon, Gwangju Gwangyang, Daegu, Busan, Ulsan, Jeju	Daejeon, Gwangju ⇓ Imshil, Ganghwa (EANET Site)		
	Hg by chemical specie	-	1 stations Taean	1 stations Jeju	
	Hg in precipitation	2 stations Seoul Incheon	2 stations Taean Jeju	1 stations Chuncheon	



Management Plan (Current State and Expansion Plan of Mercury Monitoring Stations)



- Included in the national acid precipitation monitoring system
- Monitoring of TGM in 12 stations
- Mercury wet deposition monitoring sites
  (Seoul, Incheon, Taean, and Jeju in 2016)
  (Chuncheon in 2017)
- Monitoring sites for mercury by species
  (Taean and Jeju in 2017)

Managed by Air Quality Research Division, NIER

Management Plan of Mercury Monitoring Stations)

National Mercury Monitoring Network

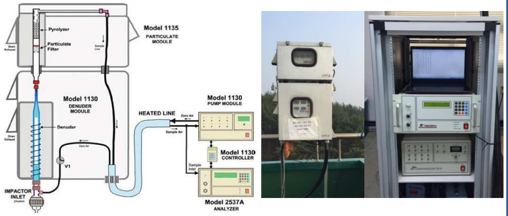
Measurement Items

State			Measurement Items
Dry	Gaseous	Manual	HNO_3, NH_3
	Particle	Manual	Mass concentration and ionic components of $PM_{2.5}$
Wet	Liquid	Manual	Electric conductivity, pH, and ionic components of rain or snow
Hg	Auto		Total gaseous mercury and mercury by specie
	Manual		Wet deposition of mercury
Weather factor	Dry		Wind direction, wind speed, temperature, and humidity
	Wet		Precipitation (rainfall and snowfall), sampling and collection amount, and temperature

Method of Measurement

National Institute of Environmental Research

Concentration of atmospheric Hg by chemical specie

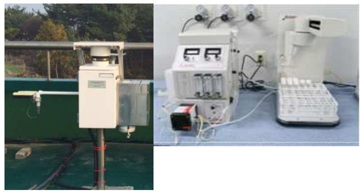


Tekran 2537/1130/1135, Canada

- TGM: 5-minute interval using Tekran 2537
- GOM & PBM: 2-hour interval using Tekran 1130/1135
- QC: accuracy with reference samples using Tekran 2505

  : reference value adjustment via zero air measurement per 2 min.

Hg concentration in precipitation



- Cumulative precipitation sampling per week (N-CON, Canada)
- Total Hg analysis using Tekran 2600
- Comparative experiments among labs
  - Subsampling through homogenization and stabilization of the samples
  - APMMN, Taiwan Central University, and GIST

Method of Measurement

National Institute of Environmental Research

Sampling Preparation
- 4N HCl solution, 65-75 ℃ for 48 hrs
- Cleansing over 3 times in distilled water

Precipitation sampler installation
- At a place without nearby obstacles
- Installing an auto thermostat

Sampling
- Injection of 10 ml HCl
- Replacement per week, acid cleaning container

Transport
- Cold storage at 4 ℃ for 12 hrs and foil-wrapped in a ziplock bag
- 0.5% BrCl injection of the weight difference between before and after sampling

Analysis

< EPA method 1631 >

Add 0.5ml of BrCl into 100ml of sample, and oxidize it for 24 hrs.

↓

Remove the free halogen gas by adding 0.2-0.25ml of $NH_2OH \cdot HCl$ to the oxidized sample.

↓

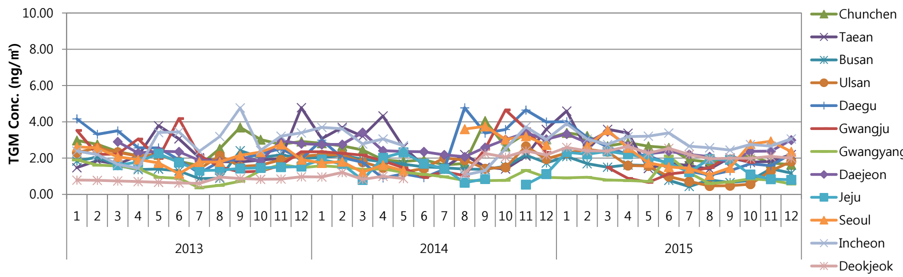
Reduce the oxidized mercury by adding 0.5ml of $SnCl_2$ to the sample.

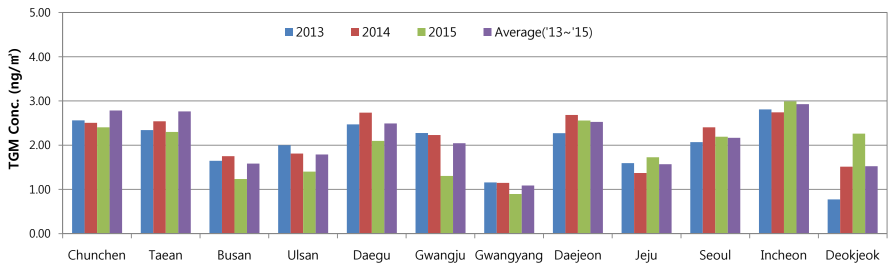
↓

Purge with Ar gas and absorb in the gold amalgam tube. Then, analyze with CVAFA.

Results of Mercury Monitoring

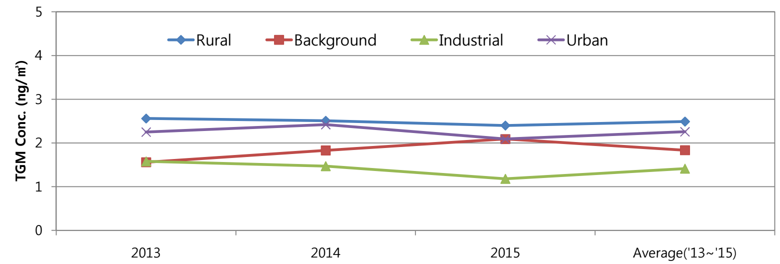
National Institute of Environmental Research

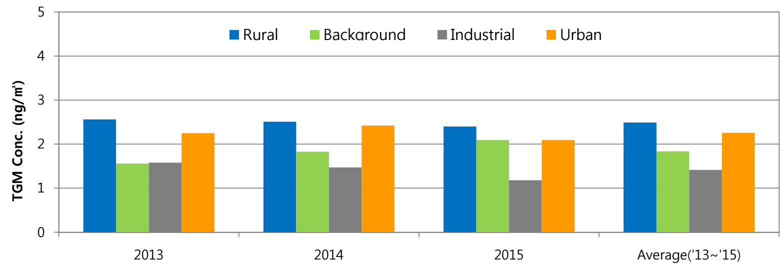




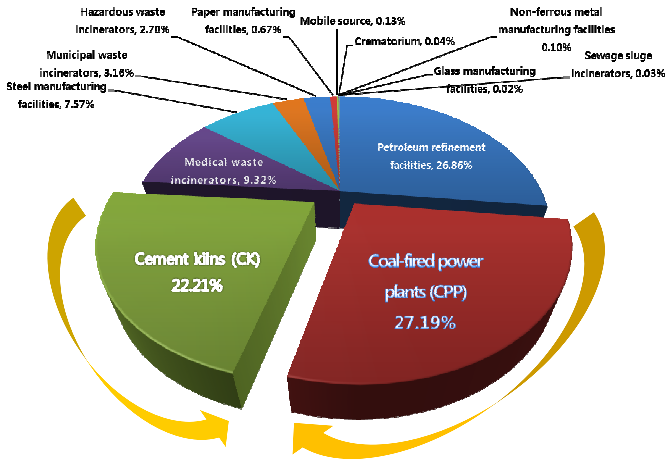
Results of Mercury Monitoring

National Institute of Environmental Research

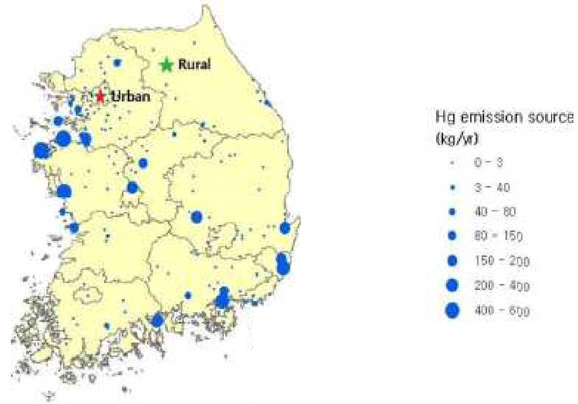




Tested Emission Sources – multiple mercury emissions (2012)



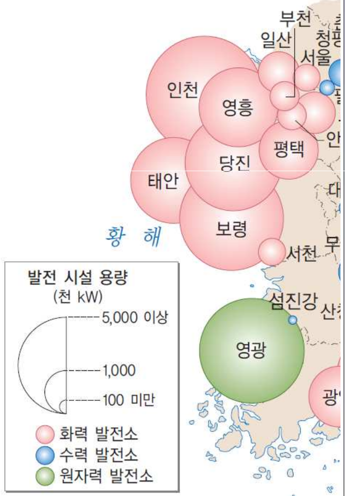
Emission Sources – multiple mercury emissions

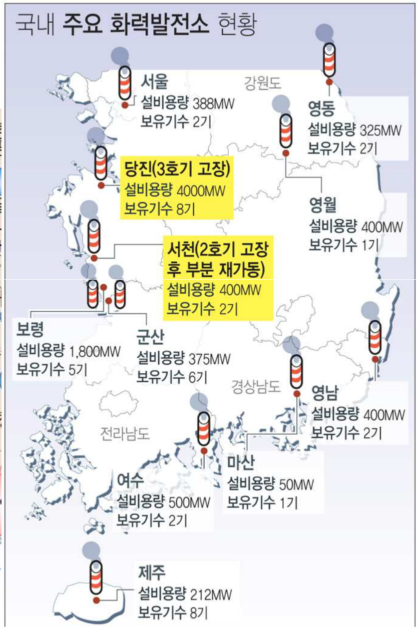


(Korea's Hg emission sources Y. Lee, '11)

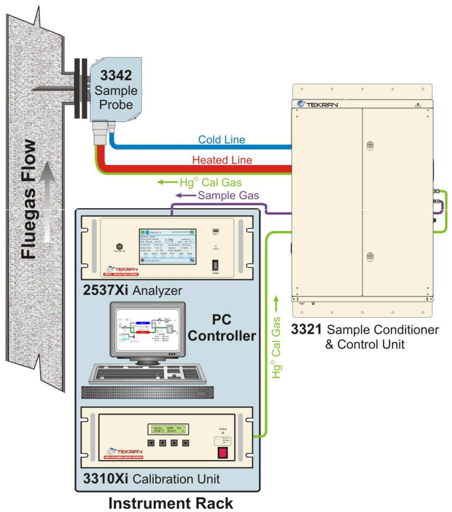
Emission Sources – Coal fired power plants

(한국 전력 공사, 2011)





The appearance and general structure of a CEM system



Comparison of Pros & Cons. For each mercury method

Method	Pros	Cons
Method 101A (Official test method on air pollution)	• Preparation and analysis are easier than OHM.	• It is impossible to assort the chemical species of gaseous mercury. • It greatly consumes manpower and causes risks and economic issues. • The complex sample preparations and recovery can cause errors.
Ontario Hydro Method	• It is possible to assort the chemical species of mercury.	• It consumes manpower a lot and causes risks and economic issues. • The complex sample preparations and recovery can cause errors.
Method 30B (Sorbent trap)	• Preparations and analysis are simple. • It is more economical than other methods. • It can be used to validate the data of CEM equipment.	• It is impossible to analyze particulate. • It can be applied only to the final outlet with low concentration of dust.

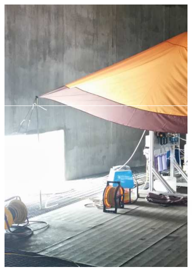
✓ Most mercury exists in the form of vapor among burned emissions.

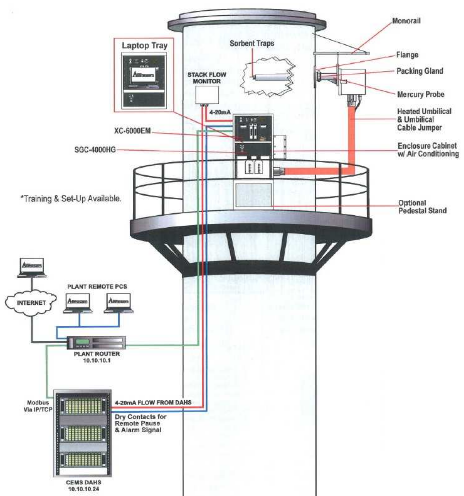
✓ Most of major emission facilities in Korea are equipped with particulate mercury control systems.

Solvent trap Method (EPA METHOD 30B)

Field Installation of a CEM system

National Institute of Environmental Research

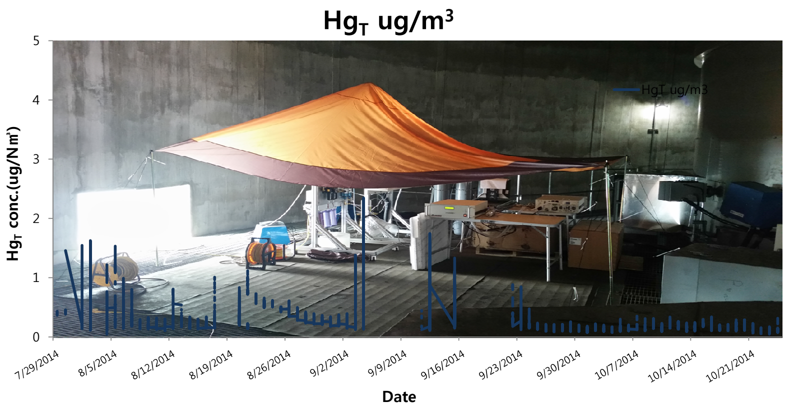




Field Installation of a CEM system

National Institute of Environmental Research

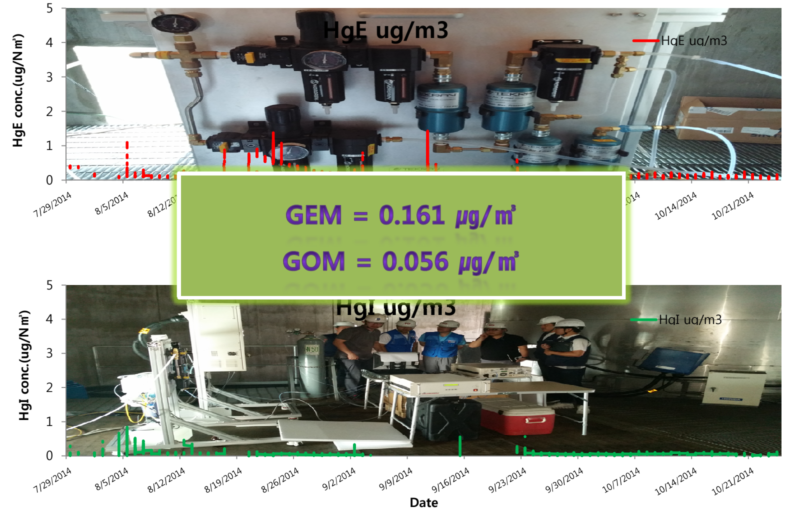
Result of analyzing flue gas through CEM



Hg_T Conc.(gaseous mercury) = 0.217 ㎍/㎥ (July 29 ~ Oct. 24)

Result of analyzing flue gas through CEM

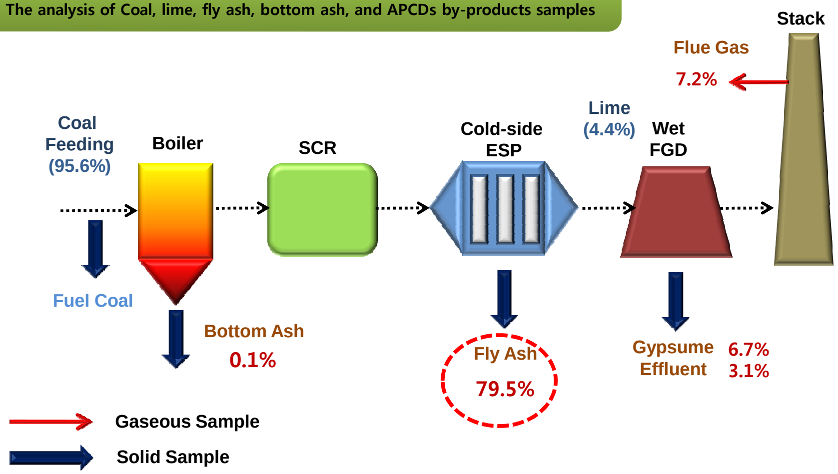
National Institute of Environmental Research



Hg Mass balance in CPP

National Institute of Environmental Research

- Comparative evaluations of exhaust gases using EPA Method 101A, 30A and 30B
- The analysis of Coal, lime, fly ash, bottom ash, and APCDs by-products samples

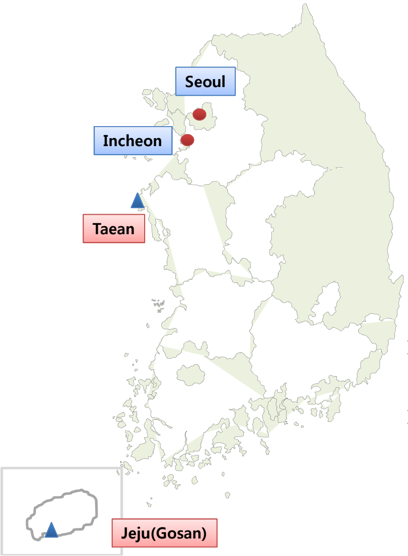


Hg Mass balance in CPP

National Institute of Environmental Research

ID	Input			Output					
	Total	Fuel/ Coal	Lime/ Limestone	Total	F/A	B/A	Gypsum	Effluent	Flue gas
Hg mass Flow rate (g/day)	226.8	224.2	2.6	180.7	152.8	0.9	10.9	5.8	10.3
Mass balance (%)	100	98.9	1.1	79.67	67.38	0.41	4.79	2.56	4.52
Coal사용량 = 7915 ton/day, Lime사용량 =137 ton/day, F/A발생량 = 537 ton/day, B/A발생량 = 95 ton/day, Gypsum 생산량 = 187 ton/day, Effluent 발생량 = 73 ton/day, 배출가스 유량 = 64,081,903 ㎥/day									
Hg mass Flow rate (g/day)	139.5	133.4	6.1	134.8	110.9	0.08	9.4	4.3	10.1
Mass balance (%)	100	95.6	4.4	96.6	79.5	0.1	6.7	3.1	7.2
Coal사용량 = 7463 ton/day, Lime사용량 =108 ton/day, F/A발생량 = 495 ton/day, B/A발생량 = 95 ton/day, Gypsum 생산량 = 242 ton/day, Effluent 발생량 = 63 ton/day, 배출가스 유량 = 63,170,872 ㎥/day									

Characteristics of Atmospheric Total Gaseous Mercury Concentrations



- TGM assessment in bkgd./urban areas (using the AMMS results)
- Concentration of atmospheric mercury by chemical specie (Taean)
- Mercury wet deposition in bkgd./urban areas

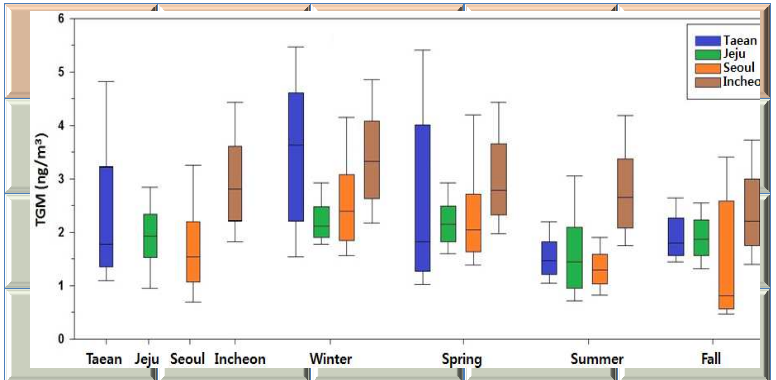
➢ Long-term monitoring data for effectiveness evaluation under the Minamata Convention

➢ Participation in the Asia-Pacific Mercury Monitoring Network

Averaged seasonal TGM concentrations at 4 sampling sites (Jan. ~ Dec. 2015)

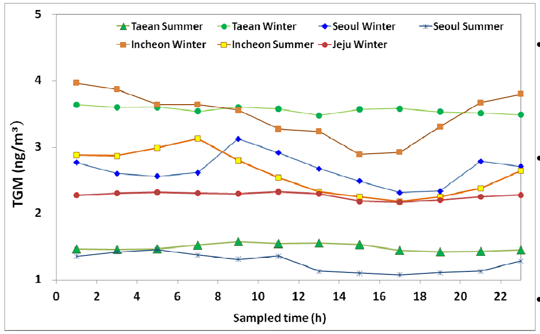
	Seoul	Incheon	Taean	Jeju
Winter (Dec-Feb)	2.5 ± 1.0	3.3 ± 0.5	3.1 ± 1.5	1.8 ± 0.8
Spring (Mar-May)	2.6 ± 2.2	3.0 ± 0.3	2.8± 1.8	2.2 ± 0.0.5
Summer (Jun-Aug)	1.3 ± 0.5	2.9 ± 0.4	1.6 ± 0.5	1.6 ± 0.9
Fall (Sep-Nov)	2.4 ± 1.5	2.6 ± 0.2	1.9± TGM (ng/m³) 0.7	1.3 ± 0.6
Total (range)	2.19 ± 1.57 (0.29-29.35)	2.97 ± 1.18 (1.01-15.97)	2.32 ± 1.40 (0.69-10.96)	1.73 ± 0.80 (0.40-4.68)

Comparison of seasonal TGM concentrations between sampling sites

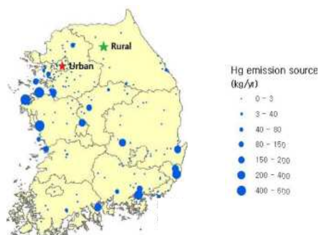


Jeju	.082	.123	.349	1

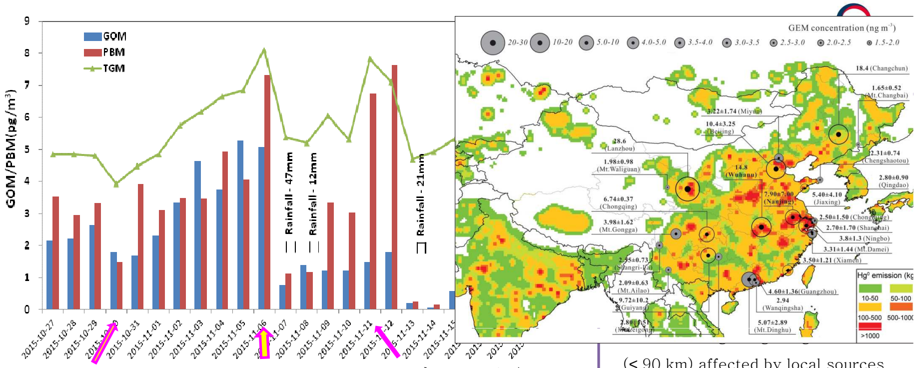
Comparison of hourly TGM concentrations



- Little change in Jeju and Taean
  ⇒ Affected by long-range inflow more than local sources
- Changes with time in Incheon
  ⇒ Local sources
  Air diffusion increases continuously (day)
  Air stagnation decreases continuously (night)
- High concentration at certain times in Seoul



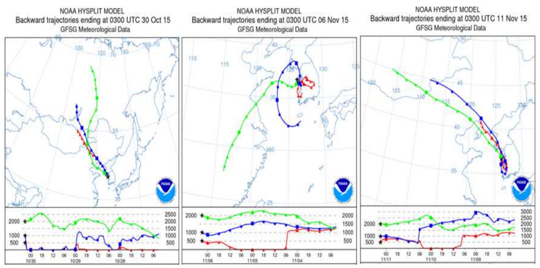
(Korea's Hg emission sources Y. Lee, '11)



(< 90 km) affected by local sources

- GOM/PBM, PBM/GEM ratio
  → long-range effect

GOM, PBM 낮음　　GOM, PBM 높음　　GOM 낮고, PBM 높음



National Institute of Environmental Research

THANK YOU

rhokho@me.go.kr

National Institute of Environmental Research

Incheon, Republic of Korea

Environment and Climate Change Canada | Environnement et Changement climatique Canada | Canada

Atmospheric Mercury Monitoring in Canada

Dr. Alexandra (Sandy) Steffen

Air Quality Research Division

Science and Technology Branch

Mercury is an important issue in Canada

- Certain Canadian populations are at higher risk of exposure
- MeHg levels can be high enough (>0.3 µg g^{-1}) to pose a risk to the reproductive health of fish and fish-eating wildlife
- ~ 90% of annual provincial/ territorial fish consumption advisories are from high Hg levels
- Hg levels exceed the Canadian limit for commercial sale of fish at many sites across Canada
- 95% of anthropogenic Hg deposited in Canada comes from external source regions
- Canada is a net recipient of mercury

Environment and Climate Change Canada | Environnement et Changement climatique Canada | Canada

Canadian Mercury Science Assessment

Synthesis of mercury research results collected within Canada

- Understand the status of mercury in the Canadian environment and the impact on ecosystems and the Canadian population
- Quantify current and past levels of Hg in the environment
- Determine knowledge gaps of transport routes from points of emission to exposure to ecosystems
- Identify key indicators of stress and exposure
- Develop the capacity to predict changes in indicators
- **Develop a baseline status for mercury levels in Canada**

Environment and Climate Change Canada | Environnement et Changement climatique Canada | Canada

Highlights of scientific findings

- ✓ Mercury remains a risk to Canadian ecosystems and human health
- ✓ In humans, the average exposure of Canadians to mercury is low
- ✓ Levels of Hg in the air in Canada are mostly decreasing
- ✓ Trends in the levels of Hg in biota vary
- ✓ Significant global-scale reductions in mercury emissions are predicted to be required to reduce mercury levels in fish below those currently observed across Canada.

Environment Canada | Environnement Canada | Canada

Policy questions

? 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?

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

Policy Answers

- ✓ 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
- ✓ More monitoring and research is required to entirely understand atmospheric transformation and deposition of mercury
- ✓ Atmospheric monitoring is undertaken to address several different goals including: (1) to measure the input levels of mercury to ecosystems; (2) to measure ambient levels resulting from domestic and regional emission sources; and (3) to assess transboundary transport of mercury into Canada.

Air Monitoring Networks in Canada over time

Initiated cohesive monitoring in 1997

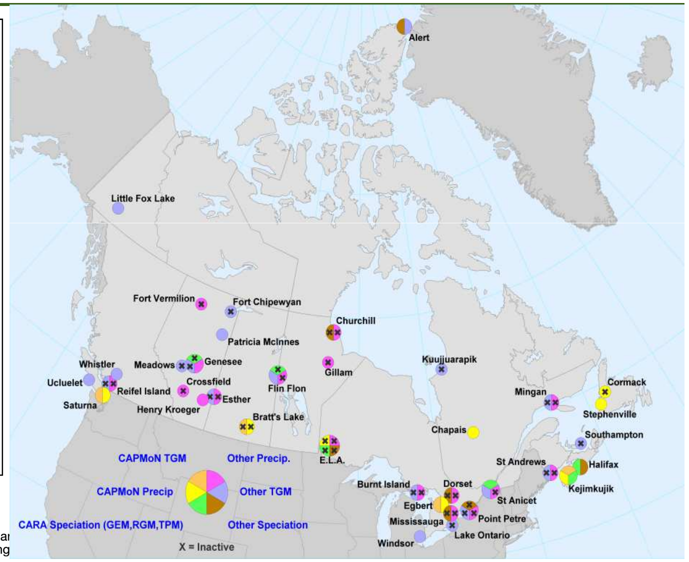
- Canadian Atmospheric Mercury Measurement Network (CAMNet)
- Canadian Air and Precipitation Monitoring Network (CAPMoN)
- Northern Contaminants Program (NCP)
- Environment Canada – Clean Air Regulatory Agenda (CARA)
- Environment and Climate Change Canada (CCAP)

- ✓ Atmospheric total gaseous Hg (TGM) / gaseous elemental Hg (GEM)
- ✓ Wet deposition (total and methyl Hg)
- ✓ Atmospheric speciation
  - Gaseous elemental Hg (GEM)
  - Reactive Gaseous Hg (RGM)
  - Particulate Hg (PHg)
- ✓ Passive sampling research to initiate monitoring

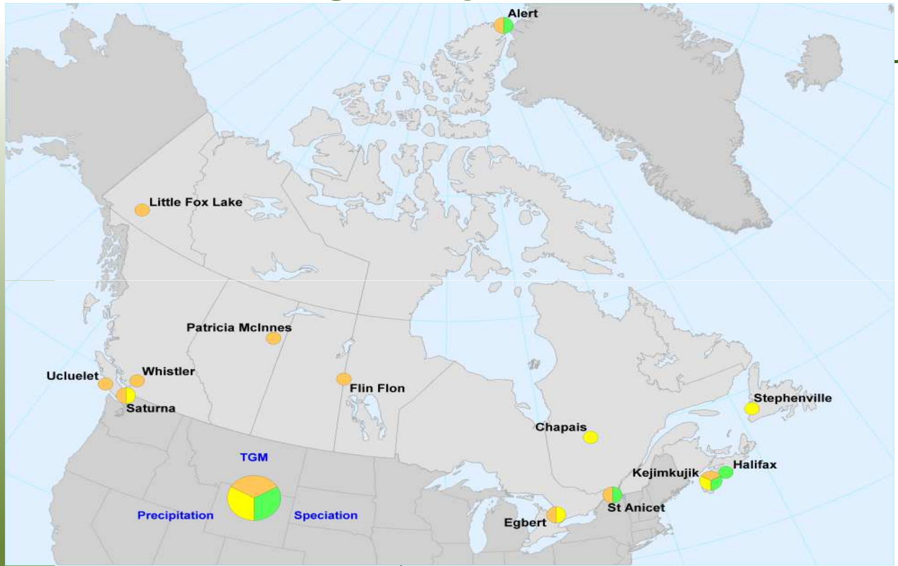
Air Monitoring in Canada over time

Air monitoring

1. **CAMNet** (1996-2007) 9-13 sites
2. **CAPMoN** (2007-present) 4 sites
3. **Wet deposition** (1996-now) 5-6 sites CAMNet/CAPMoN
4. **NCP** (1995-now)
5. **CARA** (2005-2015)
6. **IPY** (2008-2010)
7. **CCAP** (2015 - …)



Air Monitoring today in Canada



TGM - total gaseous Hg; Speciation – air gas and particles; Precipitation - total and methyl Hg

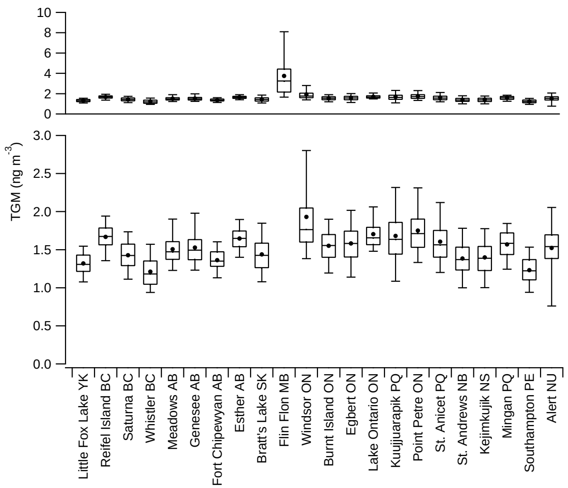
Canadian research products

- Monitoring
  - Assess spatial and temporal air concentration levels (Cole *et al*., 2014)
  - Determine trends with time (Cole *et al*., 2014)
  - Provide data for modeling
- Processes
  - Select specific environments of concern
  - Investigate transport, transformation and deposition
  - Provide information to research community (esp. modelers)
- Modelling
  - Assess concentration levels across all of Canada
  - Produce deposition maps across all of Canada
  - Assess source regions of Hg coming into Canada

TGM concentration in Canada (over all years)

- **Total gaseous mercury**
- **23 sites**
- **Different time periods**
- **Inset Flin Flon***

***metals smelter**

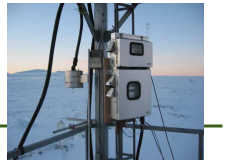


Temporal trends for TGM

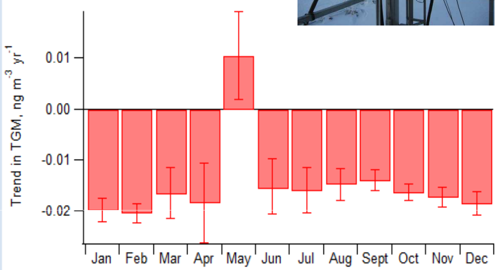
Site	Time period	TGM trend, pg m^{-3} yr^{-1}	TGM trend, % yr^{-1}
Reifel Island	1999-2004	-55 *(-70 to -40)*	-3.3 *(-4.2 to -2.4)*
Genesee	2004-2010	-6 *(-21 to +1)^{ns}*	-0.4 *(-1.4 to +0.1)^{ns}*
Bratt's Lake	2001-2010	-37 *(-48 to -23)*	-2.5 *(-3.4 to -1.6)*
Burnt Island	1998-2007	-15 *(-22 to -7)*	-1.0 *(-1.4 to -0.4)*
Egbert	1996-2010	-20 *(-27 to -16)*	-1.3 *(-1.7 to -1.0)*
Kuujjuarapik	1999-2009	-40 *(-55 to -23)*	-2.4 *(-3.4 to -1.4)*
Point Petre	1996-2007	-29 *(-38 to -20)*	-1.7 *(-2.2 to -1.2)*
St. Anicet	1995-2009	-24 *(-29 to -19)*	-1.5 *(-1.8 to -1.2)*
St. Andrews	1996-2007	-30 *(-42 to -20)*	-2.2 *(-3.1 to -1.5)*
Kejimkujik	1996-2010	-14 *(-20 to -6)*	-1.0 *(-1.4 to -0.5)*
Alert	1995-2009	-11 *(-15 to -6)*	-0.7 *(-1.0 to -0.4)*

- **Overall levels declined 10-26%** *(-0.9% to -3.3% yr^{-1} - over varying years)*
- **Greater decreases closer to emission sources**
- **Arctic shows different patterns**
- **Canadian Emissions decreased 85% since 1990**

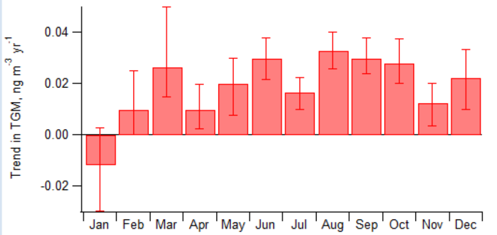
Arctic TGM trends differ from temperate regions



High eastern Arctic (Alert)
overall annual trend
(1995-2013)
-0.987% per year



Western Arctic (Little Fox Lake)
overall annual trend
(2007-2014)
+ 1.40 % per year

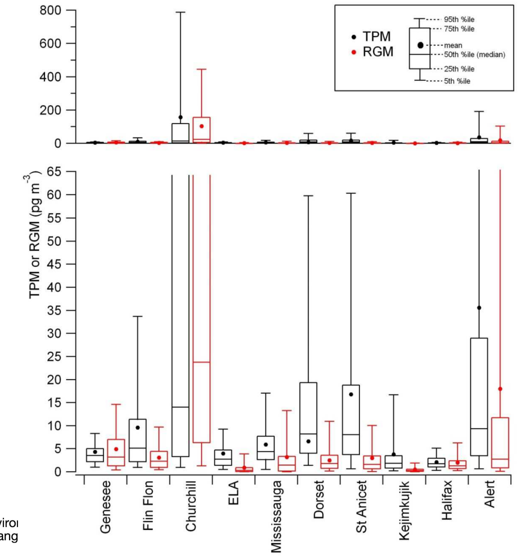


Above zero – increasing trend
Below zero – decreasing trend

Speciation Concentration in Canada Particulate (TPM), Reactive Gaseous Hg (RGM)

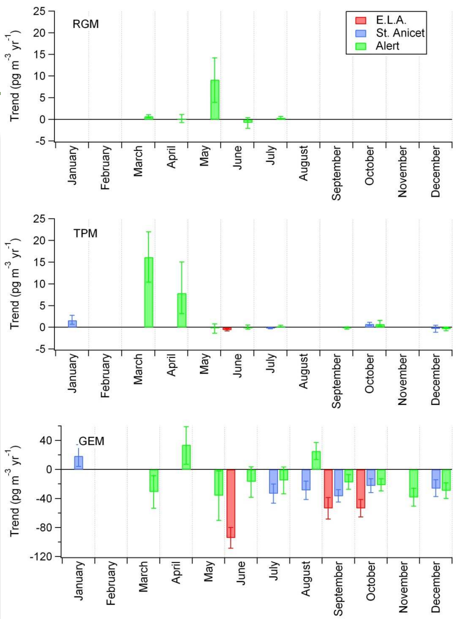
- **Hg^0 converts to Hg^{2+}**
- **Reactive gaseous mercury (RGM)**
- **Total particulate mercury (TPM)**
- **11 sites**
- **Inset includes Churchill***
- * over a very short time during spring

Environment and Climate Change Canada



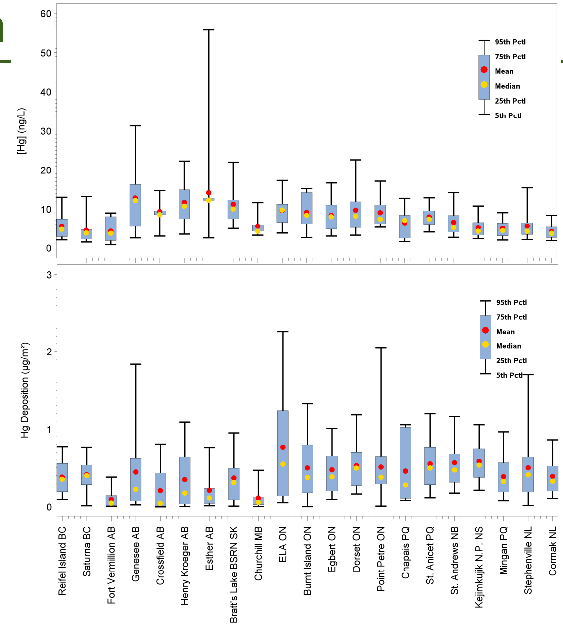
Trends of Hg speciation

- **Overall trends not reported**
- **Very small trends**
- **Monthly trends**
  - **RGM Alert May +6.8 % increase**
  - **Other no trend for RGM**
  - **TPM ELA and St A, some months -3 to +12%**
  - **TPM Alert April +7%**
  - **GEM decreasing**
- **Speciation starting to increase at some locations**



Mercury concentration and deposition in precipitation

- **Total Hg concentrations**
- **Total Hg deposition**
- **Part of US MDN**
- **22 sites**
- **Flin Flon (smelter)**
  - **Conc:158 ng L^{-1}**
  - **Dep: 6.05 ug m^2**
- **Higher levels close to local emission sources**



Hg concentration trends in precipitation

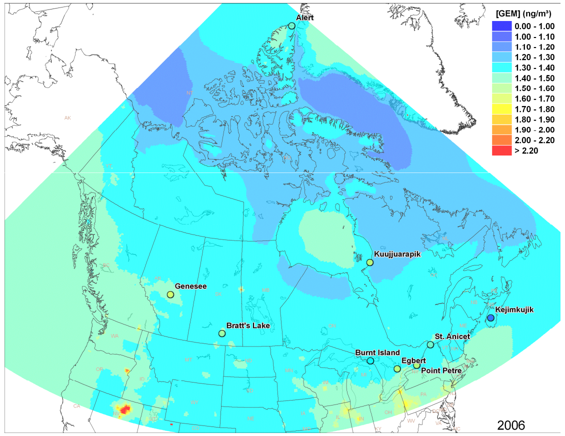
Site	Time period	[Hg] trend, [a] ng L^{-1} yr^{-1}	[Hg] trend, % yr^{-1}
Egbert	2000–2010	-0.18 (-0.31 to -0.05)	**-2.1** (-3.7 to -0.6)
St.Anicet	1998–2007	-0.22 (-0.41 to -0.05)	**-2.8** (-5.2 to -0.6)
St.Andrews	1996–2003	-0.25 (-0.43 to -0.02)	**-3.7** (-6.5 to -0.3)
Kejimkujik	1996–2010	-0.12 (-0.17 to -0.06)	**-2.2** (-3.3 to -1.2)
Mingan	1998–2007	-0.13 (-0.23 to +0.01) (NS)	**-2.5** (-4.6 to +0.2) **(NS)**
Cormak	2000–2010	-0.07 (-0.15 to +0.01) (NS)	**-1.7** (-3.5 to +0.3) **(NS)**

Volume weighted monthly means
95% confidence limits in parentheses
Data for sites > 5 years
NS not statistically significant from zero

Trends also differ over time periods

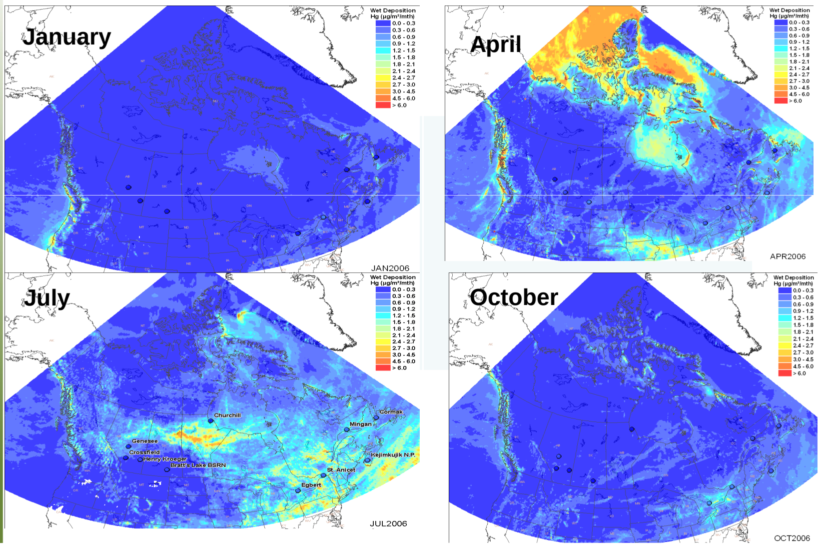
Model results
Global/Regional Atmospheric Heavy Metals Model

Modelled annual means of GEM and TGM measurements at Canadian sites active throughout 2006



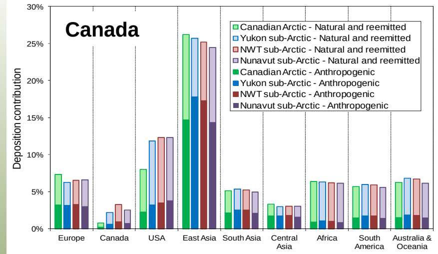
Environment and Climate Change Canada Environnement et Changement climatique Canada Canada

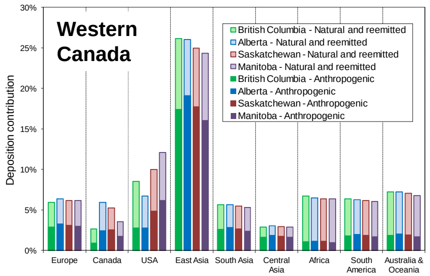
Wet deposition concentrations as modelled and measured (dots) in 2006



Hg deposition regional contribution

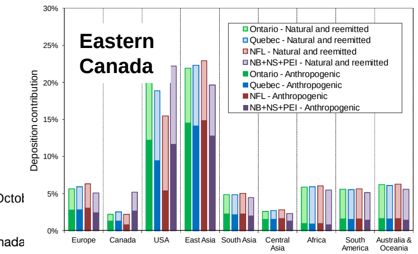
Global/Regional Atmospheric Heavy Metals Model for 2005





Relative contributions from individual source regions to net mercury deposition

Over 95% of anthropogenic Hg deposited in Canada comes from sources outside of Canada



Information courtesy of Ashu Dastoor, Environment Canada from the Canadian Mercury Science Assessment - Chapter 4

: et limatique Canada