



National Institute of
Environmental Research

Current operation and action plans of a national mercury monitoring network in Korea

JUNE 14, 2016



Ministry of
Environment

National Institute of Environmental Research

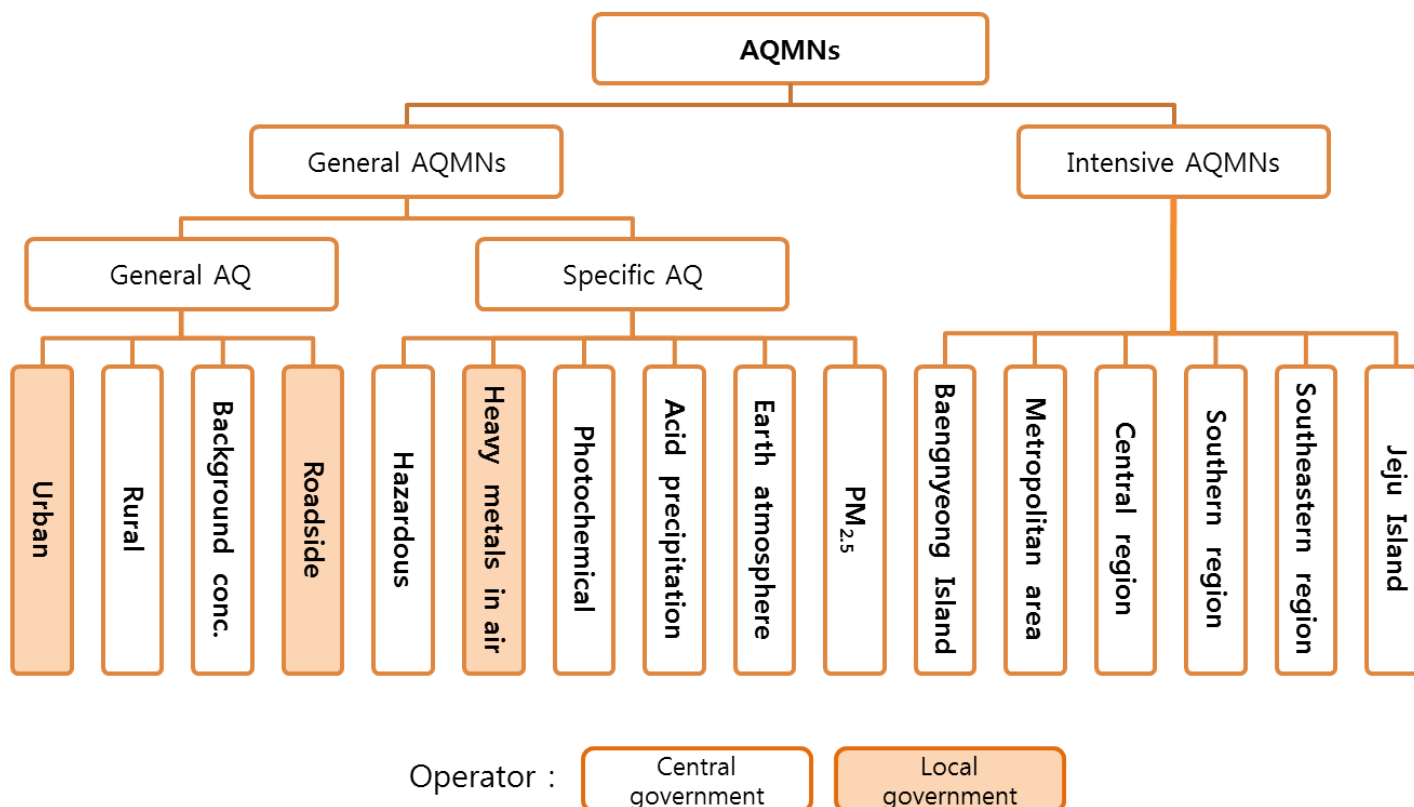
Rhokho Kim

Installation/Management of the Air Quality Monitoring Network

- The Korean government (Ministry of Environment) has installed and managed air quality monitoring stations (AQMSs) since 1973 to monitor air pollution and evaluate the implementation of the air quality improvement policies.
- Since 2011, the AQMSs have been managed in 2 groups. The first is for general monitoring including general and specific AQ monitoring (four and six stations, respectively) and the second is for intensive monitoring (six stations).
 - (General AQ) Urban/rural/roadside AQ and background concentrations
 - (Specific air quality) hazardous / photochemical / acid air pollutants (AP), atmospheric heavy metals, Earth's atmosphere, and PM_{2.5} components
 - (Intensive AQMSs)

Installation/Management of the Air Quality Monitoring Network

- Total of 505 stations in 344 locations nationwide (as of December 2015)
 - (MOE) 154 stations (76 locations)
 - (Local governments) 351 stations (306 locations)



Background & Necessity



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Risk of Mercury

- ▷ Effects on the developing nervous system
- ▷ Effects on brain functions at lower levels of Mercury

Global Pollutants

- ▷ The Global Mercury Partnership is now ready to be enforced.

Mercury Exposure Levels

- ▷ The exposure levels of Koreans were higher than those of the U.S. and Germany.

Geographical Location

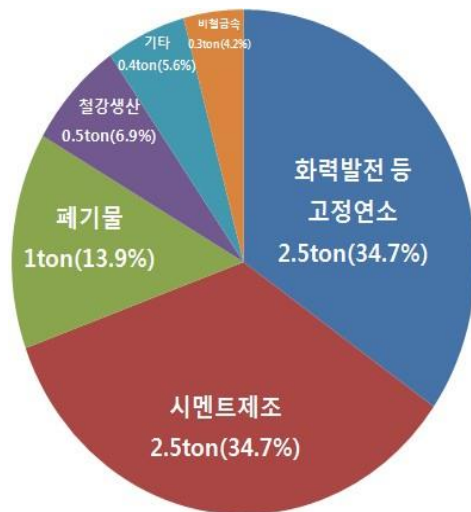
- ▷ Asian countries contributed to the global mercury emissions from anthropogenic sources.

Form	Chemical State	Roles in Hg cycle	Atmospheric concentrations
Hg^0 (ng/m ³)	GEM, Gaseous Elemental Mercury (>95%)	Low solubility, High vapor P. Lifetime: 0.5 – 2 years Global pollutant	N. America. Urban: 1.6–4.5 ng/m ³ Bkgd.: 1.3–1.6 Europe Urban: 1.9–3.4 Bkgd.: 1.4–1.9 China Urban: 9.7 ± 10.2 Bkgd.: 0.48–1.73
Hg^{2+} (pg/m ³)	GOM, Gaseous Oxidized Mercury (Divalent, ionic, oxidized)	Lifetime: Days Emitted by emission sources GEM is oxidized in the ocean (Br, Cl) Rapid removal through wet & dry deposition Local pollutant	N. America Urban: 6.9–37.2 pg/m ³ Bkgd.: 0.5–5.6 Europe Urban: 2.5 Bkgd.: 9.1–26.5 China Urban: 34.7 ± 43.9 Bkgd.: 5.7 ± 6.8
$\text{Hg}_{(p)}$ (pg/m ³)	PBM, Particulate-Bound Mercury	Lifetime: Days – weeks Emitted by emission sources GEM is combined with particles. Wet & Dry deposition Regional pollutant	N. America Urban: 2.5–25.4 pg/m ³ Bkgd.: 1.6–13.7 Europe Urban: 12.5 Bkgd.: 3.0–32.2 China Urban: 276 ± 368 Bkgd.: 18.9 ± 15.6

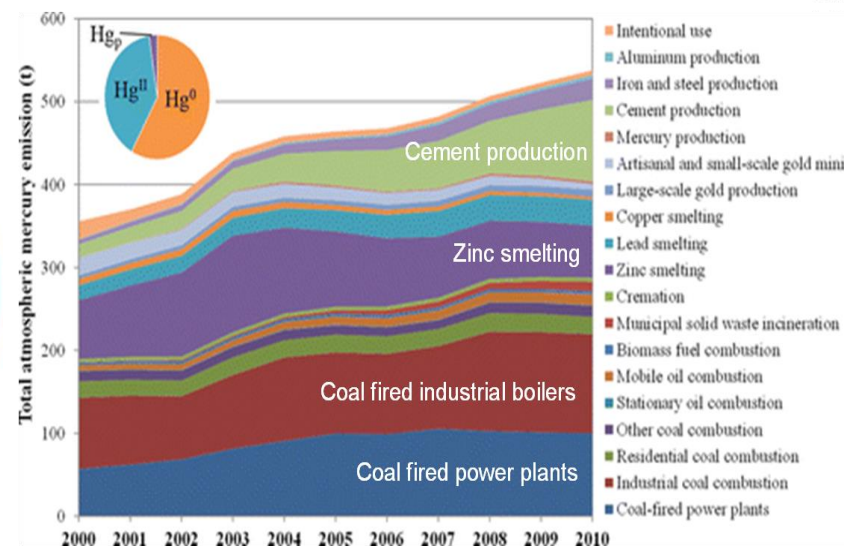
* TGM (Total Gaseous Mercury) = GEM + GOM

Anthropogenic Mercury Emission (UNEP, '13)

Country (ton/year)	Emission(2010) 1,960 ton	%	Classification			
			Coal-fired	Industrial	Small-scale gold production	other
China	575.2	29.3	180.3	203.0	167.7	25.2
U.S.	56.3	2.87	41.8	6.6	0.0	7.8
Japan	17.2	0.88	1.6	11.7	0.0	3.9
Korea	7.2	0.37	2.5	3.2	0.0	1.5

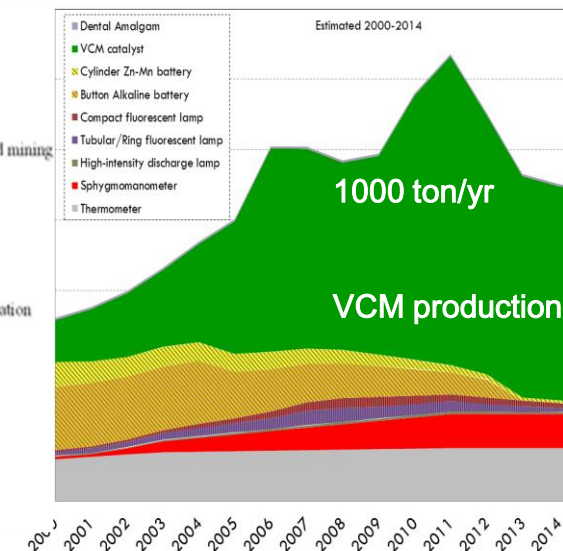


<Mercury Emission in Korea>



< Mercury Emission and use in China(L. Zhang'15)>

Annual Hg demand (tons)

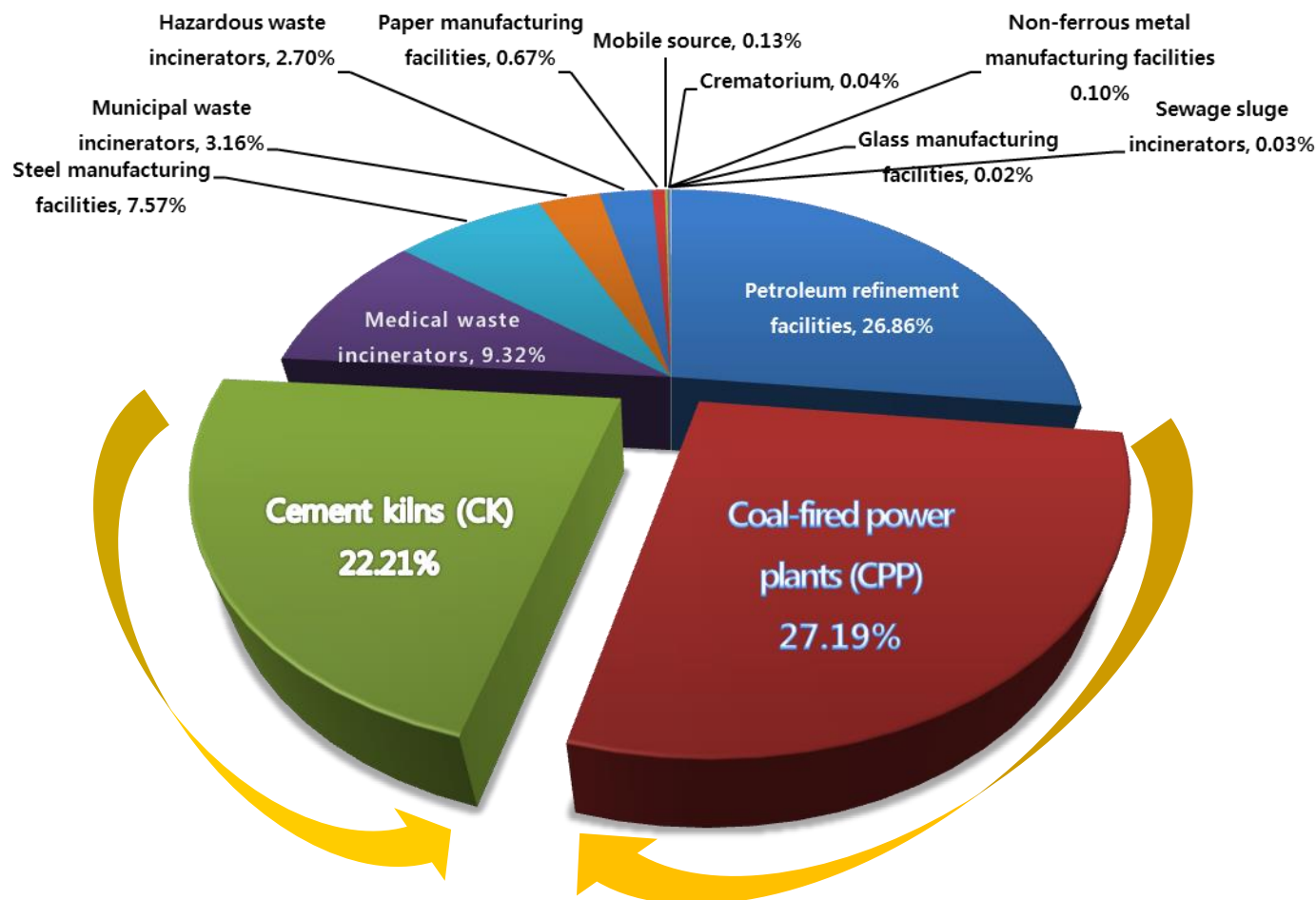


Tested Emission Sources

– multiple mercury emissions (2012)



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Minamata Convention, agreed in Oct. 2013, expected to take effect in 2016

Article 19 Research, Development & Monitoring

Article 22 Effectiveness evaluation

Global mercury monitoring network

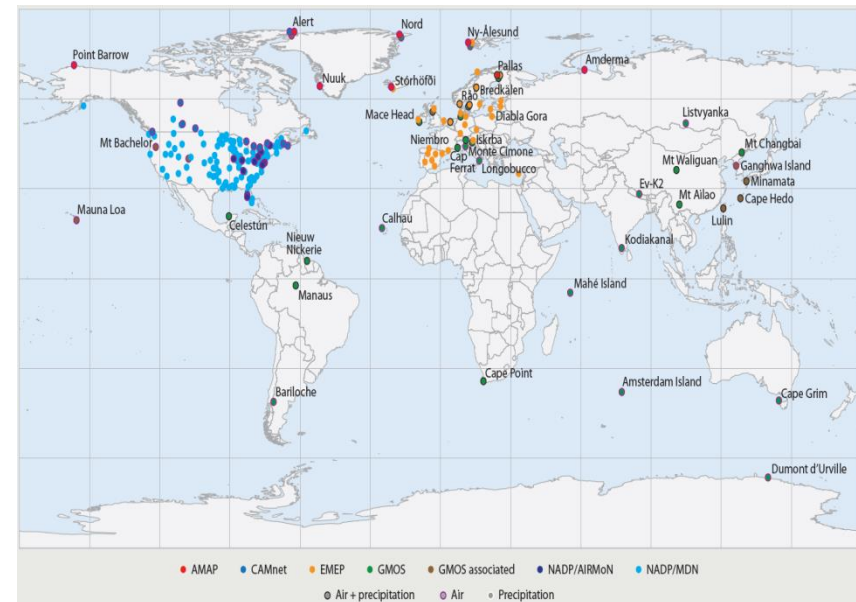
Europe : GMOS(Global Mercury Observation system)

U.S.A. : MDN(Mercury Deposition Network)

AMNet (Atmospheric Mercury Network)

APMNN(Asia –Pacific Mercury Monitoring Network)

- Korea plans to join (requires site selection and reliability of the measurement data)



Acid precipitation monitoring network



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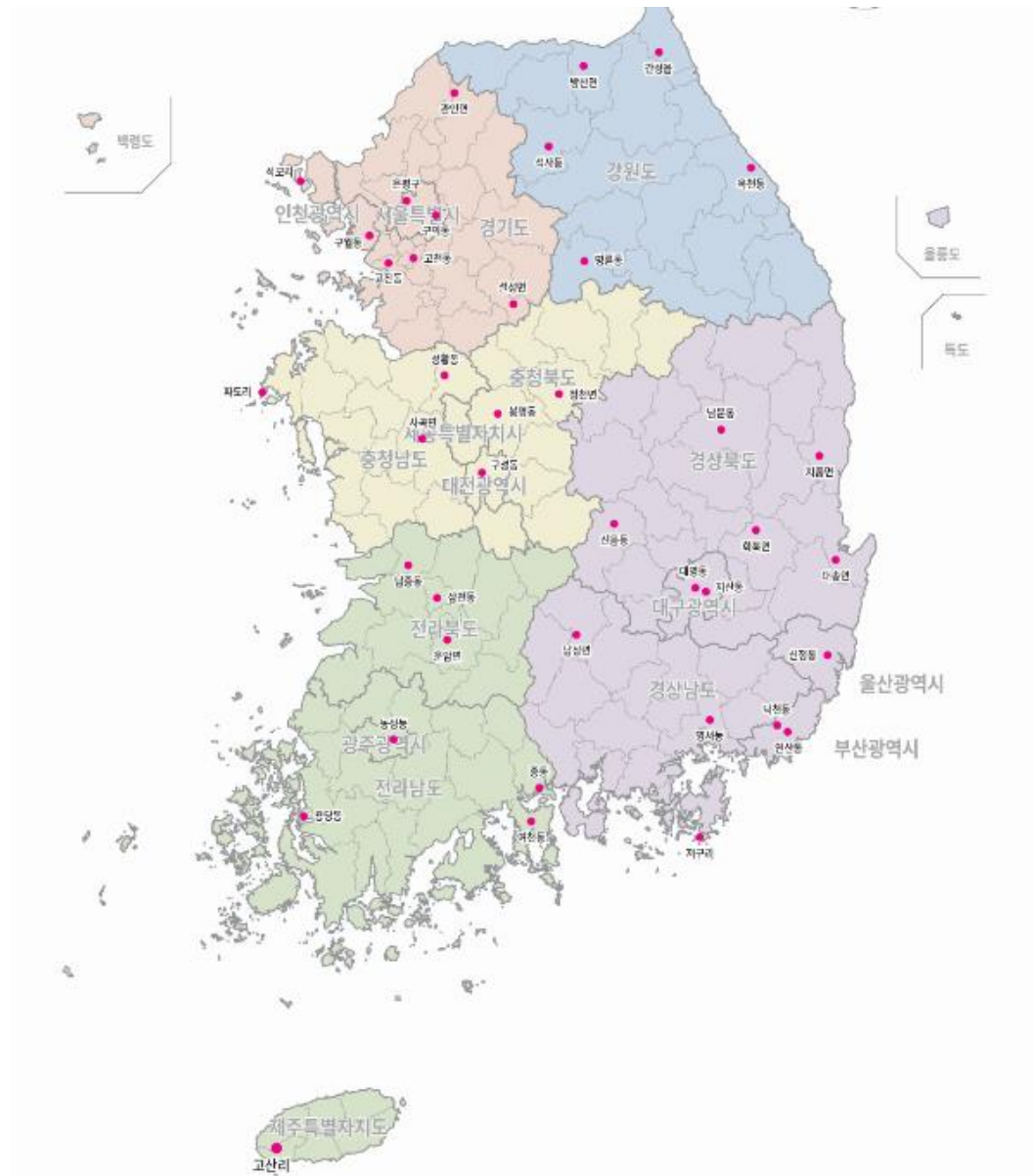
■ Purpose

- 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.
- ✂ EANET was established in 1993, led by Japan, to address the challenges caused by acid deposition in East Asia. Currently, it has 13 East Asian member countries including Korea, Japan, China, Indonesia, Malaysia, Mongolia, Philippines, Russia, Thailand, Vietnam, Cambodia, Laos, and Myanmar.

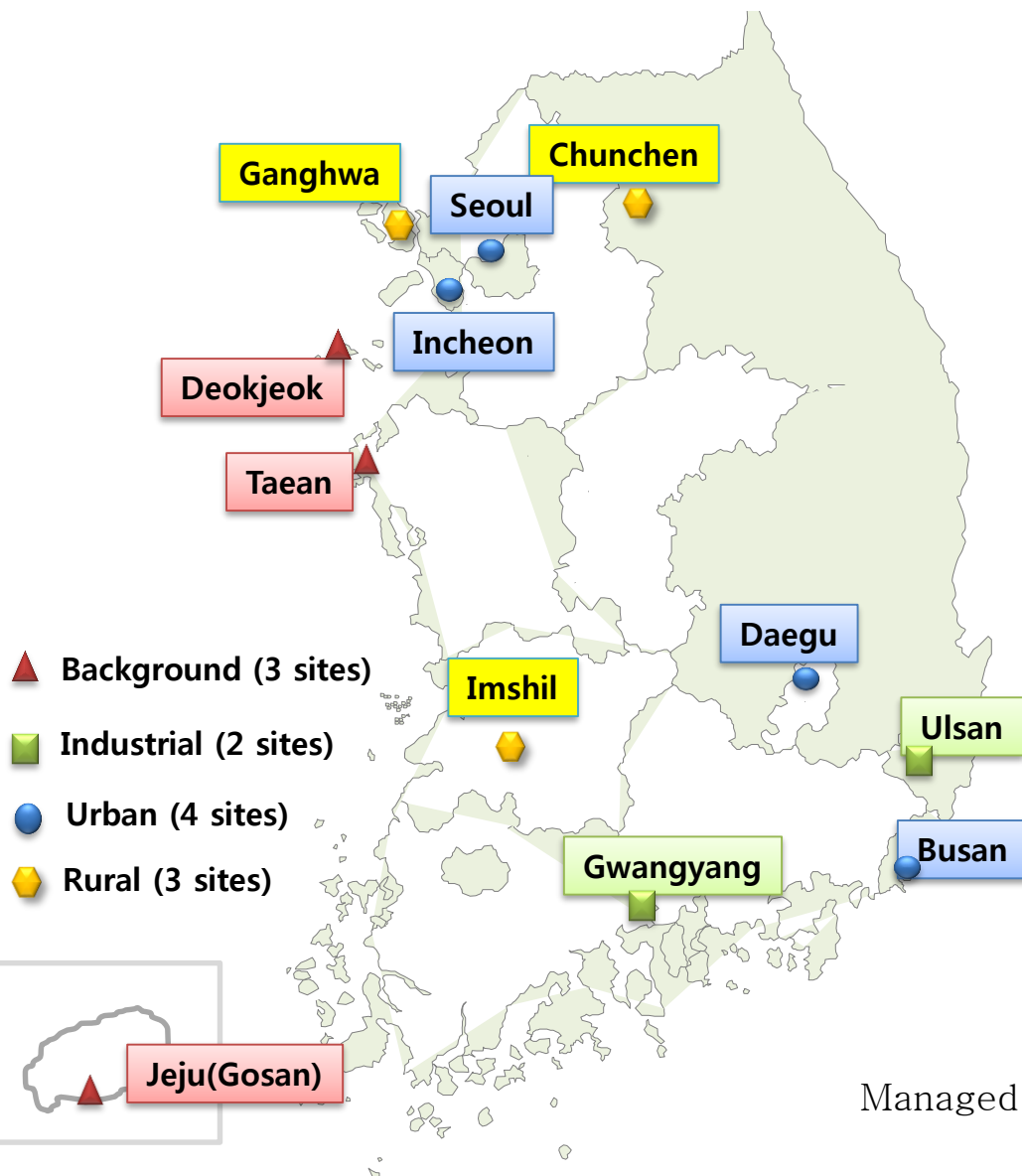
Acid precipitation monitoring network in Korea (40 stations)



■ 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.

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, Taeon, and Jeju in 2016)
(Chuncheon in 2017)
- Monitoring sites for mercury by species
(Taeon and Jeju in 2017)

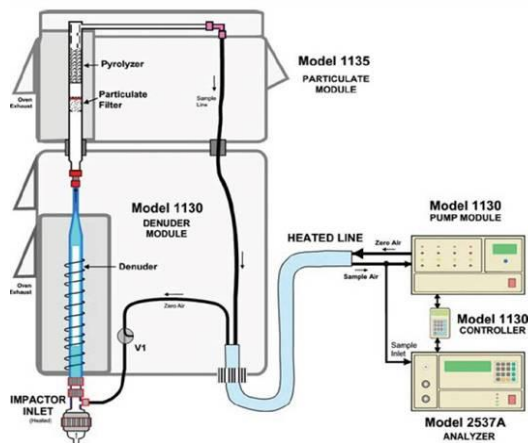
National Mercury Monitoring Network

■ 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

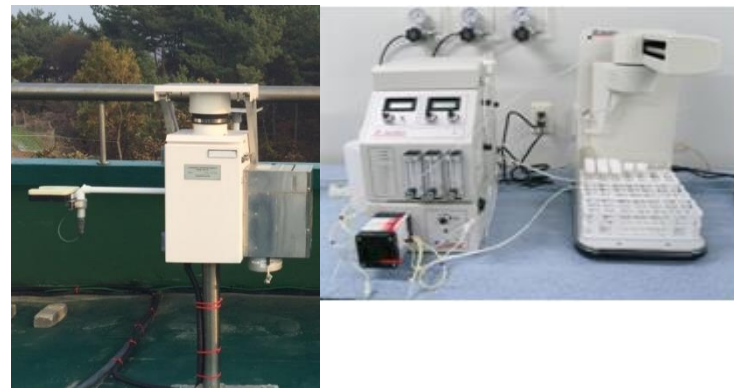
Concentration of atmospheric Hg by chemical specie



Tekran 2537/1130/1135, Canada

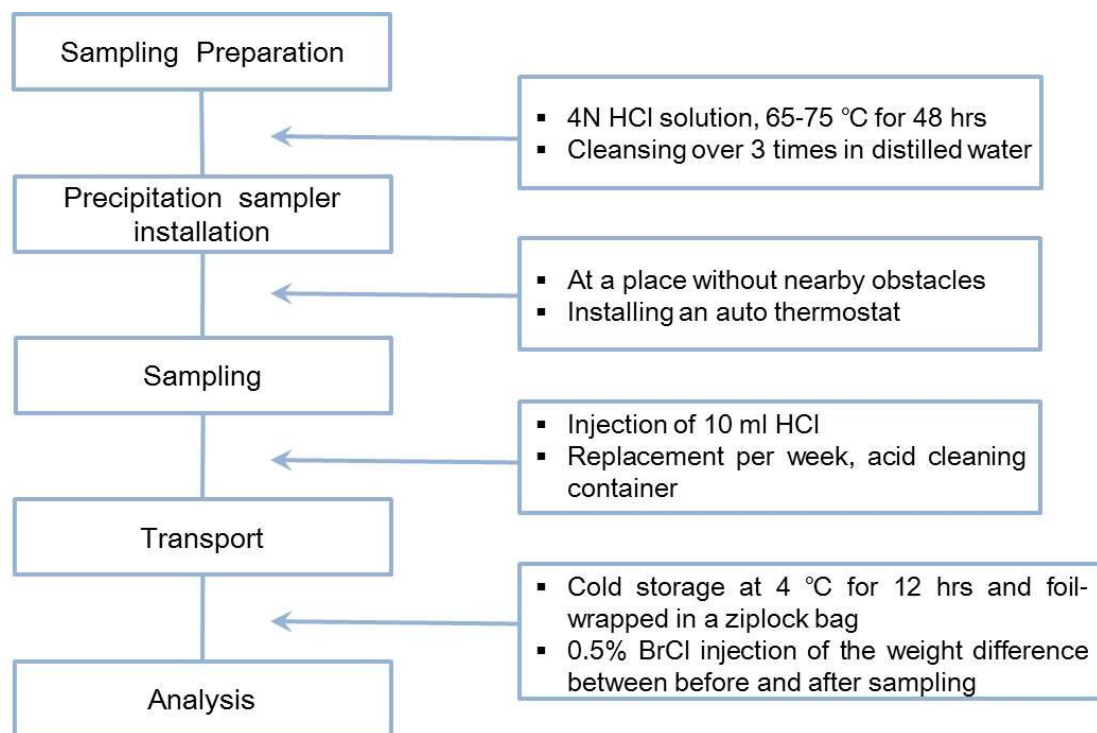
- TGM: 5-minute interval using Tekran 2537
- GOM & PBM: 2-hour interval using Tekran 1130/1135
- QC: accuracy with reference samples using Tekran 2505
: reference value adjustment via zero air measurement per 2 min.

Hg concentration in precipitation

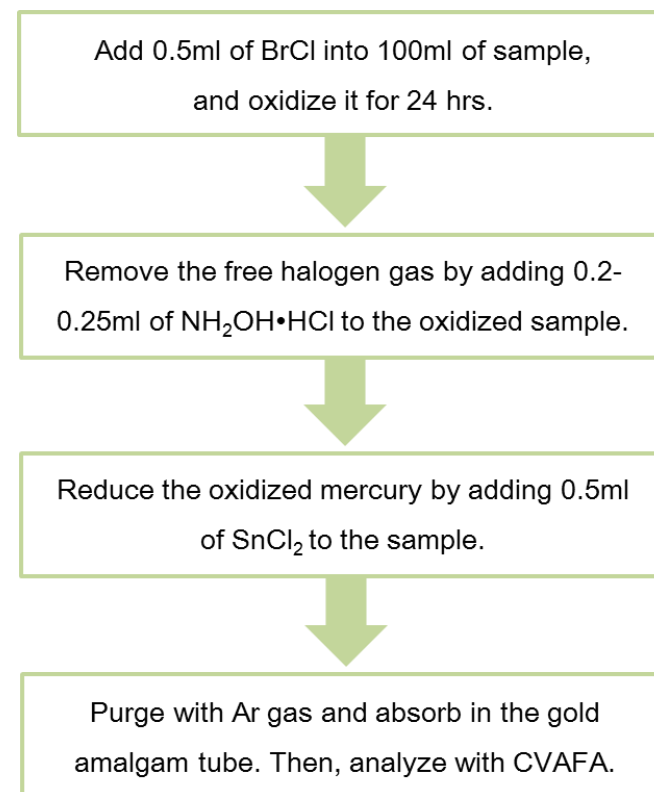


- Cumulative precipitation sampling per week (N-CON, Canada)
- Total Hg analysis using Tekran 2600
- Comparative experiments among labs
 - Subsampling through homogenization and stabilization of the samples
 - APMN, Taiwan Central University, and GIST

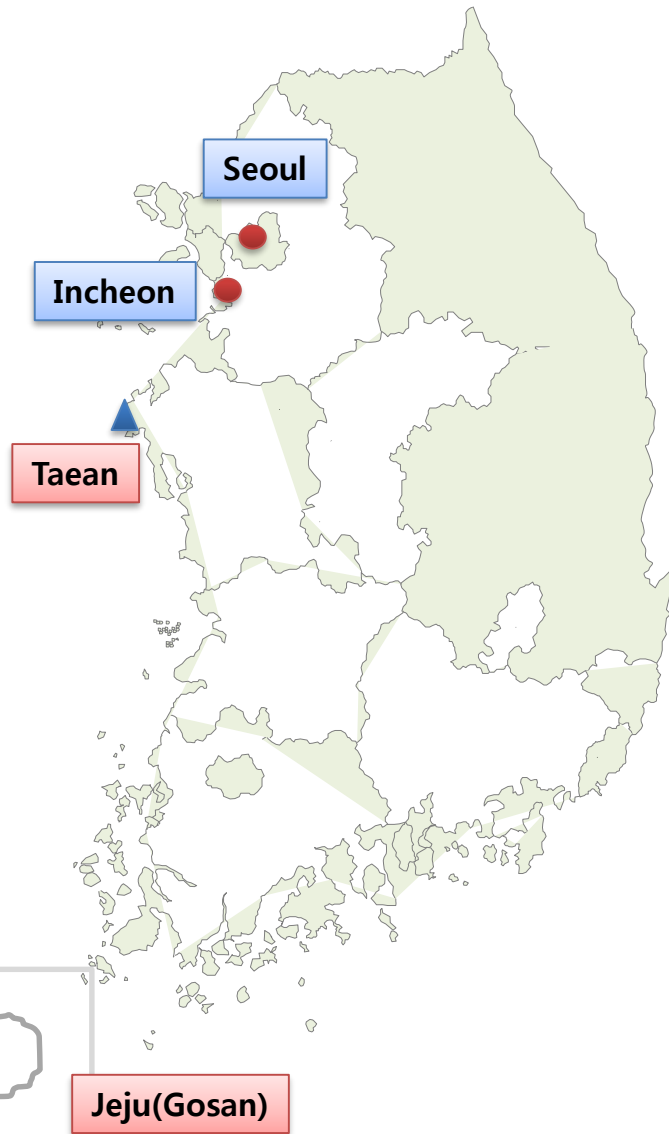
Method of Measurement



< EPA method 1631 >



Characteristics of Atmospheric Total Gaseous Mercury Concentrations



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



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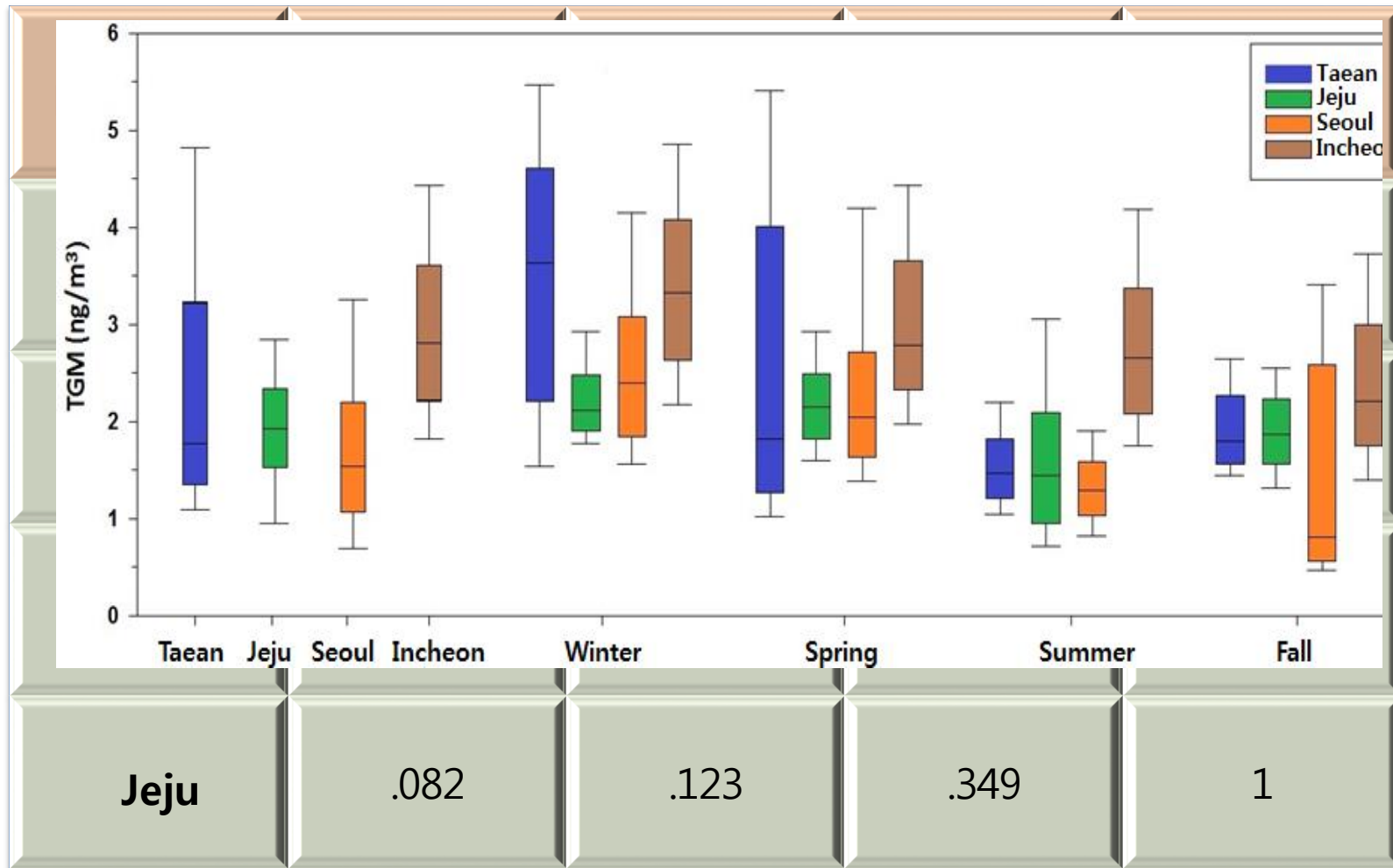
	Seoul	Incheon	Taeon	Jeju
Winter (Dec-Feb)	2.5 ± 1.0	3.3 ± 0.5	3.1 ± 1.5	1.8 ± 0.8
Spring (Mar-May)	2.6 ± 2.2	3.0 ± 0.3	2.8 ± 1.8	2.2 ± 0.05
Summer (Jun-Aug)	1.3 ± 0.5	2.9 ± 0.4	1.6 ± 0.5	1.6 ± 0.9
Fall (Sep-Nov)	2.4 ± 1.5	2.6 ± 0.2	1.9 ± TGM (ng/m ³) 0.7	1.3 ± 0.6
Total (range)	2.19 ± 1.57 (0.29-29.35)	2.97 ± 1.18 (1.01-15.97)	2.32 ± 1.40 (0.69-10.96)	1.73 ± 0.80 (0.40-4.68)

0.71

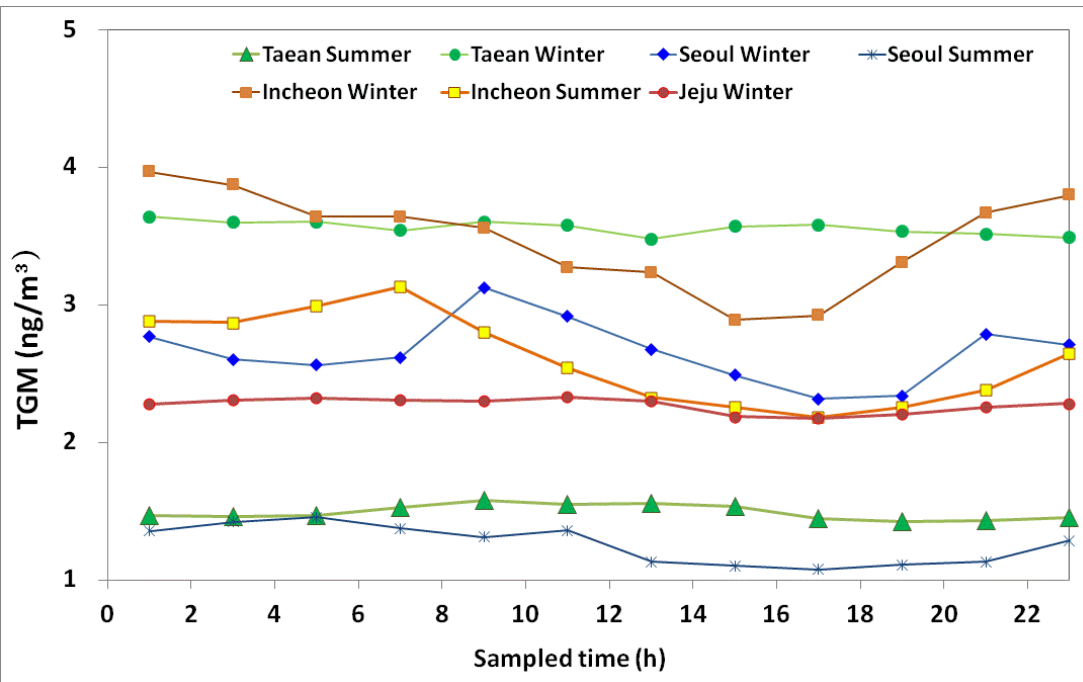
0.61

0.46

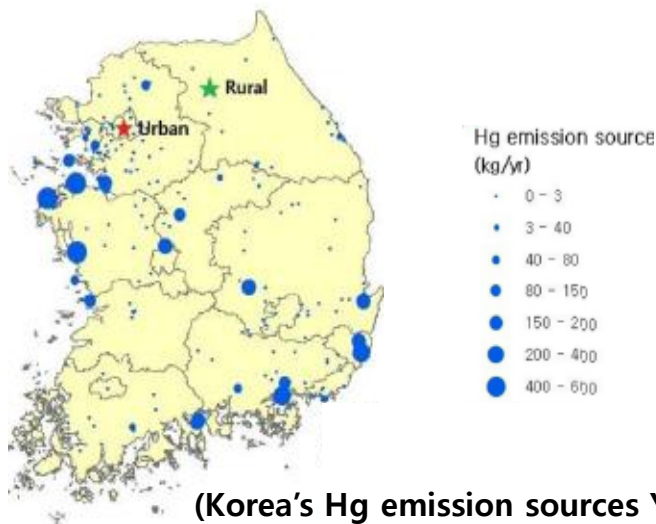
Comparison of seasonal TGM concentrations between sampling sites



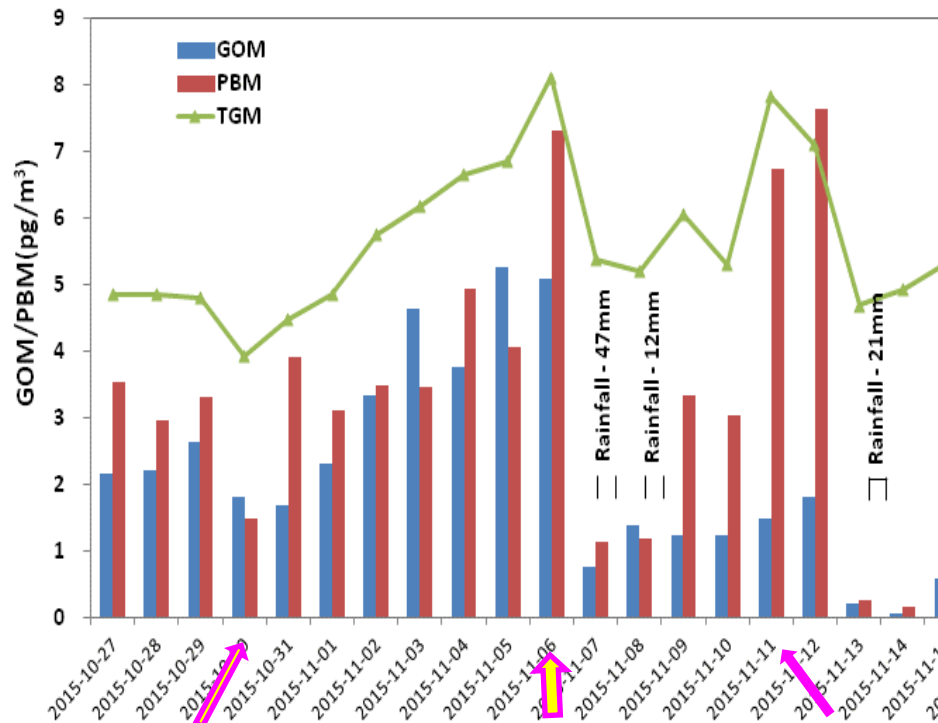
Comparison of hourly TGM concentrations



- Little change in Jeju and Taejeon
⇒ 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



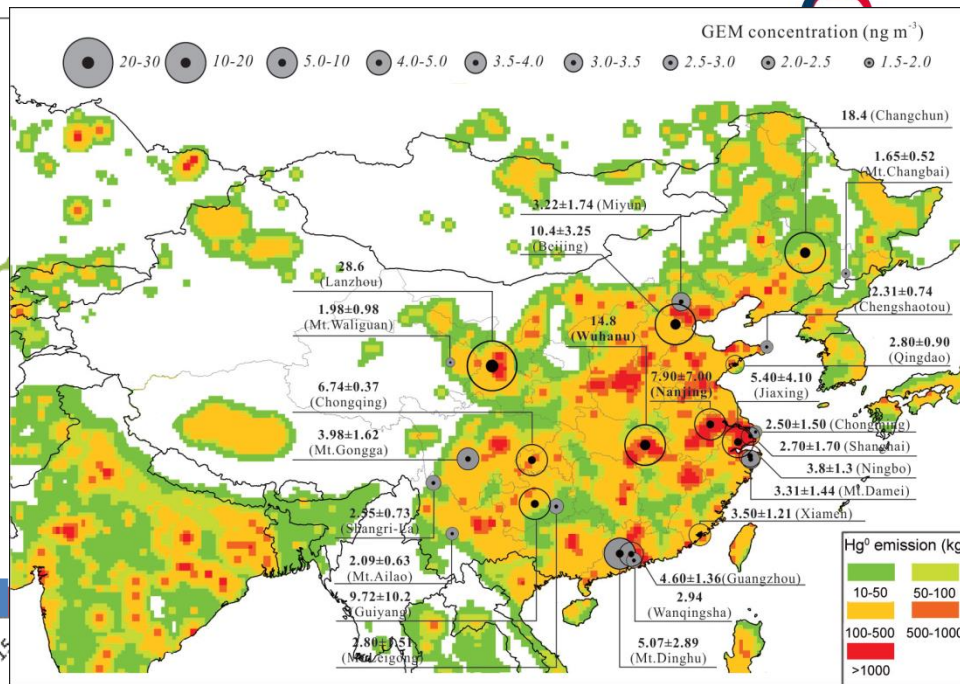
(Korea's Hg emission sources Y. Lee, '11)



GOM, PBM 낮음

GOM, PBM 높음

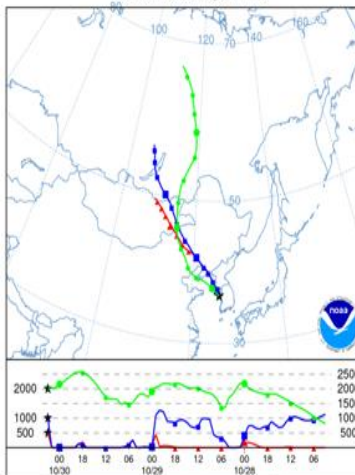
GOM 낮고, PBM 높음



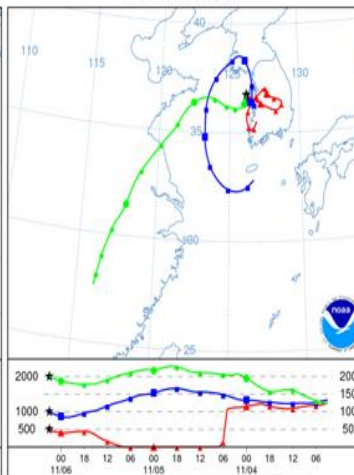
(< 90 km) affected by local sources

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

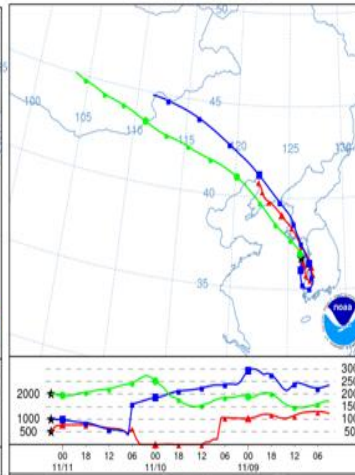
NOAA HYSPLIT MODEL
Backward trajectories ending at 0300 UTC 30 Oct 15
GFS Meteorological Data



NOAA HYSPLIT MODEL
Backward trajectories ending at 0300 UTC 06 Nov 15
GFS Meteorological Data



NOAA HYSPLIT MODEL
Backward trajectories ending at 0300 UTC 11 Nov 15
GFS Meteorological Data

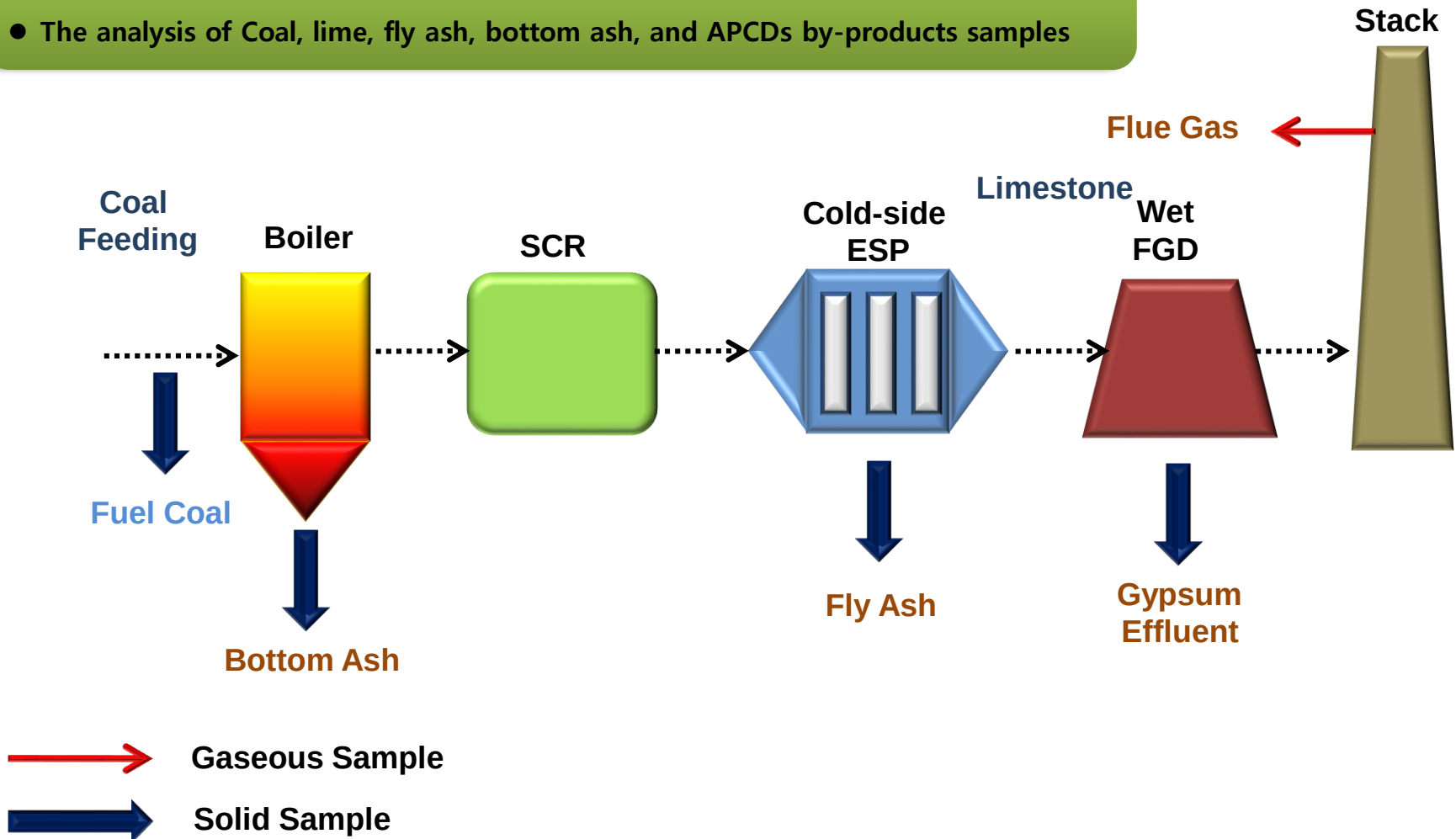


Schematic diagram of coal-fired power plants(CPP)



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- 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



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)



Characteristics of Continuous Emission Monitoring(CEM) systems

- Thermo

- Difficulty measuring lower levels (below $0.5 \mu\text{g}/\text{m}^3$) unless nitrogen dilution system is used.
- Game cube probe has plugging problems with high particulate environments

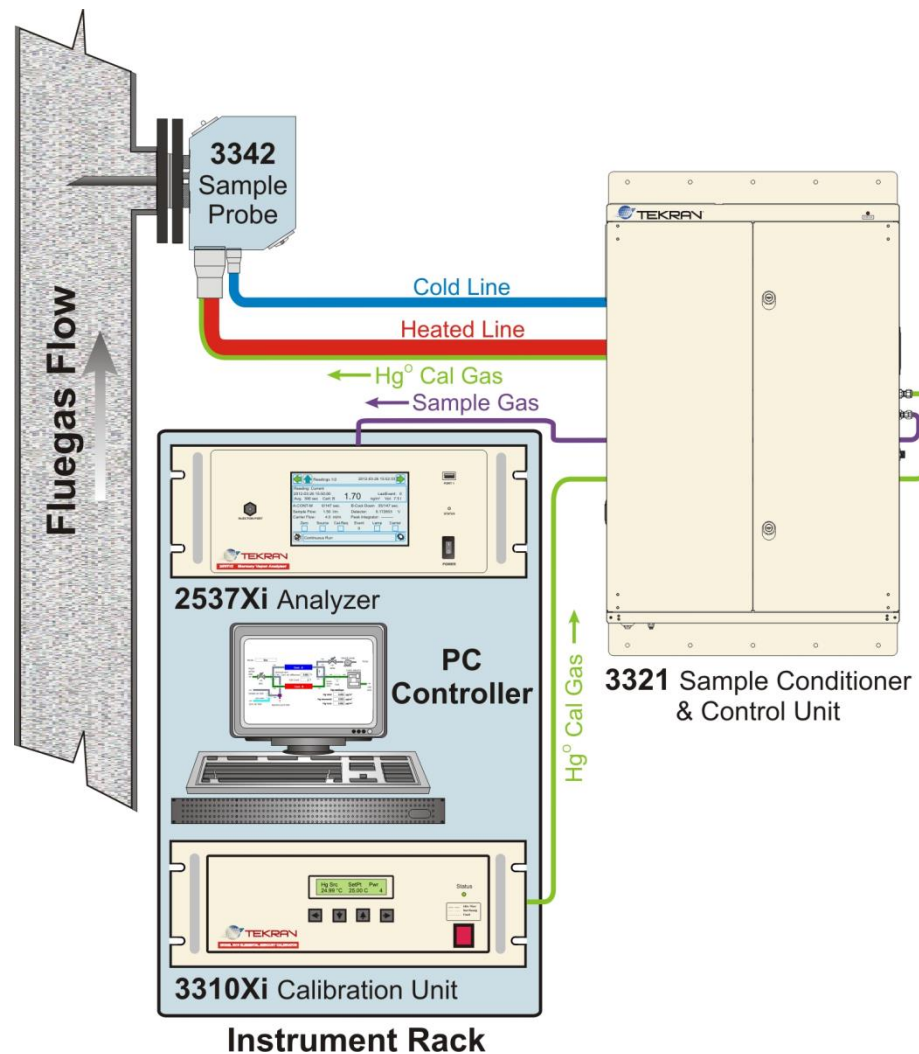
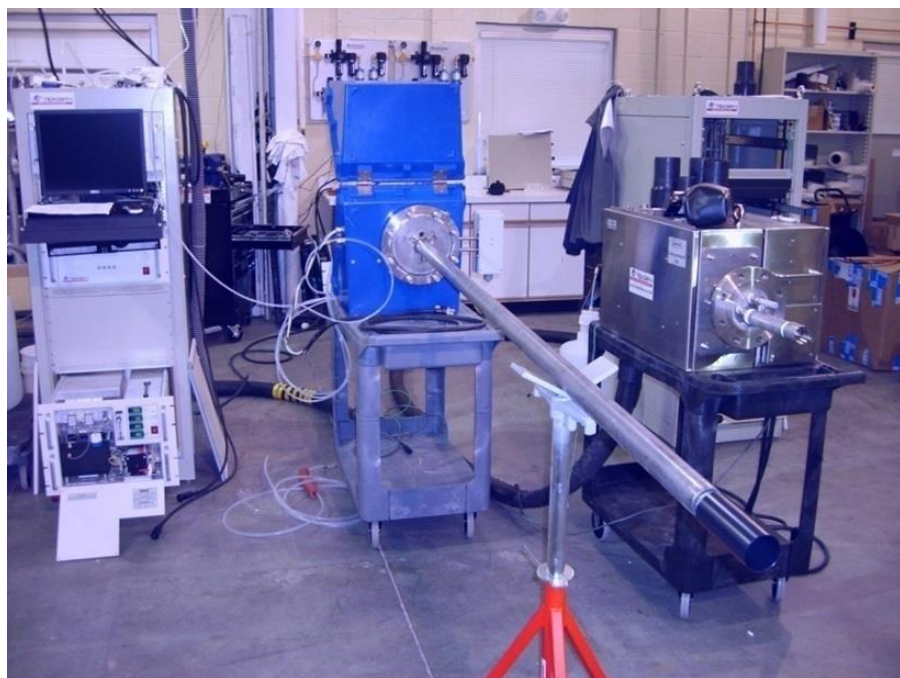
- Tekran

- Probe is very heavy
- Calibrator output Audit recommended

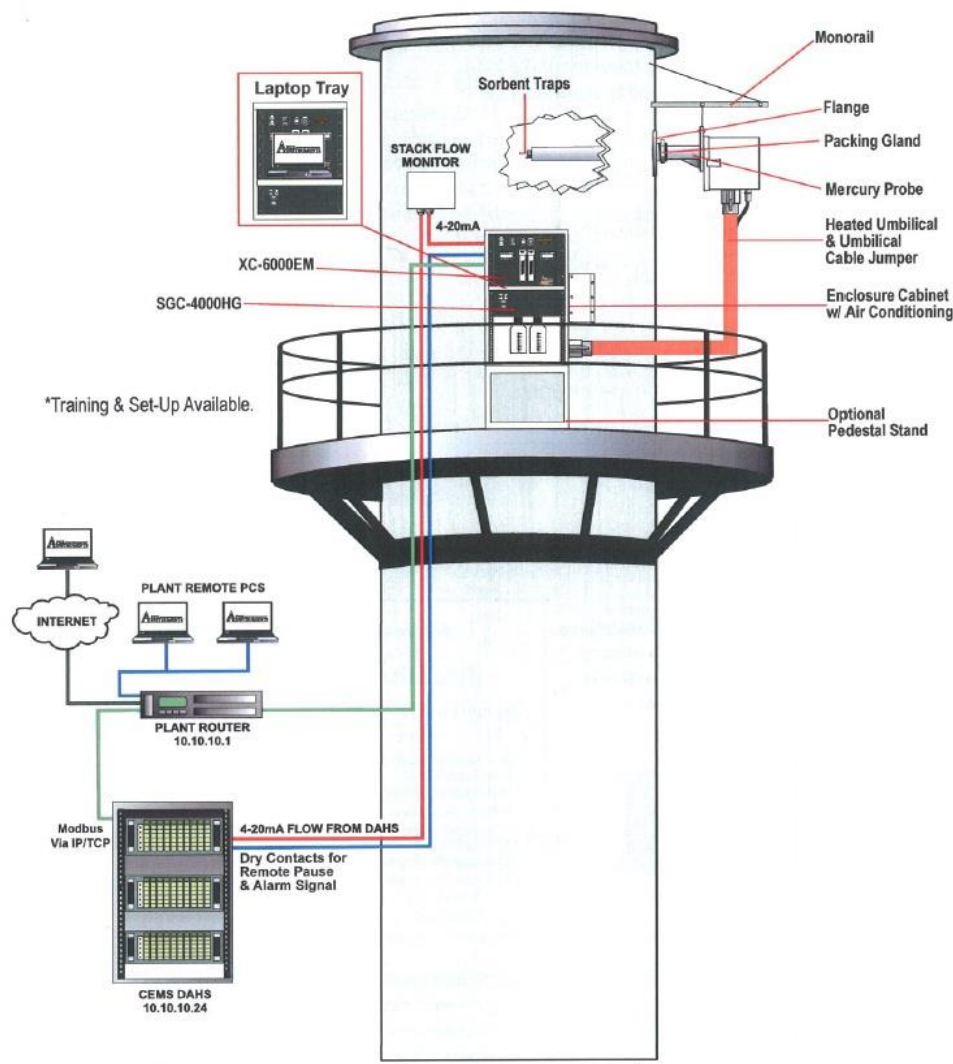


All Mercury CEMs are expensive, require lots of maintenance need reliable certified source of Hg calibration gas, have converter efficiency problems, require constant testing of calibrator outputs using sorbent sampler but they offer real time measurements

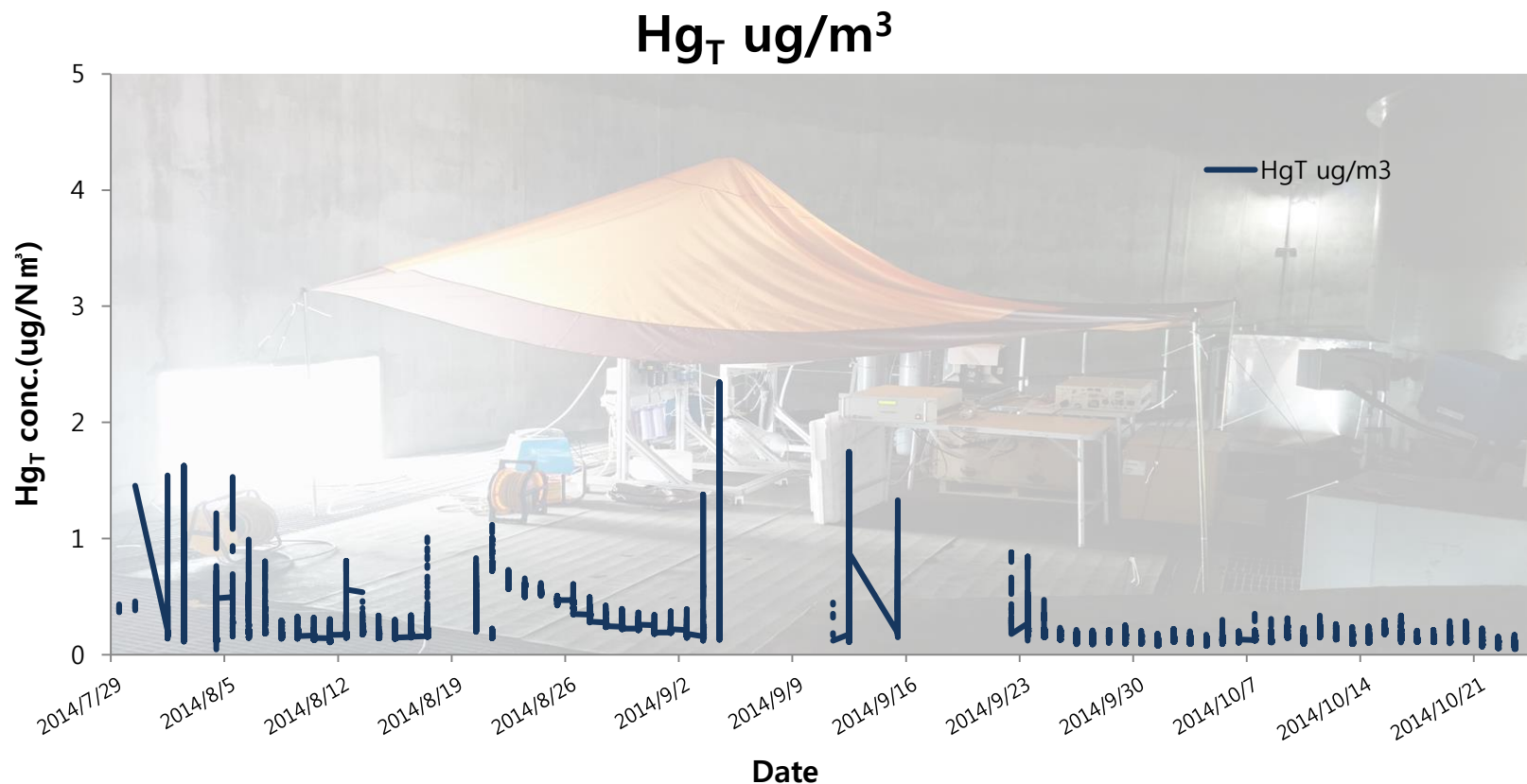
The appearance and general structure of a CEM system



Field Installation of a CEM system



Result of analyzing flue gas through CEM

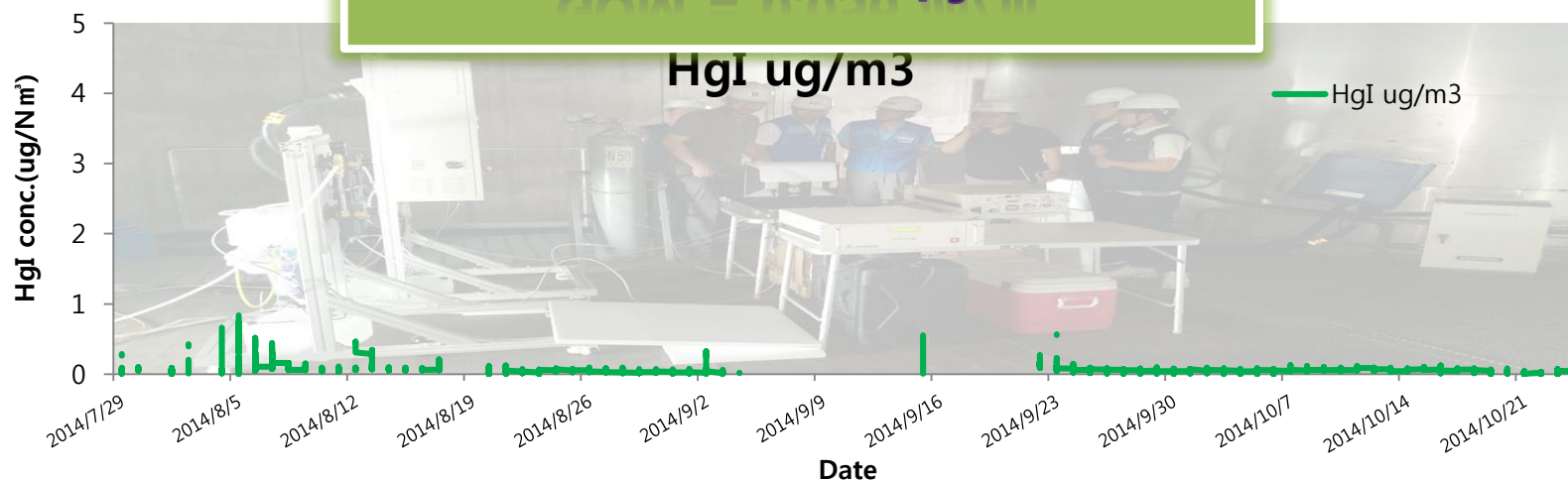
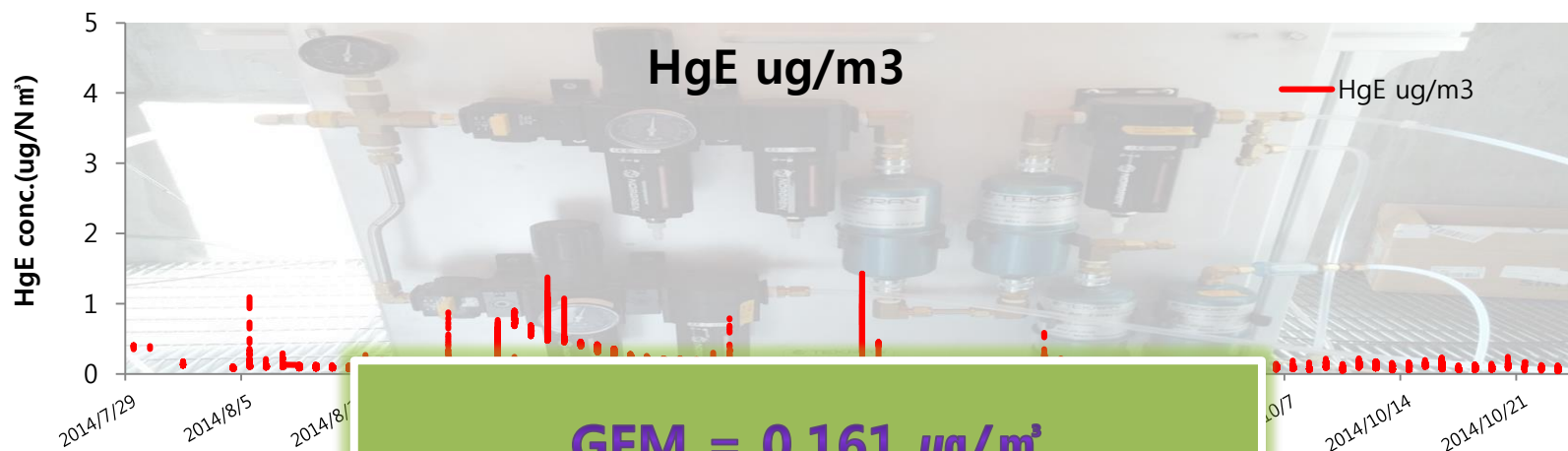


$\text{Hg}_T \text{ Conc. (gaseous mercury)} = 0.217 \text{ } \mu\text{g/m}^3 \text{ (July 29 ~ Oct. 24)}$

Result of analyzing flue gas through CEM

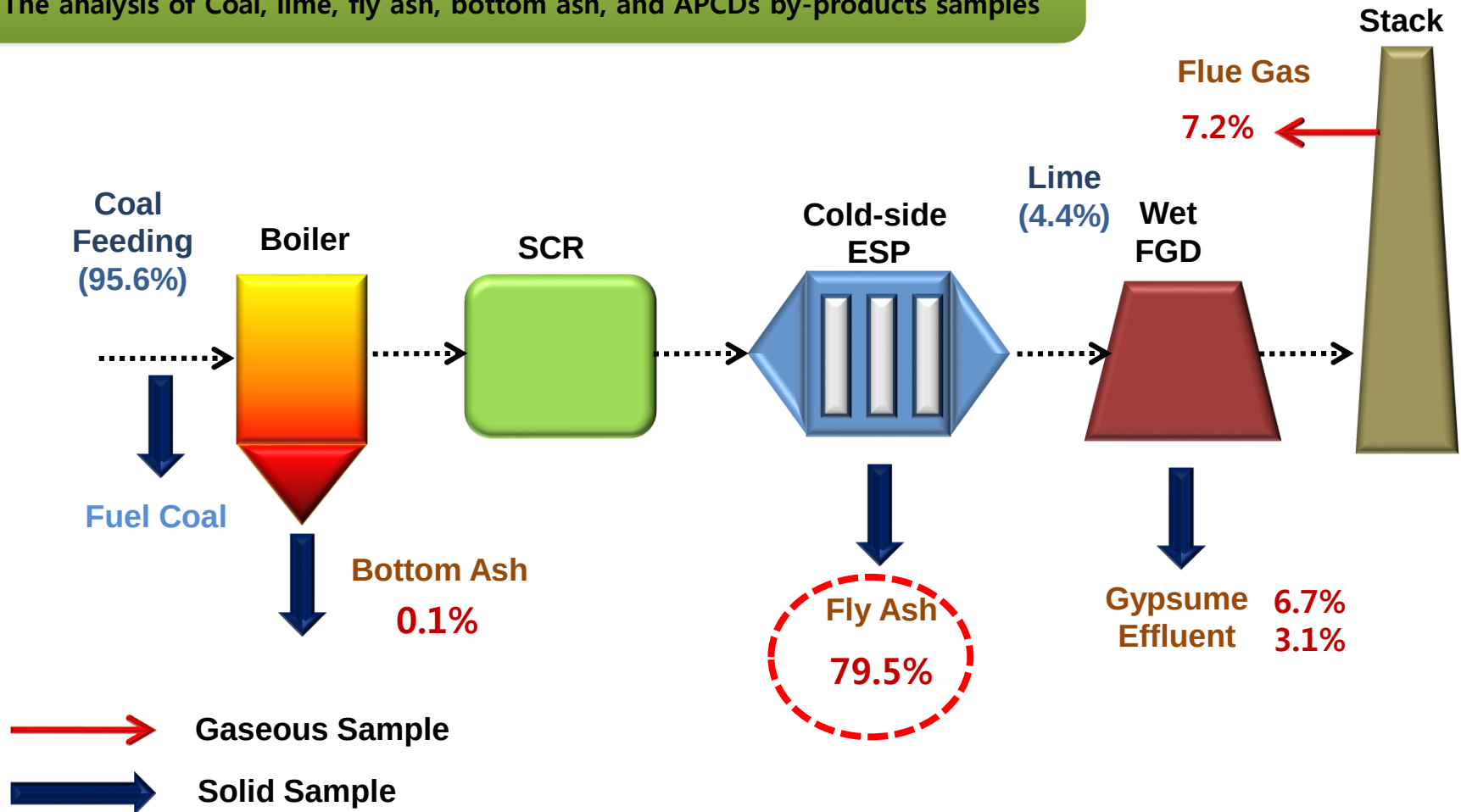


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Hg Mass balance in CPP

- 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



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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 m³/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 m³/day



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THANK YOU

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