MerPAS Overview

Mercury Passive Air Sampler

MerPAS@Tekran.com

2025

*Mer*PAS Development Summary

- **Mer**cury **P**assive **A**ir **S**ampler
- Developed at U. of Toronto by David McLagan, Frank Wania and Carl Mitchell
- U. of Toronto global study documented that MerPAS is capable of accurate and precise background ambient air measurements (1-3 ng/m^3 = 100-350 ppqv)
- Sample rate (SR) calibrated with Tekran 2537 Ambient Air Monitors at multiple sites
- On-going studies for contaminated sites and indoor air

MerPAS Studies
U. of Toronto

ENVIRONMENTAL Science & Technology LETTERS

Letter

pubs.acs.org/journal/estlcu

A High-Precision Passive Air Sampler for Gaseous Mercury

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Supporting Information

ABSTRACT: Passive air samplers (PASs) provide an opportunity to improve the spatial range and resolution of gaseous mercury (Hg) measurements. Here, we propose a sampler design that combines a sulfur-impregnated activated carbon sorbent, a Radiello diffusive barrier, and a protective shield for outdoor deployments. The amount of gaseous Hg taken up by the sampler increased linearly with time for both an 11-week indoor (r^2 = 0.990) and 12-month outdoor (r^2 = 0.996) deployment, yielding sampling rates of 0.158 ± 0.008 m^3 day^{-1} indoors and 0.121 ± 0.005 m^3 day^{-1} outdoors. These sampling rates are close to modeled estimates of 0.166 m^3 day^{-1} indoors and 0.129 m^3 day^{-1} outdoors. Replicate precision is better than for all previous PASs for gaseous Hg, especially during outdoor deployments (2 ± 1.3%). Such precision is essential for discriminating the relatively small concentration variations occurring at background sites. Deployment times for obtaining reliable time-averaged atmospheric gaseous Hg concentrations range from a week to at least one year.

Atmos. Chem. Phys., 18, 5905–5919, 2018
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Atmospheric Chemistry and Physics Open Access EGU

Global evaluation and calibration of a passive air sampler for gaseous mercury

David S. McLagan[1], Carl P. J. Mitchell[1], Alexandra Steffen[2], Hayley Hung[2], Cecilia Shin[2], Geoff W. Stupple[2], Mark L. Olson[3], Winston T. Luke[4], Paul Kelley[4], Dean Howard[5], Grant C. Edwards[5], Peter F. Nelson[5], Hang Xiao[6], Guey-Rong Sheu[7], Annekatrin Dreyer[8], Haiyong Huang[1], Batual Abdul Hussain[1], Ying D. Lei[1], Ilana Tavshunsky[1], and Frank Wania[1]

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Atmospheric Measurement Techniques Open Access EGU

The effects of meteorological parameters and diffusive barrier reuse on the sampling rate of a passive air sampler for gaseous mercury

David S. McLagan, Carl P. J. Mitchell, Haiyong Huang, Batual Abdul Hussain, Ying Duan Lei, and Frank Wania

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Revised: 4 September 2017 – Accepted: 5 September 2017 – Published: 5 October 2017

JGR Atmospheres

RESEARCH ARTICLE
10.1029/2018JD029373

Key Points:
- Gaseous Hg concentrations, ranging over 4 orders of magnitude, can be measured concurrently at numerous sites
- The concentrations are averaged

Characterization and Quantification of Atmospheric Mercury Sources Using Passive Air Samplers

David S. McLagan[1], Fabrizio Monaci[2], Haiyong Huang[1], Ying Duan Lei[1], Carl P. J. Mitchell[1], and Frank Wania[1]

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Technical note

Application of sodium carbonate prevents sulphur poisoning of catalysts in automated total mercury analysis

David S. McLagan, Haiyong Huang, Ying D. Lei, Frank Wania, Carl P.J. Mitchell *

Department of Physical & Environmental Sciences, University of Toronto Scarborough, 1265 Military Trail, Toronto, ON M1C 1A4, Canada

Identifying and evaluating urban mercury emission sources through passive sampler-based mapping of atmospheric concentrations

David S McLagan[1], Batual Abdul Hussain[1], Haiyong Huang[1], Ying D Lei[1], Frank Wania[1] and Carl P J Mitchell[1,2]

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Basics of *Mer*PAS

High sulfur carbon media in stainless steel screen insert

- Design resulted in precise, stable & robust **S**ampling **R**ate (**SR**)
- Jar provides protection, eliminates wind effects and used as a container for transport
- SR determined using the Tekran 2537 Hg Monitor

Concentration derivation equation:

gaseous Hg concentration (ng m^{-3}) — sampling rate (m^3 day^{-1})

$$C = m / (SR * t)$$

mass of sorbed Hg (ng) — deployment time (days)

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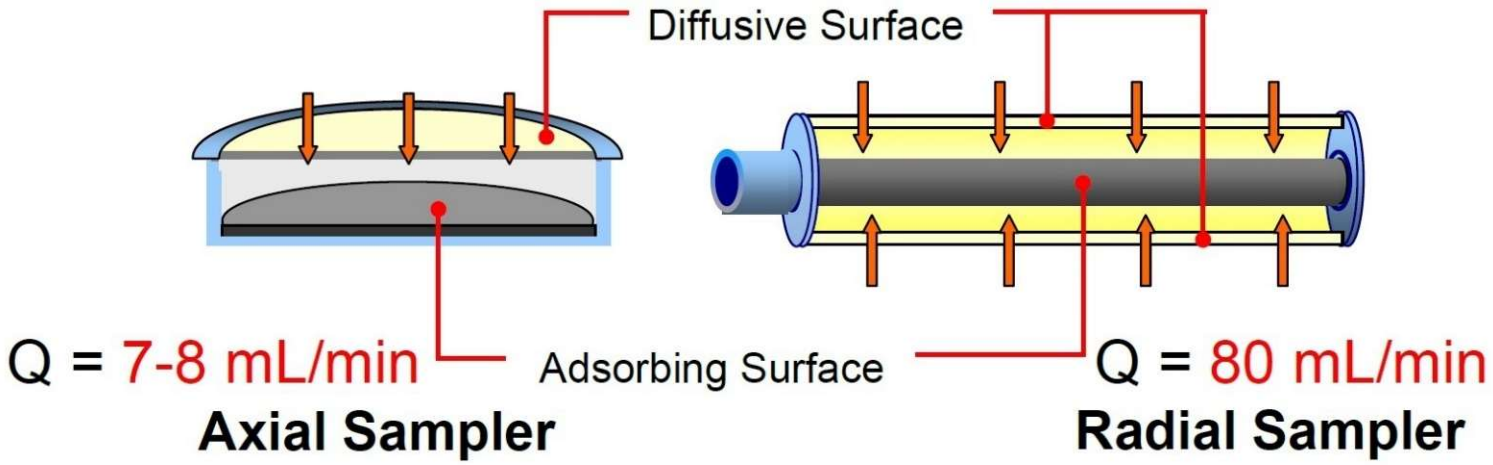
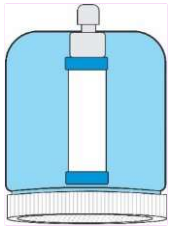
Significant Advantage of Radial Design



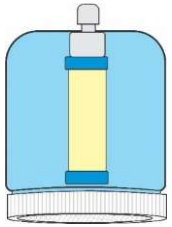
Diffusive sampling rate for benzene and activated charcoal

- Radiello diffusive surface has:
  - Consistent sample rate performance
  - Non-detectable Hg blank
  - Very minimal wind and temperature effect

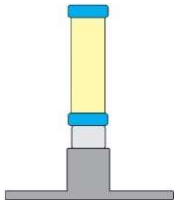
MerPAS Configurations



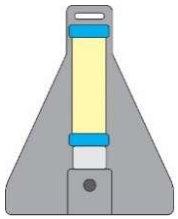
- OUTDOOR AMBIENT AIR
  - 0-50 ng/m^3 | 7 to 365 Days



- OUTDOOR CONTAMINATED AIR
  - 0.050-1000 ug/m^3 | hours to 7 days



- INDOOR AIR
  - 0-1000 ug/m^3 | hours to weeks



- PERSONAL EXPOSURE
  - 0-1000 ug/m^3 | 8-hours typical

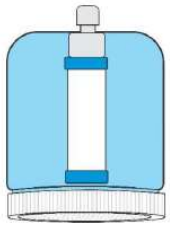
*Mer*PAS Configuration & Sample Time Guidelines

*Mer*PAS Configuration Options

Rev: 121319

Outdoor Ambient Air - White Body with Jar

The MerPAS sampler fitted with the white body diffusive barrier is best used for sampling outdoor ambient air of low to intermediate mercury concentrations (0-50 ng/m^3). The sampler may be deployed for intervals of 1 week to 1 year. This sampler may also be used at concentrations of 50 to 1000 ng/m^3 for shorter time intervals. Mounting brackets available (*Part # 04-2HPAS-02*).

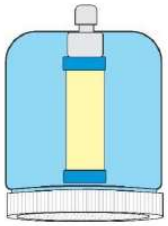


Example Applications ***(Part #: MerPAS-WJ, jar included)***

- Background Ambient Air
- Heavy Industry Areas
- Urban Air
- Site Survey Mapping

Outdoor Contaminated Ambient Air -

The MerPAS sampler fitted with the yellow body diffusive barrier is best used for sampling outdoor ambient air with highly elevated mercury concentrations (50 ng/m^3 ~ 1 mg/m^3). The sampling time is typically hours up to 7 days, depending on the expected Hg levels and project goals. Mounting brackets available (Part # *04-2HPAS-02*).



Example Applications ***(Part #: MerPAS-YJ, jar included)***

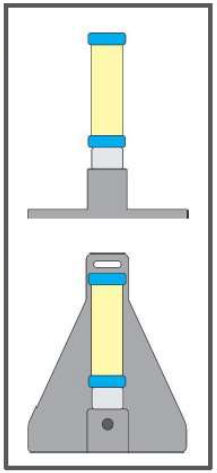
- Mercury Remediation Sites
- Artisanal Gold Mining Areas
- Hg Hot Spot Mapping
- Hg Recycling Perimeter

Indoor Air - Yellow Body (Mount sold separately)

For indoor applications, the *Mer*PAS sampler is deployed without the protective jar housing at any Hg concentration. Sample time is determined by monitoring goals and expected air Hg levels. The yellow body diffusive barrier samples at a slower rate and reduces the Hg loading onto the *Mer*PAS sampler. Indoor mounting brackets available (Part #: *MerPAS-PEM*).

Personal Exposure - Yellow Body (Mount sold separately)

The *Mer*PAS sampler may also be configured as a personal sampler. For this configuration, the yellow body diffusive barrier is used without any protective housing. The sampler is attached to a plastic plate and then attached to the lapel or shirt pocket to keep the device near the worker breathing zone. Typical sample time is 8 hours. Personal exposure mounting brackets available (Part #: *MerPAS-PEM*).



Example Applications ***(Part #: MerPAS-Y)***

- Private Residence Testing
- Real Estate Inspections
- Dental Offices
- Industrial Hygiene Monitor
- Schools and Science Labs
- Laboratory & Hospitals
- Hg Recycling Interior

Estimated Sampling Intervals

The below table provides some general guidelines on *Mer*PAS configuration and recommended deployment times for a variety of sampling applications. Note that the minimum and maximum deployment times take into consideration the target range of the instrument used for analysis. The sampling rates of the white-body and yellow-body sampler are listed below. Confirm the suggested ranges listed below are compatible with the instrument used for analysis.

White-Bodied w/ Jar Sample Rate (outdoor air) = 0.132 m^3/day
Yellow-Bodied w/ Jar Sample Rate (outdoor air) = 0.06 m^3/day*
Yellow-Bodied - No Jar Sample Rate (indoor air) = 0.070 m^3/day*

Outside Ambient Air	Typical Hg Range (ng/m^3)	Recommended Sampler Type	Deployment Time (Days)		
			Minimum	Recommend	Maximum
Remote	0.5-2.5	White-Jar	7	30	365
Urban Industrial	2-20	White-Jar	5	14	90
Hg Contaminated - Fenceline	10-5,000	Yellow-Jar	1	7	30
Hg Contaminated - Onsite	200-100,000	Yellow-Jar	1	1	7
Active Hg Use - Artisinal Mining > 100 meters distant	500-1,000,000	Yellow-Jar	0.25	1	7
Active Hg Use - Artisinal Mining <10 meters distant	50,000-10,000,000	Yellow-Jar	0.1	0.1	1

Indoor Air	Typical Hg Range (ng/m^3)	Recommended Sampler Type	Deployment Time (Hours)		
			Minimum	Recommend	Maximum
Uncontaminated	2-30	Yellow: Fixed or Lapel	24	168	720
Low Contaminated	30-500	Yellow: Fixed or Lapel	8	24	168
High Contaminated	500-100,000	Yellow: Fixed or Lapel	2	8	24
Hg Spill Cleanup	200-100,000	Yellow: Fixed or Lapel	2	8	24
Industrial Hg Contamination	500-1,000,000	Yellow: Fixed or Lapel	2	8	24

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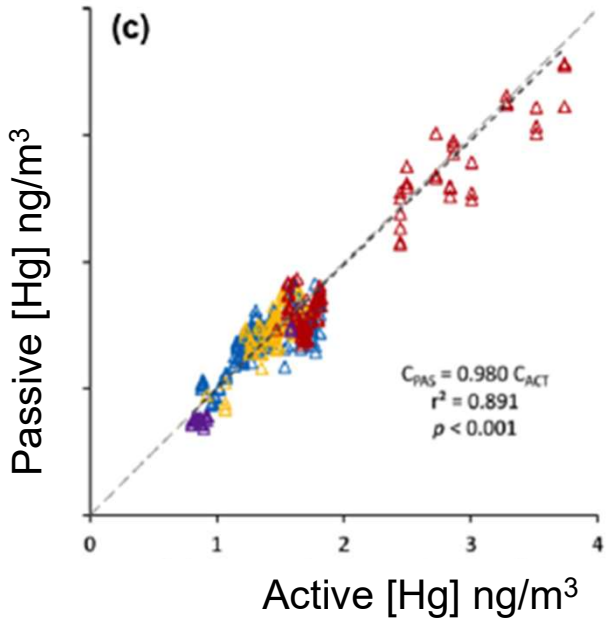
Global Ambient Air Study Performance

- Precision based uncertainty = 3.6 ± 3.0%
- Active-Passive mean normalized difference = 8.7 ± 5.7%

(includes active sampler uncertainty)



Site	Adjusted SR	
	Passive conc. (ng m^{-3})	Uncertainty MND (%)
Ningbo	2.81 ± 0.38	6.8 ± 4.8
Xiamen	–	–
Mt. Lulin	1.47 ± 0.02	6.7 ± 1.2
Salt Lake City	1.60 ± 0.12	5.2 ± 5.8
Beltsville	1.47 ± 0.10	17.5 ± 4.6
Put-in-Bay	1.40 ± 0.07	3.1 ± 1.4
Grand Bay	1.49 ± 0.03	11.9 ± 2.1
New York City	1.64 ± 0.12	7.6 ± 4.6
Mauna Loa	0.76 ± 0.03	12.2 ± 4.6
Kejimkujik	1.24 ± 0.13	5.1 ± 3.5
Little Fox Lake	1.51 ± 0.12	6.3 ± 4.4
Alert	1.40 ± 0.20	7.0 ± 6.0
Ucluelet	1.39 ± 0.08	8.1 ± 3.1
St. Anicet	1.40 ± 0.06	15.4 ± 1.7
Egbert	1.54 ± 0.06	8.7 ± 2.1
Waldhof	1.53 ± 0.15	11.0 ± 6.8
Hunter Valley	–	–
Sydney	–	–
Cape Grim	1.03 ± 0.02	17.4 ± 2.2
Gunn Point	0.90 ± 0.03	6.3 ± 2.0
TOTAL	–	8.7 ± 5.7

Ambient Air Sampling SOP Flowchart

- Documents available at www.tekran.com
  - Siting guidelines
  - Sampler configuration options
  - Sample time guidelines
  - Blank selection
  - Sampling SOPs

*Mer*PAS Features

- No power required
- Simple to deploy & retrieve
- Low entry cost – low temporal resolution
- Range likely unlimited (1 ng/m^3 to 5 mg/m^3)*
- Confirmed linear SR to ug/m^3 levels
- Relatively immune to wind speed (WS) and temperature (T) effects
- Uses well known Radiello diffusive barrier

* See specifics in subsequent slide

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*Mer*PAS Analysis

- Analysis must be done in a trace-clean analytical lab by skilled mercury chemists
- Direct thermal analysis is preferred, no acid digestion (EPA Method 7473)

Nippon MA-3000

- Multiple instrument vendors
- EPA Method 1631, acid digestion may be required for very high Hg loading (e.g. artisanal gold mining)

Tekran *Mer*PAS Analysis

- Sulfur-carbon is a challenging matrix and can degrade the catalyst quickly
- Use of acid gas scrubbing materials applied to carbon mitigates sulfur impacts
- *Tekran currently offering analysis and can act as an independent reference laboratory for scientists and international networks*

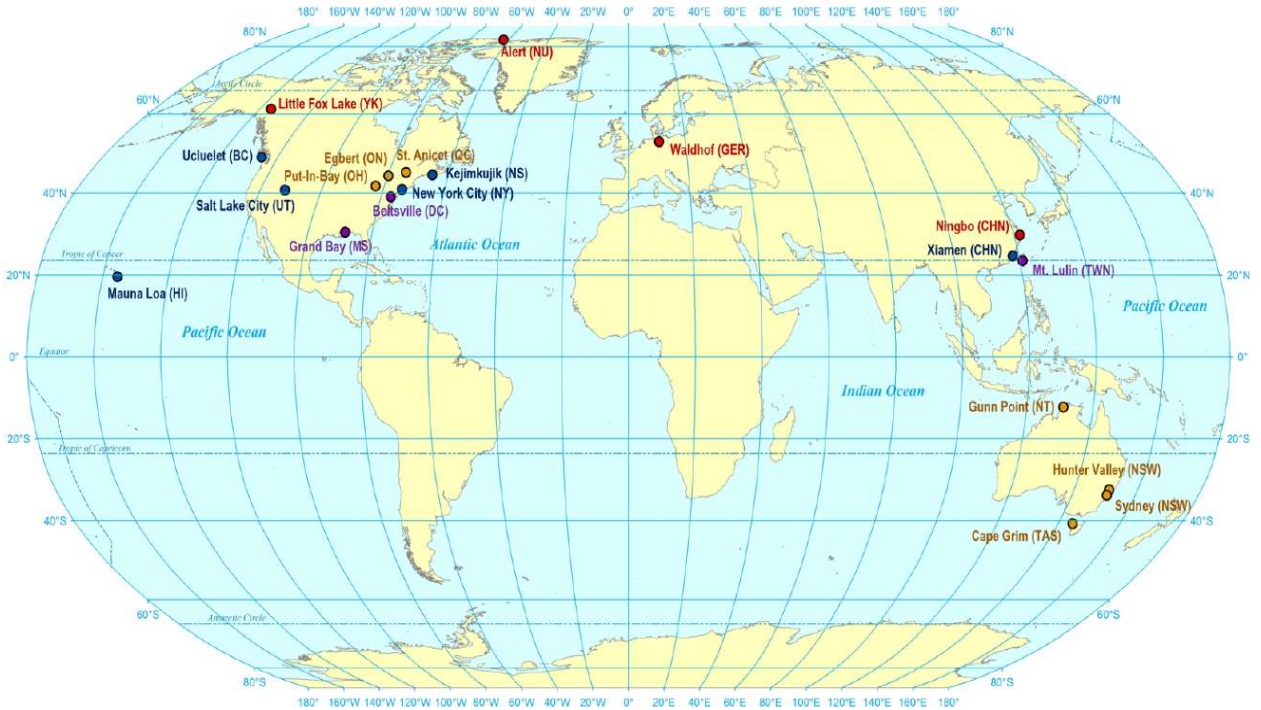
Applications

Research

Minimata Compliance

Network Monitoring & Trends

U. of Toronto Global Study Sampling Locations



- All samplers deployed in triplicate for precision
- Active, calibrated Tekran 2537 GEM measurements at all sites
- Updated and improved SR includes T and WS correction
- Site colors indicated *Mer*PAS sample frequency

From McLagan et al., (https://doi.org/10.5194/acp-18-5905-2018)

Active and Proposed Network

Organized by Alexandra Steffen, Env. & Climate Change Canada
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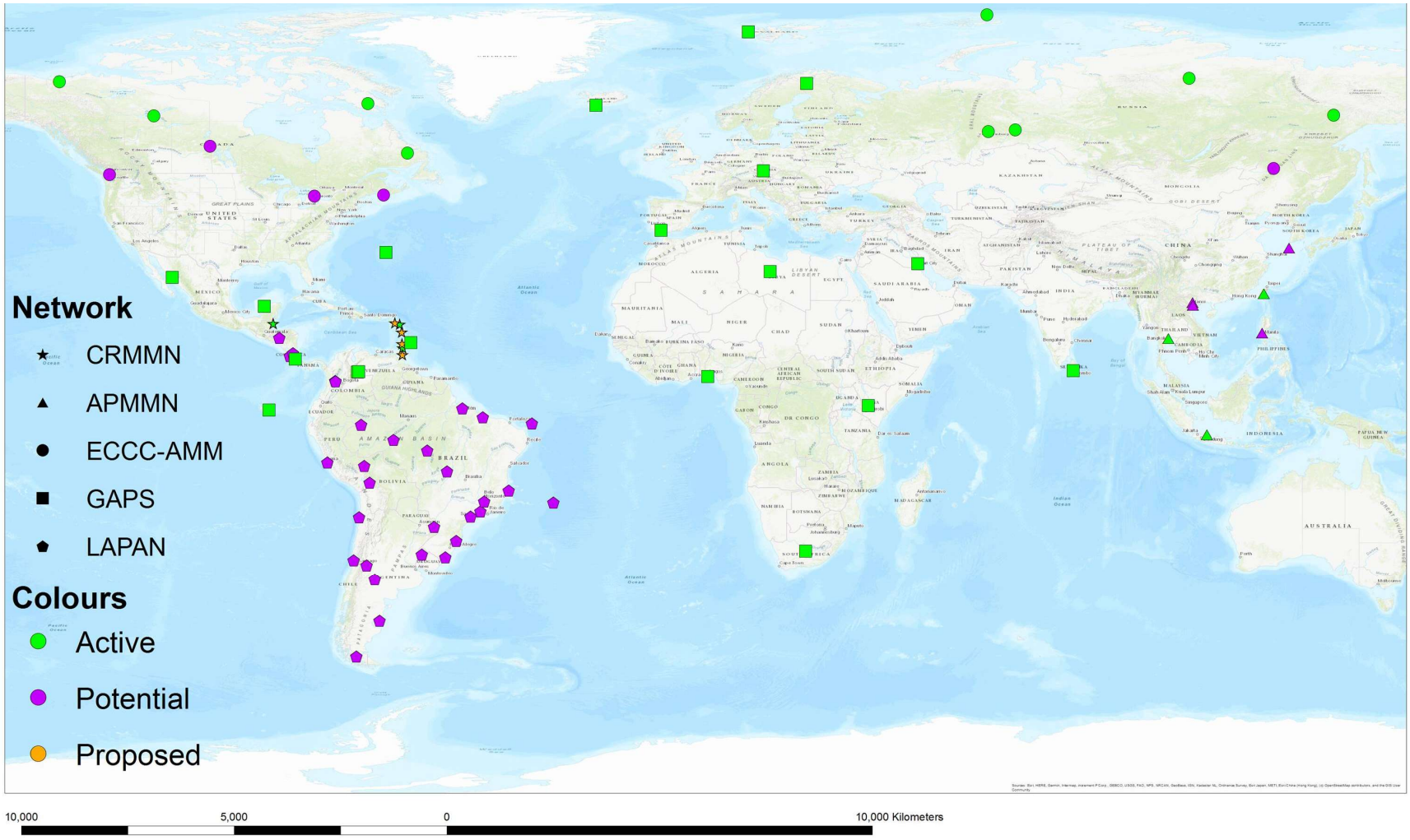


Urban Hg Source Mapping – Greater Toronto

David S. McLagan et al. (2018) *Environ. Res. Lett.* 074008

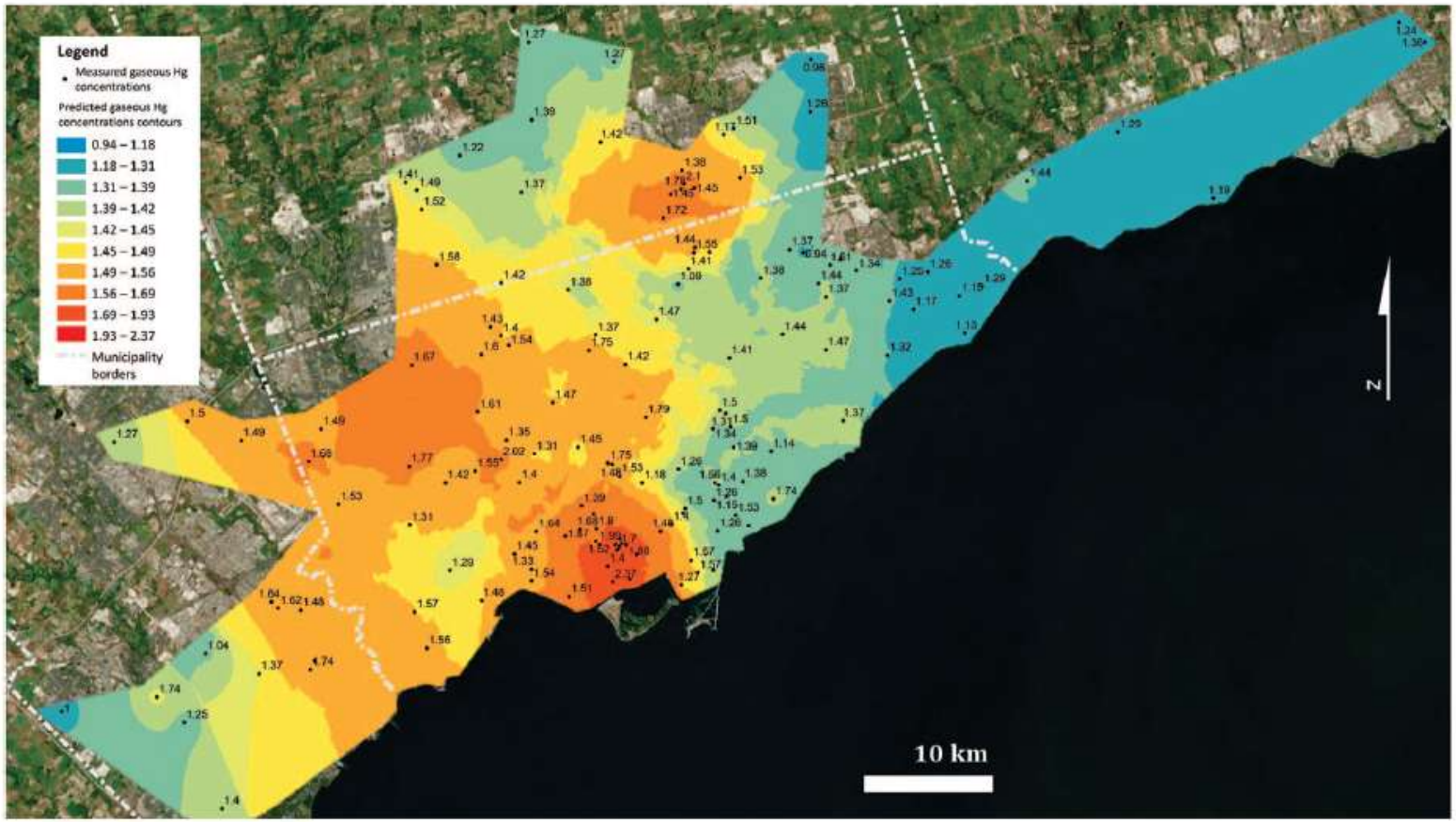
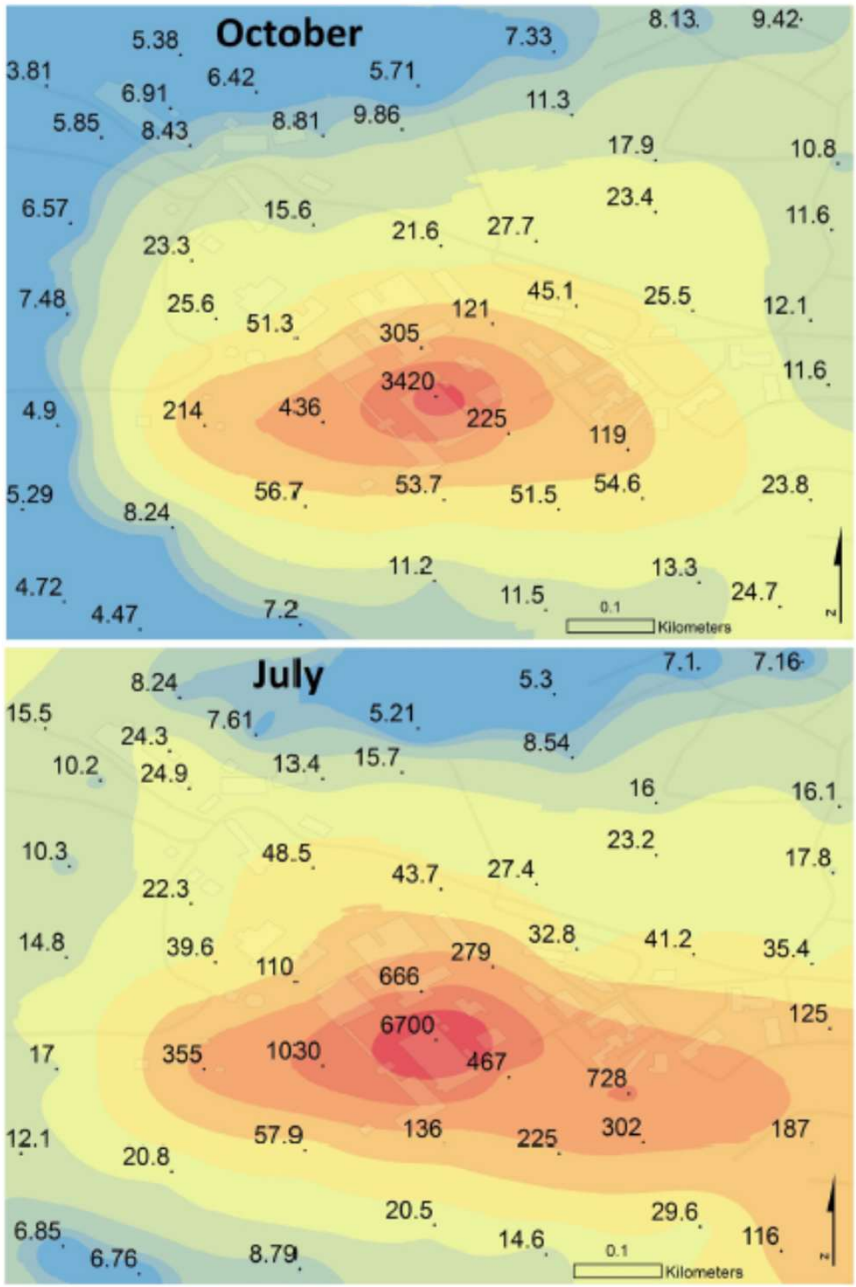


Figure 3. Measured and predicted gaseous Hg concentrations (ng m^{-3}) averaged over a period of 4–6 weeks in July/August 2016 in the Greater Toronto Area. Prediction contours are derived from an empirical Bayesian kriging model.

Former Hg Mine Site Mapping

McLagan et al.,
https://doi.org/10.1029/2018JD029373

- Mine site buildings survey
- Values in ng/m^3 | Area of ~0.6 km^2
- 7-Day sample deployment
- Seasonal differences observed
- Emissions estimated at 80±40 and 150±75 kg/yr for October and July, respectively



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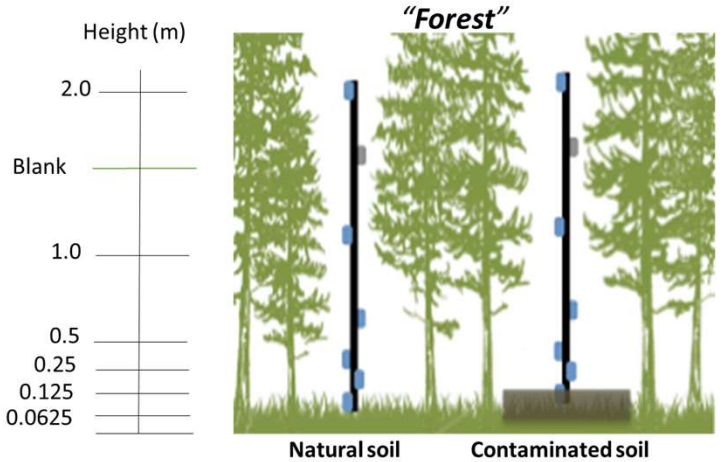
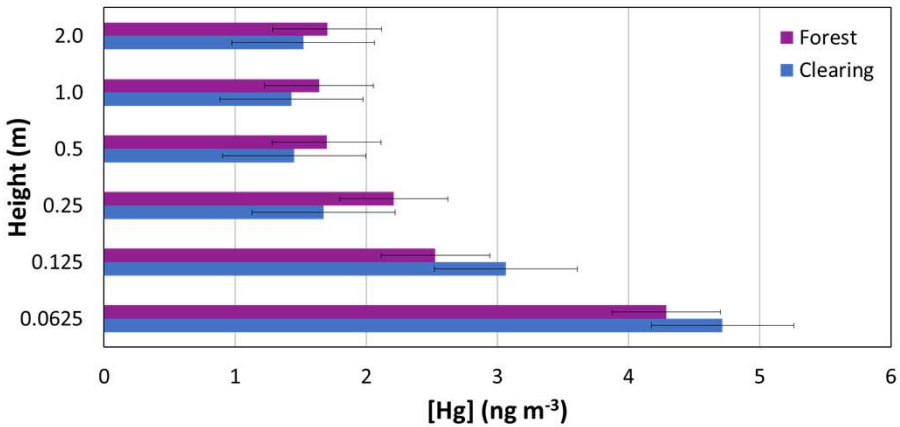
U. of Toronto *Mer*PAS Gradient Studies

Feigis, Mistry, Snow, Mitchell, Lei and Wania. Assessing the atmosphere-surface exchange of GEM using passive air samplers. 29th Annual Meeting of SETAC Europe, Helsinki, Finland, May 26-30, 2019.

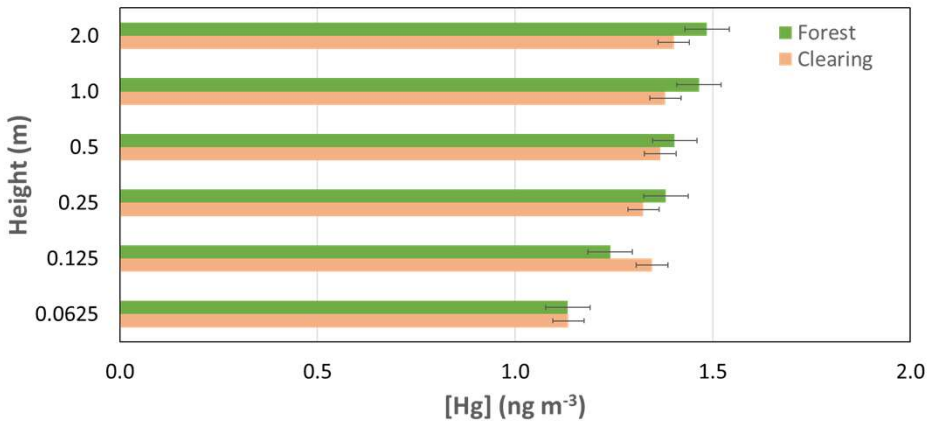
- Month-long sample time capable of detecting statistically significant gradient profiles
- Measured gradients and temporal trends are consistent with expected Hg air-surface exchange
- Interpretation limited to semi-quantitative relative comparison of flux strength



Time Averaged Vertical Profiles



Over Contaminated Soil



Over Natural Soil

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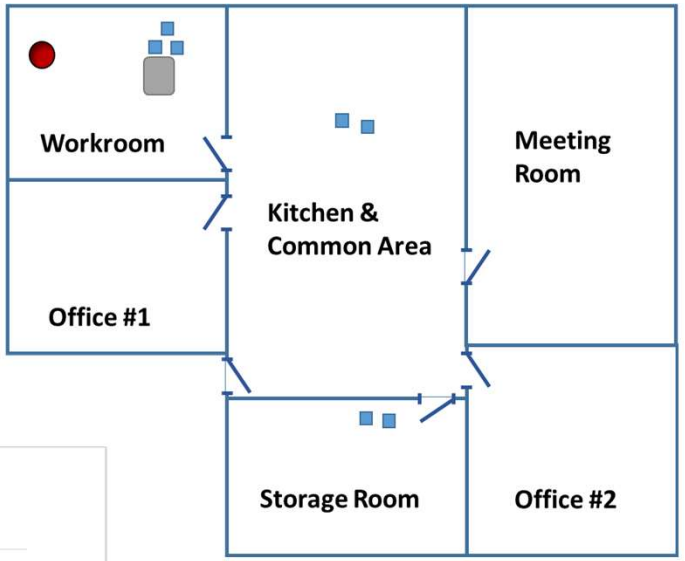
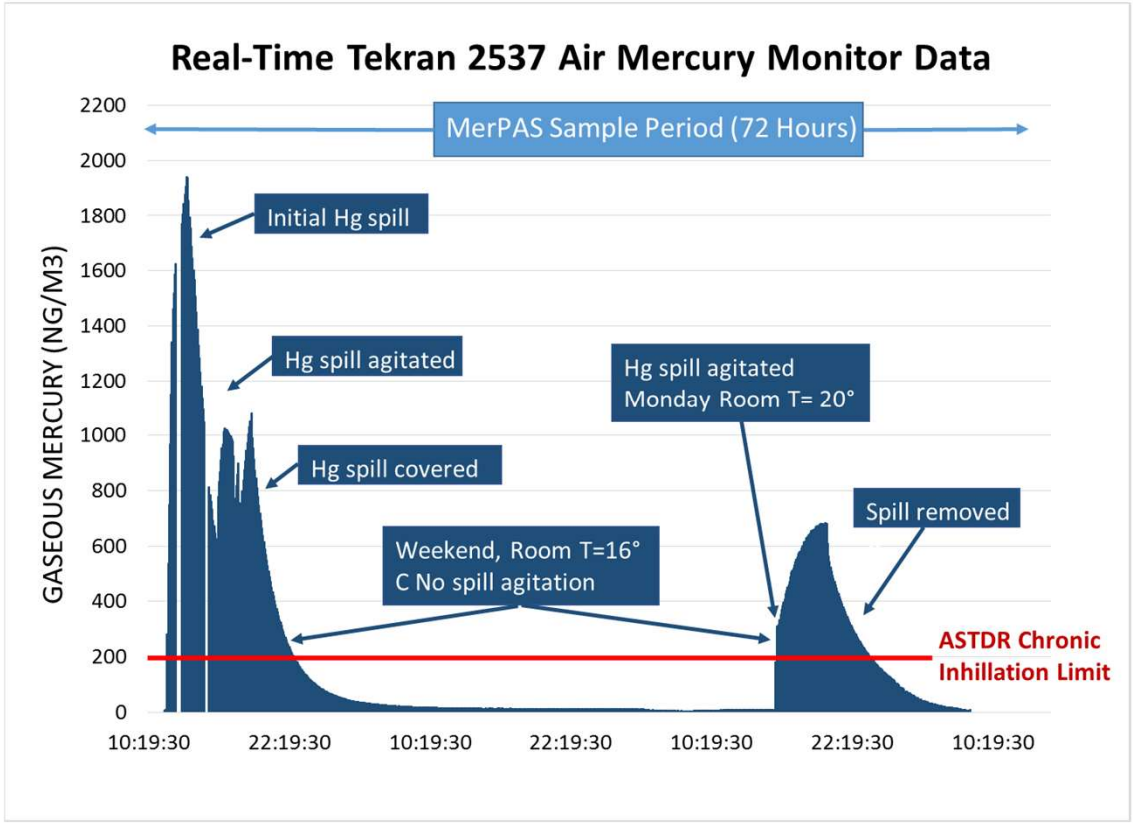
MerPAS: Indoor Mercury Spill Example

- Work Room MerPAS = 200 ng/m^3
- Work Room Tekran = 192 ng/m^3
- Kitchen MerPAS = 51.4 ng/m^3
- Storage Room MerPAS = 46.9 ng/m^3





Mercury Spill

MerPAS Samplers

Tekran Monitor

Select Applications for Monitoring, Research & Exposure

Vertical profile industry site

- National & international networks
- Artisanal gold mining
- Identifying and mapping hot spots
- Community exposure monitoring
- Contaminated site cleanup monitoring
- Indoor spill cleanup and monitoring
- Personal exposure industry, schools, workplace & homes
- Area source emissions

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MerPAS Ongoing Studies

- Hg passive sampler international intercomparison
- Internal Tekran SR calibrations
- Intercomparison with U. of Mississippi
- Global Atm. Passive Sampler (GAPS) Network
- ECCC spatial mapping and vertical gradient in high arctic
- Chamber-based climate study
- U. of Toronto studies of indoor air SR and use at an artisanal gold mine

Conclusion: Why Use *Mer*PAS for New and Complimentary Mercury Networks

- Radial diffusive surface has better performance than 2-D badge type passive air samplers
- Proven to be sensitive, accurate and precise at background Hg levels
- Media has low consistent blanks and massive uptake capacity
- Robust packaging and simple to deploy
- Direct thermal analysis can be faster, easier and lower cost compared to liquid acid digestion and analysis