MerPAS Overview

Mercury Passive Air Sampler

MerPAS@Tekran.com

2020

UNIVERSITY OF TORONTO

MerPAS by TEKRAN

*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

www.tekran.com
MerPAS@tekran.com

MerPAS Studies
U. of Toronto

Environmental Science & Technology Letters

Letter

pubs.acs.org/journal/estlcu

A High-Precision Passive Air Sampler for Gaseous Mercury

David S. McLagan,[†] Carl P. J. Mitchell,[†] Haiyong Huang,[†] Ying Duan Lei,[†] Amanda S. Cole,[‡] Alexandra Steffen,[‡] Hayley Hung,[‡] and Frank Wania*[,†]

[†]Department of Physical and Environmental Sciences, University of Toronto Scarborough, 1265 Military Trail, Toronto, ON M1C 1A4, Canada

[‡]Air Quality Processes Research Section, Environment Canada, 4905 Dufferin Street, North York, ON M3H 5T4, Canada

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
https://doi.org/10.5194/acp-18-5905-2018

Atmospheric Chemistry and Physics

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]

[1]Department of Physical and Environmental Sciences, University of Toronto Scarborough, Toronto, M1C 1A4, Canada
[2]Air Quality Processes Research Section, Environment and Climate Change Canada, Toronto, M3H 5T4, Canada
[3]Atmospheric Mercury Network, National Atmospheric Deposition Network, Champaign, 61820-7495, USA
[4]Air Resources Lab, National Oceanic and Atmospheric Administration, Maryland, 20740, USA
[5]Department of Environmental Sciences, Macquarie University, Sydney, 2109, Australia
[6]Center for Excellence in Regional Atmospheric Environment, Institute of Urban Environment, Xiamen, 361021, China
[7]Department of Atmospheric Sciences, National Central University, Taoyuan City, 32001, Taiwan
[8]Air Monitoring, Eurofins GfA, Hamburg, 21107, Germany

Correspondence: Frank Wania (frank.wania@utoronto.ca)

Received: 23 December 2017 – Discussion started: 8 February 2018
Revised: 10 April 2018 – Accepted: 12 April 2018 – Published: 26 April 2018

Atmos. Meas. Tech., 10, 3651–3660, 2017
https://doi.org/10.5194/amt-10-3651-2017

Atmospheric Measurement Techniques

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

Department of Physical and Environmental Sciences, University of Toronto Scarborough, 1065 Military Trail, M1C 1A4, Toronto, Ontario, Canada

Correspondence to: Frank Wania (frank.wania@utoronto.ca)

Received: 15 March 2017 – Discussion started: 2 May 2017
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]

[1]Department of Physical and Environmental Sciences, University of Toronto Scarborough, Toronto, ON, Canada, [2]Department of Life Sciences, Università di Siena, Siena, Italy

Spectrochimica Acta Part B 133 (2017) 60–62

Contents lists available at ScienceDirect

Spectrochimica Acta Part B

journal homepage: www.elsevier.com/locate/sab

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

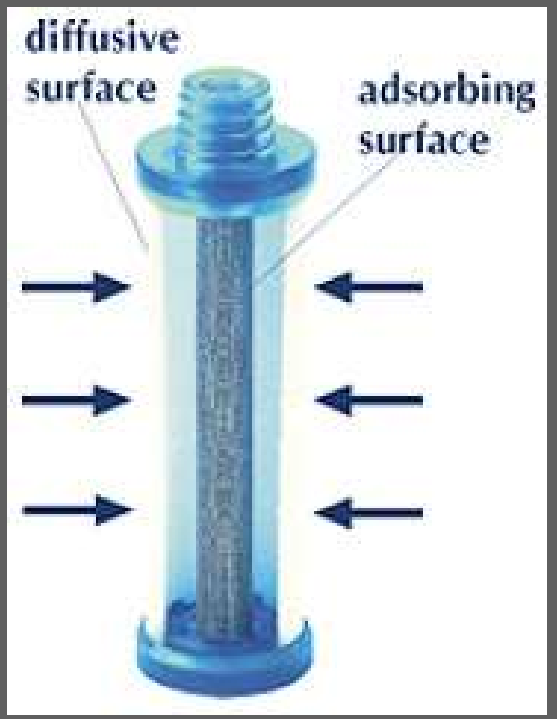
Identifying and evaluating urban mercury emission sources through passive sampler-based mapping of atmospheric concentrations

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]

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

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:

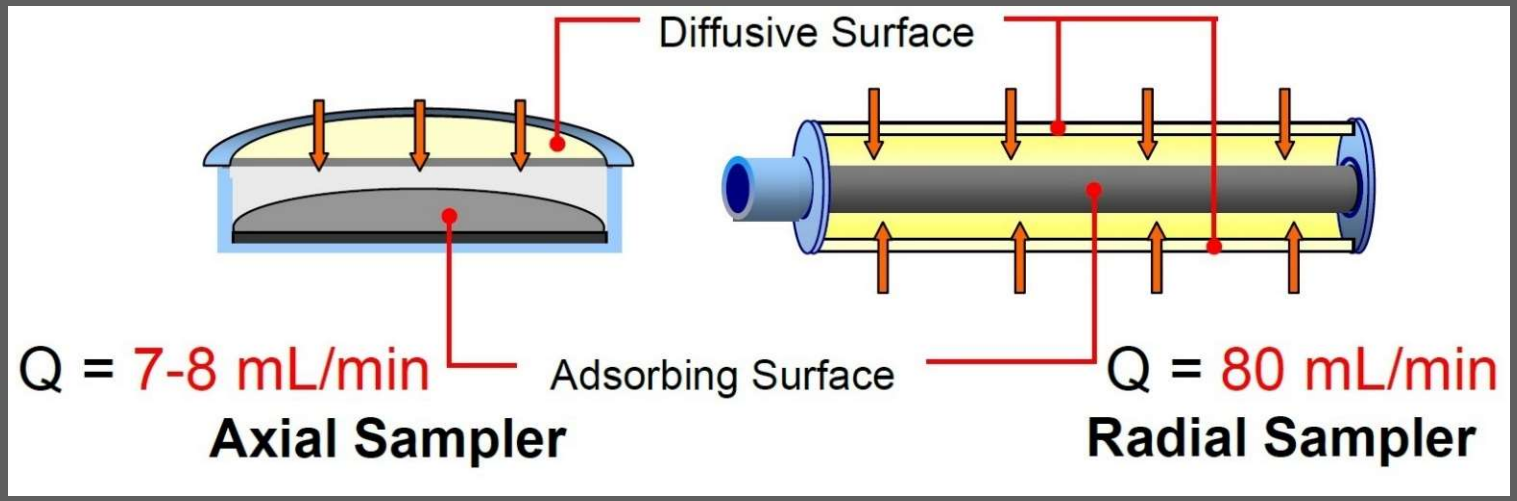
gaseous Hg concentration (ng m^{-3}) — sampling rate (m^3 day^{-1})

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

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

www.tekran.com
MerPAS@tekran.com

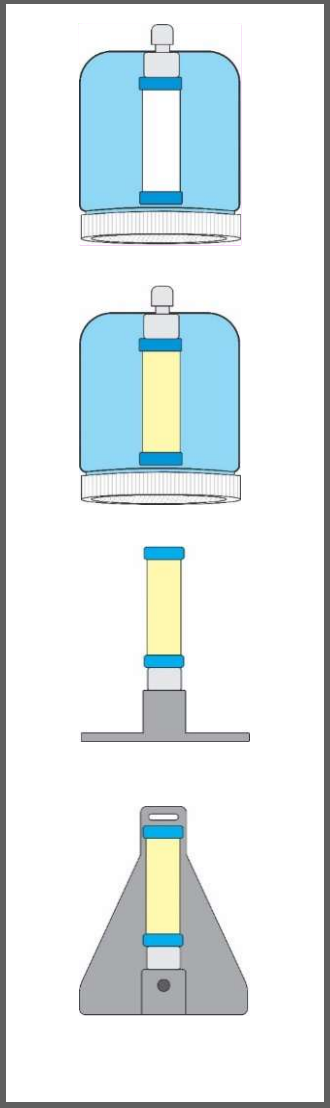
Significant Advantage of Radial Design



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

www.tekran.com
MerPAS@tekran.com

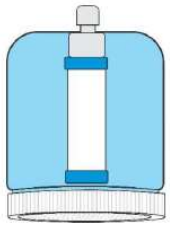
*Mer*PAS Configuration & Sample Time Guidelines

*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*).

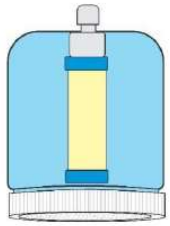


Example Applications ***(Part #: MerPAS-WJ, jar included)***

- 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)***

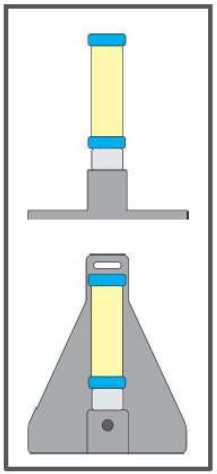
- Mercury Remediation Sites
- Artisanal Gold Mining Areas
- Hg Hot Spot Mapping
- Hg Recycling Perimeter

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) = 0.111 m^3/day
Yellow-Bodied w/ Jar Sample Rate (outdoor air) = 0.06 m^3/day*
Yellow-Bodied - No Jar Sample Rate (indoor air) = 0.069 m^3/day*

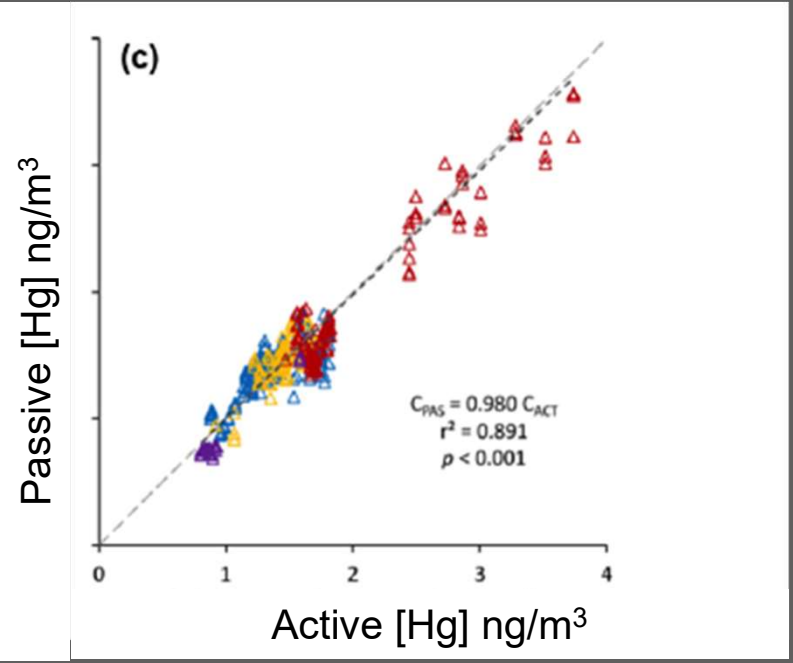
Outside Ambient Air	Typical Hg Range (ng/m^3)	Recommended Sampler Type	Deployment Time (Days)		
			Minimum	Recommend	Maximum
Remote	0.5-2.5	White-Jar	7	30	365
Urban Industrial	2-20	White-Jar	5	14	90
Hg Contaminated - Fenceline	10-5,000	Yellow-Jar	1	7	30
Hg Contaminated - Onsite	200-100,000	Yellow-Jar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

www.tekran.com
MerPAS@tekran.com

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

www.tekran.com
MerPAS@tekran.com

Ambient Air Sampling SOP Flowchart

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


MerPAS by TEKRAN

330 Nantucket Boulevard, Toronto, Canada M1P 2P4
MerPAS@tekran.com Tel:+1-416-449-3084 Fax: +1-416-449-0298
Toll Free: (US and Canada) 1-888-583-5726 (1-888-5-TEKRAN)

DEPLOYMENT & SAMPLING START

1. Open bag - use gloves!
2. Remove tape from lid
3. Remove solid lid & put in bag
4. Attach screened lid to jar
5. Good concave screen shape
6. Bad convex screen shape
7. Label sample with date/time
8. Attach jar to bracket

SAMPLING STOP & RETREIVAL

9. To collect, remove top nut
10. Removed screened lid
11. Retrieve solid lid
12. Screw on solid lid TIGHTLY!
13. Seal lid with tape
14. Record sample end time
16. Seal in Bag
18. Ship to lab for analysis

WHERE MEASUREMENT BEGINS™ - Page 2 of 2 - Order & technical support : MerPAS@tekran.com

*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

www.tekran.com
MerPAS@tekran.com

*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)

www.tekran.com
MerPAS@tekran.com

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*

www.tekran.com
MerPAS@tekran.com

Applications

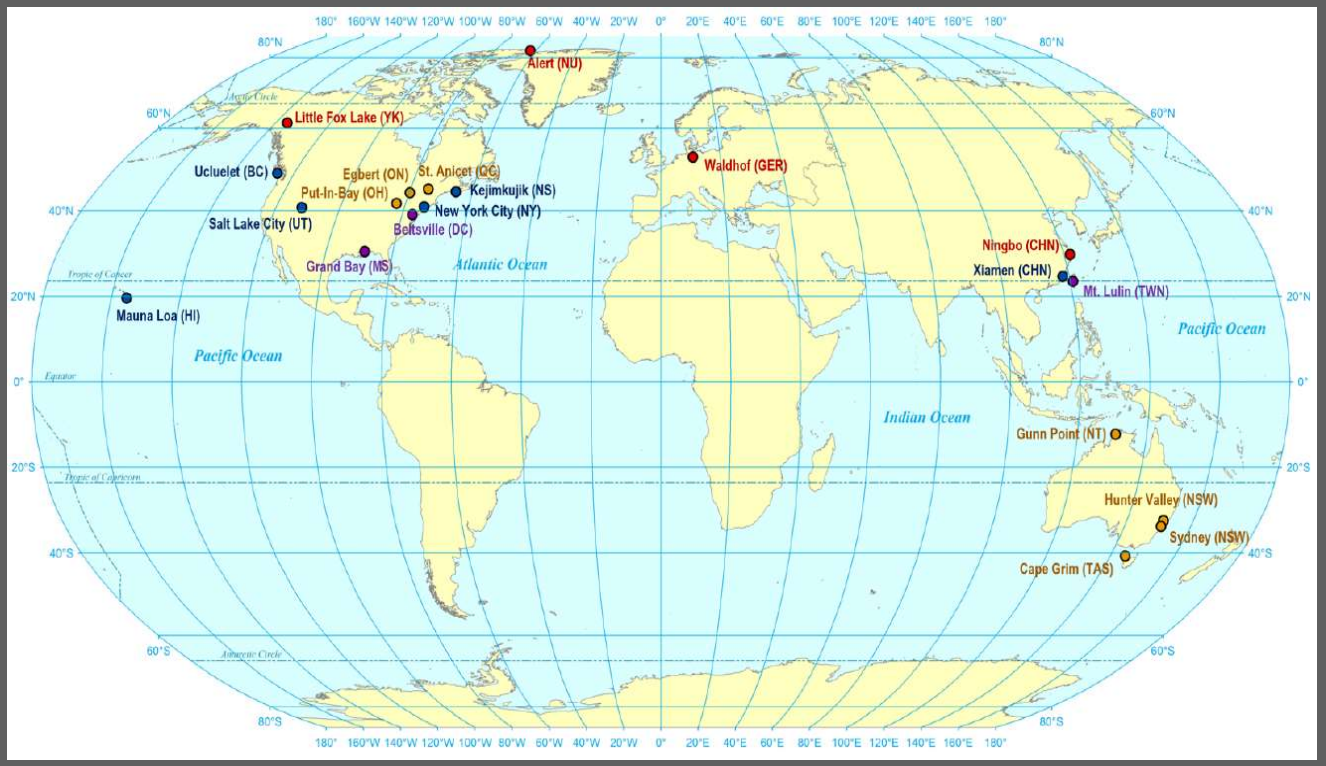
Research

Minimata Compliance

Network Monitoring & Trends

www.tekran.com
MerPAS@tekran.com

U. of Toronto Global Study Sampling Locations



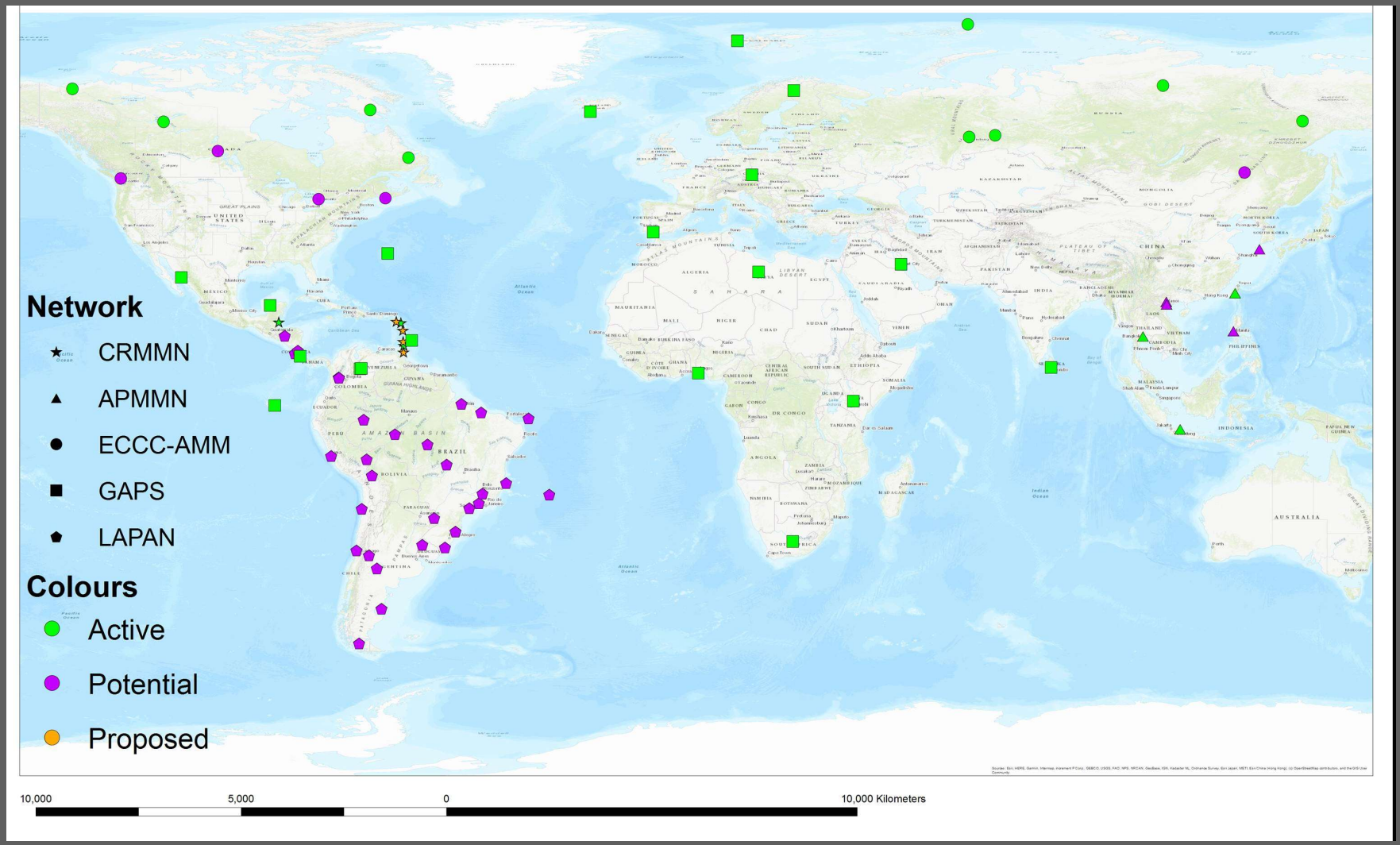
- All samplers deployed in triplicate for precision
- Active, calibrated Tekran 2537 GEM measurements at all sites
- Updated and improved SR includes T and WS correction
- Site colors indicated *Mer*PAS sample frequency

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

www.tekran.com
MerPAS@tekran.com

Active and Proposed Network

Organized by Alexandra Steffen, Env. & Climate Change Canada
alexandra.steffen@canada.ca



Urban Hg Source Mapping – Greater Toronto

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

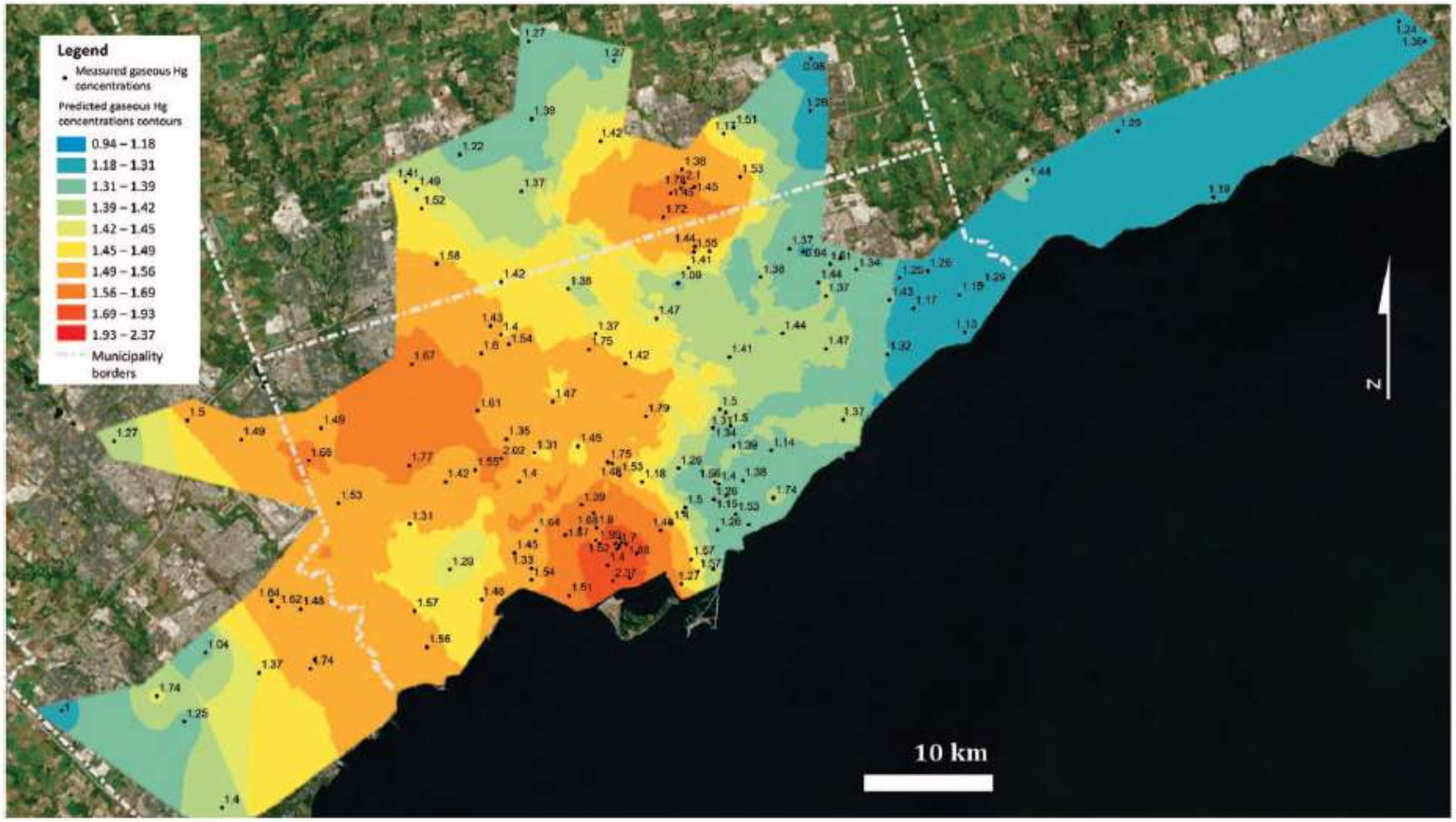
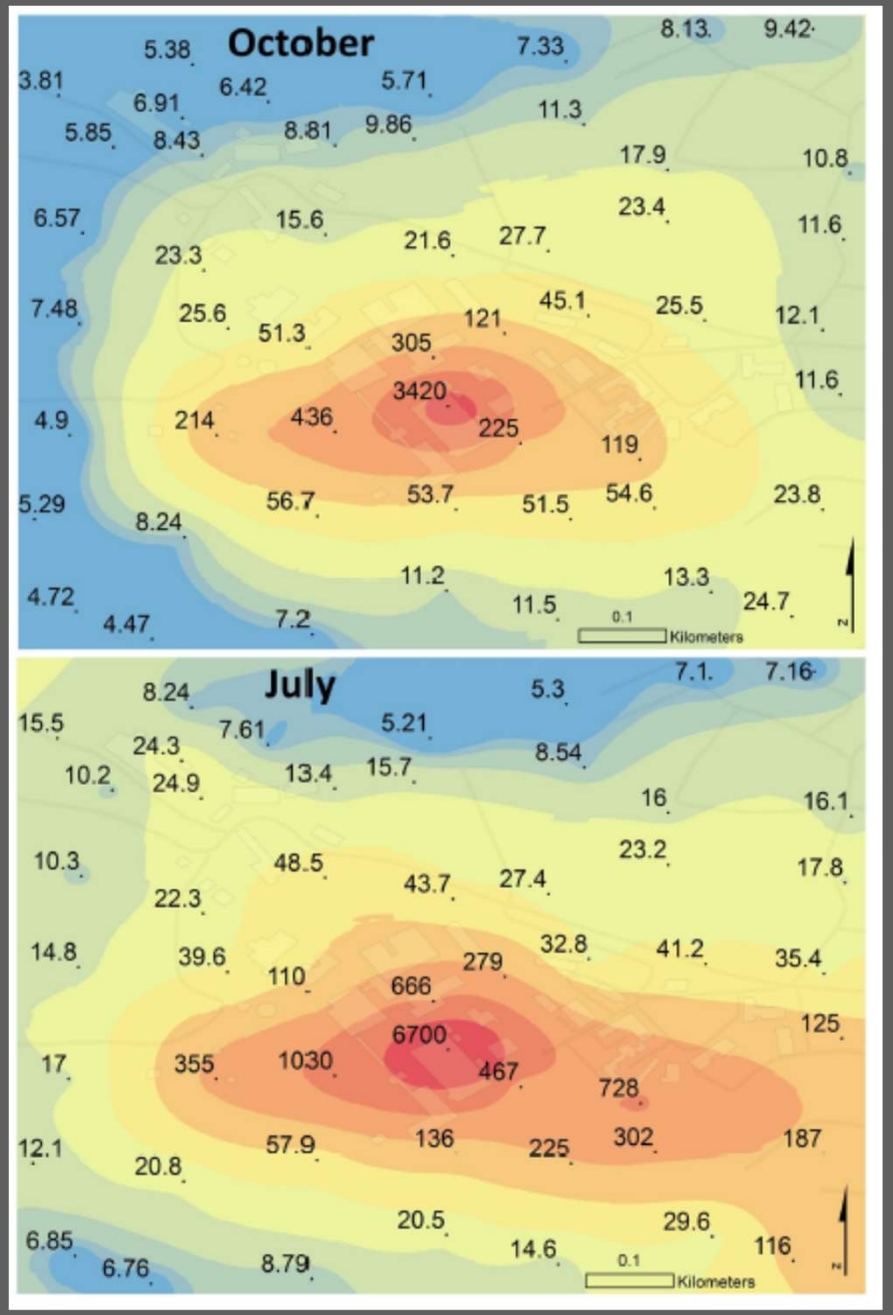


Figure 3. Measured and predicted gaseous Hg concentrations (ng m^{-3}) averaged over a period of 4–6 weeks in July/August 2016 in the Greater Toronto Area. Prediction contours are derived from an empirical Bayesian kriging model.

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

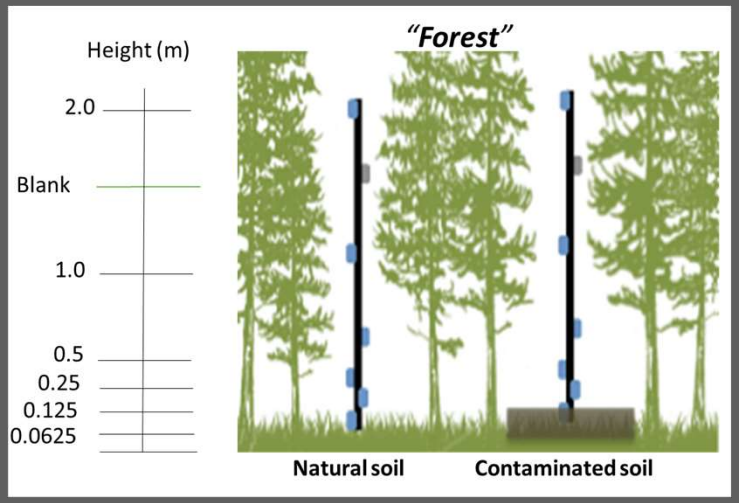


www.tekran.com
MerPAS@tekran.com

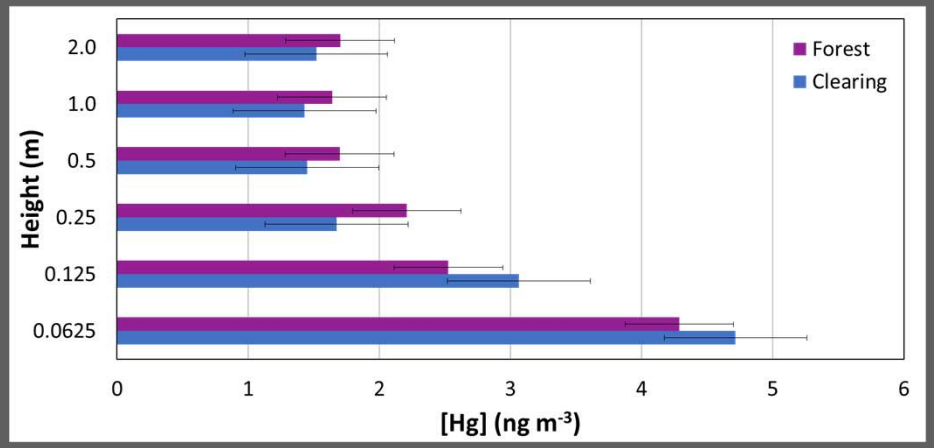
U. of Toronto *Mer*PAS Gradient Studies

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.

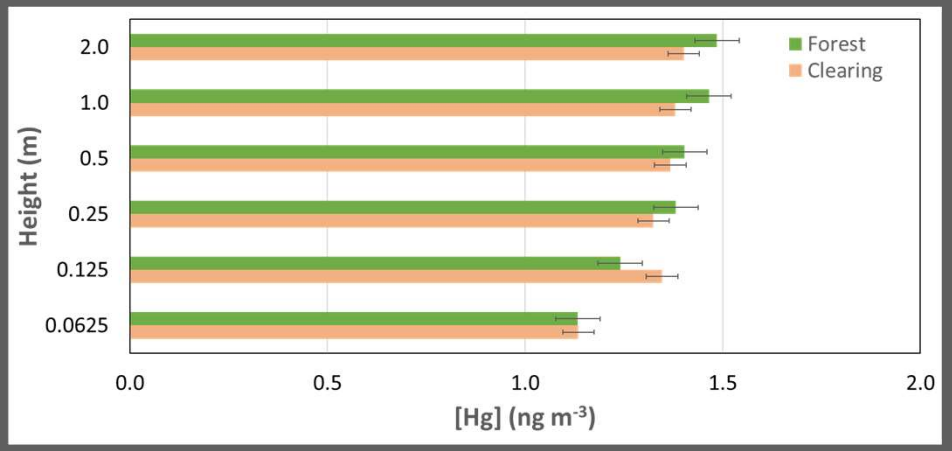
- Month-long sample time capable of detecting statistically significant gradient profiles
- Measured gradients and temporal trends are consistent with expected Hg air-surface exchange
- ***Interpretation limited*** to semi-quantitative relative comparison of flux strength



Time Averaged Vertical Profiles



Over Contaminated Soil



Over Natural Soil

www.tekran.com
MerPAS@tekran.com

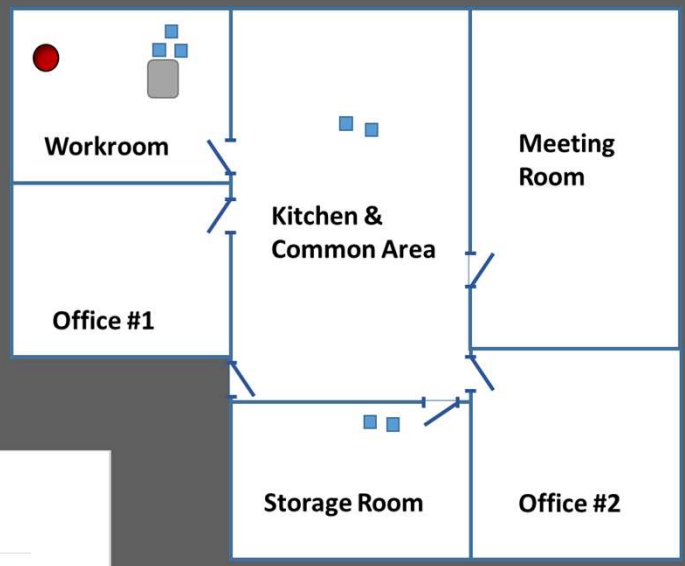
MerPAS: Indoor Mercury Spill Example

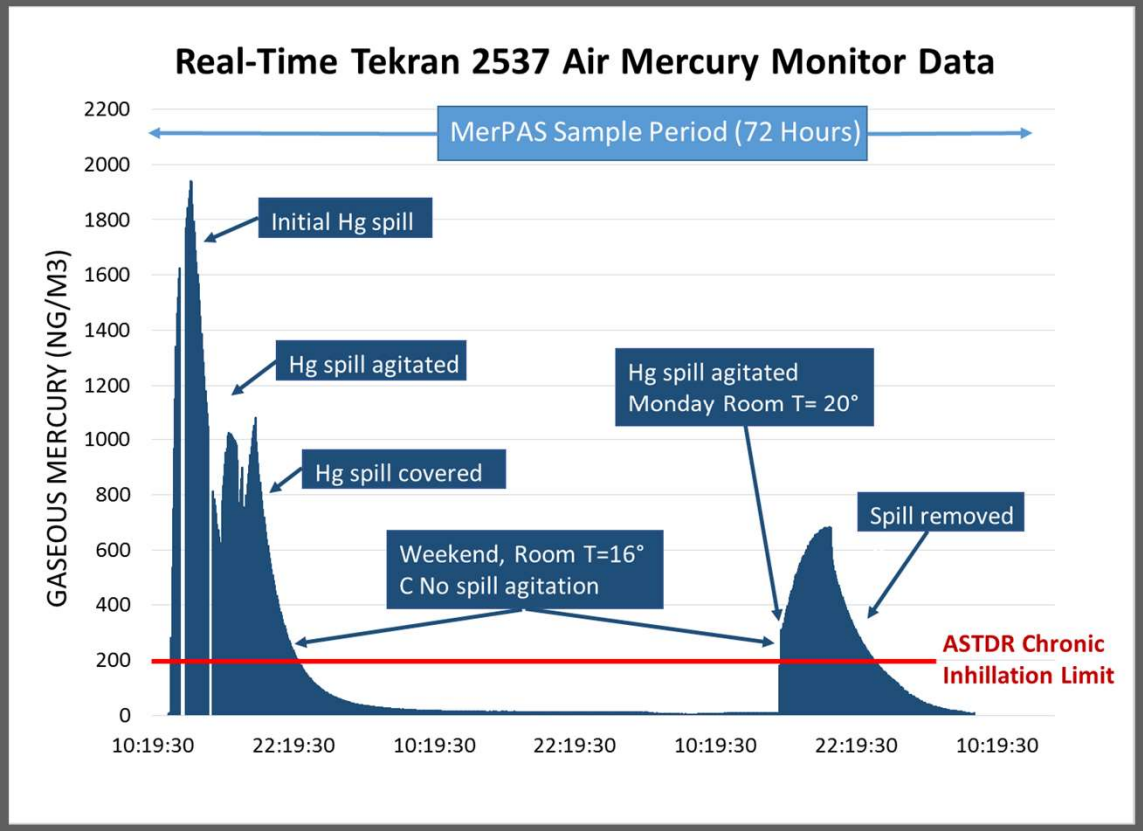
Work Room *Mer*PAS = 200 ng/m^3

Work Room Tekran = 192 ng/m^3

Kitchen *Mer*PAS = 51.4 ng/m^3

Storage Room *Mer*PAS = 46.9 ng/m^3





Mercury Spill

*Mer*PAS Samplers

Tekran Monitor

www.tekran.com
MerPAS@tekran.com

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

www.tekran.com
MerPAS@tekran.com

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

www.tekran.com
MerPAS@tekran.com

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

www.tekran.com
MerPAS@tekran.com