A LOW COST PASSIVE SAMPLING & ANALYSIS SOLUTION FOR AIR QUALITY SAMPLING

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Typical Sampling Methods for Airborne Volatile Organic Compounds

- Continuous/instantaneous measurement instruments
- Integrative
  - Whole air grab samples
  - Whole air samples with flow controllers
  - Active sampling methods
  - Passive Sampling Devices (PSDs)

Electropolished Canister

- Instantaneous or Integrative
- Precise flow control issues
  - Limiting orifice
    - Canister fill time?
  - Calibration required
- Hysteresis effects (artefacts)

- Time Consuming
  - Costly

Active Samplers

- Requires pump
  - Time consuming calibration procedures
- Require power or limited battery life
- Noise issues
- Thermal Desorption Tubes – Hysteresis effects (artefacts)

Passive Sampling Devices (PSDs)

3M 3500 OVMs

- No pumps = no calibration
- No pumps = no noise
- Small
  - Unobtrusive
  - Easy to transport
- Low training requirements

- e.g. 3M 3500 Organic Vapour Monitor

Active Samplers & Residential Surveys

- Multi-residence/area surveys are expensive & time consuming
  - Severely limits the number of homes
- Some government agencies recognized these limitations and undertook long term research programs to look at alternative approaches

PSD use in International Studies of Indoor & Outdoor Monitoring

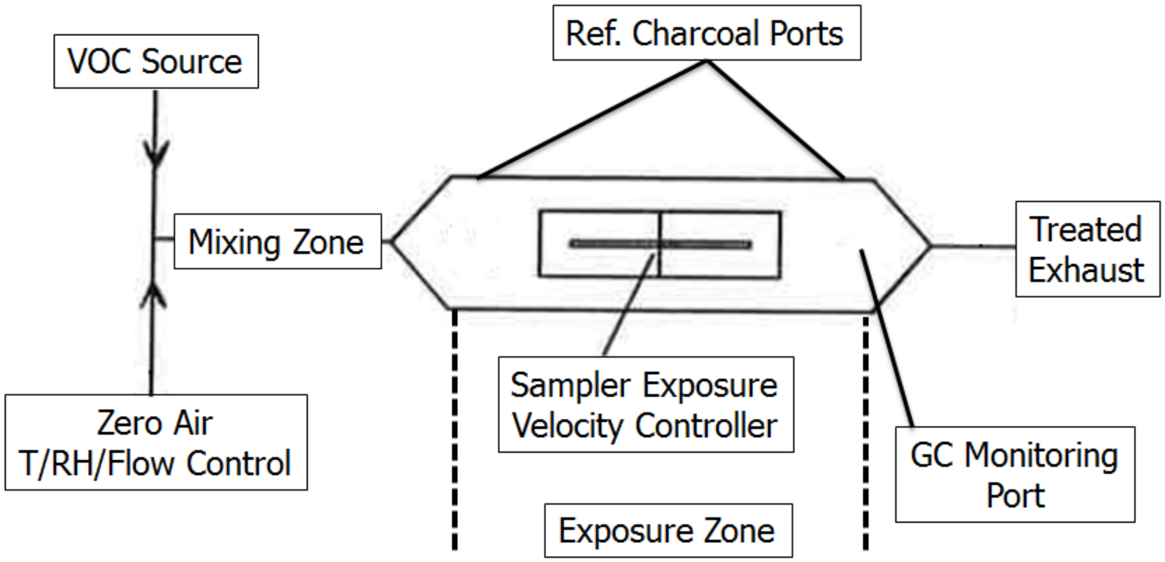
- Health Canada (1992/1993) – national VOC exposure survey (754 homes; 3M OVM 3500)
- Multimedia (air, water & food) exposure studies in Canadian residence and exposure assessment (3M OVM 3500 for VOCs, Ogawa Samplers for NO_x, O_3, SO_2)
- Vehicle exposure studies in urban areas (Winnipeg, Medicine Hat, Windsor, Ottawa & Stockholm [Sweden]) (3M OVM 3500 for VOCs; Ogawa Samplers for NO_x, O_3, SO_2)
- Alberta Cattle Health – 18,000 PSDs for ambient air VOC determination (3M OVM 3500)
- US Forestry Service (inorganic gases) – (Ogawa)
- Ambient air studies in Europe for VOCs & inorganic compounds – (Radiello)
  - MACBETH (Monitoring Benzene in European Towns and Homes)
  - RESOLUTION (high spatial resolution atmospheric monitoring to verify emissions reduction of ozone precursors foreseen by Auto-Oil program),
  - LIFE99ENV/IT/081, LIFE 00 ENV/IT/000005 & ARTEMIDE (High temporal resolution monitoring of VOC's).
- US & in California - (Radiello) for VOCs

Methodology for Development of PSDs

- Initially developed for occupational exposure monitoring in the 70's at ppm or mg/m^3 levels
- Of interest for indoor air studies
  - ease of deployment
  - ease of acceptance by typical residents
- Required method improvement and validation

Fellin, Otson & Brice (1989)

- Test Atmosphere Generation System (TAGS)
  - Face velocities = stagnant, 0.5 m/s, 1.8 m/s
  - Concentrations, T, RH, co-pollutants, VOC mix
  - PSDs: 3M OVM 3500 & Pro-Tek G-AA (and others)
  - Co-located with charcoal tubes (reference)

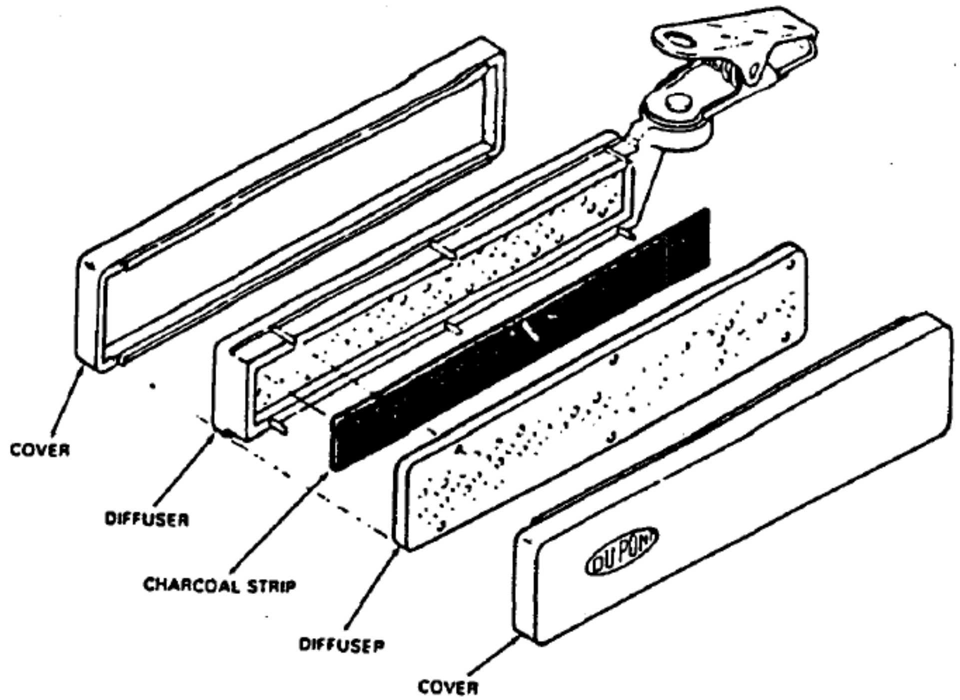


Otson & Fellin (1991)

- Pro-Tek G-AA (& other devices)
  - Sampling Rates increased significantly with face velocity
  - Precision was poorer at high face velocity
- 3M OVM 3500
  - Sampling rates varied by <10% with face velocity
  - r = 0.95 correlation coefficient (reference charcoal sorbent tube)

Otson (1990)

- Pro-Tek
  - significant variation in sampling rates with face velocity, T, RH, and analyte concentration
- These effects not seen with 3M OVM 3500
- 3M PSD chosen for full field test



Otson (1990)

- Indoor Field Test
  - 3M OVM 3500 and charcoal tube showed excellent correlation (r > 0.95)
  - MDL: 1 to 2 $\mu g/m^3$
  - Precision for duplicate determinations
    - +/- 7 to 10 % - 3M OVM 3500
    - +/- 5 to 14% - charcoal

Otson, Fellin & Barnett (1992)

- Duplicate, collocated 3M PSDs & charcoal tubes
  - 17 single family dwellings and 1 office
  - Samples collected in Summer and Winter
- 3M PSDs showed excellent correlation with charcoal reference ($r^2 > 0.96$)
- 3M PSD precision was slightly better than charcoal
- 3M PSD MDL estimated at 2 $\mu g/m^3$

Development of Passive Sampling Devices

- Contracts with Health Canada to further develop 3M OVM PSDs
- Developments included:
  - Improvements to blank levels and detection limits
  - Improvements to linear dynamic range
  - Testing of performance under broader range of air velocity (< 0.1 to 5 m/s, RH 5 to 95%, concentrations 2 to 5,000 µg/m^3, and co-pollutants [NO_x, SO_2, O_3])
  - Comparisons with reference methods
  - Solvent extraction & gas chromatography-mass spectrometry

Case Study – Residential Vapour Intrusion Study

- ~ 7,500 indoor samples collected from ~ 500 homes & businesses.
- Compounds of Interest
  - Trichloroethylene (TCE)
  - Perchloroethylene (PCE)
  - 1,1,1-trichloroethane (1,1,1-TCE)
  - 5 potential degradation

Sampling Methodology

- Originally used vacuum canisters with TD/GC/MS
  - Difficult to deploy
  - Issues with flow orifice & uneven filling
  - Reproducibility of duplicate measurements relatively poor
- Cumbersome, costly & long turn-around times

Method Validation for Vapour Intrusion Study

- Sample collected on PSD (3M OVM 3500)
- Replacing canister method with PSD approach required field trials to demonstrate performance
  - QA/QC involved validation vs vacuum canisters, charcoal tubes & thermal desorption tubes
  - Parallel sampling with canisters & thermal desorption tubes by MOECC

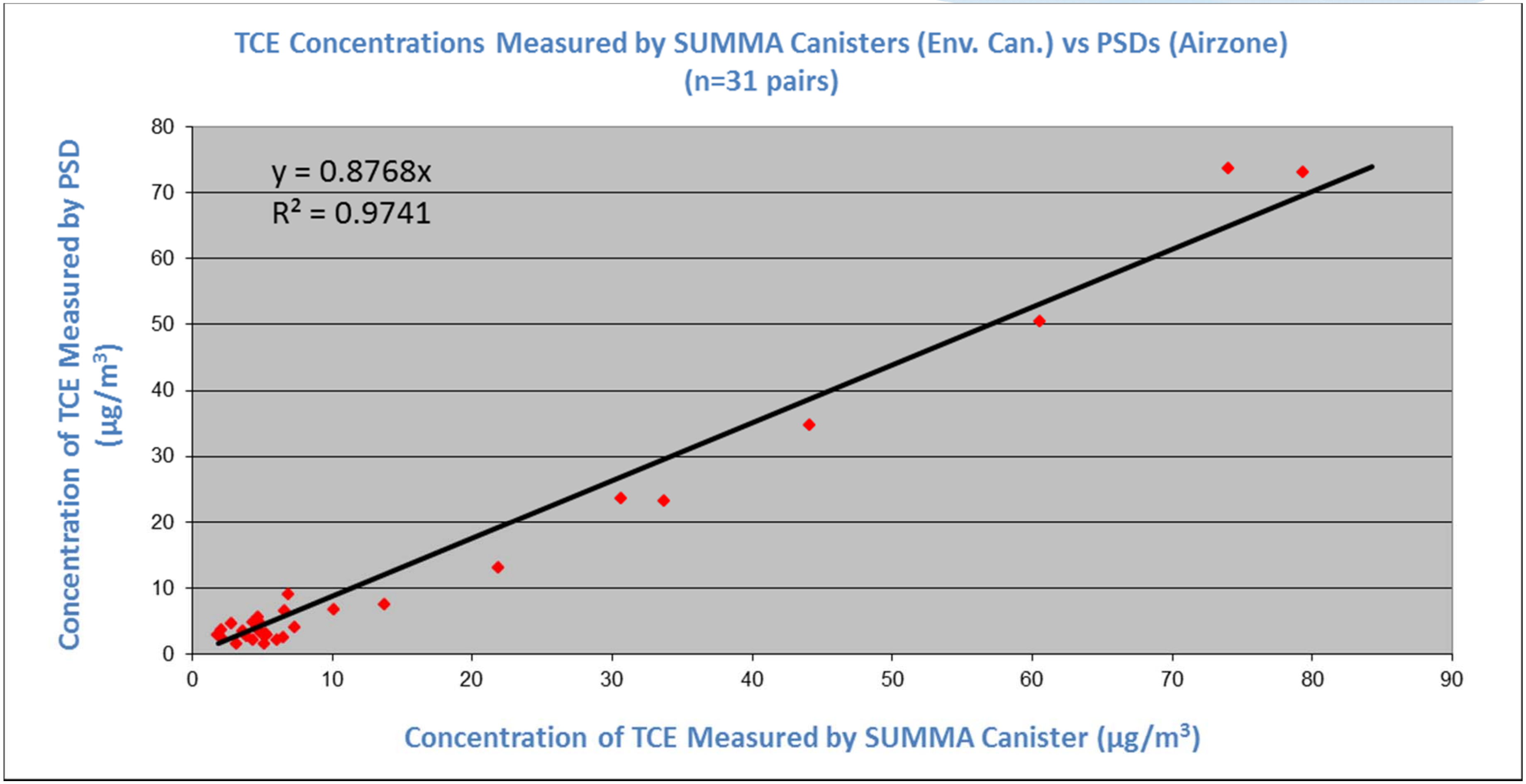
Method Validation for VI Study

- Detection limit of 0.1 µg/m^3
  - 1/5th of target concentration for TCE of 0.5 µg/m^3
- Internal QA/QC
  - Field blanks (one per batch of samples)
  - Field duplicates (1 in 10 or one per batch)
  - Lab replicates (1 in 10 and external reference standards)

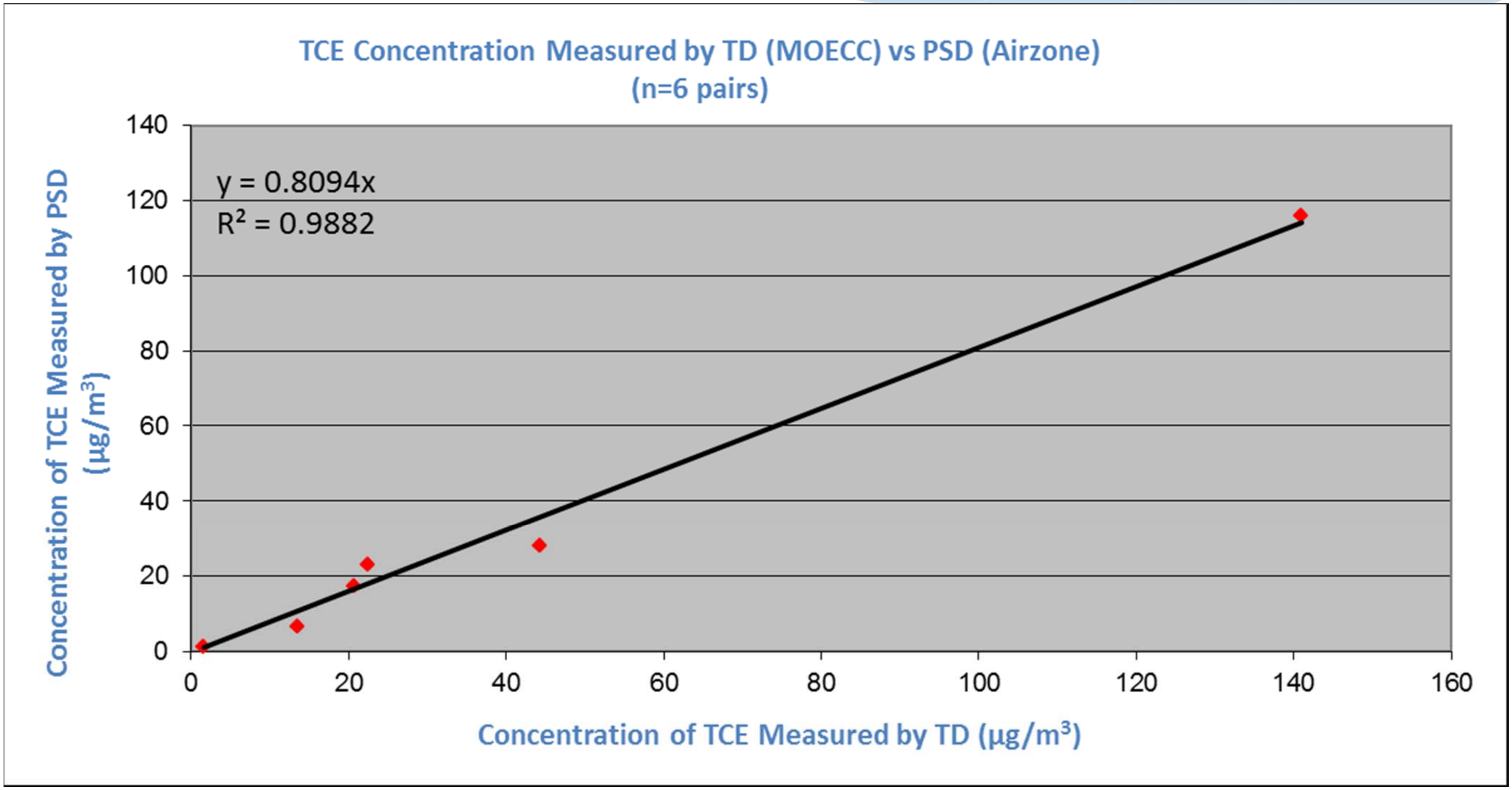
Precision Based on Duplicate Sampling

Method	# Duplicates	Reproducibility %
3M OVM PSD	258	5.6
Charcoal Tubes	12	11.2
Vacuum Canisters	9	18.6

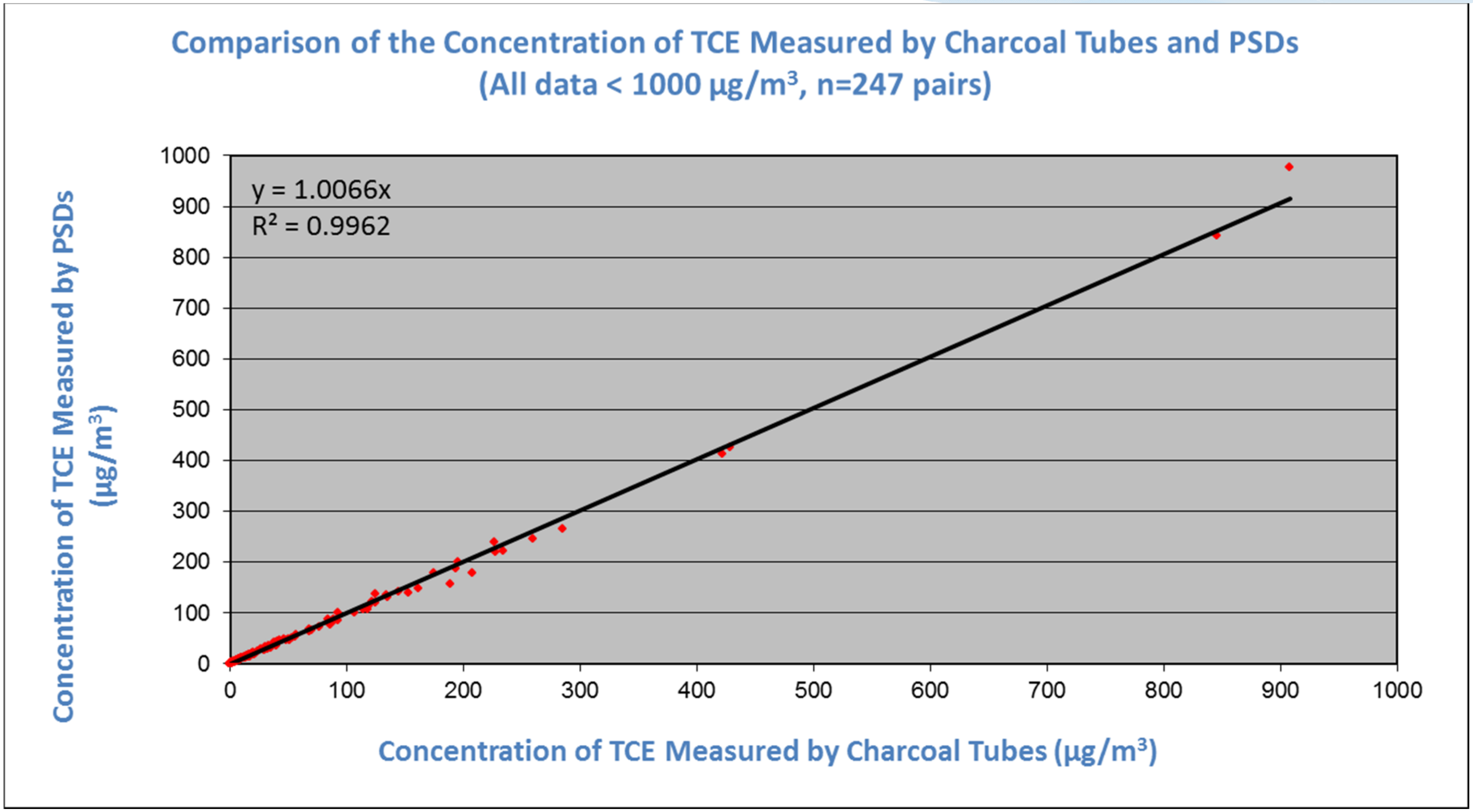
Comparison of 3M PSDs vs Canisters



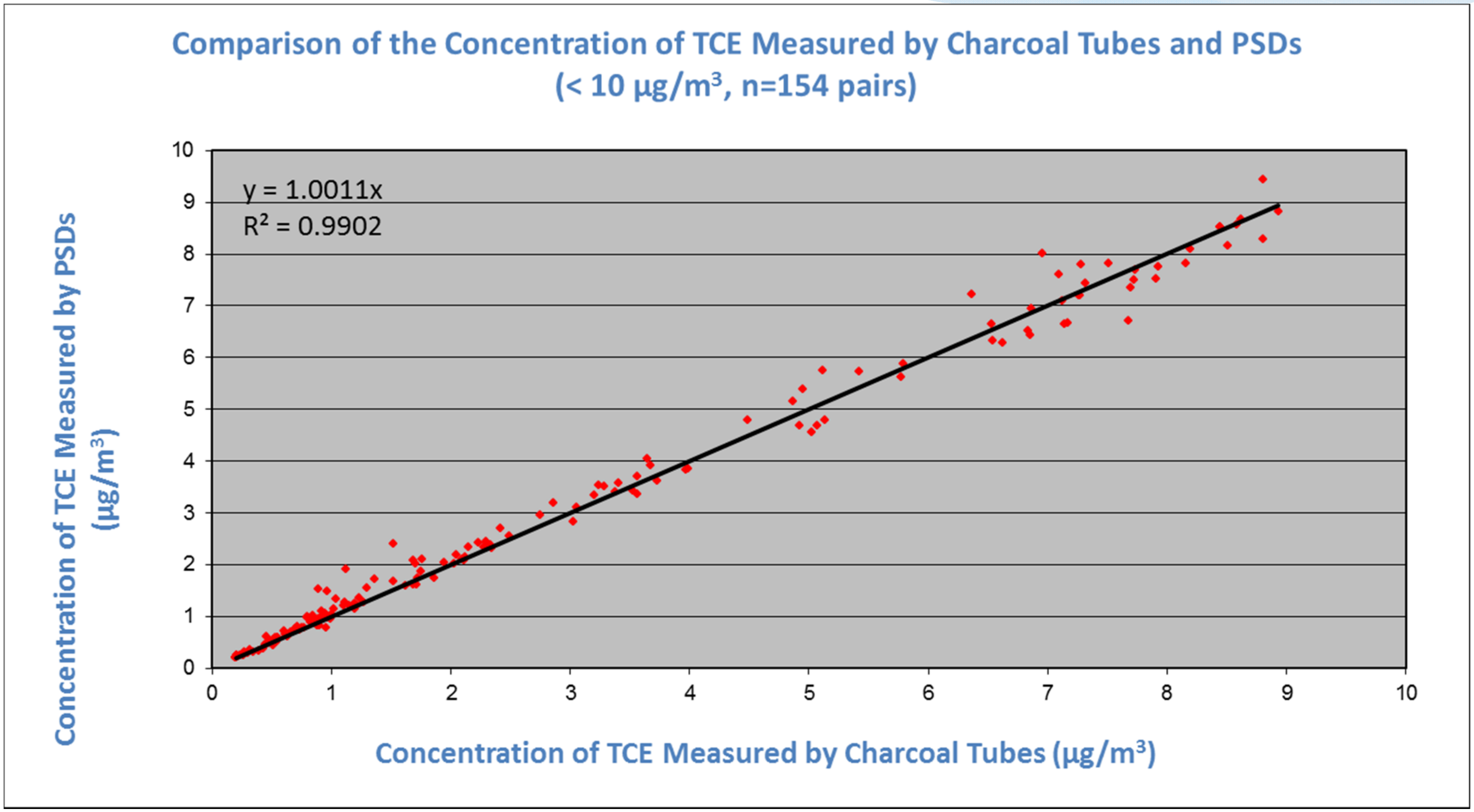
Comparison of 3M PSDs vs Thermal Desorption Tubes



Comparison of 3M PSDs vs Charcoal Tubes Full Range of Measurements



Comparison of 3M PSDs vs Charcoal Tubes Low Range Measurements



Low Concentration Comparison In Ambient Air Samples

*Airzone charcoal and 3M PSD duplicate samples

TCE in µg/m^3	TD [MOECC]	Canister [Env. Can.]	Charcoal [Airzone*]	3M PSD [Airzone*]
Site 1 [outdoors]	1.46	1.25	1.51/1.55	1.39/1.51
Site 2 [outdoors]	0.060	0.064	<0.1/<0.1	<0.1/<0.1
Site 3 [NAPS outdoors]	0.050	0.038	<0.1/<0.1	<0.1/<0.1
Site 4 [outdoors]	0.060	0.068	<0.1/<0.1	<0.1/<0.1
Site 5 [indoors]	0.76	0.74	0.90/0.88	0.83/0.83
Site 6 [indoors]	0.21	0.21	0.27/0.30	0.32/0.29

Detection Limits

Volatile Organic Compounds	Method Detection Limit (MDL)		
	8 hrs	24 hrs	7 days
	μg/m³		
Benzene	0.80	0.27	0.04
1,2-Dichloroethane	0.34	0.11	0.02
Ethylbenzene	0.46	0.15	0.02
1,1,2,2-Tetrachloroethane	0.17	0.06	0.01
Tetrachloroethylene	0.29	0.01	0.01
Toluene	0.55	0.18	0.03
Trichloroethylene	0.27	0.09	0.01
Xylene (m- +p-)	0.42	0.14	0.02
Xylene (o-)	0.36	0.12	0.02

Summary

- PSDs have been accepted by provincial regulatory agencies for use in large scale vapour intrusion and ambient air studies
- PSDs offer several significant advantages
  - Small & unobtrusive
  - Silent & require no power
  - Cost effective
  - Wide range of sampling periods available
- Validation of additional target compounds (e.g., vinyl chloride) still underway
- Detection limits suitable for most applications

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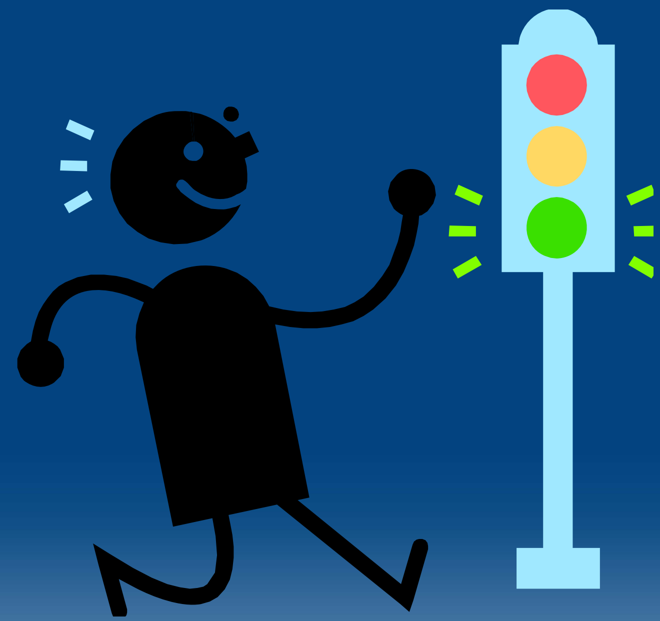
The End

Thank You!



Questions/Discussion?

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