

Development of a Method for Measuring Soil Vapour Intrusion to Indoor Air by Diffusive Sampling

Geosyntec
consultants

Development of a Method for Measuring Soil Vapor Intrusion to Indoor Air by Diffusive Sampling

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Krakow, 15 september 2009

Subsurface vapour intrusion

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Project facts

- ❑ Development Of More Cost-effective Methods For Long-term Monitoring Of Soil Vapor Intrusion To Indoor Air Using Quantitative Passive Diffusive-adsorptive Sampling Techniques (ER 0830)
- ❑ Lead organization: **Geosyntec** consultants
- ❑ Funding under **ESTCP (Environmental Security Technology Certification Program)**

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Project team

Organization	Name	Role
Geosyntec Consultants, Inc. Guelph (Canada)	Todd McAlary Hester Groenevelt	Overall project direction & reporting
US EPA Labs, Las Vegas (NV)	Brian Schumacher John Nocerino	Experimental Design & Statistics
Arizona State University (AZ)	Paul Johnson	Practicality for Vapor Intrusion Sites
University of Waterloo (Canada)	Tadeusz Gorecki Suresh Seethapathy	PDMS Membrane Sampler
Cranfield University (UK)	Derrick Crump	ATD Passive and Active Samplers
Fondazione Salvatore Maugeri (Italy)	Paolo Sacco	Radiello Samplers
Columbia Analytical Services (CA)	Michael Taday	Ultra 11™ samplers & canisters High Conc. Laboratory Testing
Air Toxics	Heidi Hayes	Low Conc. Laboratory Testing

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Background

- ❑ Contaminated soil and groundwater require human health risk assessment in indoor air
- ❑ Long-term monitoring often needed
- ❑ **VOCs commonly measured by passivated stainless steel containers (Summa canisters) analyzed by EPA method TO-15**
- ❑ Alternatively active sampling (rechargeable battery-pumps), adsorption on **ATD (automated thermal desorption) tubes, analyzed by EPA method TO-17**

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Summa Canisters

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Summa Canisters

Key points

- Typical sampling duration up to 24-h
- Summa Canister & TO-15 is a standardised procedure



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Drawbacks

- High costs for canister purchase (\$1,000) or rental (\$75) and VOC analysis (~\$250)
- Canister cleaning time-consuming
- Canister bulky to ship
- Potential for leaks

ATD Tubes



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ATD Tubes

Key points

- Sampling duration longer than 24 hour
- ATD tubes and TO-17 very accurate and precise, with ppt level capability
- Standardised method for industrial hygiene and indoor/ambient air

Drawbacks

- Power required
- Need for reliability of pump flow-rate
- Potential breakthrough in high concentration zones



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Project aim

- Demonstrate the applicability of **low-cost techniques** for sampling and analysis of VOCs during investigations of subsurface vapor intrusion to indoor air
- Identify by a comparative study *whether and under which conditions* the diffusive samplers provide good quality data

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Technical Objectives

- Head-to-head testing under laboratory and field conditions of 4 different diffusive sampling techniques
- Identify capabilities and limitations (*whether and under which conditions these diffusive sampling methods can provide good quality VOCs measurements*)
- Characterize potential savings for users

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Research program

- Task 1: Planning – experimental design
- Task 2: Controlled Laboratory Testing
 - Familiarity Testing (*are factors under control ?*)
 - 1-Way ANOVA (6 x 3 replicates x 4 samplers)
 - Fractional Factorial (5 factors: C, T, v, t, RH)
 - High concentration testing (*simulating soil gas*)
- Task 3: Field Testing (US Dept of Def. Site)
 - Existing vapor intrusion study area
 - Indoor & outdoor air, sub-slab & deeper soil gas
- Project schedule 3 ½ years

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Compounds to measure

- Vapor intrusion guidance of US EPA Office of Solid Waste and Emergency Response (OSWER)
 - Compounds relevant for vapour intrusion assessment
- OSWER list include **114 compounds** which could pose a potential risk
 - Span a wide range of properties
- Only a few actually involved in vapor intrusion impacts
 - Volatile and toxic enough to pose a potential inhalation risk
 - Reasonably common at sites with contaminated soil and groundwater

Selection criteria

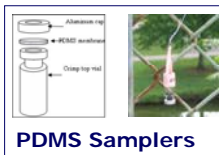
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10 Target compounds

Analyte	OSWER indoor conc. at 10 ⁻⁶ risk (ppb)	Vapour pressure (atm)	Water solubility (g/l)
1,1,1-Trichloroethane	400	0.16	1.33
1,2,4-Trimethylbenzene	1.2	0.00197	0.0708
1,2-Dichloroethane	0.023	0.107	8.52
2-Butanone (MEK)	340	0.1026	~ 256
Benzene	0.10	0.125	1.75
Carbon tetrachloride	0.026	0.148	0.793
Naphthalene	0.57	0.000117	0.031
n-Hexane	57	0.197	0.0128
Tetrachloroethene	0.12	0.0242	0.2
Trichloroethene	0.0041	0.0948	1.1

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The diffusive samplers under study



PDMS Samplers



Radiello



ATD Tubes



SKC Ultra II badges

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SKC Ultra II Badge

Can be filled with

- Tenax TA
- Chromosorb 106
- Anasorb GCB1 (Carbopack B)
- Carbopack X

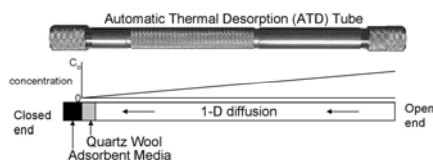


Uptake rates
(24-h Chromosorb 106)

- benzene 11.48 cm³/min
- TCE 10.18 cm³/min

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ATD Tube Sampler



- Can be filled with Tenax TA, Carbograph 1, Carbopack X, Chromosorb 106
- Uptake rate for benzene (7-d Chromosorb 106) 0.48 cm³/min

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Radiello sampler

Can be filled with

- Activated charcoal (for solvent desorption)
- Carbograph 4
- Carbopack X (for thermal desorption)



Uptake rates
(7-d Act. Charcoal)

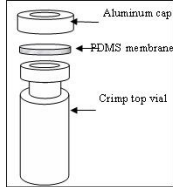
- benzene 80 cm³/min
- TCE 69 cm³/min

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PDMS Sampler

- 1.8 ml headspace vial
- Axial diffusion through a Polydimethylsiloxane (PDMS) membrane



Filled with Anasorb 747 (synthetic carbon)

benzene 2.15 cm³/min
TCE 3.28 cm³/min

Diffusion rate can be estimated from GC retention indices (PDMS used as GC stationary phase)



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Factors affecting performance

Variables considered in laboratory testing

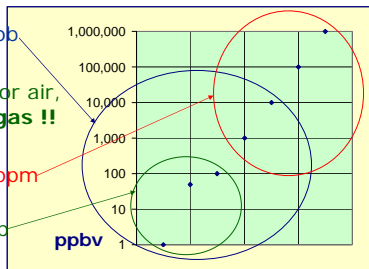
- concentration
- temperature
- gas flow velocity (face velocity)
- sampling duration
- relative humidity



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Which range of concentrations ?

- initial plan 1 – 10,000 ppb
- it covers indoor air, but **not soil gas !!**
- split in two
- high 1-1000 ppm (soil gas)
- low 1-100 ppb (indoor)



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Controlling face velocity

~0 to 0.4 m/s – possible solutions:

- velocity control section area and (Ø 30 cm needs
- recirculate air in chamber by fan
- move samplers,



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Factors' range

- temperature 10 – 30 °C
- relative humidity 30 – 90 %
- sampling duration 1 – 7 days
- in vapour intrusion studies average concentrations minimize uncertainty due to short-term variability



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Chamber requirements

- accommodate 12 samplers (3 repl. x 4 types)
- avoid cross competitions between samplers
- allow the control of face velocity (motors with steady rotation rate)
- set up and keep control of atmosphere parameters (C, T, RH)



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Building fit-for-purpose test apparatuses

low concentration tests

- ❑ oil-less pump
- ❑ activated charcoal filter
- ❑ three bubbler humidifiers
- ❑ six mass flow controllers
- ❑ three lines of specialty gas mixture
- ❑ three lines of source gas
- ❑ to three exposure chambers in parallel
- ❑ 12 samplers per chamber

high concentration tests

- ❑ zero gas tank
- ❑ gas purifier
- ❑ bubbler humidifier
- ❑ infusion chamber with syringe pump
- ❑ two mass flow controllers
- ❑ cylindrical, low volume exposure chamber with top opening lid
- ❑ one sampler per test



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Chambers under construction



photo by
George Chittenden



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Experimental design for laboratory testing

- ❑ developed by B. Schumacher and J. Nocerino of EPA Research Labs with Design-Expert software (strategies outlined by Deming and Morgan, 1987)

Familiarity Testing (*low concentration tests*)

- ❑ set-up controlled conditions and demonstrate stability and consistency
- ❑ measure T and RH with a probe, concentrations by ATD-tube samplings
- ❑ check three chambers, changing factors one at a time



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Laboratory testing (*low conc.*)

ANOVA Test

- ❑ each factor set at mid-point
- ❑ six replicate testings at the same conditions
- ❑ three chambers to be checked, changing factors one at a time



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Laboratory testing (*low conc.*)

One-half fraction two-level factorial test

- ❑ low/high value for each factor
- ❑ changing more than one factor at a time
- ❑ minimise number of tests (18) needed to assess the effects of factors and their interactions

Run	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Response
1	1.00	10.00	1.00	1.00	100.00	0.00
2	1.00	10.00	1.00	2.00	100.00	0.00
3	1.00	10.00	2.00	1.00	100.00	0.00
4	1.00	10.00	2.00	2.00	100.00	0.00
5	1.00	20.00	1.00	1.00	100.00	0.00
6	1.00	20.00	1.00	2.00	100.00	0.00
7	1.00	20.00	2.00	1.00	100.00	0.00
8	1.00	20.00	2.00	2.00	100.00	0.00
9	2.00	10.00	1.00	1.00	100.00	0.00
10	2.00	10.00	1.00	2.00	100.00	0.00
11	2.00	10.00	2.00	1.00	100.00	0.00
12	2.00	10.00	2.00	2.00	100.00	0.00
13	2.00	20.00	1.00	1.00	100.00	0.00
14	2.00	20.00	1.00	2.00	100.00	0.00
15	2.00	20.00	2.00	1.00	100.00	0.00
16	2.00	20.00	2.00	2.00	100.00	0.00
17	1.00	10.00	1.00	1.00	10.00	0.00
18	1.00	10.00	1.00	1.00	1000.00	0.00



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Laboratory testing (*high conc.*)

- ❑ Flow-through cell, ~ 1 m long
- ❑ One diffusive sampler at a time
- ❑ 30 min at 100 ml/min (above max. diff. UR)
- ❑ RH close to 100%, ambient temperature
- ❑ 4 sequences at 1, 10, 100, 1000 ppm
- ❑ 12 samplers per sequence (3 repl. x 4 types)
- ❑ Ref. conc. by active sampling (start, middle, end of the sequence)



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