Tracer Estimation of Attenuation Factors at Vapor Intrusion Sites

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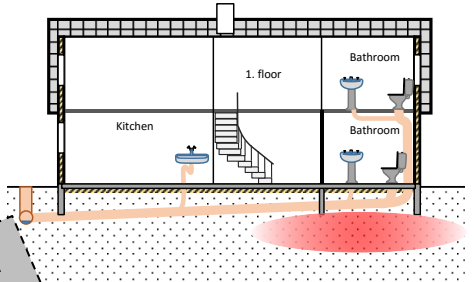
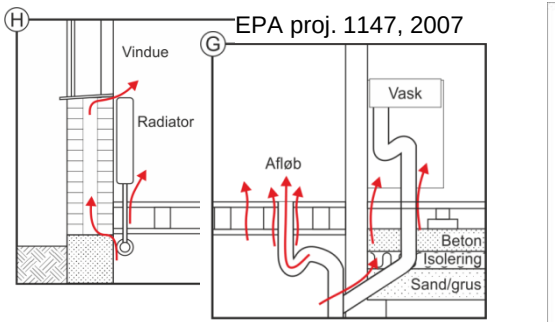
Vapor Intrusion Framework

- The subsurface contribution of VOCs to the indoor environment is a function of:
  a. Sub-slab VOC concentrations and spatial distribution.
  c. Vapor intrusion pathways – number and placement.
  d. Differential pressure (subsurface to indoor).
  e. Building ventilation



Vapor intrusion varies in both place and time!



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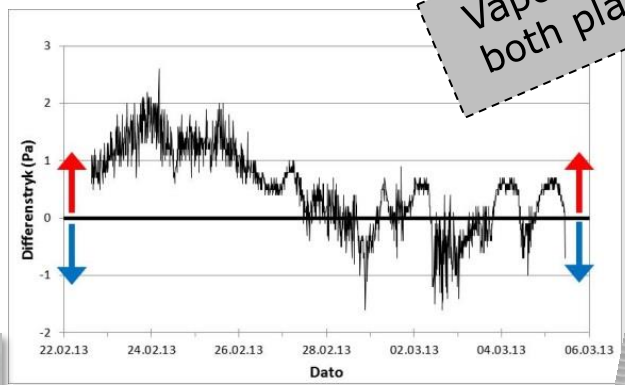


Under Danish conditions, the pressure driven contribution is approx. 70-85% of the total contribution (diffusion + advection).

The Tracer Technology

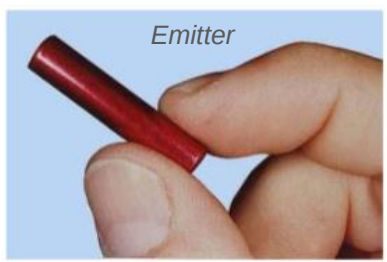
- Two PFT (PerFluorcarbon Tracers) tracer gasses (PMCP & PMCH).
- Tracers are released at a constant rate on the source side.
- Passive sampling (2 weeks) on both source and receptor side.

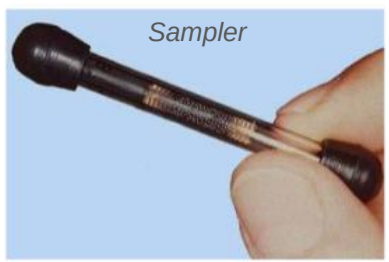
TABLE 6.6—PROPERTIES OF THE MOST FREQUENTLY APPLIED PERFLUOROCARBON GAS TRACERS (after Dugstad[11])

Perfluorocarbons Tracer	Abbreviation	Chemical Formula	Molecular Weight	Boiling Point
Perfluoromethylecyclopentane	PMCP	C_6F_{12}	300	48
Perfluorodimethylcyclobutane	PDMCB	C_8F_{12}	300	45
Perfluoromethylecyclohexane	PMCH	C_7F_{14}	350	76
1,3 Perfluorodimethylcyclohexane	1,3-PDMCH	C_8F_{16}	400	102

Source: PetroWiki.org

- Based on tracer results, an attenuation factor (AF) is estimated.
- COCs measured on source side.
- The contribution from a given source (area) can then be estimated.
- Two commercially available systems in Denmark:





Danish Building Research Institute (Brookhaven NL)

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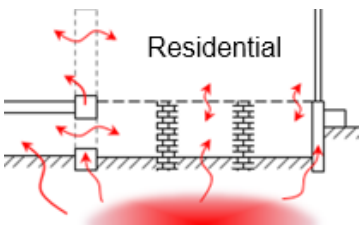
Indoor air concentrations are measured using passive samplers – ORSA (2 week samples).

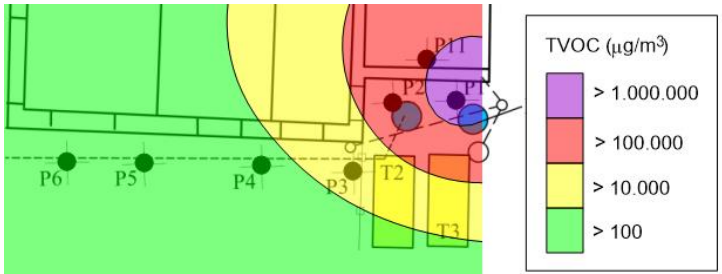
Overview of applications

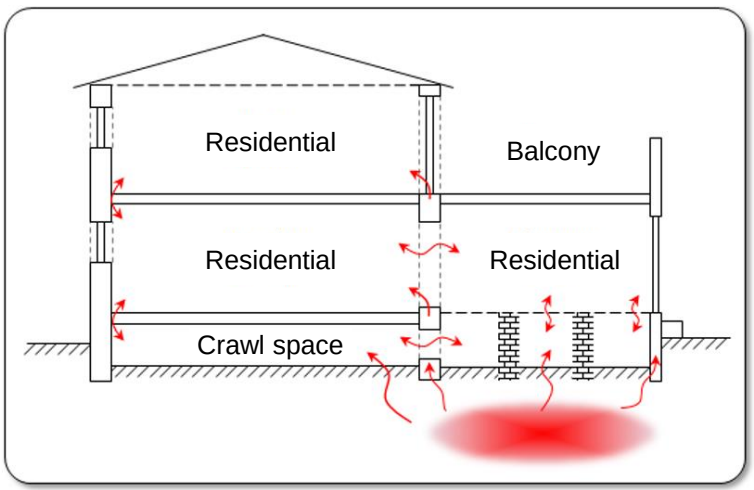
- We have applied the PFT technique on different problems relating to the vapor intrusion framework.
  - Both quantitative and qualitative problems.
  - Hypothesis testing, some of which are related to concentration vs. flux.
- We have applied the technique to a variety of problems and structures, including:
  - Vapor intrusion through a crawl space.
  - Vapor intrusion through cavity walls.
  - Vapor intrusion due to industrial activities.
  - Vapor transport across floor decking in apartment buildings.
  - Vapor intrusion through basements.
  - Vapor intrusion through sewer systems.

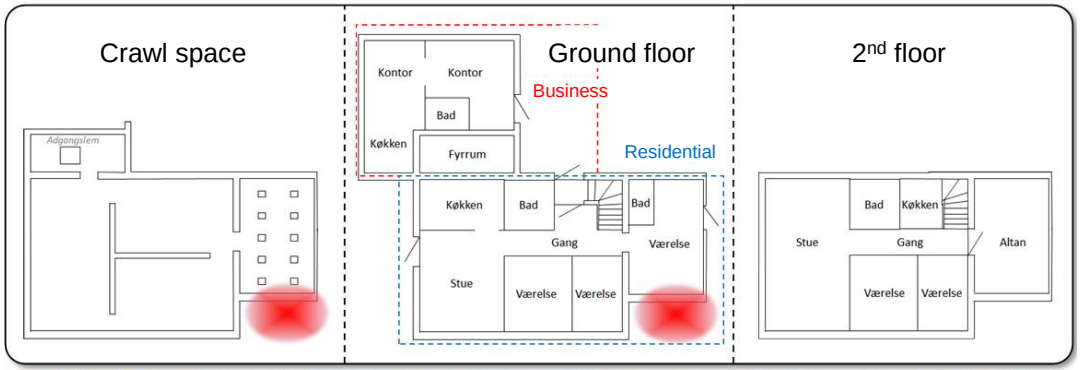


Contribution from Crawl Space and Cavity Walls

Vapor phase concentrations in the UZ:

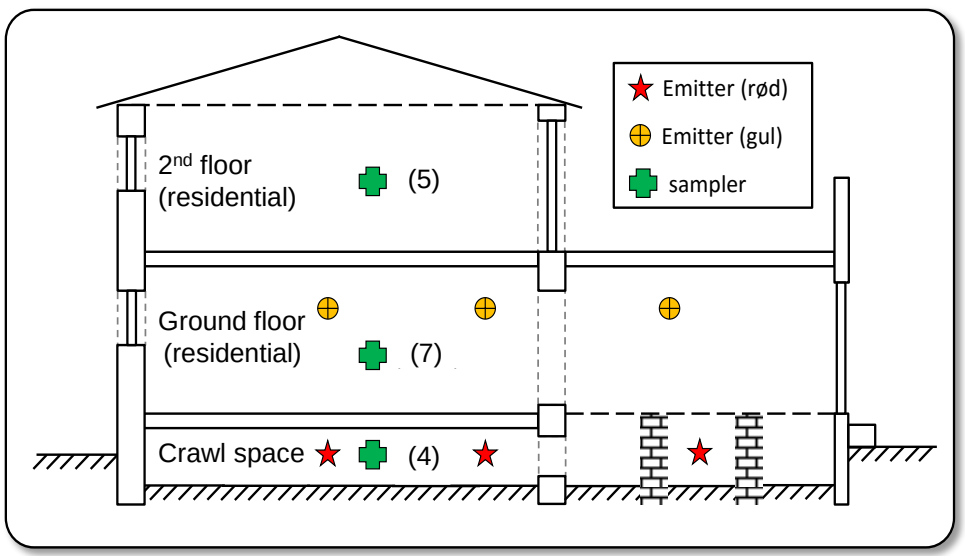






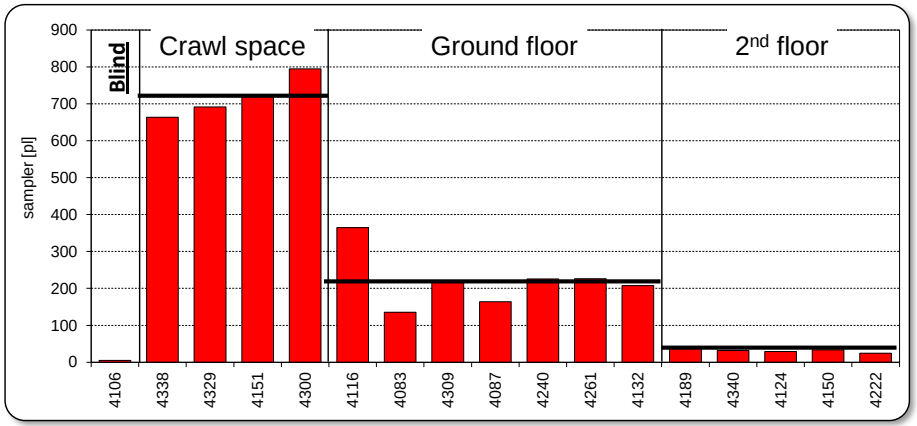
Crawl Space: Tracer Study Set-up

- PFT set-up (emitters deployed 1 week before samplers).
  - 5 PCMH emitters deployed in the crawl space.
  - 7 PCMP emitters deployed in ground floor rooms.
  - 16 samplers: 4 in the crawl space, 7 at ground floor and 5 on the 2nd floor.

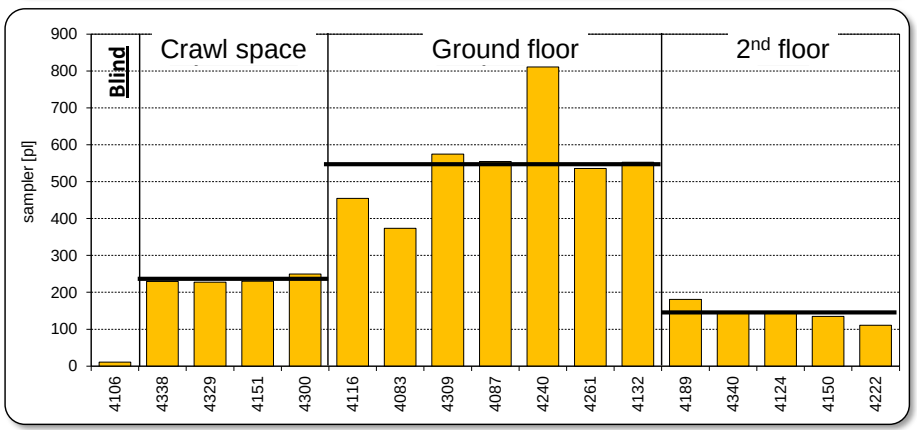


- 4 ORSA-samplers for measuring TVOC in the crawl space (same positions as PFT samplers) – 2 week sampling period.

Crawl Space: Results



PMCH deployed in crawl space



PMCP deployed in ground floor rooms

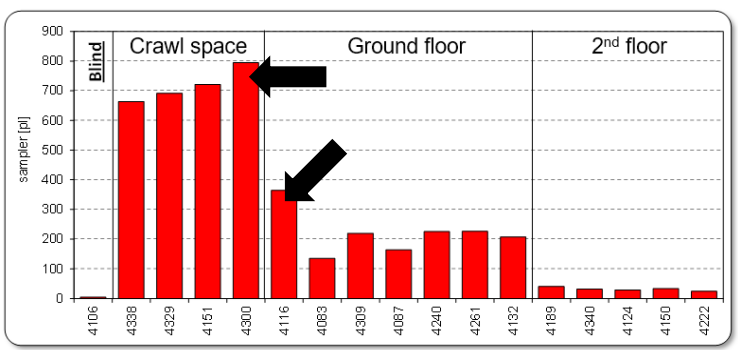
Crawl Space: Attenuation Factors

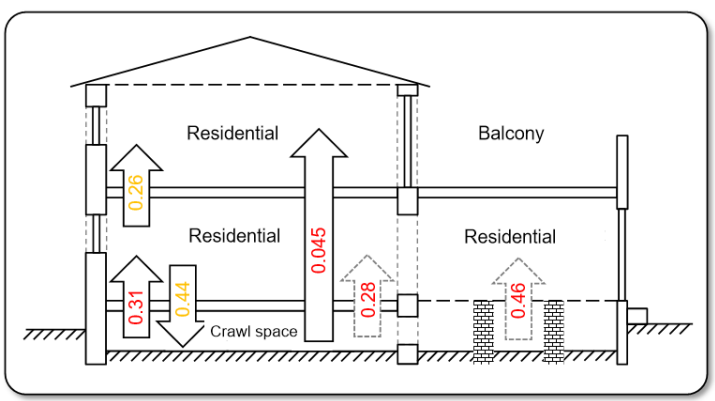
- Attenuation factors based on average results:

	PMCH [pl]	PMCP [pl]
2nd floor	32,0	143
Ground floor	220	551
Crawl space	718	234

  - Crawl space to ground floor (220/718): 0.31
  - Crawl space to 2nd floor (32/718): 0.045
  - Ground floor to crawl space (234/551): 0.44
  - Ground floor to 2nd floor (143/551): 0.26
  - Ground floor to 2nd floor (32/220): 0.15

- Two different types of flooring (just approximate estimates):
  - Wood (365/795): 0.46
  - Concrete (196/692): 0.28

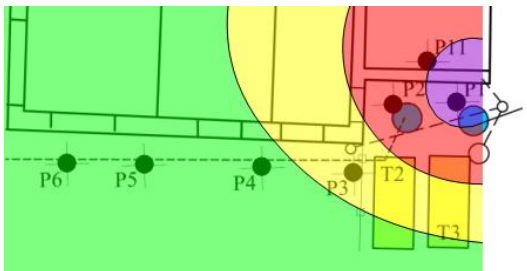


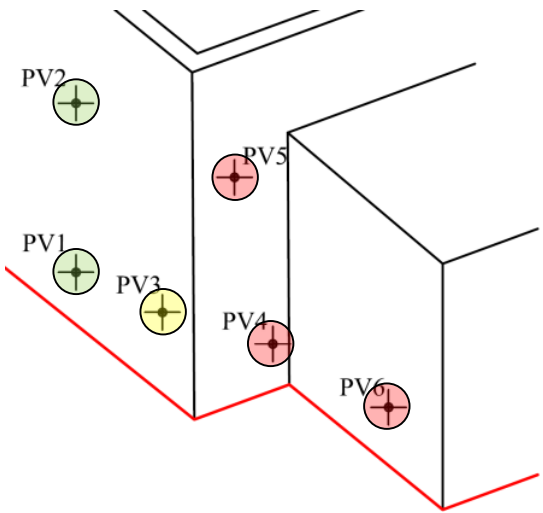


- Crawl space contribution estimated from VOC concentration and AFs.

Cavity Walls

- We suspected an issue with VI through cavity walls.
  - So we measured the TVOC concentration in six spots (active sampling on Dräger carbon tubes).

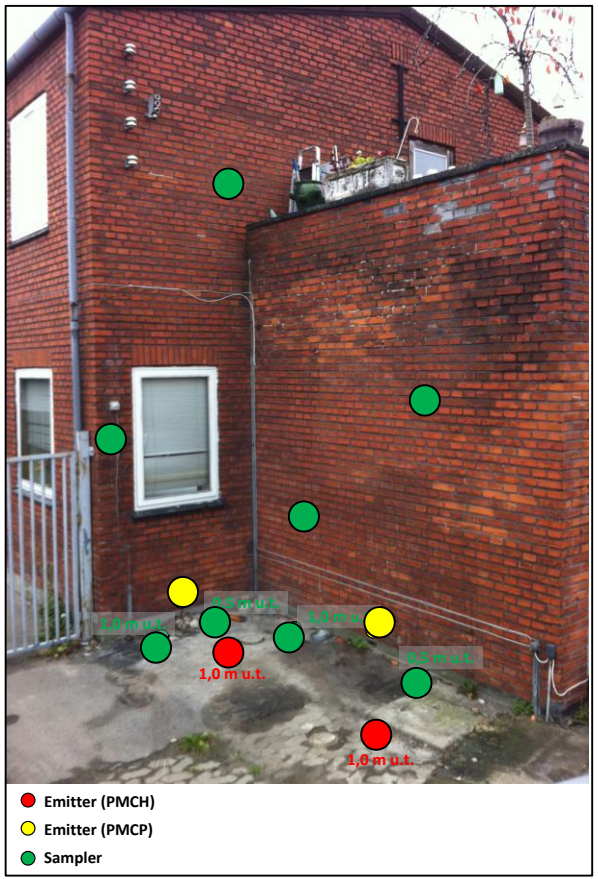




- But we are interested in the mass flux – not just concentration.

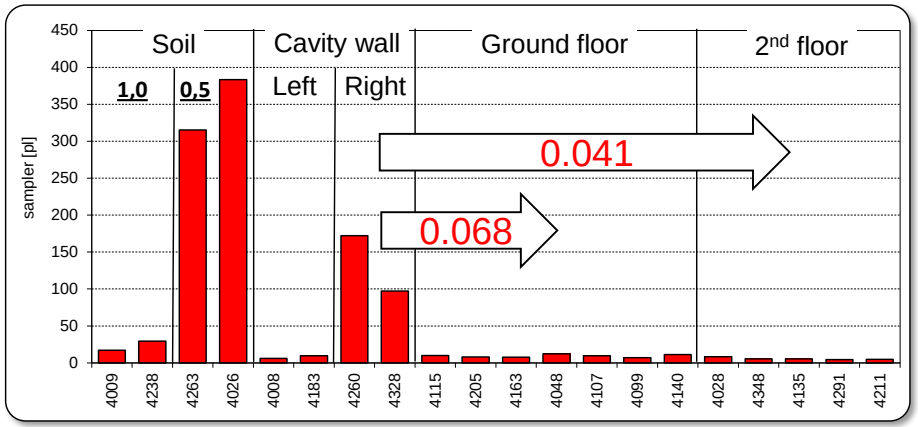
Cavity Wall: Tracer Study Set-up

- PFT set-up (emitters deployed 1 week before samplers):
  - 2 PMCH emitters deployed in hot-spot (1 m bgs.)
  - 2 PMCP emitters deployed in cavity wall.
  - 4 samplers in UZ (0.5 and 1 m bgs.)
  - 4 samplers in cavity walls (left and right)
  - 11 samplers in rooms (as before)

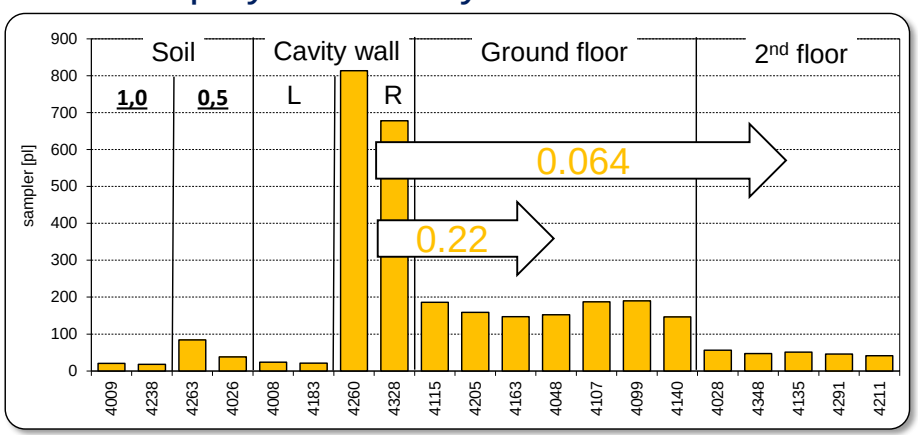


Cavity Wall: Results

PMCH deployed in the hot-spot (1 m bgs.)



PMCP deployed in cavity walls above foundation



- Hardly any lateral tracer transport.
- Nice break-through to soil 0.5 m bgs.
- Very low break-through to left wall.
- Nice break-through to right wall.
- Low tracer concentrations in building.
- Slight back-flow to soil 0.5 m bgs.
- No vertical transport in left wall.
- Good vertical transport in right wall.
- Nice break-through to building; more to ground floor than 2nd floor.

Attenuation factors:

Cavity wall to ground floor (167/746): 0.22

Cavity wall to 2nd floor (48/746): 0.064

Cavity wall to ground floor (9,3/135): 0.068

Cavity wall to 2nd floor (5,6/135): 0.041

Basement Activities

- Complaints about gasoline smell by workers and parents in a pre school daycare center (ground level) in building complex.
  - Suspected link to motorcycle repair shop in basement (no direct access).
  - Other possible sources: Parking basement and other businesses.

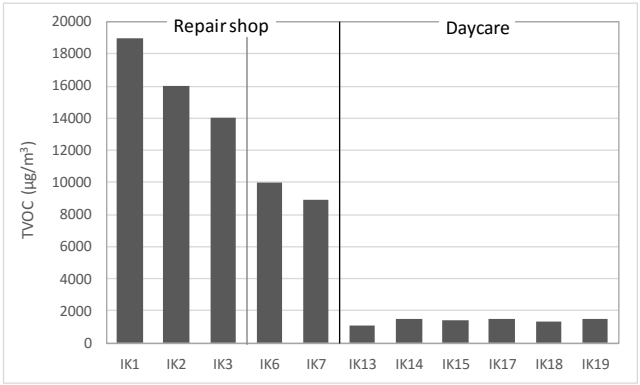
- We did initial measurements at the site:
  Shop: 14.000 µg/m^3 TVOC and 410 µg/m^3 benzene.
  Daycare: 1.300-3.000 µg/m^3 TVOC and 28-96 benzene.
- No regulatory limits for this type of situation (business to daycare) in Denmark.

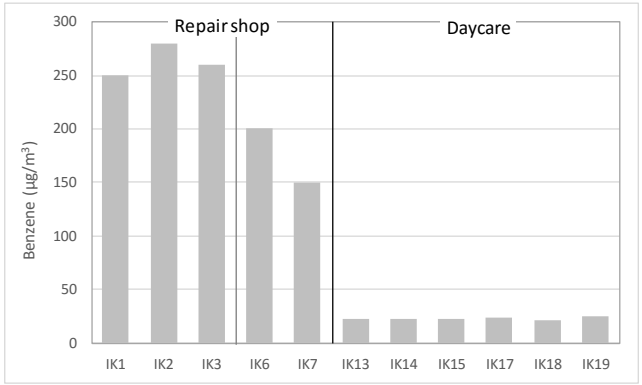
Basement Activities: Study Set-up

- PFT set-up (emitters deployed 4 days before samplers).
  - 3 PMCP emitters deployed in repair shop
  - 5 samplers in repair shop
  - 6 samplers in daycare
  - VOCs measured in same points

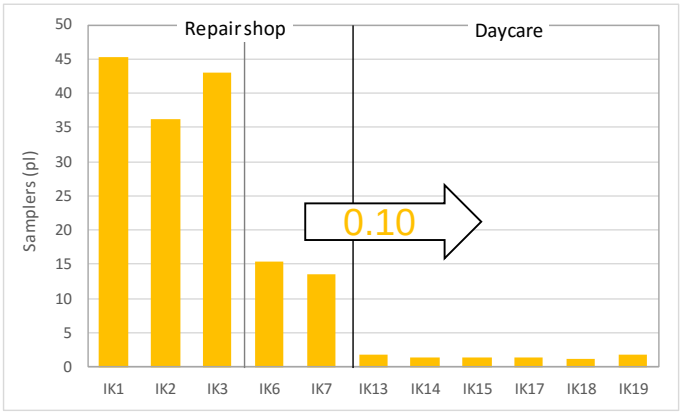
} 2 week sampling period

Basement Activities: Results





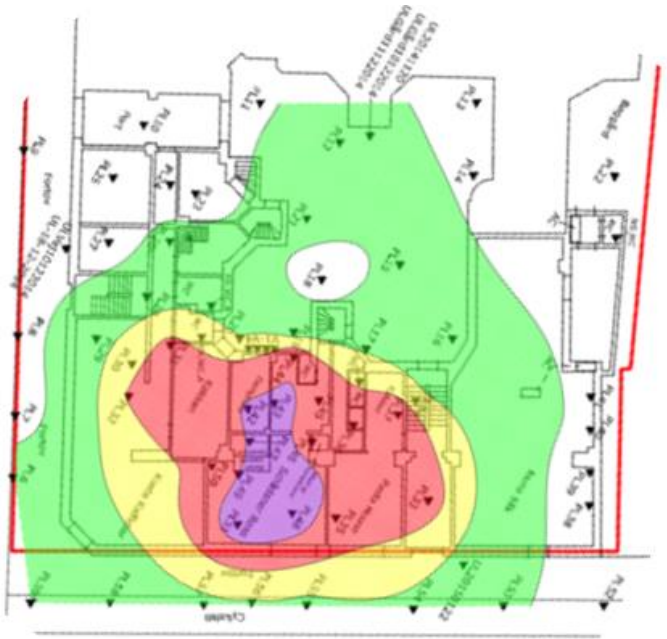
Based on the VOC results, the public health physician had the daycare moved to another location.

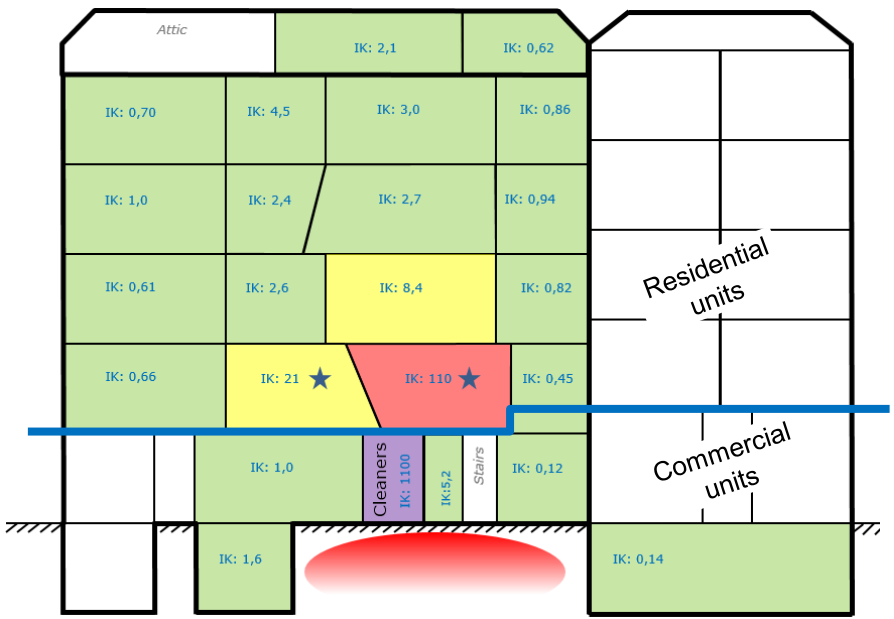


- 70-80% of TVOC and benzene in daycare could be explained by repair shop.
- The rest is due to internal sources (e.g. paints and house hold products).

Active Dry Cleaning vs. Old Soil Contamination

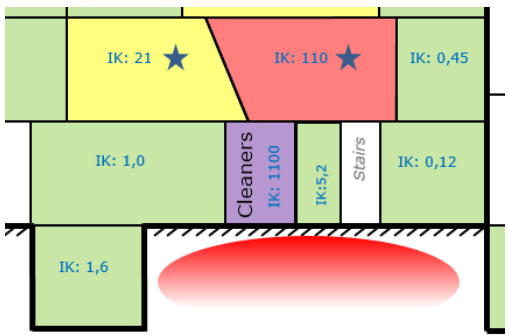
- At a site with an old PCE spill under a still active Dry Cleaners we had to estimate the contribution of PCE to above apartments.
  - 6 µg/m^3 can be tolerated from the old spill.
  - 100 µg/m^3 can be tolerated from the Dry Cleaners (only in ★ apartments).

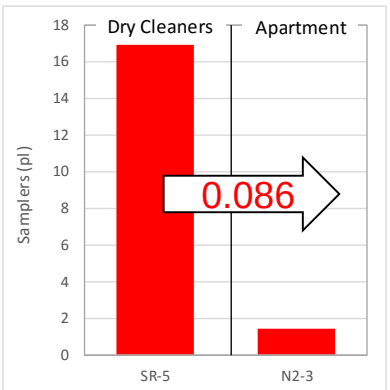


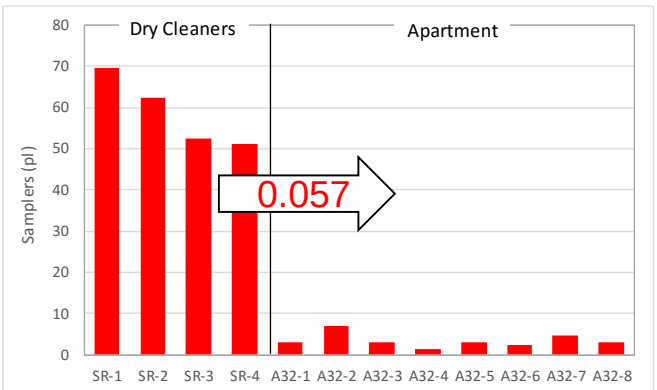


Active Dry Cleaners: Set-up and Results

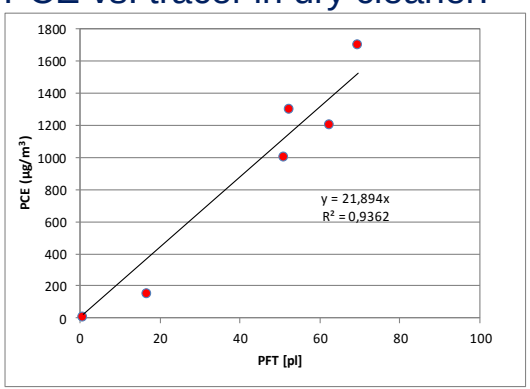
- Study focused on apartments right above the Dry Cleaners.
  - 4 PMCH emitters deployed in Dry Cleaners.
  - 5 samplers in Dry Cleaners.
  - 8 samplers in each apartment.







PCE vs. tracer in dry cleaner:



Left apartment:

AF (1.4/16,9): 0.083

Est. contribution: 13 µg/m³

Right apartment:

AF (3.4/59): 0.057

Est. contribution: 74 µg/m³

- Contribution from Dry Cleaners 54-67% of total PCE. Both < 100 µg/m³.

Summary and Conclusion

- PFT tracers have been successfully applied as a powerful tool in several vapor intrusion studies.
  - An excellent tool for hypothesis testing.
- Average 2 week ”long” term building behavior is investigated (using passive samplers), rather than random short term behavior.
- Attenuation factors can be estimated and used to quantitatively assess contributions from different sources.
- Use of tracers can lead to a better system understanding/CSM –> better risk assessments and remediation decisions.

Questions?