Vapor intrusion – state of the art

- Program
  - **State-of-the-art studies of vapor intrusion and migration pathways - Per Loll, Ph.D. R&D section manager (DMR, DK)**
  - Remediation techniques using passive venting systems - Mads Georg Møller (Orbicon, DK)
  - Remediation using Hybrid venting system based upon solar and wind power - Bjarke N. Hoffmark (COWI A/S, DK)
  - Monitoring strategy - Tage V. Bote (COWI, DK)
  - Discussion - Participants and speakers

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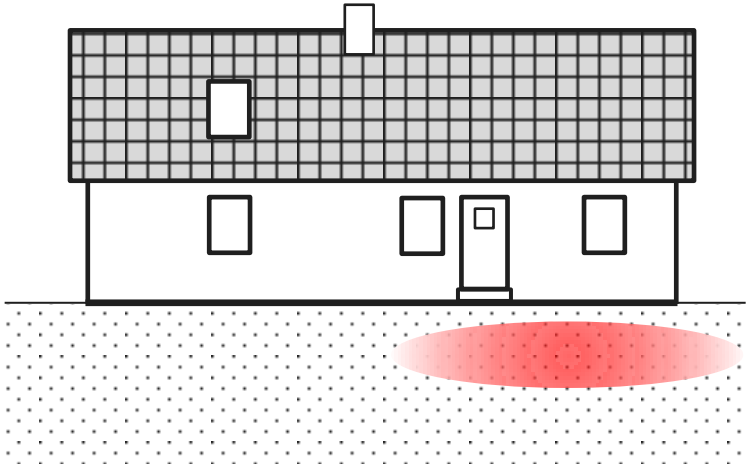
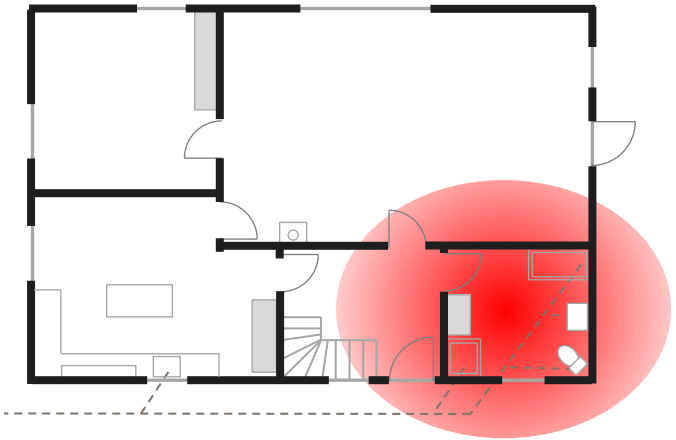
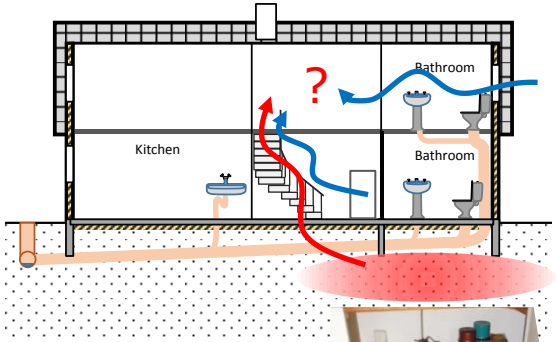
Vapor intrusion and migration pathways

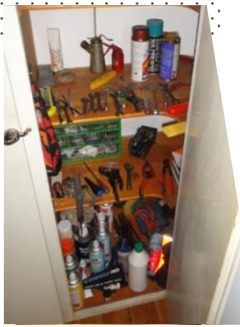




- Do the volatile organic carbons (VOCs) enter the building?
- Where are the migration pathways?

Background



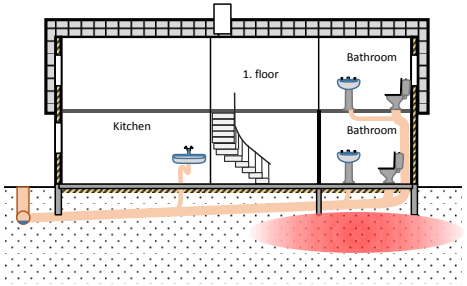


- In Denmark we have the following framework:
  - Regulatory standards are concentration based, eg.
    - Oil components: TVOC = 100 µg/m^3 & benzene = 0,13 µg/m^3
    - Chlorinated solvents: TCE = 1 µg/m^3 & PCE = 6 µg/m^3
  - Standards are <u>not</u> related to the total concentration, but to the subsurface <u>contribution</u> to the indoor concentration.
  - This can pose a problem when typical indoor concentrations are close to – or sometimes higher than the regulatory standards (we can't just measure).
  - Danish background levels - median concentrations (2010):
    - TVOC = 275 µg/m^3; benzene = 0,80 µg//m^3; TCE = 0-0,17 µg/m^3; PCE = 0,51 µg/m^3
  - Hence, we have to figure out how much is due to subsurface contaminants.
  - In Denmark, indoor air measurements are usually performed with ORSA samplers.

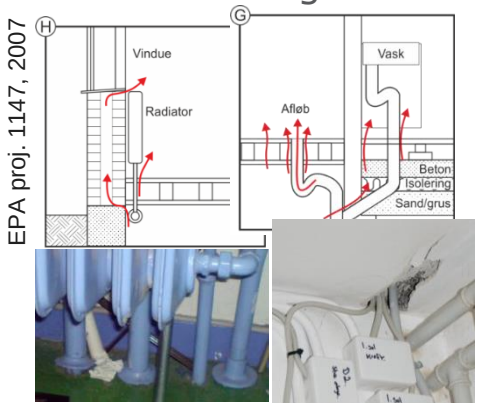
2 weeks of passive sampling.

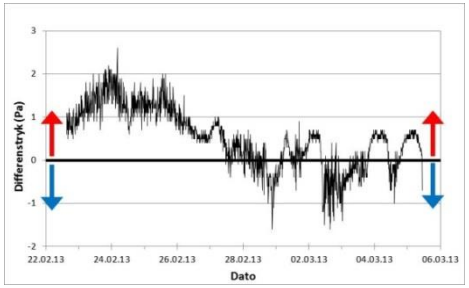
Background

Vapor intrusion varies in both place and time!



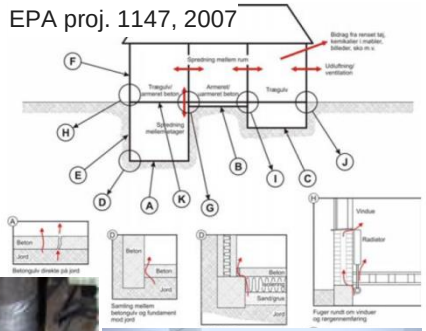
- The subsurface contribution of VOCs is a function of:
  - VOC concentrations and spatial distribution.
  - Migration pathways from the subsurface to the indoor air.
  - Differential pressure (subsurface to indoor) – air transport.
  - Building ventilation.



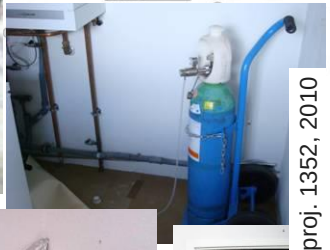


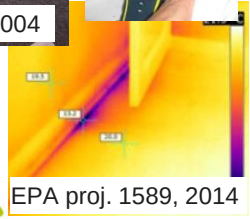
- Under normal Danish conditions; the pressure driven (advective) contribution can be expected to be 70-85% of the total contribution (diffusion + advection).

Methods (more detail in following slides)



- Technical building inspection (EPA proj. 1147, 2007)
- Foil-flux method (EPA proj. 646+647, 2001)
- ppbRAE and Vaporcover (EPA proj. 958, 2004)
- H_2-based tracer gas method (EPA proj. 1352, 2010)
- Thoron measurements (EPA proj. 1453, 2013)
- Thermography (EPA proj. 1589, 2014)
- Supporting methods:
  - Blowerdoor enhancement (EPA proj. 1589, 2014)
  - Differential pressure measurements
  - Sewer measurements
  - PFT tracer gas method





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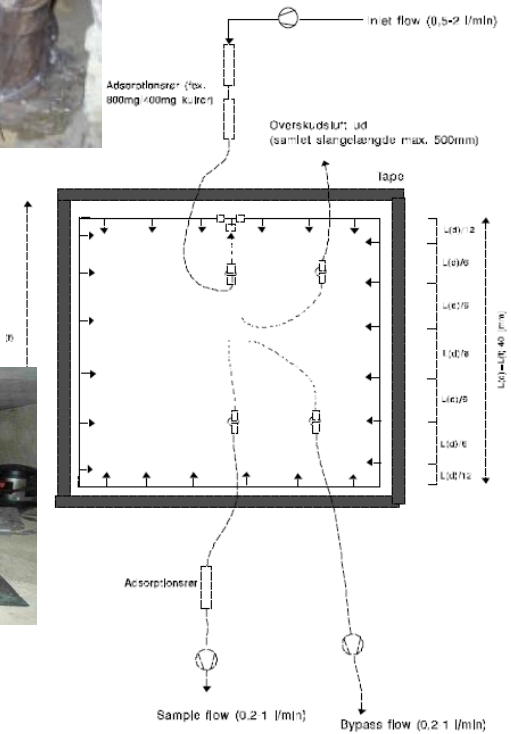
Foil-flux method (EPA 646/647, 2001)



- Basic operating principles:
  - A piece of foil is taped to the spot being tested (~0,5 m^2).
  - Clean air is pumped across the surface (under the foil).
  - Polluted air is collected on a carbon tube and analyzed.
  - Sampling time, flow registration and contaminant loading is used to calculate the vapor intrusion rate.

- Pros:
  - Actual vapor intrusion flux is quantified (µg/m^2/hr).
  - Compound specific estimates are obtained.
- Cons:
  - Only "point" measurements are obtained – many needed.
  - Waiting time for lab results.
  - Labor intensive, specialists required (= expensive).

Low use

ppbRAE and Vaporcover (EPA 958, 2004)

- Basic operating principles:
  - The Vaporcover is put on the area to be tested (40 x 40 cm).
  - A ppbRAE (PID-sensor) is used to measure the VOCs transported to the cavity underneath the Vaporcover.

- Pros:
  - Measures vapors directly.
  - Simple method - Easy to use.
  - Quick - immediate results.
  - Inexpensive.

- Cons:
  - Semi-quantitative results.
  - Not compound specific.
  - Risk of false positive results.

High use

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H_2-based tracer gas method (EPA 1352, 2010)

- Basic operating principles:
  - Tracer gas (5% H_2 and 95% N_2) is applied at the source side.
  - Source distribution is documented.
  - Receptor side of structure is tested with a hand held device (audiovisual results).
- Pros:
  - Simple and quick - immediate results.
  - Can be used across upper building floors.
  - H_2 comes with it's own "up-force".
  - Inexpensive.
- Cons:
  - Qualitative results only.
  - Holes need to be drilled.
  - Requires trained personnel.

Medium use

Thoron measurements (EPA 1453, 2013)

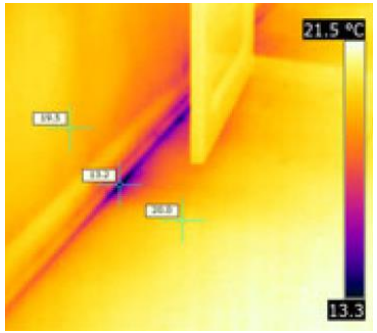
- Basic operating principles:
  - Thoron (^{220}Rn) is a naturally occurring radioactive compound in the Danish subsurface. Thoron enter buildings through the same pathways as VOCs.
  - Thoron decays to Polonium, and both has very short half-lives. Hence it's decay takes place close to advective intrusion pathways.
  - The decay of Polonium is measured over 5 minutes.

- Pros:
  - Direct result in the field.
  - Inexpensive.
- Cons:
  - Qualitative results only.
  - Cycle time (5 mins/measurement) – point measurements.
  - Requires trained personnel and expertise.

Low use (so far)

Thermography (EPA 1589, 2014)

- Basic operating principles:
  - A Blowerdoor provides relative low-pressure inside the building.
  - A thermography camera is used to measure temperature differences on surfaces.
  - Cold air entry points shows up as relatively cold areas.



- Pros:
  - Direct results in the field.
  - Once set-up is complete, large surfaces can be inspected.
  - Inexpensive.
- Cons:
  - Qualitative results only.
  - Requires cold outside air (cold climate/season).
  - Requires trained personnel –can be hard to interpret.

Uncertain

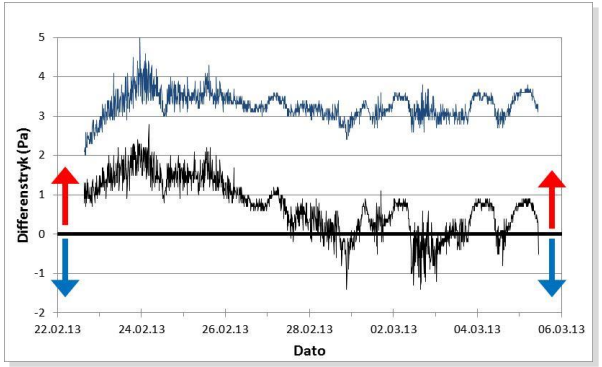
Blowerdoor can be used as an enhancement method for other tools

Differential pressure measurements

- Basic operating principles:
  - A hole is established to the source side of the structure being tested eg. through the concrete floor.
  - The apparatus measures the pressure difference between the source and receptor side of the structure.

- Pros:
  - The driving force for VI is measured directly, and can be used for interpretation of the other measurements.
  - Time series can be obtained (handle on temporal variability).
  - Inexpensive.

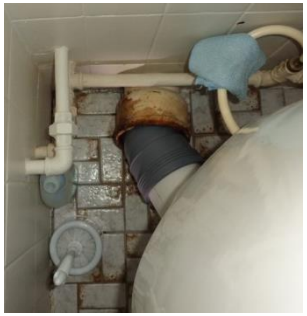
- Cons:
  - Point measurements – more needed.
  - You gain knowledge of exactly how temporally and spatially variable a phenomenon VI actually is.

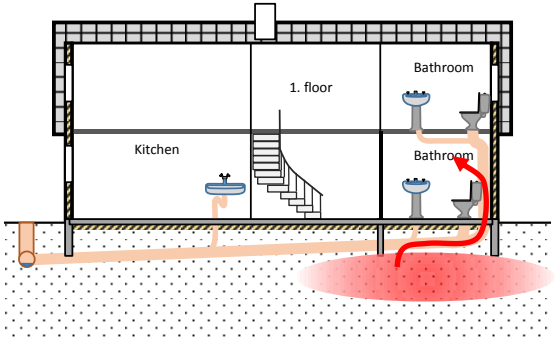


High use

Sewer measurements

- Basic operating principles:
  - A piece of PE-tubing is pushed through the water-lock.
  - Air from the sewer is pumped through a carbon absorber.
  - The absorber is analyzed at the lab.



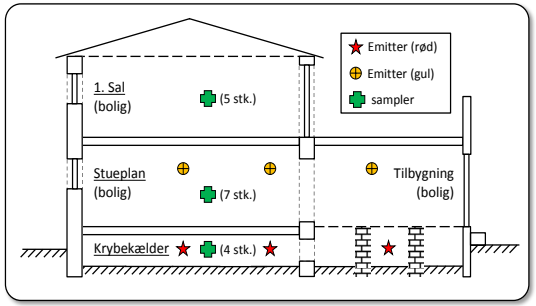


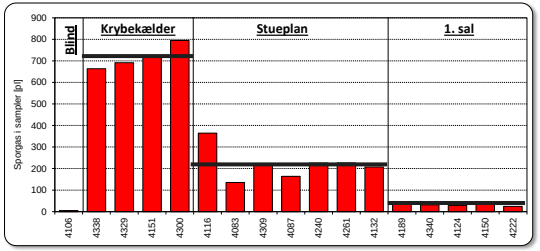
- Pros:
  - Quantitative results.
  - Compound specific.
  - Inexpensive.

- Cons:
  - Point measurements in time – more needed.
  - Waiting time for lab results.

High use

PFT tracer gas method (EPA 698, 2002)





- Basic operating principles:
  - Unique tracers compounds (2 different ones) are installed on the source side(s) of a structure. They are distributed by diffusion.
  - Concentration is measured on the source and receptor side (2 wks) and reduction factors can be estimated.
  - If pollutant concentrations are measured on the source side, estimates of VOC contribution can be obtained.

- Pros:
  - Bulk 2wk results are obtained (eg. for a room or building as a whole).
  - Quantitative results (reduction/attenuation factors).

- Cons:
  - Only works with "ventilated" air volumes on the source side.
  - Requires trained personnel/expertise.
  - Waiting time for lab results.

Still under development

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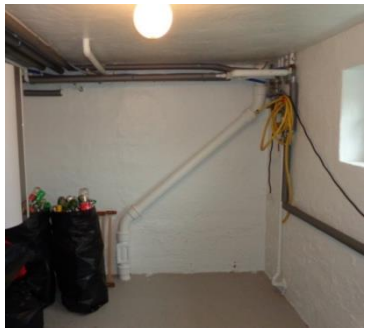
Typical vapor intrusion pathways



- Edges of poured concrete flooring.
- Holes and cracks in concrete floors.
- Around technical piping and wiring.
- Through cavity walls.
- Through basement walls.
- Through sewers.

- Pretty much where two construction details meet up and in places where we “punch holes” in the structure.
- All buildings are full of holes …

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Lessons learned

- To begin with, we hoped that small-exceedance-sites might be remediated by “plugging up the holes”. Unfortunately, we have learned that plugging up one hole will just lead to the next one being activated – maybe over time.
- Source removal is needed in most cases.
- But we now have tools that can give us a much improved CSM, both in general and for site specific purposes.
- A better CSM might in turn be used to make better risk assessments and remediation choices.
- Some of the methods can be used to document remediation effectiveness.
- Danish EPA reports can be downloaded at: http://mst.dk/service/publikationer/