The Capital Region of Denmark

Optimizing Site-Specific Ventilation-Based Mitigation Strategies using Mass Discharge Test in Vapor Intrusion Studies

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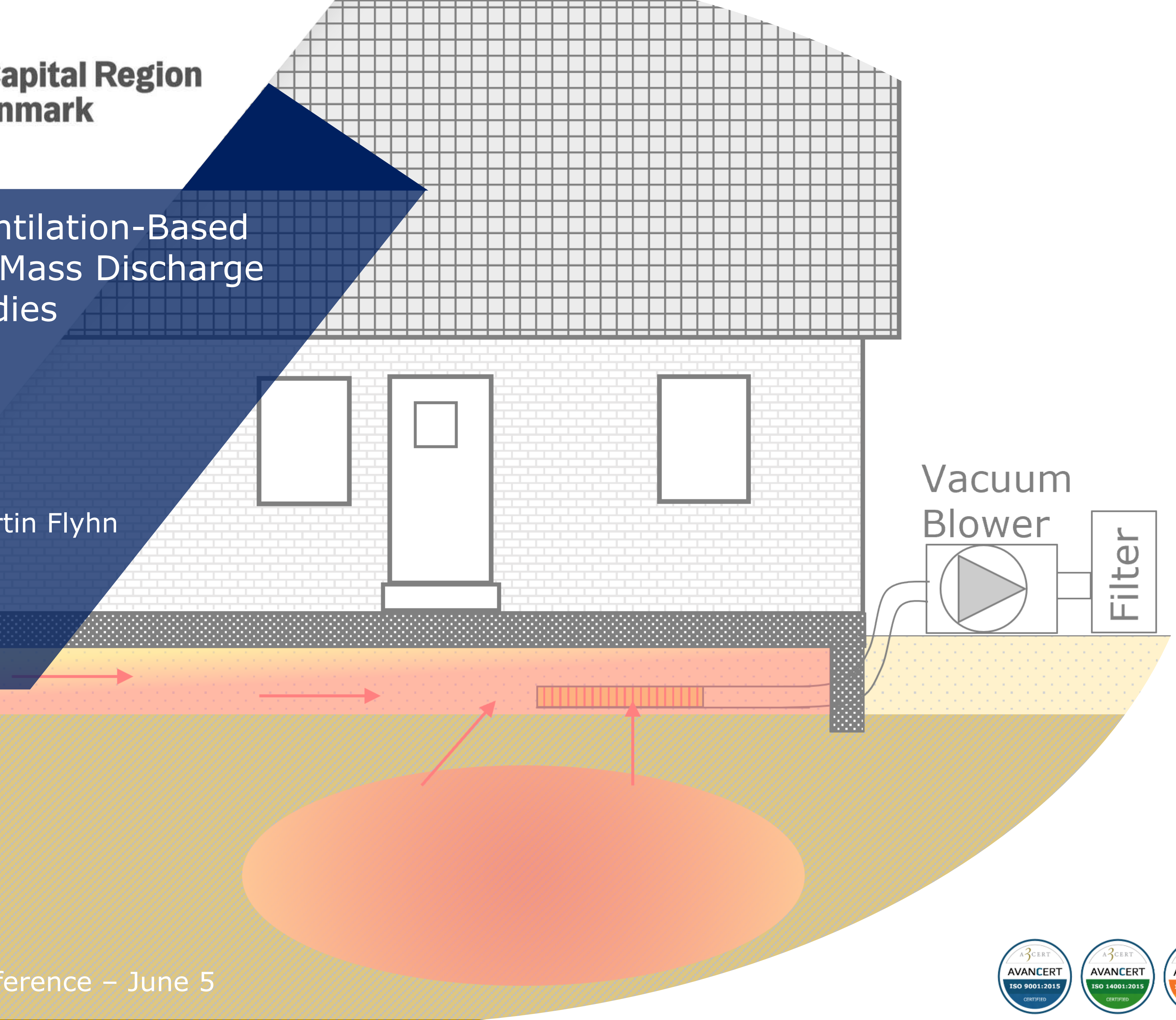

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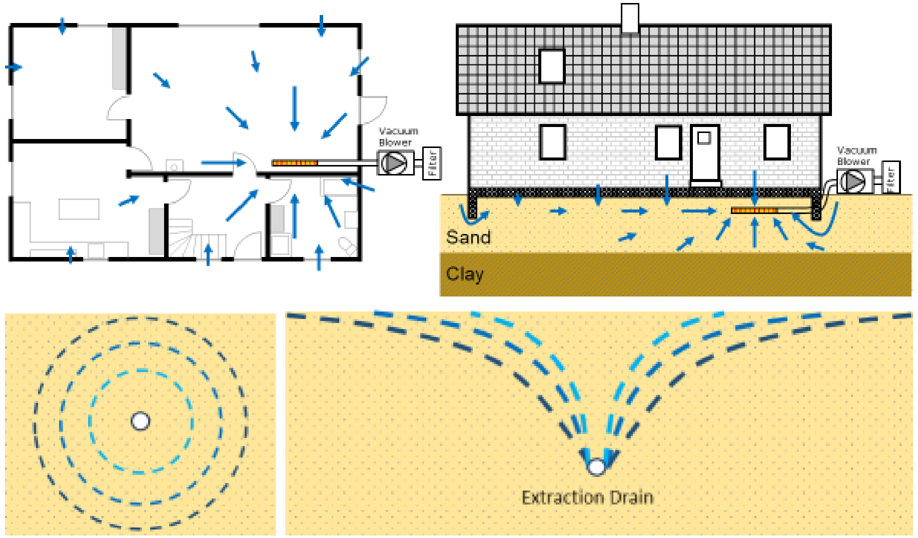
Definition - Mass Discharge Test (MDT)

Mass Discharge (µg/t) is Concentration (µg/m³) times Flow (m³/t), within the specific zone of influence.

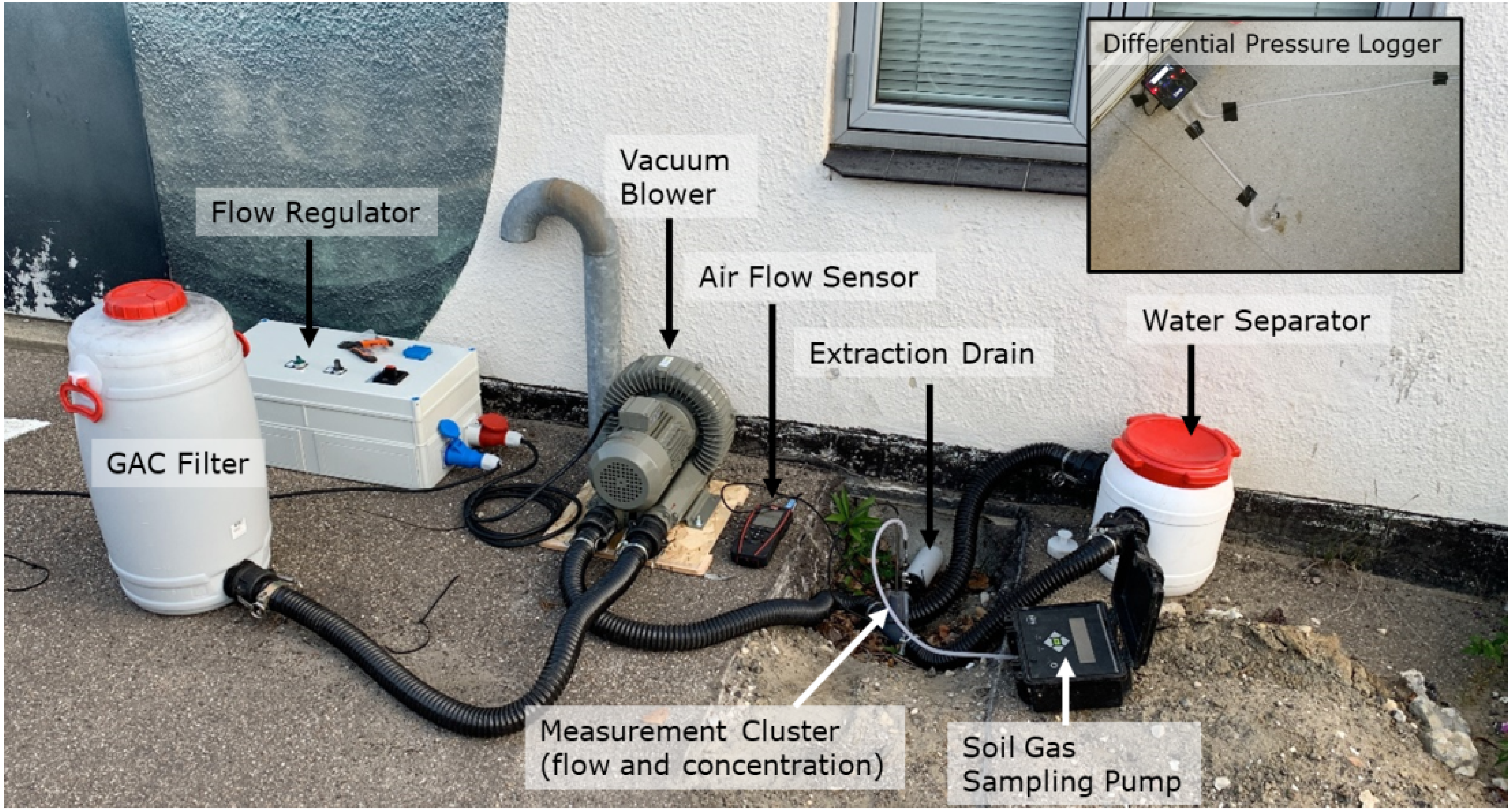
Mass Discharge (µg/t) = Concentration ($\mu g/m^3$) · Flow (m^3/t)

- Over a period of time soil gas is extracted through a drain while measuring flow and concentration.
  - Analogous to pumping test in a groundwater aquifer.
  - Spatial distribution is represented by a time series in one point, not by measurement in many scattered points.
- The MDT is a large-scale test (covering approx. the footprint of a building).
- A tool for system analysis.
- A supplement to traditional investigations:
  - Drillings (soil and water samples, geology)
  - Traditional soil gas samples
  - Samples from vapor intrusion pathways
  - Indoor air concentrations



How we do it

The MDT affects the system with forces greater than natural processes.



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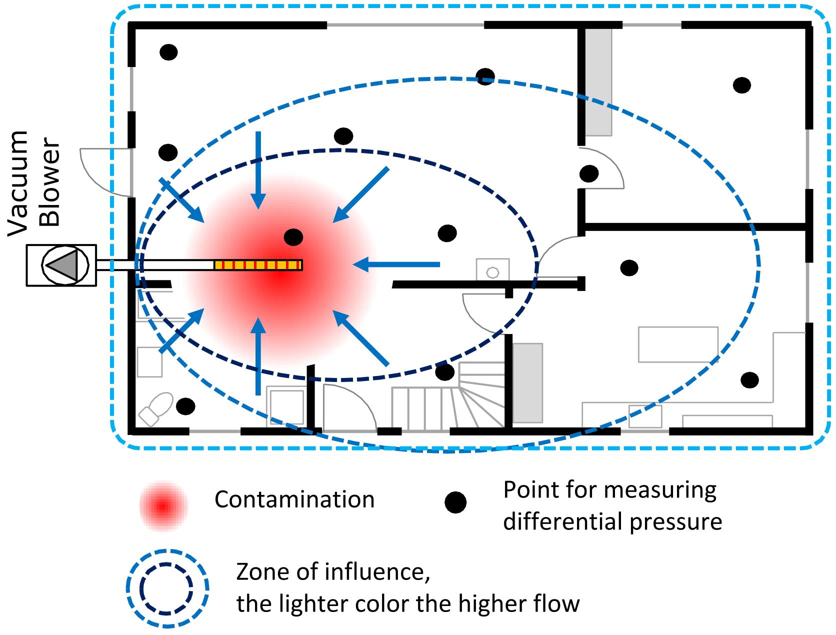
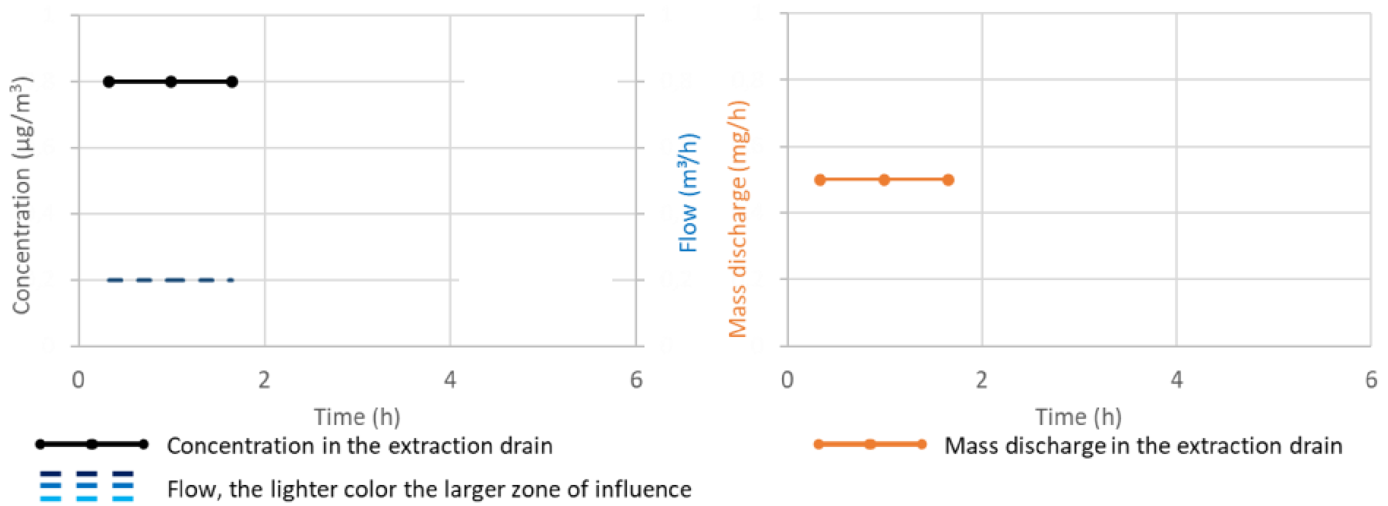
Why Mass Discharge instead of Concentration?

- The mass discharge expresses the relationship between concentration and flow -> regardless of dilution.
  - If the entire hotspot is included in the zone of influence, the mass discharge will be approx. constant, regardless of flow.
  - If flow is increased -> more ”clean” air will be drawn to the extraction drain -> the flow will be higher, and the concentration will drop -> but the mass discharge will be constant.
- It is not crucial to know the exact origin of the air in the extraction drain, which can be very difficult to ascertain in practice.

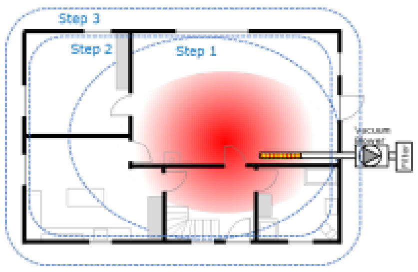




A very robust tool

Mass discharge tests (MDT) – Three test types

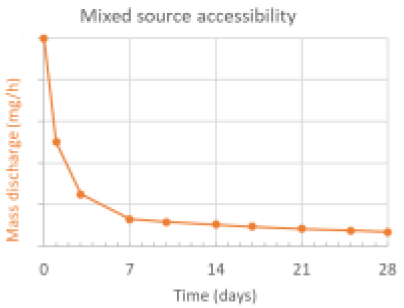
Not further covered by this presentation



Short-term MDT

- Indications of the spatial distribution and location of the hotspot in rela n to the location of the extraction drain.
- Indication of whether accumulated contaminant mass is initially remove
- Initial indication of whether the source is situated in a low or high permeability matrix.
- Initial indication of the source strength (risk potential).

Increasing flow, three to four steps (~1-2 days)

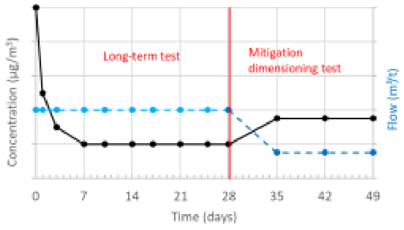


Long-term MDT

- Assessment source accessibility / rate of contaminant diffusion.
- Assessment of the source strength (potential risk).
- Assessment of the potential for a passive/active mitigation strategy.

Constant flow, high (~3-5 weeks)

Simultaneous indoor air measurements



Mitigation dimensioning MDT

- Test of the effectiveness of an active or passive mitigation solution (su b depressurization or passive/active balanced ventilation).
- Parameters for dimensioning a future mitigation solution.

Constant flow, often lower (~2-4 weeks)

The order is IMPORTANT

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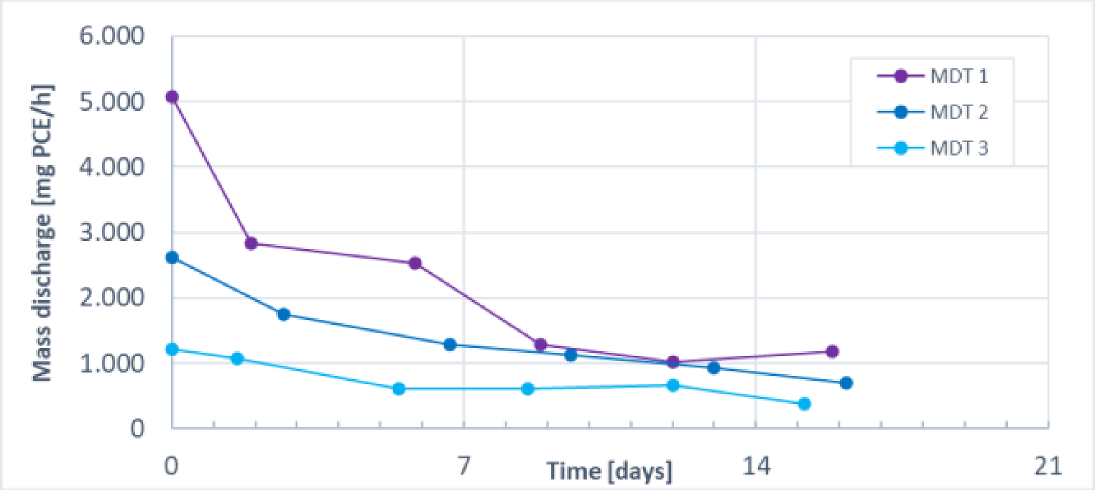
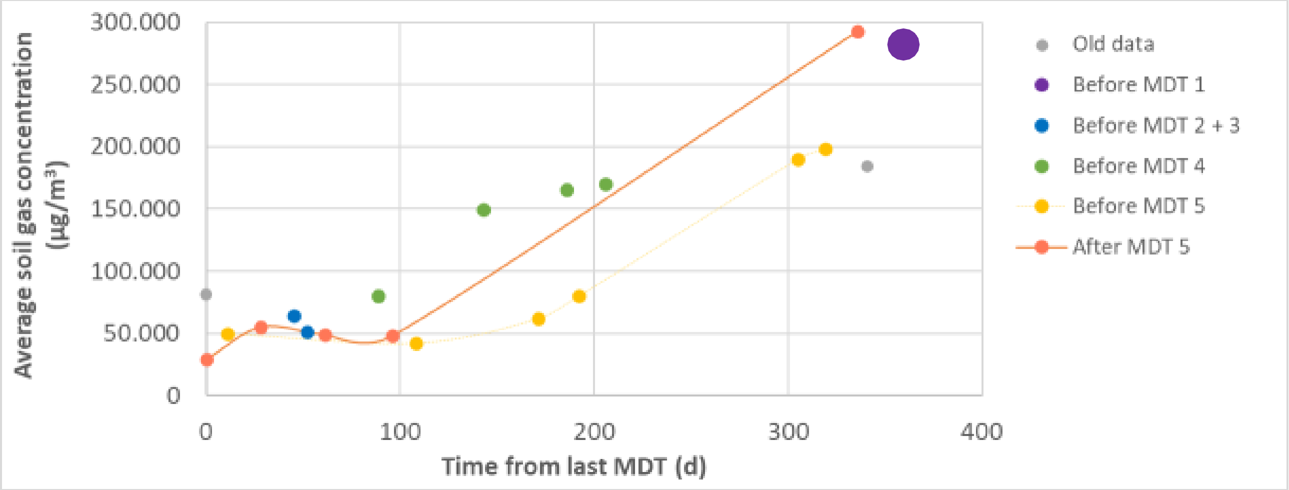
Oops: Back diffusion – A significant factor

- Subsequent MDTs at the same site -> The system was changed significantly.
- We started to sample the soil gas continuously to study the back diffusion.
  - It took approx. one year following a MDT to reach full back diffusion at one site.
  - At another location it took around one week.

You should know your site



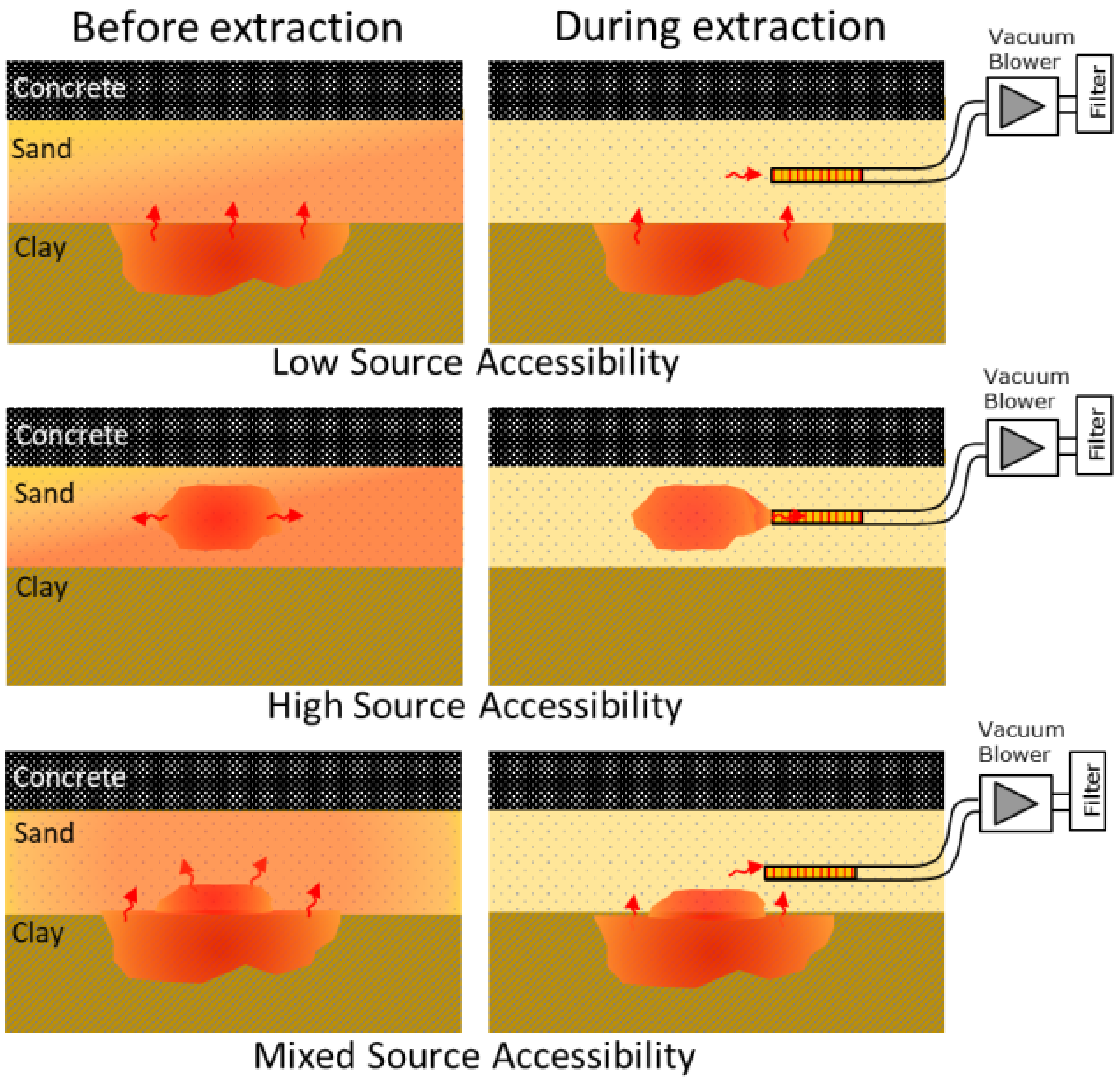


- Back diffusion is dependent on the geology in the source area.
  - It is logic, and the same theoretical basis applies to other methods related to soil gas.
  - Unexpected that the diffusion process could have such a significant impact on the system.
  - It is very relevant for the choice (and effectiveness) of mitigation strategy.

Rate of contaminant diffusion (source accessibility)

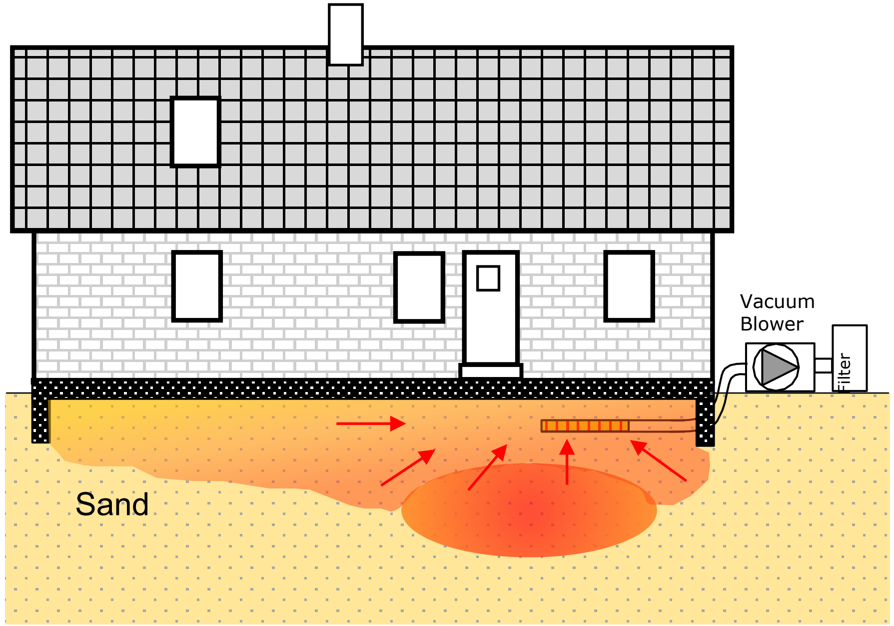
- If the source is situated in geologies of low permeability, e.g. a clay matrix:
  - Mass discharge depends primarily on diffusion out of the source matrix.

- If the source is situated in geologies of higher permeability, e.g. sand or backfill:
  - Mass discharge depends primarily on the extraction rate (flow).

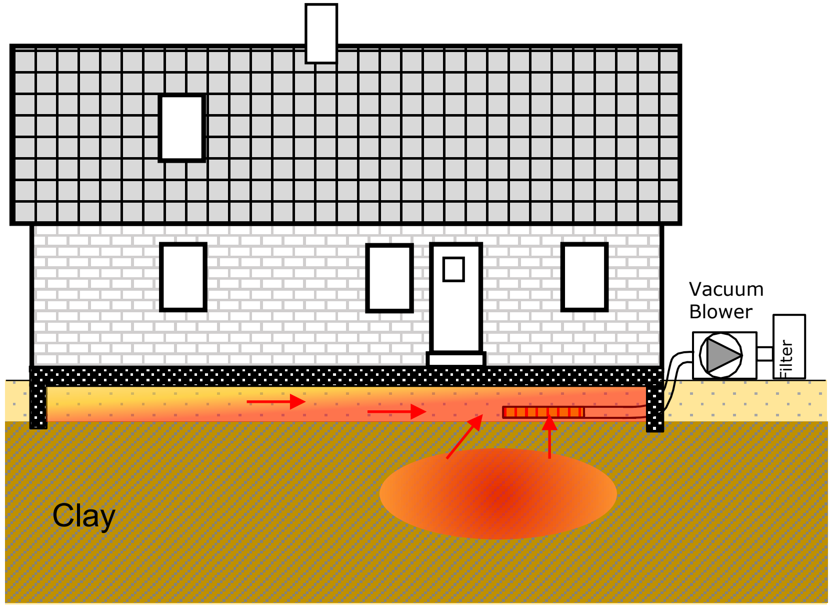


Rate of contaminant diffusion (source accessibility)

- The MDT will provide valuable information regarding the geological formation in the source area.
  - Relevant for the conceptual understanding of the contaminants and their interaction with the building/indoor air.
  - And for the choice of a possible mitigation strategy.



High source accessibility



Low source accessibility

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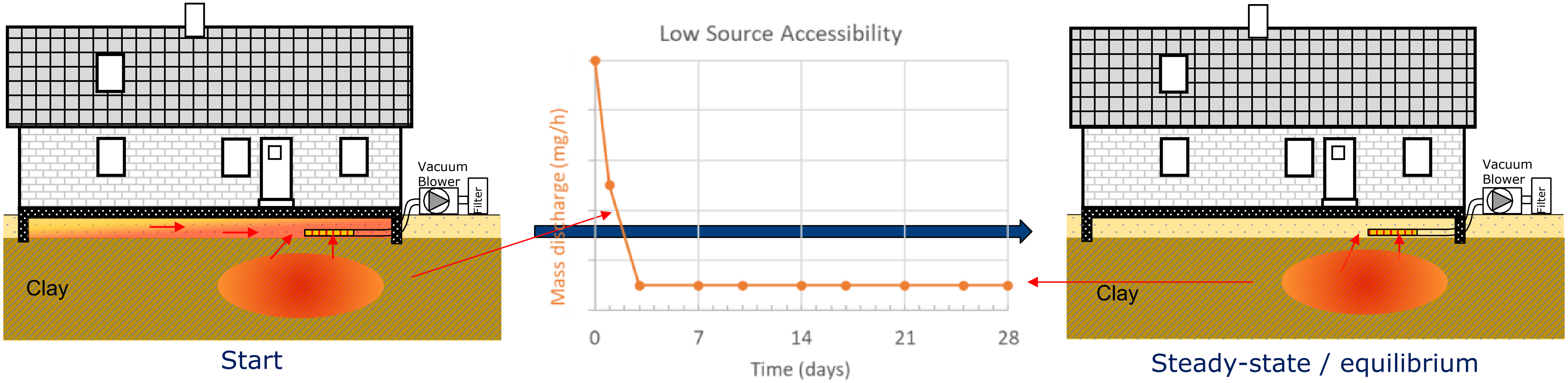
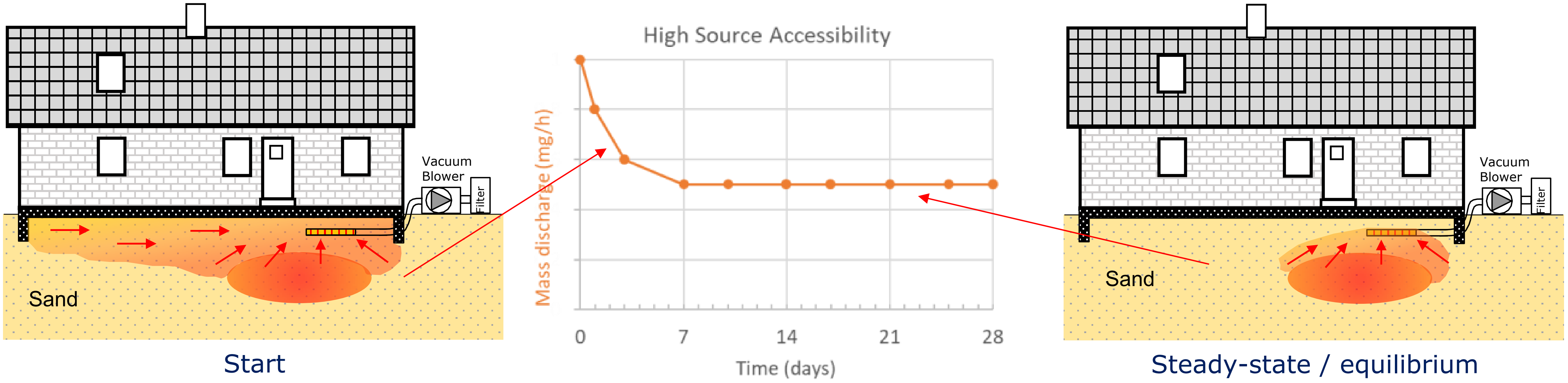
Interpretation Long-term MDT – Source accessibility



- A system with a low source accessibility is indicated by:
  - A fast removal of accumulated mass (days).
  - A mass discharge at steady state <25% of the level at the beginning of the test.

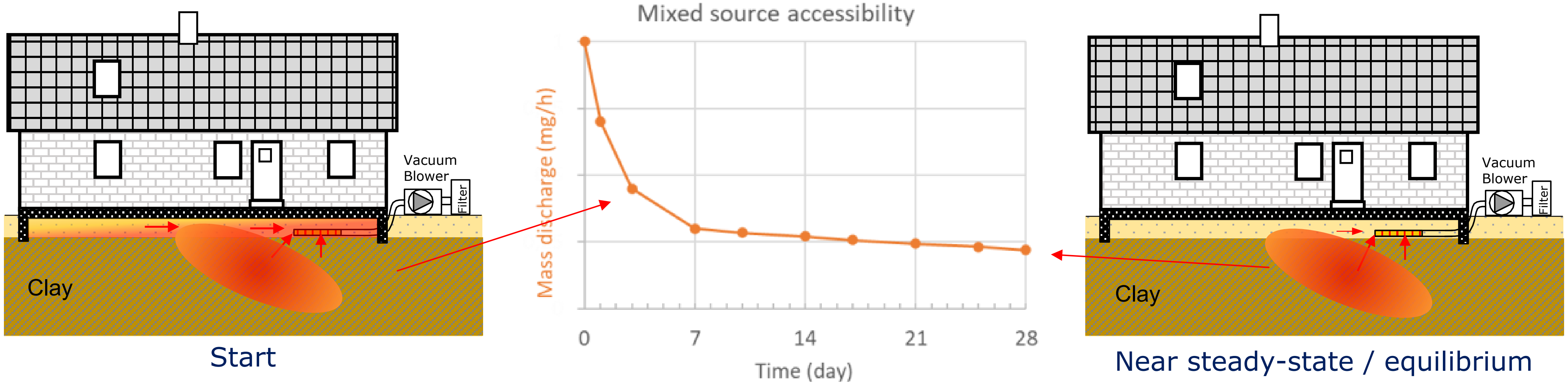
Interpretation Long-term MDT – Source accessibility



- A system with a high source accessibility is indicated by:
  - A slow removal of accumulated mass (weeks).
  - A mass discharge at steady state >25% of the level at the beginning of the test.

Interpretation Long-term MDT – Source accessibility

- Many systems are ”in between”, with a mixed source accessibility.
  - No actual steady-state mass discharge is achieved, instead the mass discharge will continue to decrease slowly.



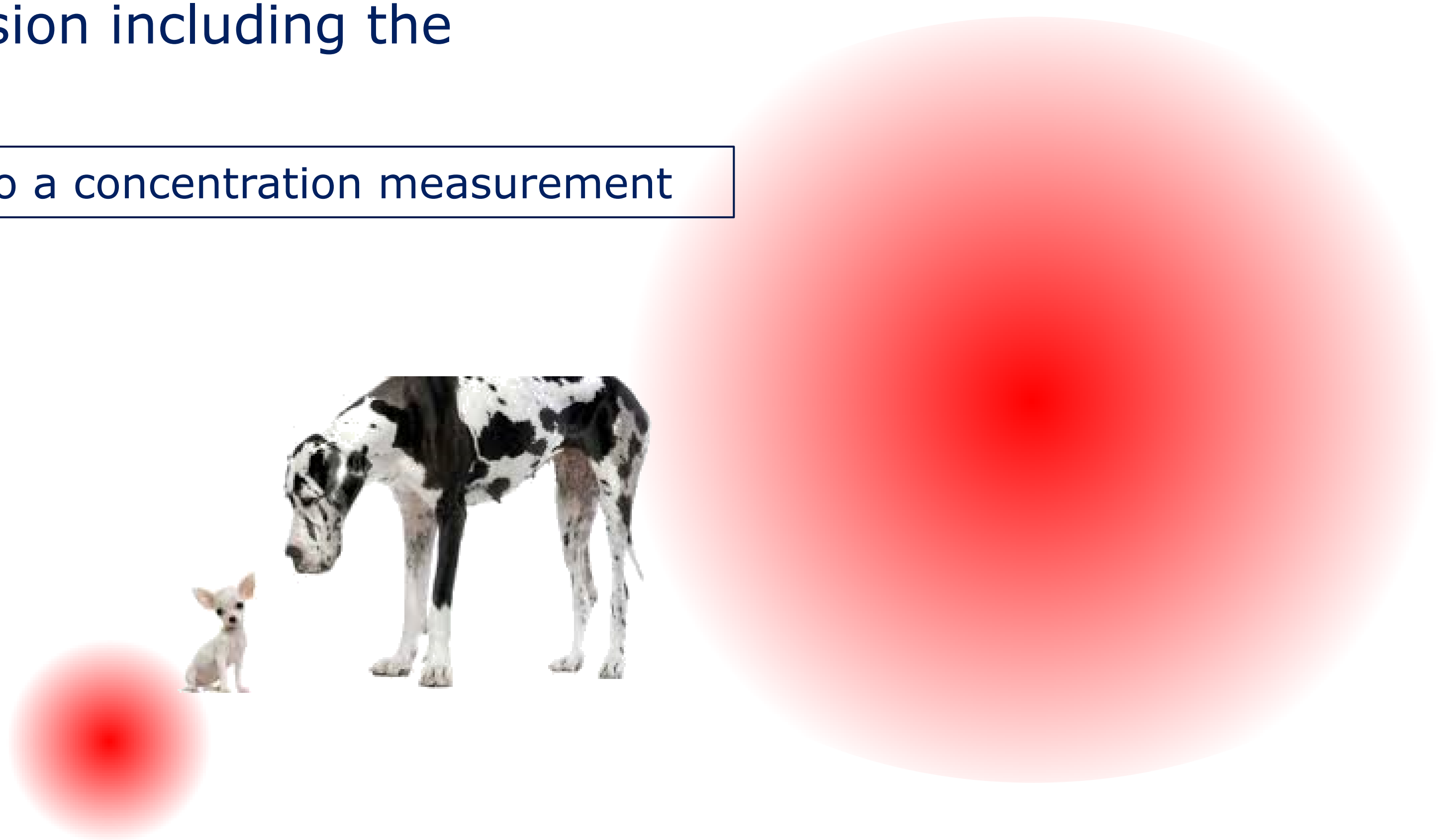
- The source accessibility is not absolute
  - A system will be more or less controlled by the contaminant diffusion.
  - The 25% is an experience-based indicator.

Interpretation Long-term MDT - Potential risk

- The strength of the contamination (potential risk) is assessed based on the absolute value of the mass discharge (mg/h) at steady-state/the end of the test.
  - A source with a steady-state mass discharge of 1,000 mg/h will have a greater potential risk than a pollution with a steady-state mass discharge of 2 mg/h.

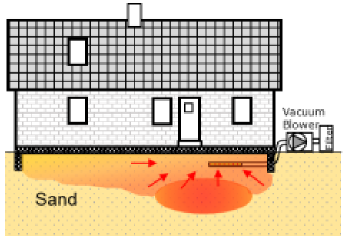
- The potential risk is an expression including the impact on the surroundings:
  - Source strength
  - Source size
  - Rate of contaminant diffusion
  - The building
  - Compound / threshold value

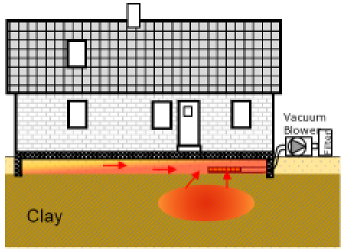
Contrary to a concentration measurement

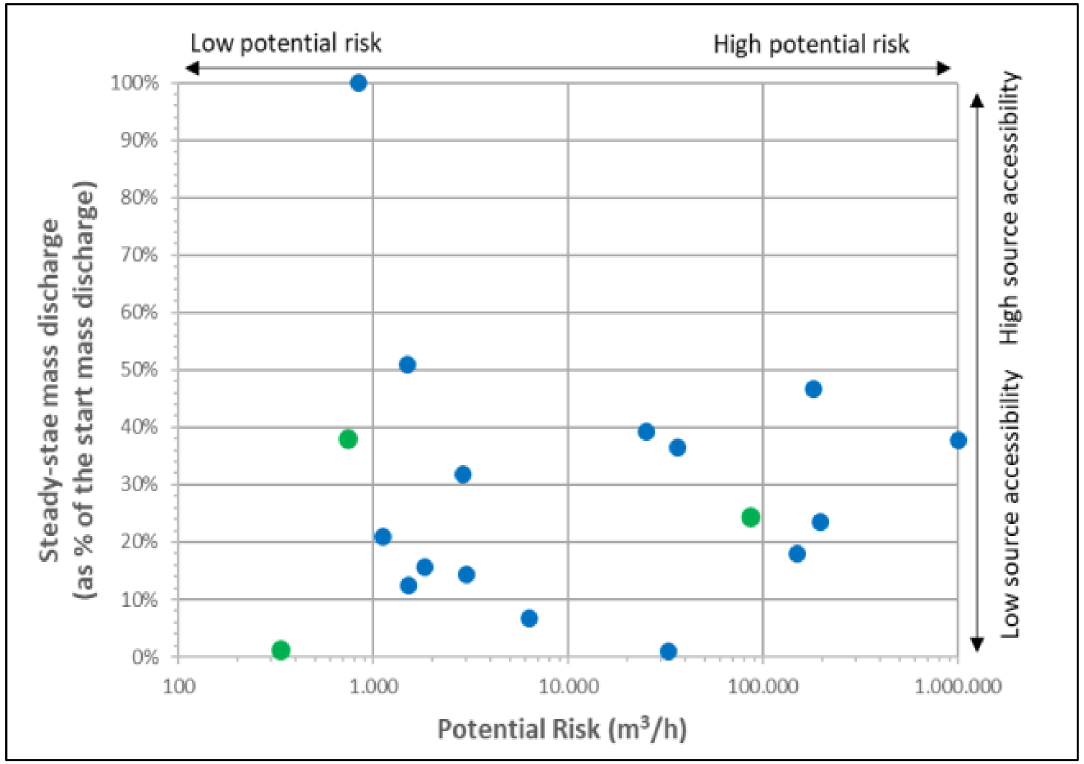


From the long-term MDT to the mitigation dimensioning MDT

We combine the two key parameters from the long-term MDT in one graph:







- Initial indications of the possible mitigation strategies.
  - If it is a heavy pollution (i.e. high potential risk) it will be difficult to solve with a passive mitigation strategi.
  - If the source has a high source accessibility (is placed in sand) it will be difficult to solve with a passive mitigation strategi.

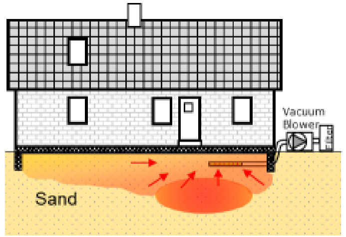
(Blue from long-term MDTs;
Green from mitigation dimensioning MDTs)

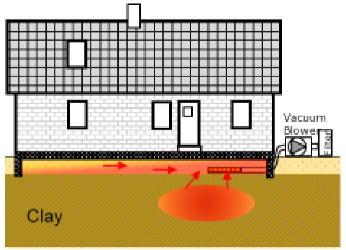
The potential risk is standardized in relation to the threshold value

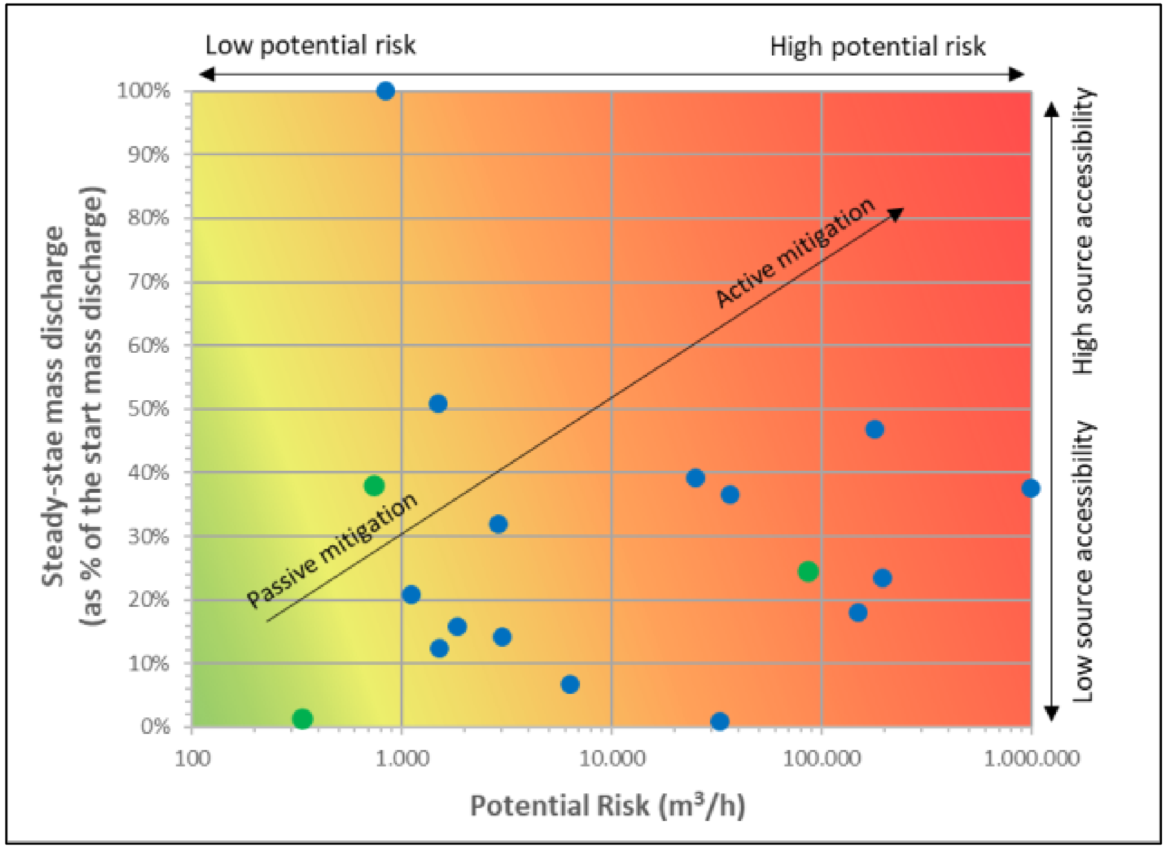
$$Potential\ risk(\frac{m^3}{h}) = \frac{Mass\ discharge\ (\frac{mg}{t}) \cdot 1000\ \mu g/mg}{Threshold\ value\ (\frac{\mu g}{m^3})}$$

Mitigation dimensioning MDT – Which design?

We can use our knowledge from the long-term test (the diagram) to guide us:







An auxiliary tool (revised continuously)

The potential risk is standardized in relation to the threshold value

$$Potential\ risk\left(\frac{m^3}{h}\right) = \frac{Mass\ discharge\ \left(\frac{mg}{t}\right) \cdot 1000\ \mu g/mg}{Threshold\ value\ \left(\frac{\mu g}{m^3}\right)}$$

Possible mitigation strategy (to test)

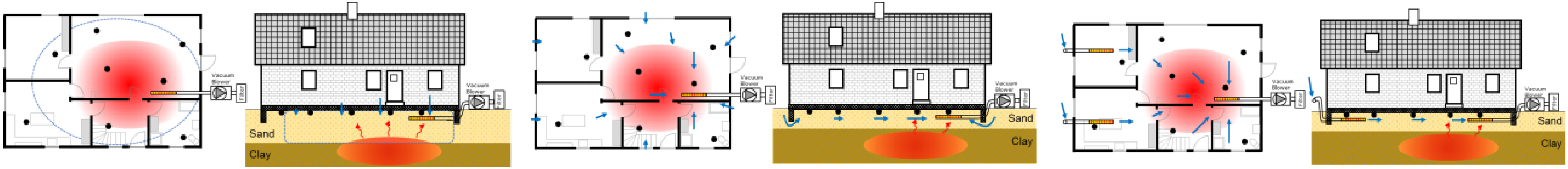
Green:	Passive air exchange
Yellow:	Active air exchange or sub-slab depressurization
Red:	Sub-slab depressurization
Dark Red:	Sub-slab depressurization and other measures

The full CSM should be included in the assessment:

- Geology and water table
- Soil gas concentrations
- Indoor air concentrations
- Building constructions and possible direct pathways
- Etc.

Mitigation dimensioning MDT

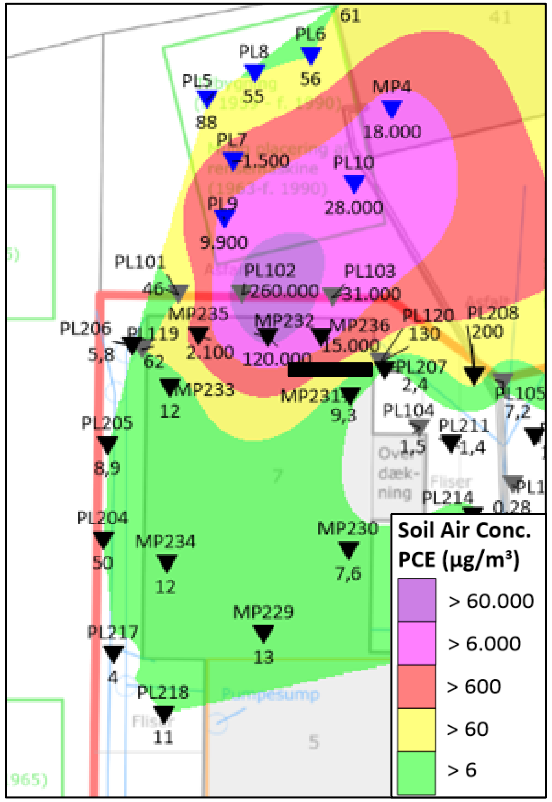
- You “guess” for an effective and robust solution.
  - The intention is to simulate a permanent sub-slab depressurization mitigation, or a permanent strategy based on air exchange (active or passive).
- The dimensioning MDT should be carried out with a configuration as close to the intended mitigation solution as possible (a pilot test).
  - Same location of the extraction drain, intake and exhaust/chimney (passive system).
  - Same type of vacuum blower and same flow.

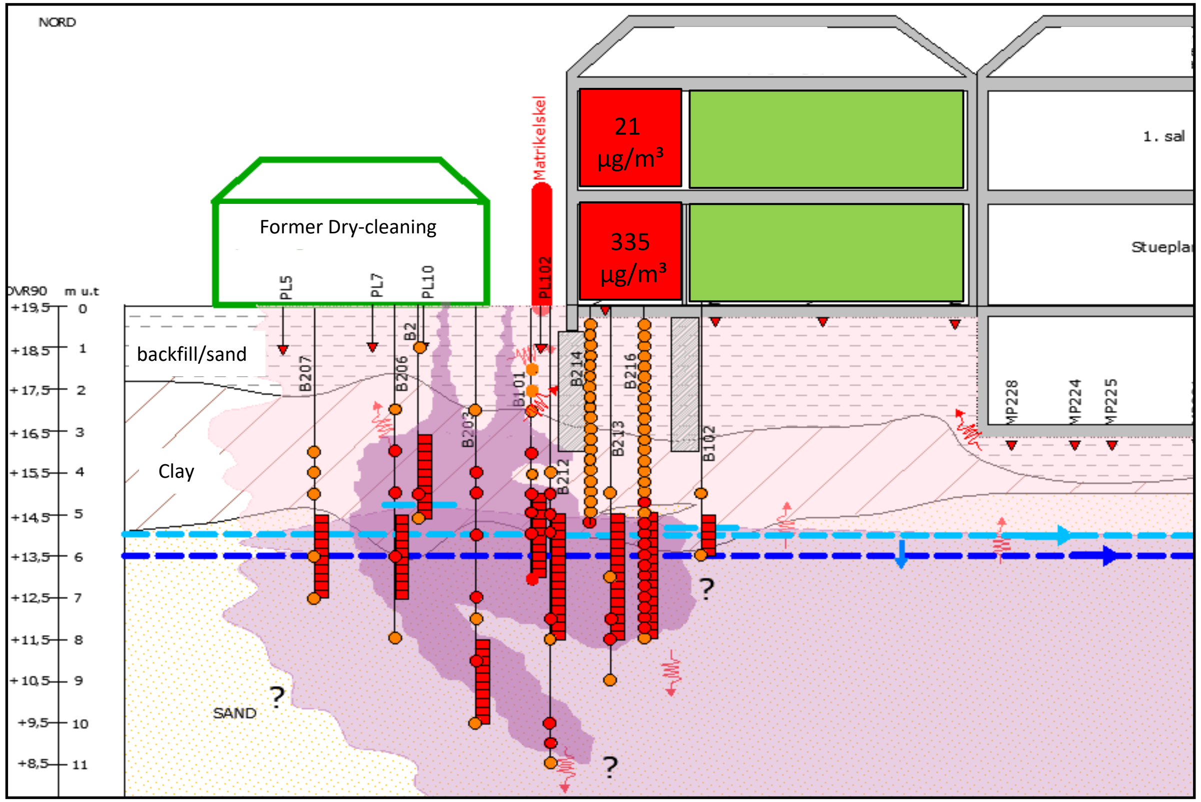


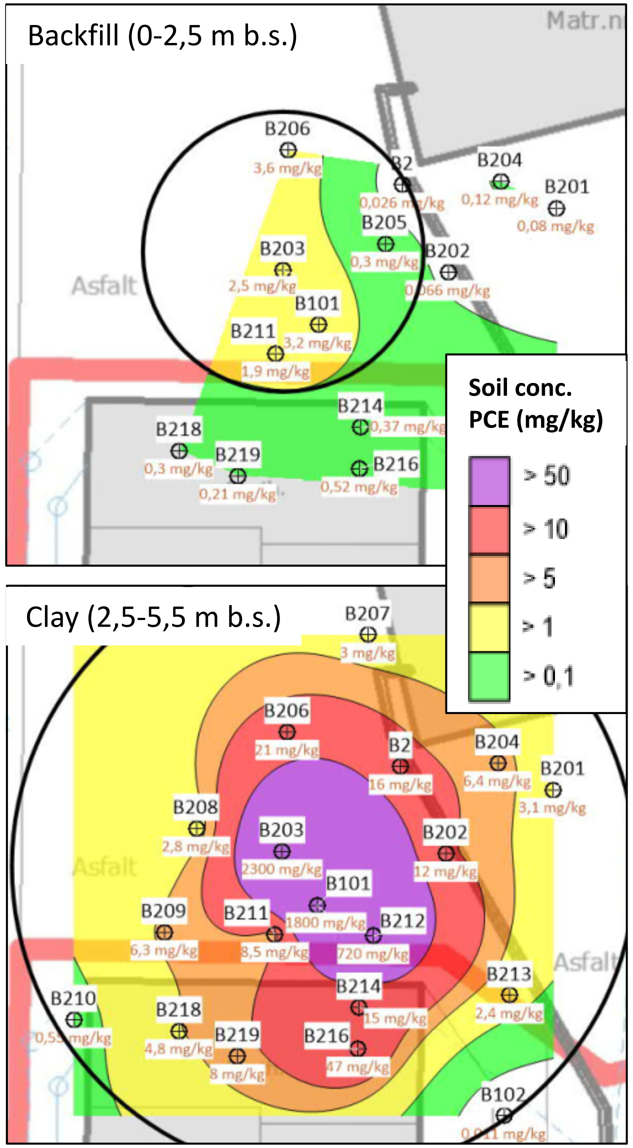
- The potential of the mitigation strategy is evaluated based on **the indoor air concentration** at the end of the test.
  - Check system parameters: Flow, concentration and differential pressure.

Case – Former dry-cleaning facility (PCE)

- Hotspot north of the building.
- Most of the mass is proven to be in the clay (with a low accessibility).
- Indoor air conc. up to 335 µg/m³ (threshold = 6 µg/m³).







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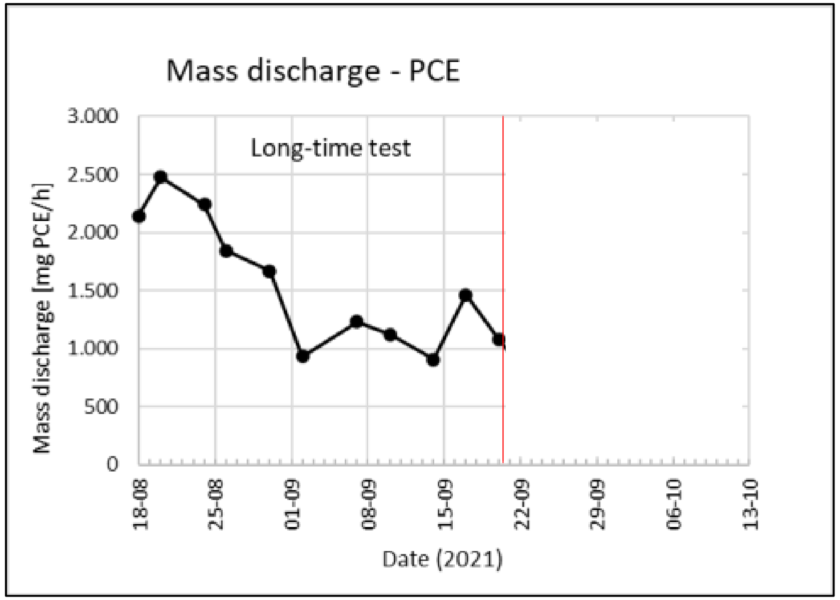
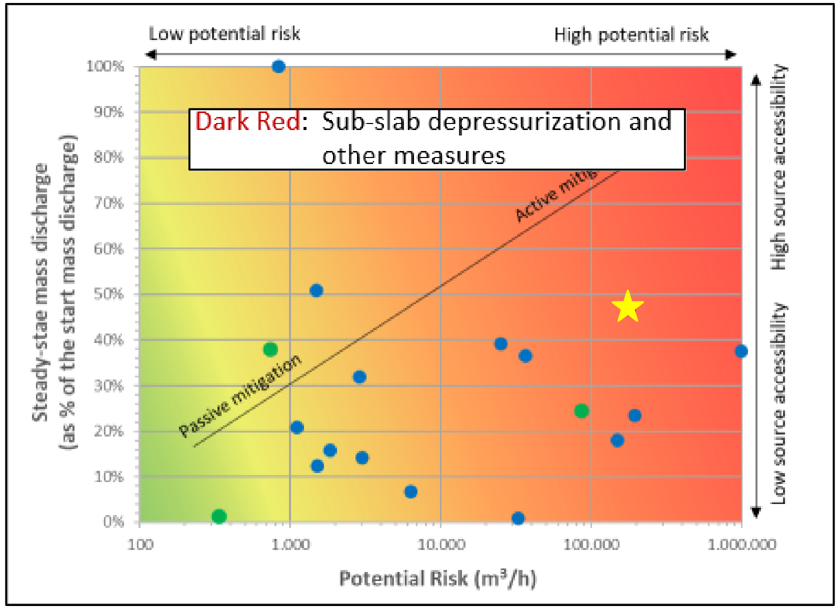
Case – Former dry-cleaning facility - MDT





The long-term MDT indicate:

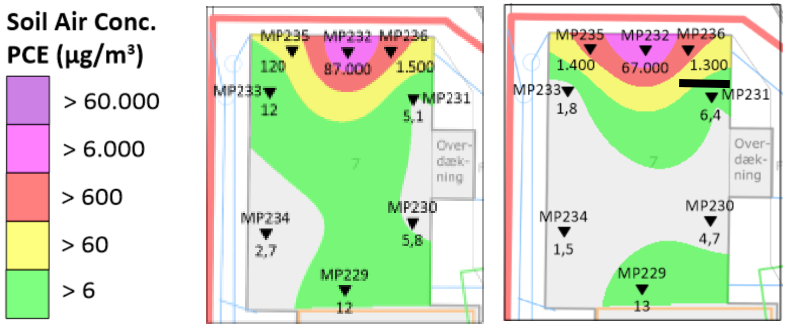
- A high potential risk (steady state mass discharge = 1,000 mg/h)
- A high source accessibility (steady state is reached after weeks, only drops to 47% of the start mass discharge)

The mitigation dimensioning MDT showed:

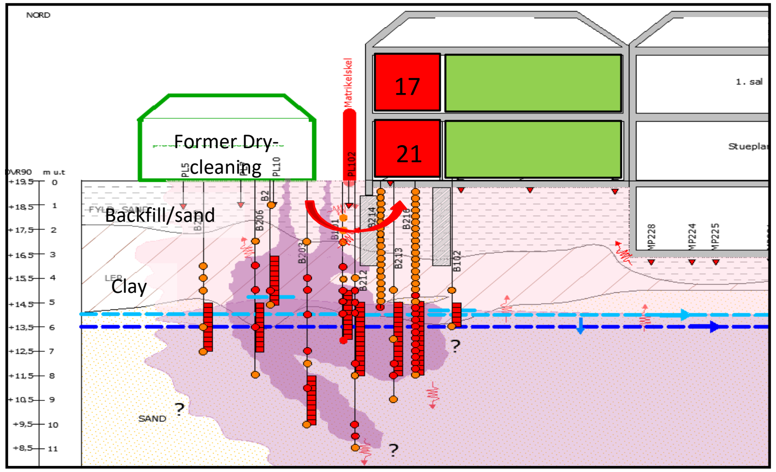
- Indoor air concentrations still too high (21 and 17 µg/m³, threshold = 6 µg/m³)
- Soil gas concentrations more or less unchanged

Assessments:

- There must be more source in the unsaturated zone than expected.
- Contamination is drawn from the source area north of the building to below the building.



Before MDT After MDT



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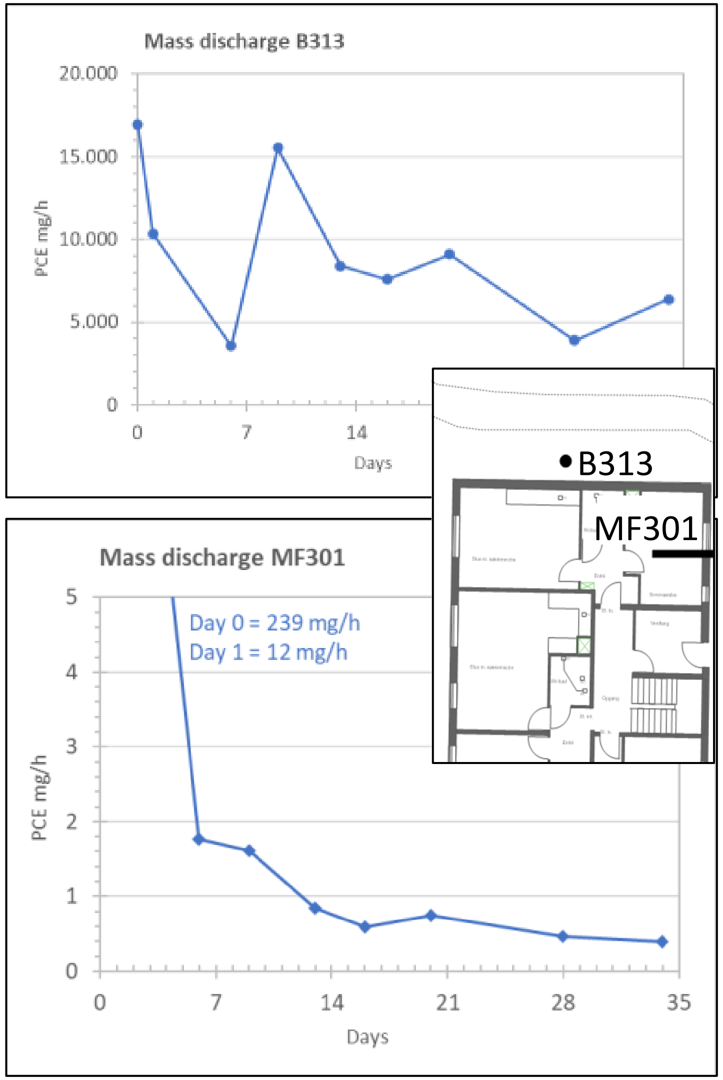
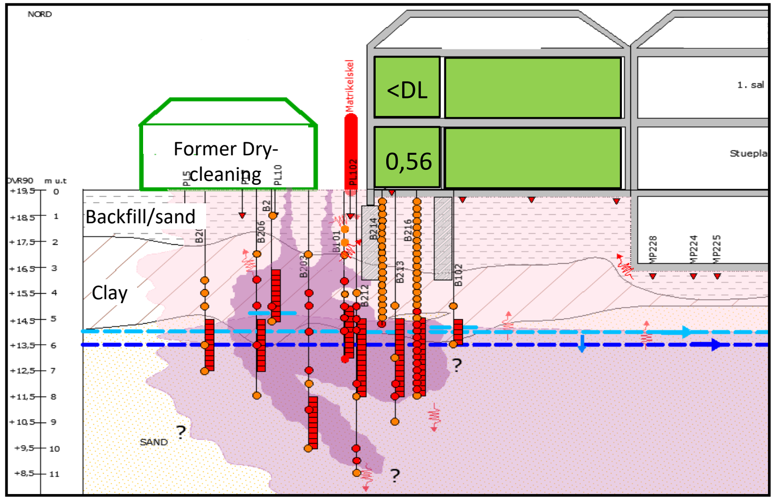
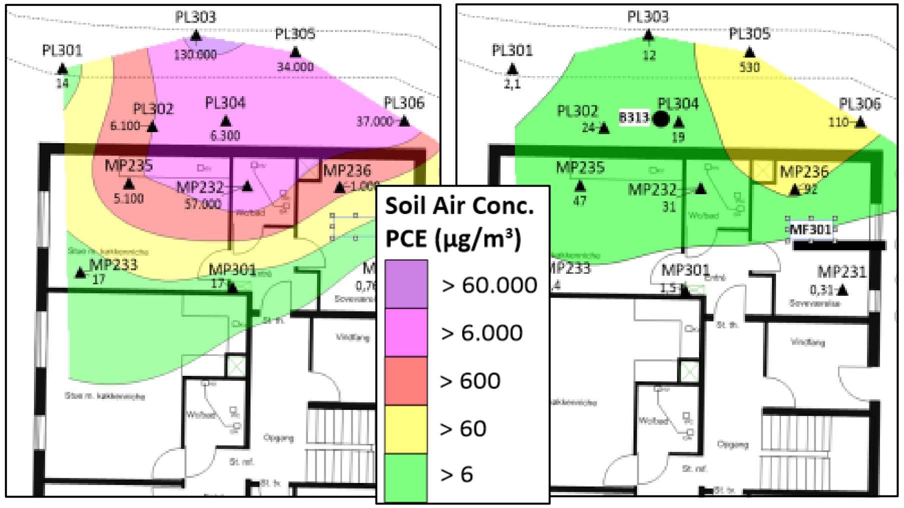
Case – Former dry-cleaning facility – double MDT



- The mass discharge in B313 is around 5,000 mg/h.
  - Indicating a significant contaminant mass in the unsaturated zone.
- The mass discharge in MF301 is <1 mg/h.
  - No significant mass in the unsaturated zone under the building.
- Ventilating in two extraction points at the same time is a robust mitigation strategy for the site.
  - The volatile contaminants from the source area is cut off from the unsaturated zone under the building.





Before MDT

After MDT

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Take Home Messages

- Rebound of the soil vapor contamination (back diffusion) may take up to one year and is highly dependent on the geological matrix in the source zone.
- The MDT has the strength to determine source accessibility.
- The source accessibility is crucial for the design of a future mitigation system.
- Combining potential risk with source accessibility (both based on MDT) is a very useful tool for evaluating the potential and robustness of different mitigation strategies at future contaminated sites.

- An easy and useful tool for **building a robust Conceptual Site Model (CSM)**.
- A tool to evaluate the **performance of future mitigation** based on passive or active ventilation.

Questions?