CONSIDERATIONS FOR EVALUATING ALTERNATIVE PATHWAYS AS PART OF VAPOR INTRUSION ASSESSMENTS

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Session: 7. Vapor Intrusion: Cal/EPA Focus on Protecting Current and Future Building Occupants - March 20, 2018

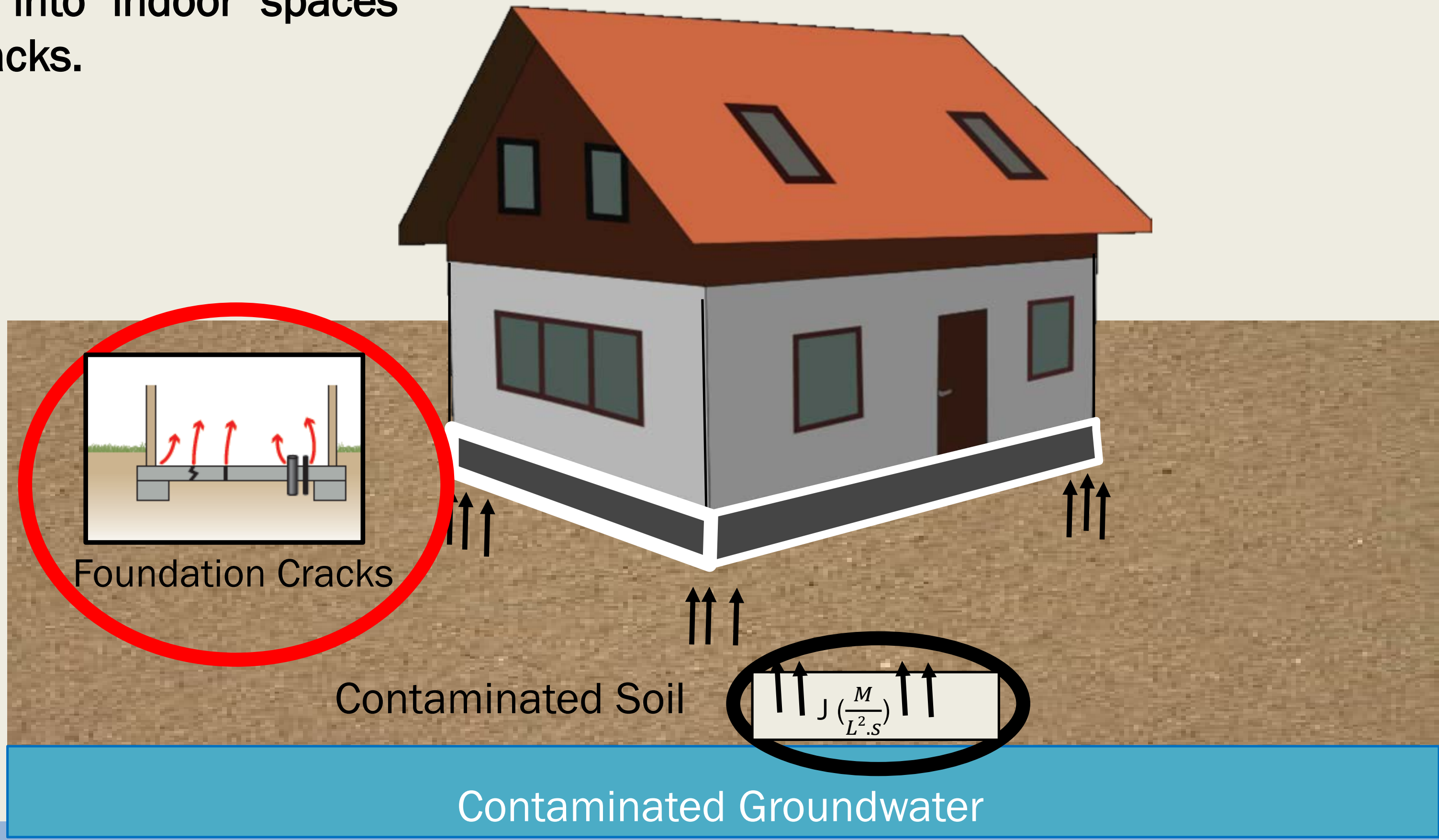
University of Kentucky

Overview of Presentation

- Overview of Alternative Pathways
  - *Sewers as One Alternative Pathway*
- Case Study
  - *Field Study in California Sanitary Sewer System*
- International Perspective: Denmark
- Lessons from Collaborating with Sewer District
- Conclusions

Classic Vapor Intrusion Conceptual Model

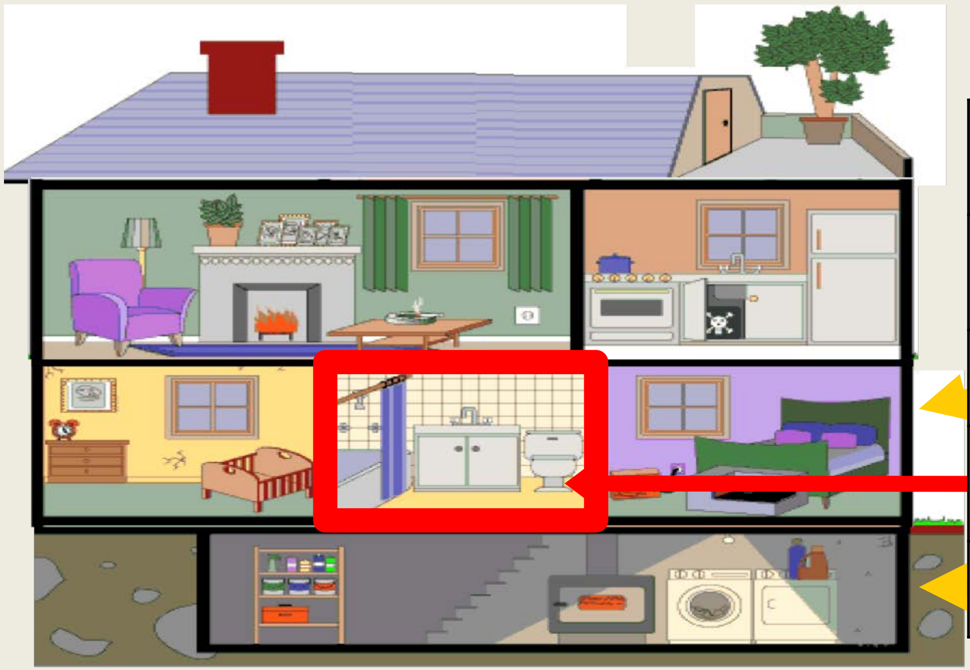
Classically, vapor intrusion was historically conceptualized as VOC entry into indoor spaces through cracks.



Alternative Pathways for Vapor Entry

- Land drains, sewers and other conduits can also provide entry routes for vapors.
- Alternative pathways were known to be a concern for vapor entry; however were not formally included as part of most vapor intrusion assessments until recently.
- Recent evidence confirming these pathways (especially sewers) has raised awareness about the role they play in vapor intrusion exposure risks .
  - *In the Central Denmark Region, it is estimated that sewer systems play a major role in vapor intrusion at more than 20% of the contaminated dry cleaner sites (Nielsen and Hvidberg, 2017).*
  - *More research is needed to determine the prevalence of alternative pathways at vapor intrusion sites in the US.*

Unexpected results in a Boston community ...plus several other examples



Measured Indoor Air Concentrations for Tetrachloroethylene (PCE)		
	Bathroom door open	Bathroom door closed off
First floor	37 µg/m^3	0.64 µg/m^3
Toilet connection	Not sampled	190 µg/m^3
Basement	3.3 µg/m^3	0.36 µg/m^3

Pennell *et al*. (2013).

Higher indoor air concentrations on upper levels as compared to lower levels is an indication for the potential of alternative pathways (Nielsen and Hvidberg (2017).

Sewers as an Important Alternative Pathway

USEPA issued guidance in 2015 that listed “sewers” as a concern to impact indoor air—many confirmed reports.

Several state agencies are beginning to require sewer gas investigations to determine if hazardous waste contamination is entering sewer systems.

Ongoing studies are confirming sewer gas as a contributing factor to vapor intrusion

Several confirmed reports of sewer gas intrusion of hazardous chemicals from contaminated groundwater, but no established screening protocols.

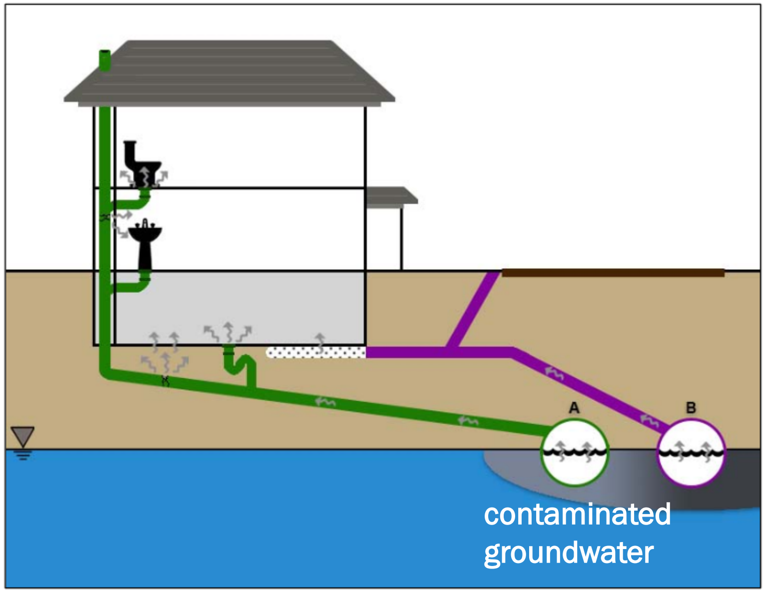


Image source: McHugh et al. (2017)

Some Key References Confirming Alternative Pathways

- Riis, C.E., Christensen, A.G., Hansen,M.H., Husum, H., 2010. Vapor intrusion through sewer systems: migration pathways of chlorinated solvents from groundwater to indoor air. Presented at the Seventh Battelle International Conference on Remediation of Chlorinated and Recalcitrant Compounds, Monterey, CA.
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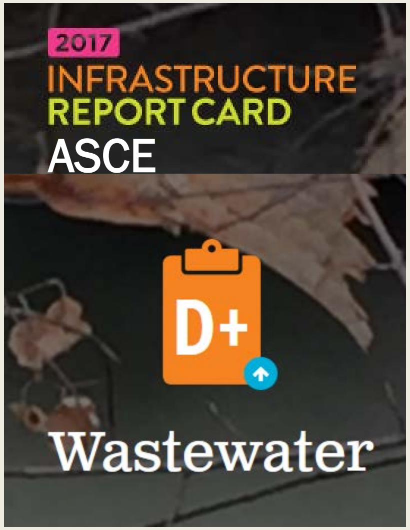
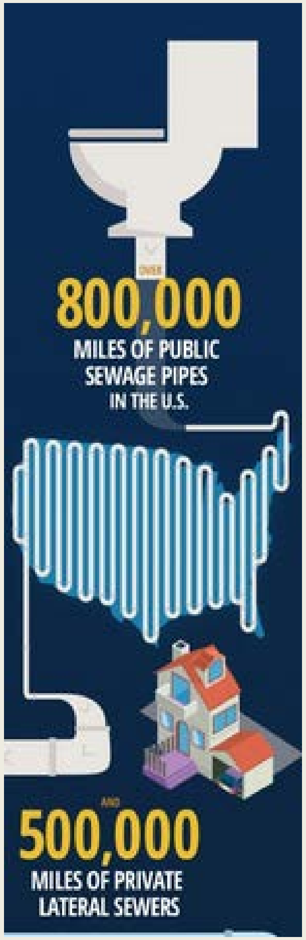
- Guo, Y., Holton, C., Luo, H., Dahlen, P., Gorder, K., Dettenmaier, E., Johnson, P., 2015. Identification of alternative vapor intrusion pathways using controlled pressure testing, soil gas monitoring, and screening model calculations. Environ. Sci. Technol. 49 (22):13472–13482.
- McHugh, T., Beckley, A., Sullivan, T., Lutes, C., Truesdale, R., Uppencamp, R., Cosky, B., Zimmerman, J., Schumacher, B., 2017. Evidence of a sewer vapor transport pathway at the EPA vapor intrusion research duplex. Sci. Total Environ. 598:772–779.
- Roghani, M., Jacobs, O.P., Miller, A., Willett, E.J., Jacobs, J.A., Viteri, C.R., Shirazi, E., Pennell, K.G. 2018. Occurrence of chlorinated volatile organic compounds (VOCs) in a sanitary sewer system: Implications for assessing vapor intrusion alternative pathways. *Science of the Total Environment,* 616-617: 1149-1162.

Aging Infrastructure: a widespread problem

https://www.infrastructurereportcard.org

Groundwater and vapors can infiltrate sewers and then be transported into indoor air spaces.

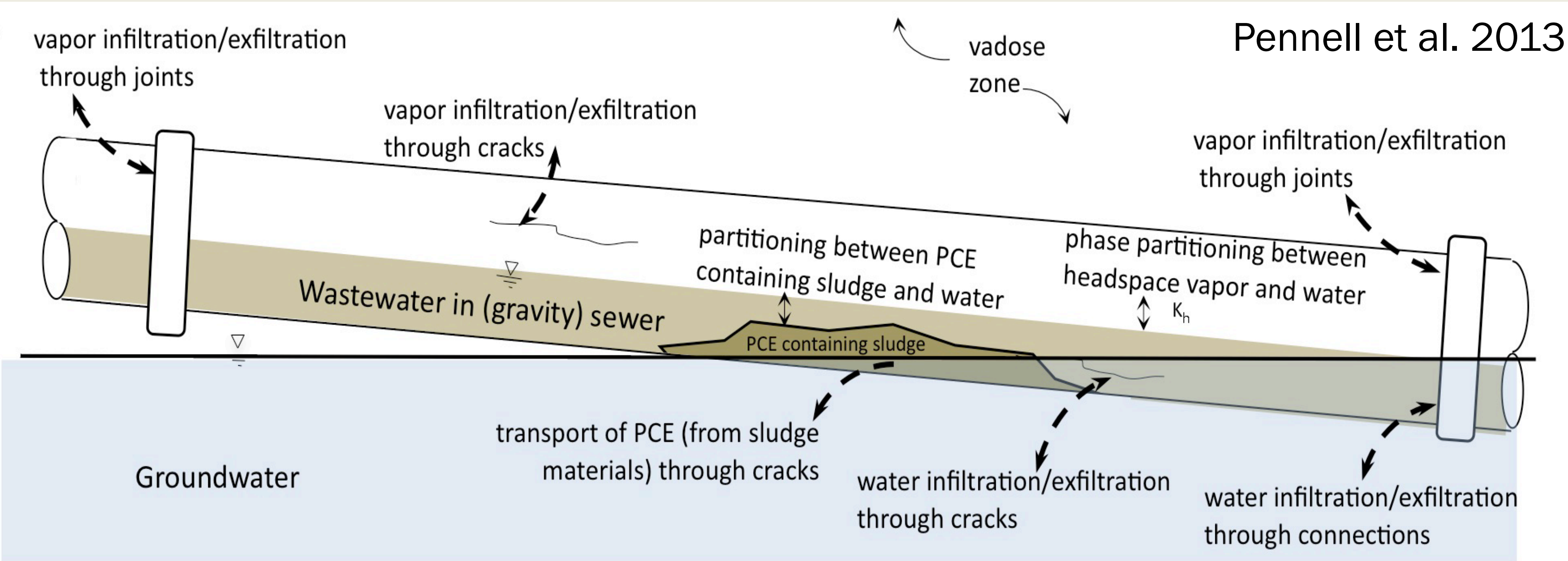




California's

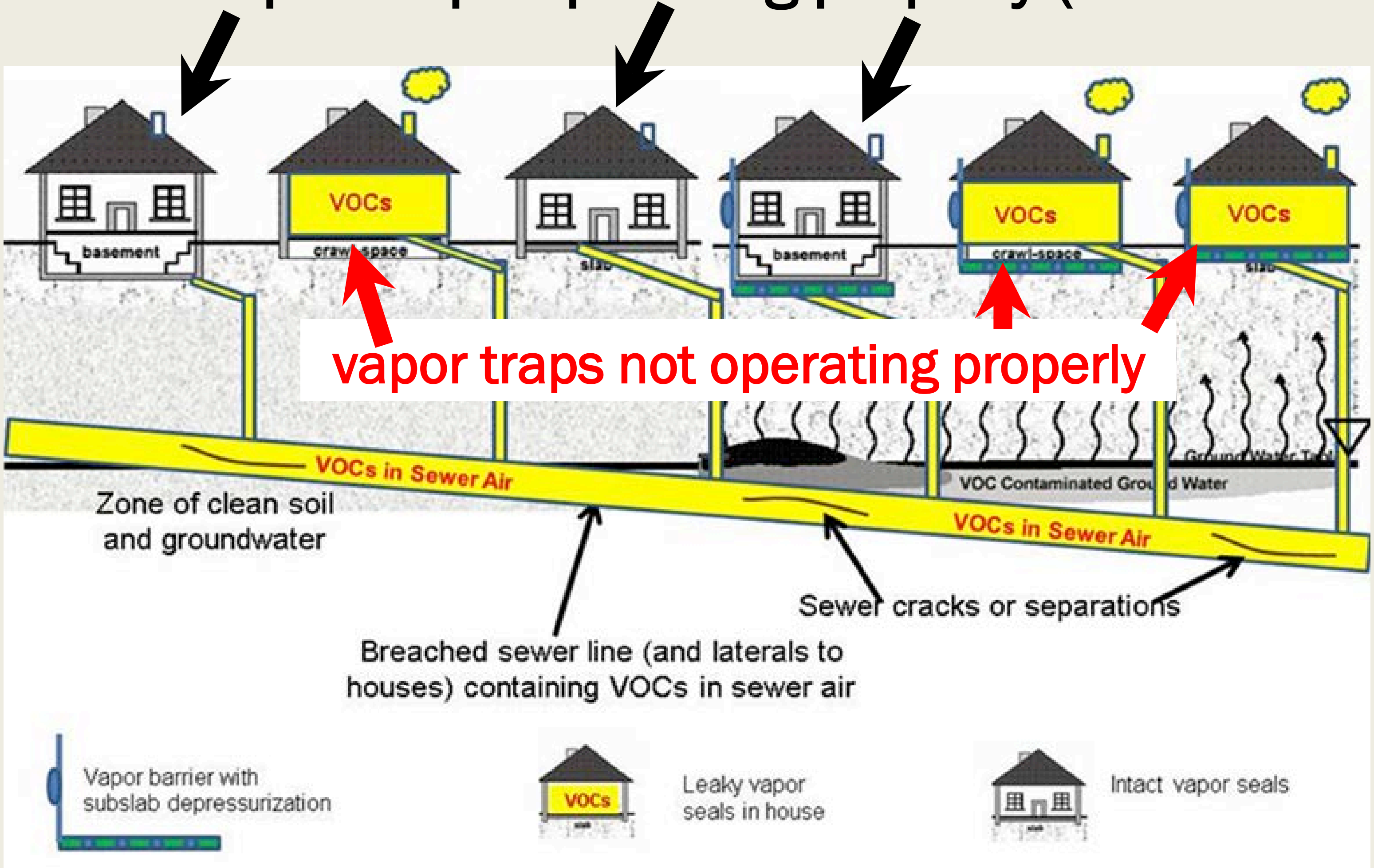
wastewater infrastructure needs $26.2 billion in over the next 20 years

VOCs in Sewer Gas



- Contaminated groundwater infiltration—especially important through aging sewers.
- Conduits that intersect contaminated groundwater are likely most important for vapors to enter indoor air spaces. In addition, conduits that contain sources of VOCs are also important.
- Present in sewage due to permitted (and unpermitted) discharges.
- Concentrated waste material in sewer.

vapor traps operating properly (*theoretically*)



Jacobs et al (2015)

However, plumbing fittings and fixtures may leak—even if traps are working properly.

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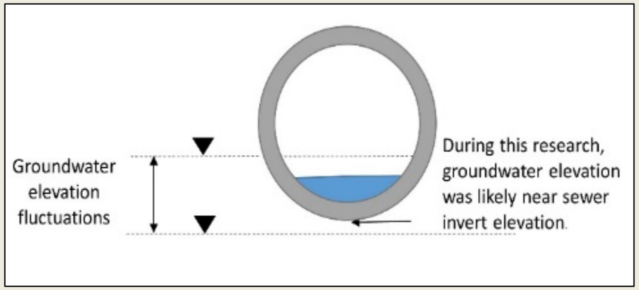
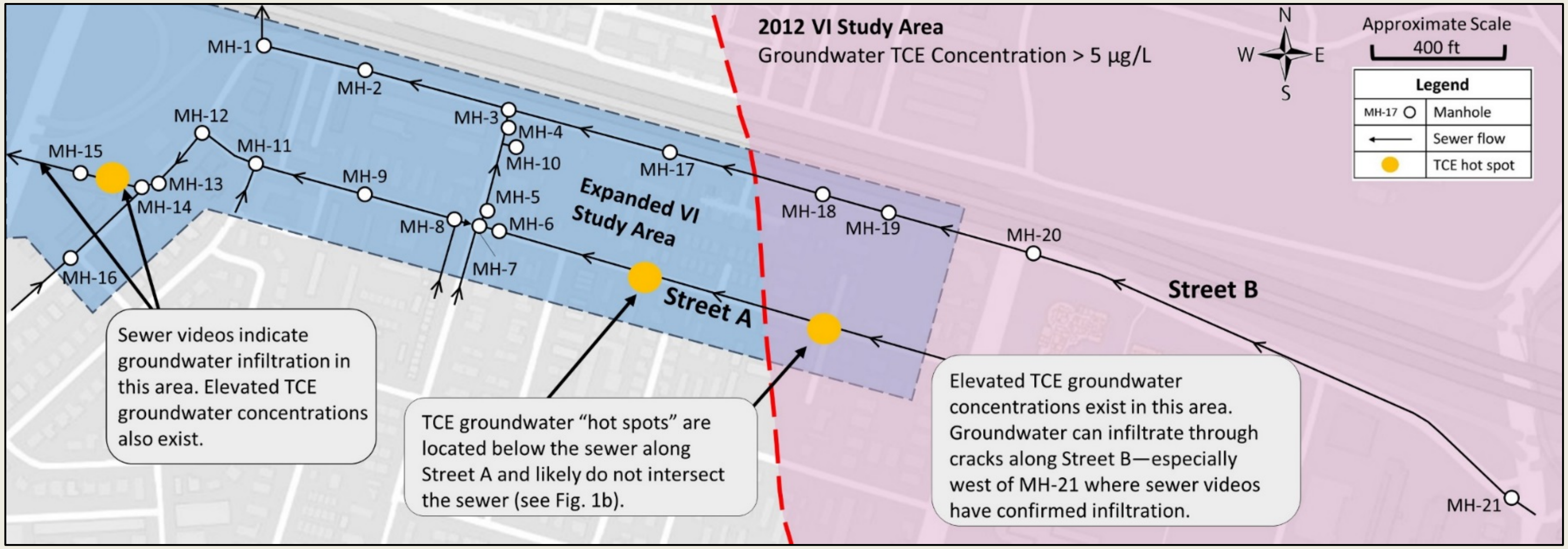
University of Kentucky (and others) conducted sewer gas sampling (Roghani *et al.* (2018))

Important information:

- Extents of contamination plumes
- Plume VOC concentrations
- Pipe failure locations (from CCTV sewer videos & reports)
- Plume and pipe intersection locations

Groundwater was "near" the sewer invert:





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Occurrence of chlorinated volatile organic compounds (VOCs) in a sanitary sewer system: Implications for assessing vapor intrusion alternative pathways

Check for updates

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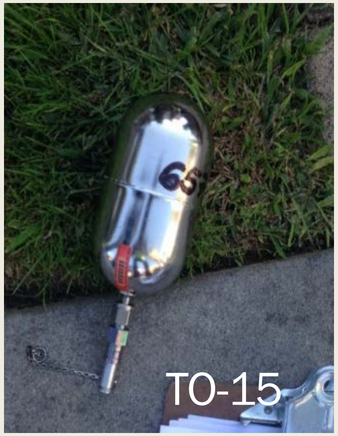
University of Kentucky (and others) conducted sewer gas sampling (Roghani *et al.* (2018))

TO-15

Passive (1-week, daytime/nighttime, 12-24 hours)

High-frequency Monitoring (AROMA)

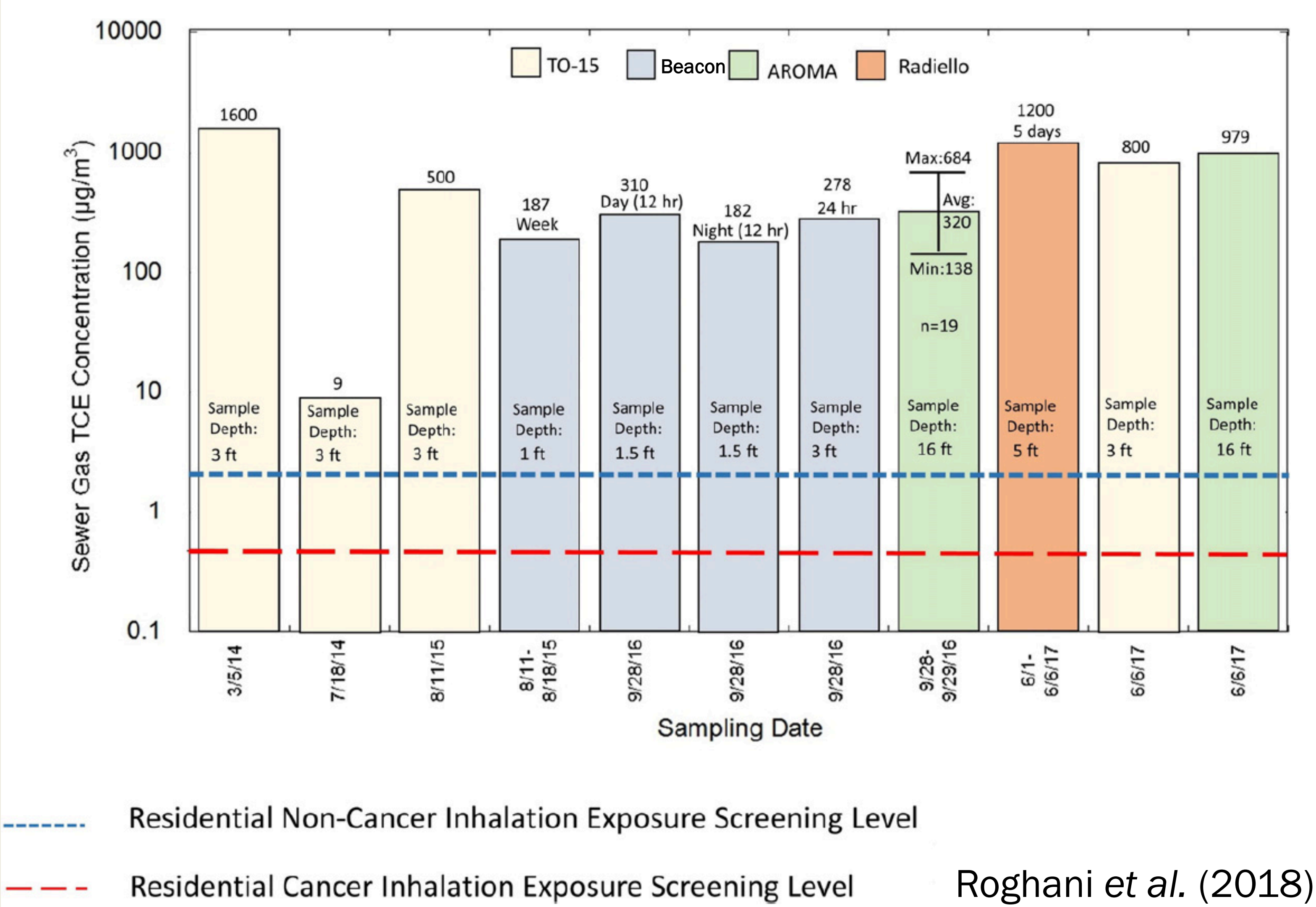
Sampled sewer liquid every 4-6 hours



AROMA Sensor
Entanglement Technologies

Passive
Beacon Environmental

Temporal Variability Example: MH-17



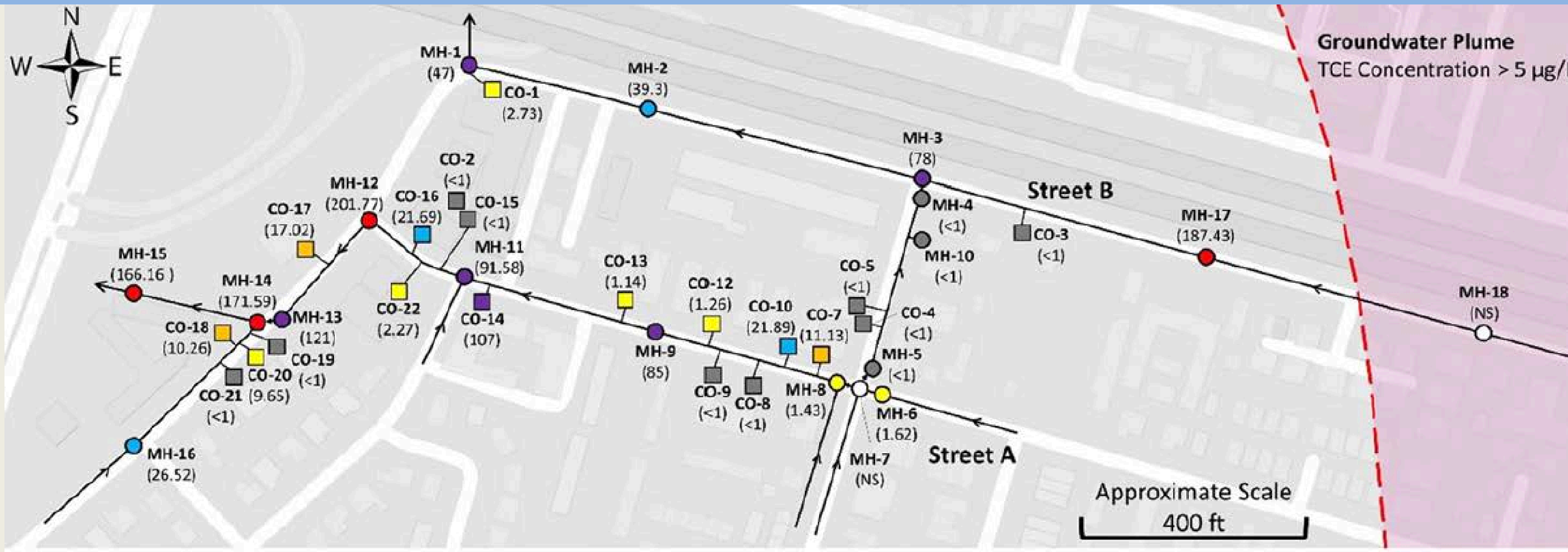
Roghani *et al.* (2018)

TCE Sewer Gas TO-15 vs. Passive vs. AROMA

Repeated sampling of a single manhole (TCE (ug/m^3))

Sampling/ Analysis	Date Range	Max ug/m^3	Min ug/m^3	n
TO-15 (grab)	March 2014-June 2017	1600	9	4
Passive	August 2015-June 2017	1200	182	5
AROMA	September 2016 (24 hour period)	684	130	19

Spatial Variability



b) TO-17 (week-long passive).

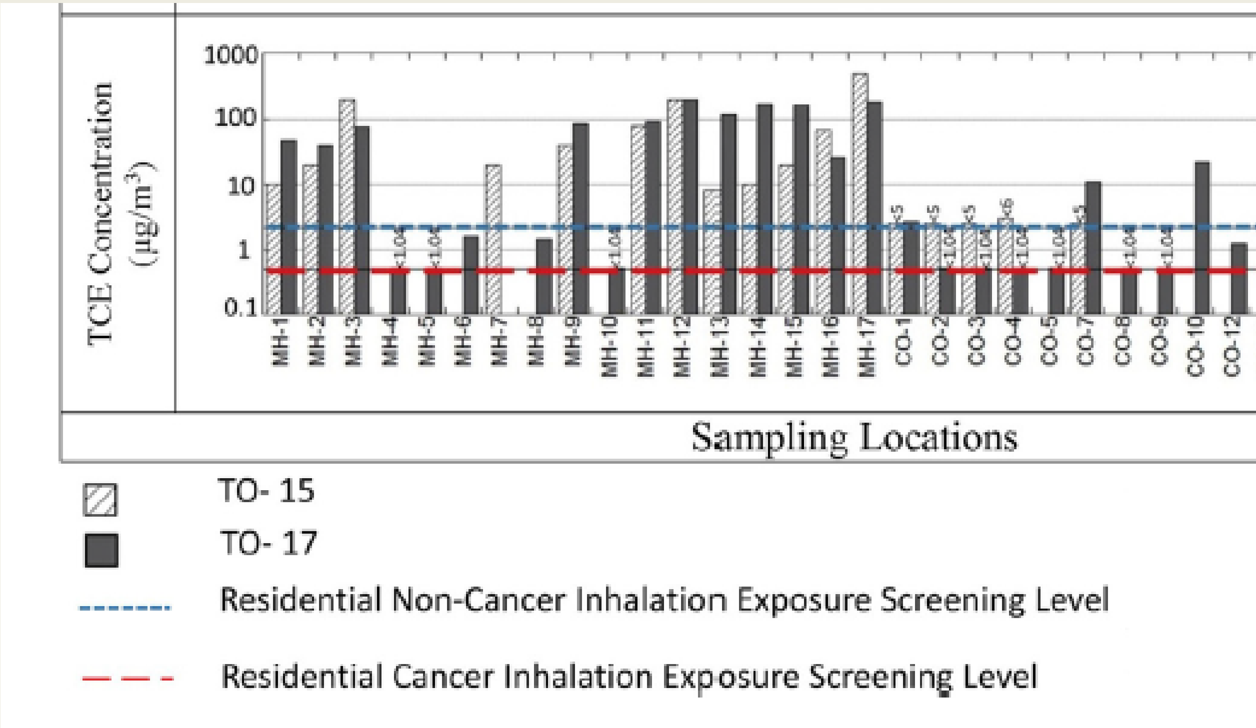
TCE Concentrations Detected in Sewer Gas (µg/m³)			
○	NS	● (orange)	> 10 – 20
● (grey)	ND	● (blue)	> 20 – 40
● (yellow)	> ND – 10	● (purple)	> 40 – 150
		● (red)	> 150

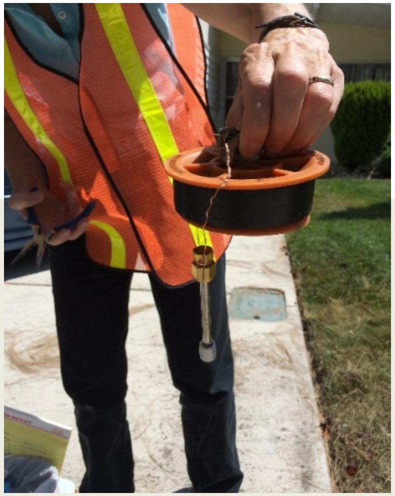
Legend

MH-17 ○	Manhole
CO-13 □	Clean out
←	Sewer flow
NS	Not Sampled
ND	Not Detected
(20)	TCE in µg/m³

Roghani *et al.* (2018)

Sampling Results for TCE





Lessons Learned

- Temporal variability in manholes was substantial
  - *TO-15 may be considered more analytically robust, but is only a snap shot. Passive sampling (with hydrophobic sorbent samplers) and high frequency monitoring also provides very useful information.*
- Sampling cleanouts near the buildings may be useful for estimating exposure risks closer to the receptor, but cleanout construction created some challenges in ensuring vapor tight sampling seals. This could be overcome in the future.
- Sewer videos and sewer construction details were extremely valuable in generating a conceptual model.
- Groundwater monitoring wells were not typically located near all of the manhole locations that were sampled. Assessing depth to water relative to sewer inverts was not easy—but important.

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International Perspective: Denmark

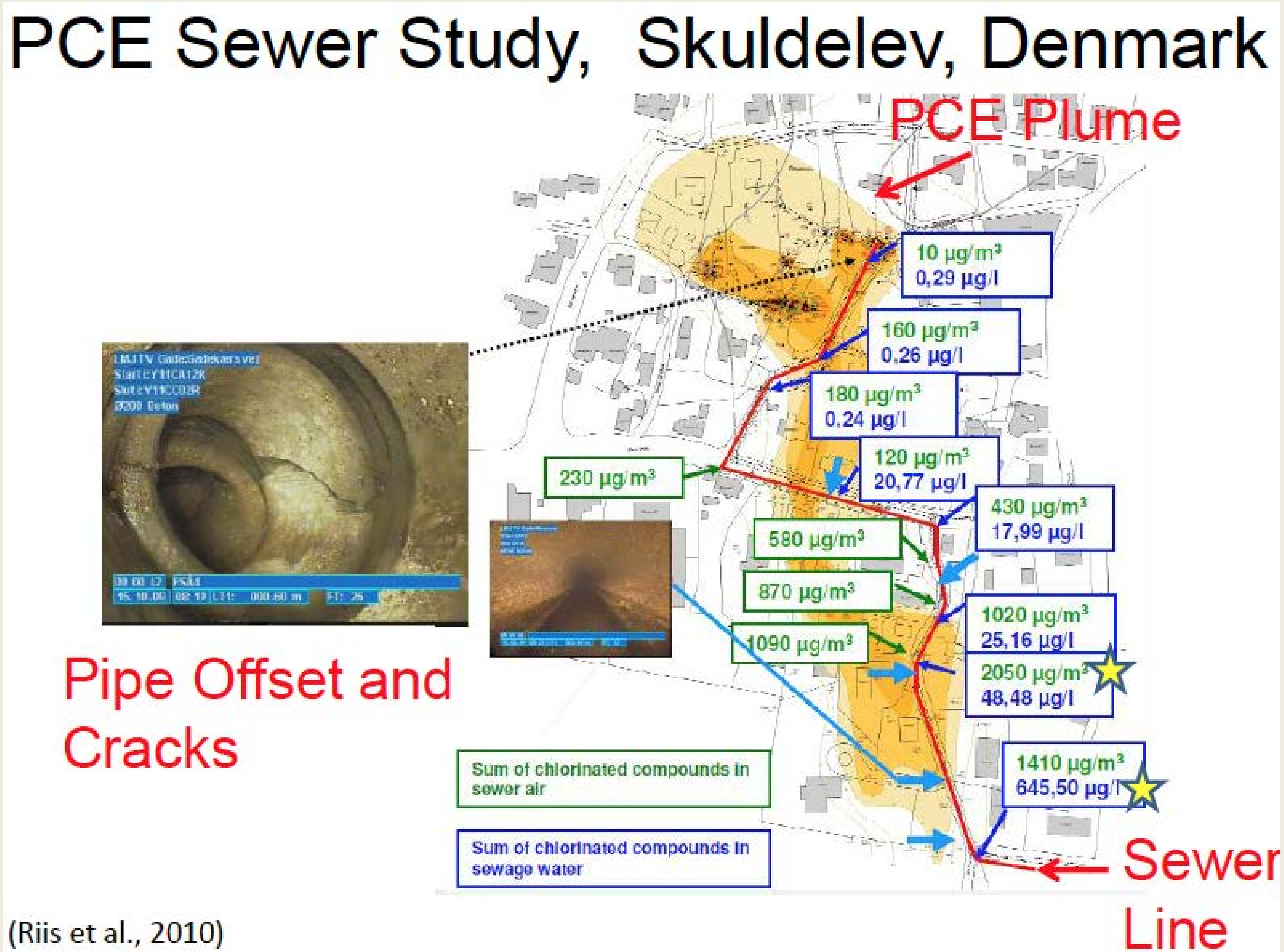
"sewer gas plays a major role in vapor intrusion at 20% of contaminated dry cleaner sites"

-Nielsen and Hvidberg

- NIRAS, Allerod, Denmark (near Copenhagen—Captial Region) were one of the first to formally report a sewer gas pathway at a vapor intrusion site (Riis et al 2010).
- The regulators in the Central Denmark Region (e.g. Borge Hvidberg and Karen Nielsen) are also active in the sewer gas pathway.

College of Engineering

International Perspective: Denmark

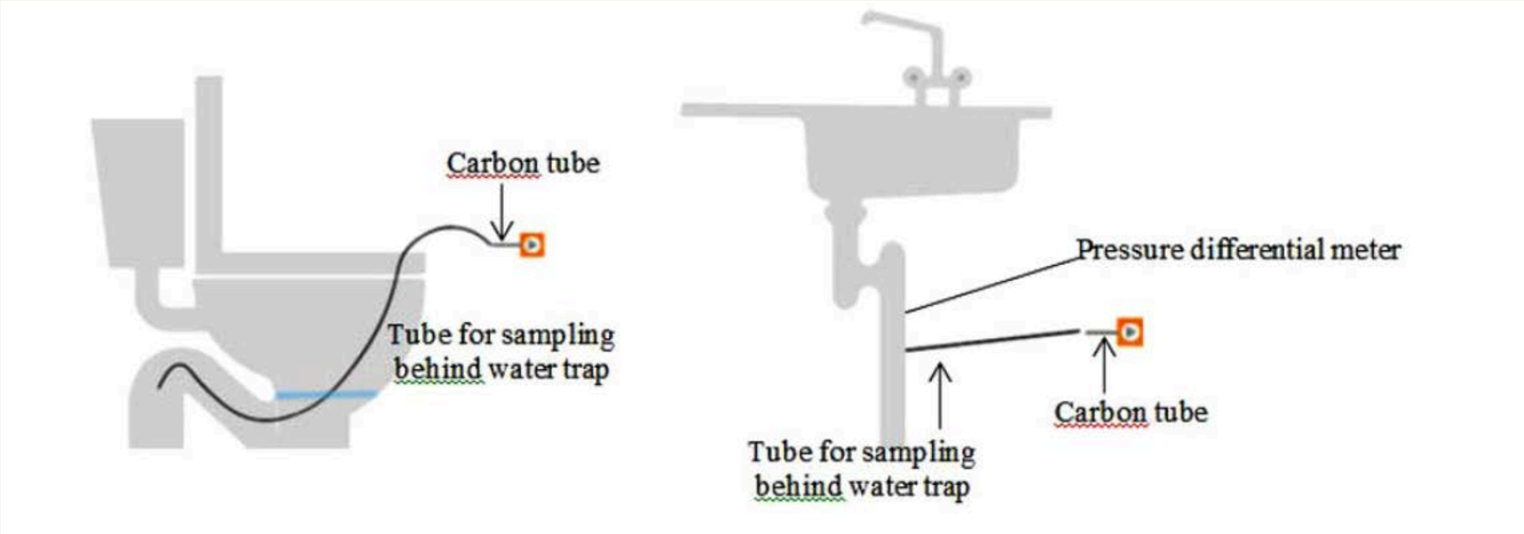


Meeting with NIRAS (Riis and Hansen) June 2017 - Key Lessons

- Some manholes have soil bottoms—this is a complication.
- Sewer videos and construction logs are extremely valuable.
- Tracers are commonly used in vapor intrusion investigations, but not for determining **“generic”** attenuation factors. They are usually used to inform conceptual site models and mitigation strategies.

- Ratios of PCE and TCE concentrations detected in indoor air to the concentrations detected in sewer gas in a nearby manhole was approximately 0.02 in **<u>one location</u>**. <u>However, this ratio is manhole and building-specific.</u>

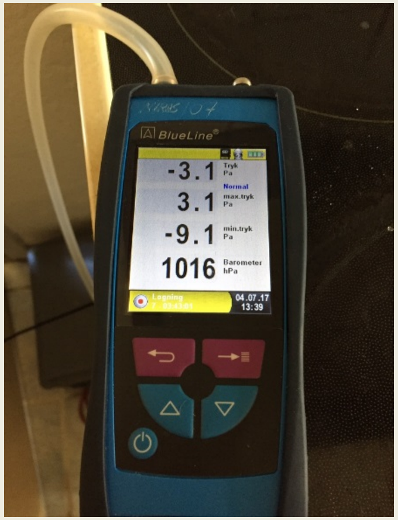
International Perspectives: Denmark

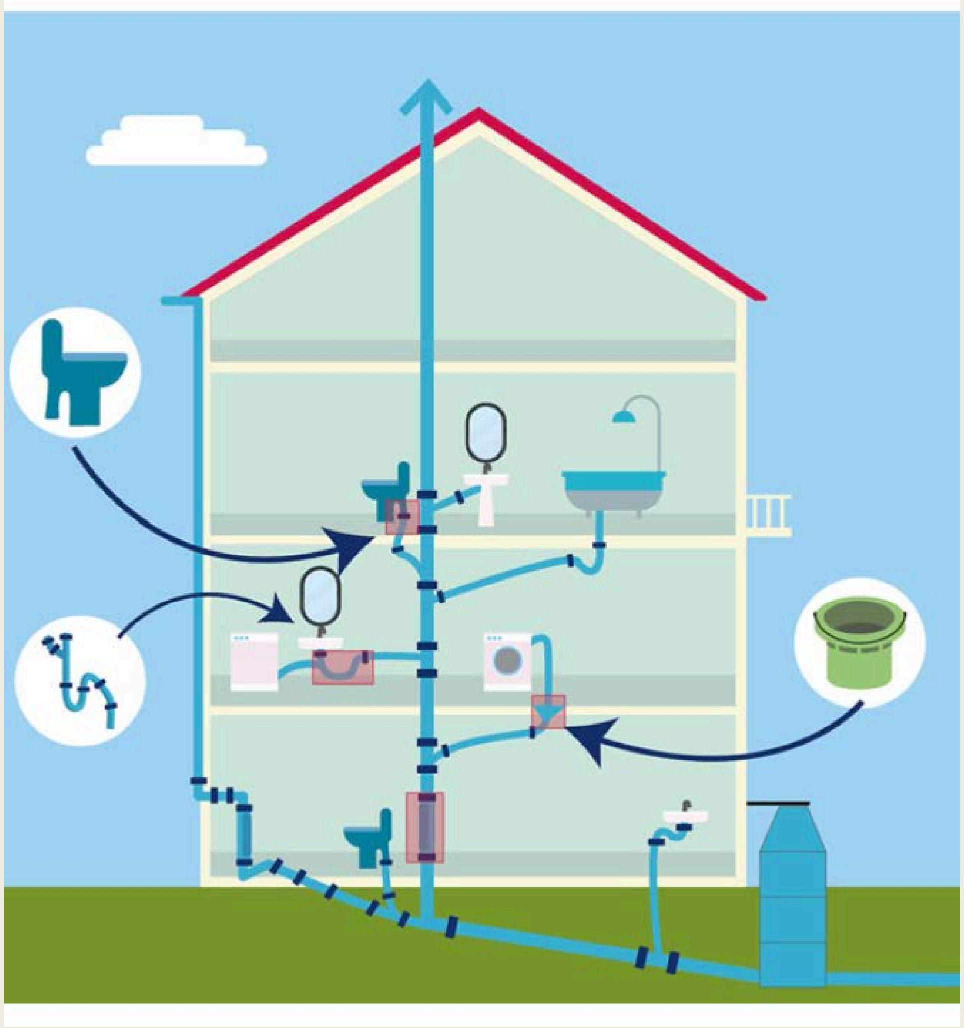


Nielsen and Hvidberg (2017)

Notes: Nielsen and Hvidberg (2017) recommend sampling behind water traps using passive samplers. They also suggest monitoring with pressure meters to determine the potential for vapor migration.

International Perspectives: Denmark





Nielsen and Hvidberg (2017)

Critical Difference: Denmark vs. US

In the US, "**responsible parties**" are responsible for characterizing and mitigating vapor intrusion —but if the problem is a sewer system this can become complicated.

- Sewer pathways are "new"—and guidance/science is evolving—therefore, progress is slow.

In Denmark, the **government** often pays for ensuring vapor intrusion exposure risks are mitigated.

"**Responsible parties**" are only responsible for characterizing and mitigating vapor intrusion exposure risks for contamination if it occurred *"recently"*.

Similarities: Denmark and US

- Similar challenges related to access to private buildings and occupants.
- Finite resources.
- Aging sewer systems.
- Emerging science.

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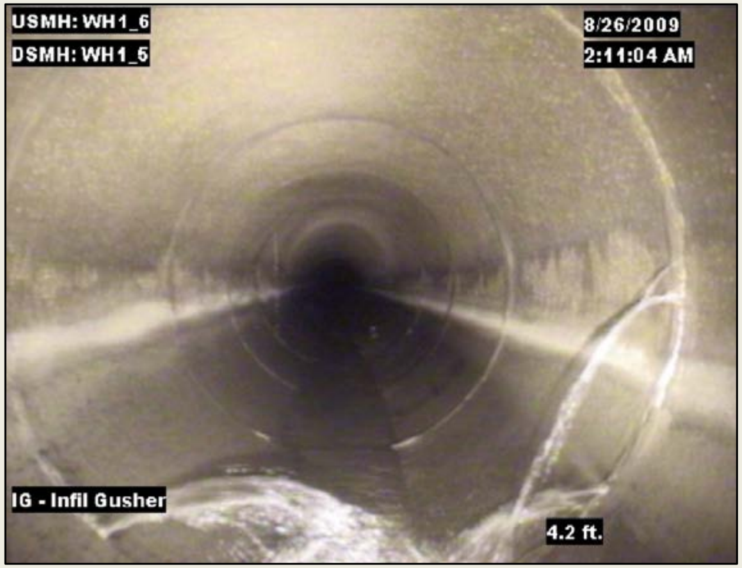
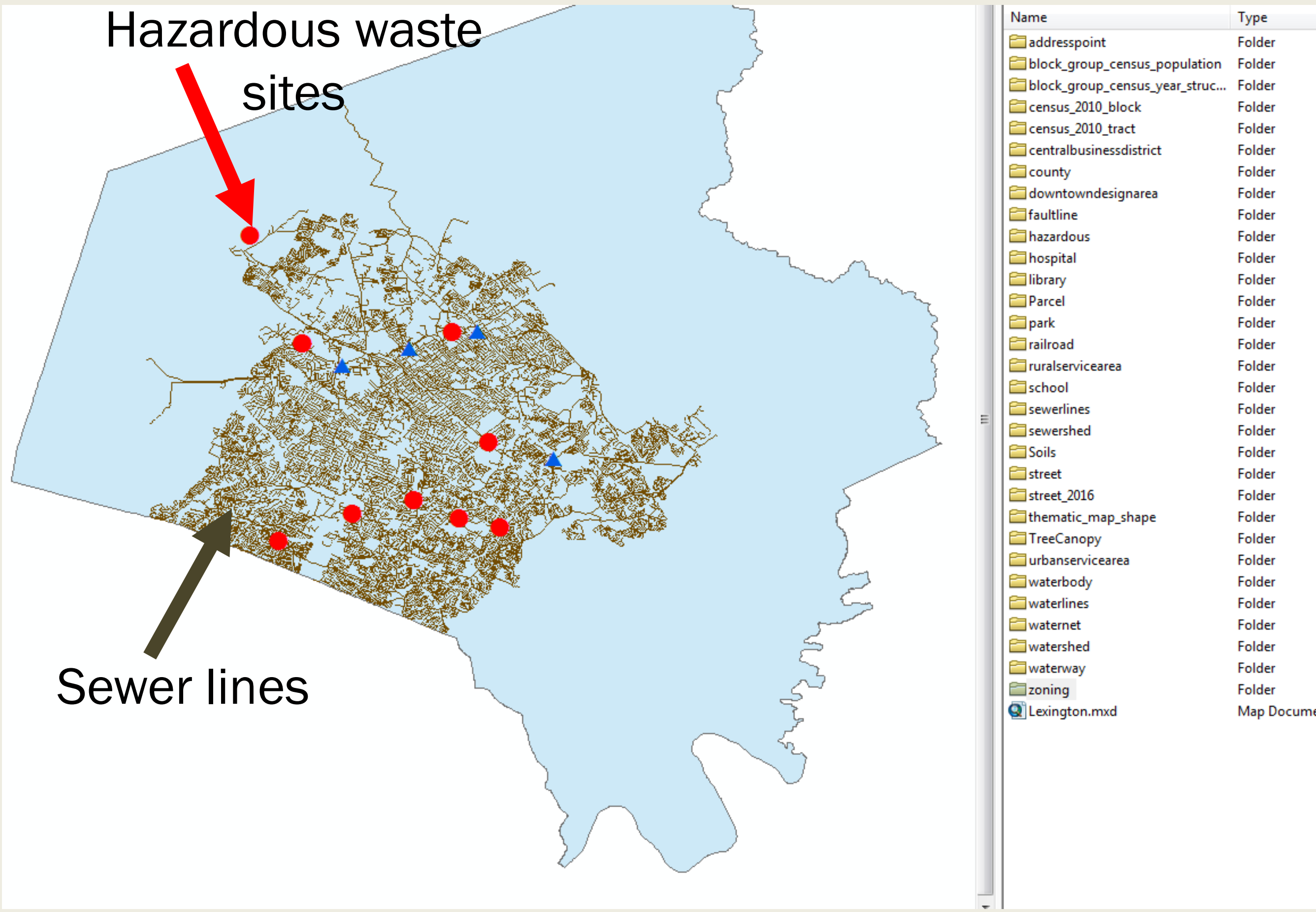
Collaboration Opportunities



- Sewer districts know their sewers. Sewer managers can be great resources for information and are extremely knowledgeable about issues related to sewer gas intrusion.
- Sewer videos and GIS data are extremely useful. Review of available information from sewer databases and files is necessary to develop a good conceptual model.
- Smoke testing and other plumbing leak detection methods can be valuable (and fairly affordable) for assessing breaches in plumbing systems.
- Access to private property for sampling can be challenging; however sewers that are owned by municipalities may be easier to gain access to for sampling.

Geospatial Screening Approach of Sewer Vapor Intrusion

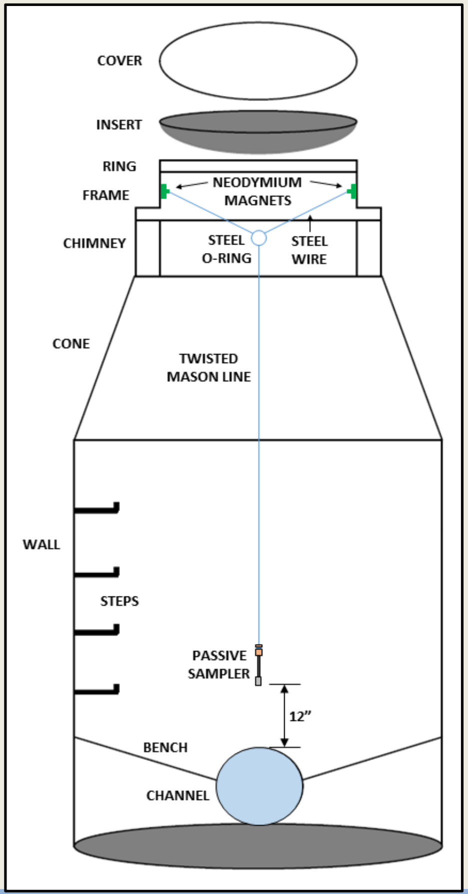


Goal : Screen in/out potential locations of concern using GIS-based approach and integrate information between hazardous waste and sewer experts.

Field sampling after geospatial analysis

Four contaminated dry cleaning sites were selected for preliminary sewer gas screening based on the geospatial evaluation. Results forthcoming…

Public manholes were selected for sampling and sewer district personnel assisted with sampling. Access to private manholes was refused.



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Conclusions

- Sewer manholes and cleanouts can be easily accessible sampling locations for sewer pathway investigation.
- Spatial and temporal variation of TCE sewer gas was observed and should be expected in sewer systems.
- Passive sampling (using hydrophobic sorbents) provides a information for assessing time-averaged sewer gas concentrations.
- Incorporating passive samplers with other methods (e.g. continuous monitoring devices) provide insight about temporal variations.
- There are several parameters controlling VOCs fluctuations within the sewer gas and these factors are not easily understood with single measurements.
- Multiple lines of evidence, such as VOC concentrations, modeling, tracer studies, sewer videos, etc. can be useful in conceptualizing field observations and making decisions about exposure risks.

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