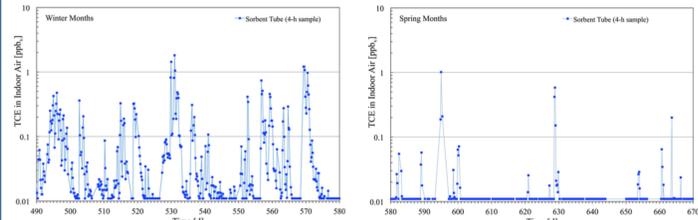


## ABSTRACT

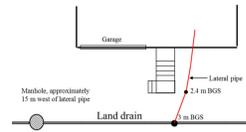
The United States Environmental Protection Agency (EPA), in their 2015 vapor intrusion guidance, has described sewer and drain lines as a potential major contributor to vapor intrusion of contaminants in residential buildings.[1] Assessing vapor intrusion in a residential building typically involves employing a conceptual model of the building to identify major pathways of contaminants. This study seeks to increase the understanding of the impact of sewer and drain lines and could be used to improve conceptual models of vapor intrusion in residential buildings. Sewer and drain lines underneath the foundation were considered. A three-dimensional finite element model of a typical residential building with a vapor intrusion problem was used in the investigation. The importance of soil and sub-slab characteristics as well as the type, configuration and geometry of typical sewer and drain lines were considered. The results suggest that sewer and drain lines may be a significant contributor to vapor intrusion. These results confirm that determining the position and nature of the sewer and drain lines should be an important consideration in evaluating vapor intrusion in a residential building.

## TCE VARIABILITY IN UTAH HOUSE

Great TCE variability can be observed when doing indoor air sampling... why?[2]



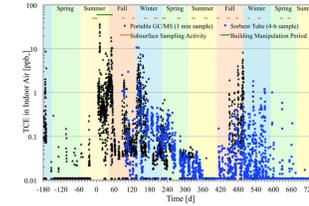
A land drain was discovered right underneath the house... could this be the culprit?[3]



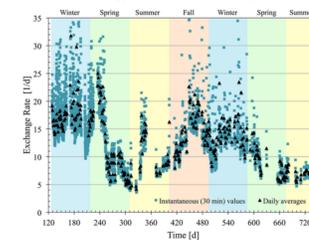
What happens if we model a contaminated land drain, equally or more contaminated than the groundwater, underneath a residence, and then blow a certain volume of gas (i.e. injection volume) through the pipe into the sub-slab space?

## AIR EXCHANGE RATE VARIABILITY

Over a longer period, the indoor air concentration variability is even more apparent.[2]



There is also great variability observed in air exchange rate... could there be some relation?[2] How can this affect the results from the previous, injection model?



## GOVERNING EQUATIONS

Darcy's Law models the air flow through the soil

$$\vec{u} = -\frac{\kappa}{\mu} \nabla P$$

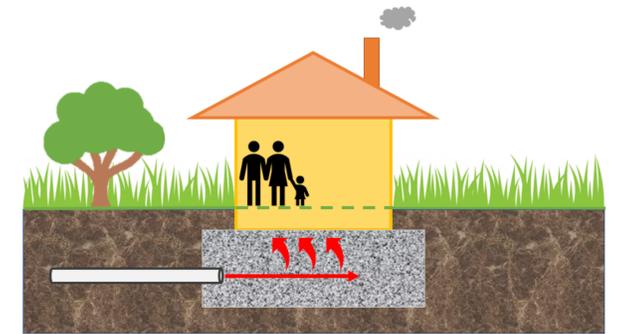
The convection-diffusion equation models the contaminant transport through the soil

$$\frac{\partial c}{\partial t} = D \nabla^2 c - \nabla(\vec{u} \cdot c)$$

An unsteady CSTR model is used to model the contaminant concentration in the house

$$\frac{\partial c}{\partial t} = (\text{IN}) - (\text{OUT}) = \frac{n_{ck}}{V} - A_e c$$

## CONCEPTUAL MODEL



## CONCLUSIONS

- Contaminant indoor air concentrations may increase rapidly on a short time scale as a result of contaminated land drains/sewers.
- A sub-base contaminant source has the potential to independently cause a VI problem; its impact may be significant in certain cases.
- Higher air exchange rates leads to larger variability in indoor air concentration.
- A land/sewer drain can cause orders of magnitude change in indoor air concentration in a few hours.

## REFERENCES

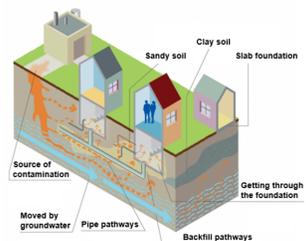
- [1] EPA. *Oswer Technical Guide For Assessing And Mitigating The Vapor Intrusion Pathway From Subsurface Vapor Sources to Indoor Air*. United States Environmental Protection Agency, June 2015.
- [2] Chase Holton, Hong Luo, Paul Dahlen, Kyle Gorder, Erik Dettenmaier, and Paul C. Johnson. Temporal variability of indoor air concentrations under natural conditions in a house overlying a dilute chlorinated solvent groundwater plume. *Environmental Science & Technology*, 47(23):13347-13354, 2013. PMID: 24180600.
- [3] Chase Holton, Yuanming Guo, Hong Luo, Paul Dahlen, Kyle Gorder, Erik Dettenmaier, and Paul C. Johnson. Long-term evaluation of the controlled pressure method for assessment of the vapor intrusion pathway. *Environmental Science & Technology*, 49(4):2091-2098, 2015. PMID: 25604884.

## CONTACT INFORMATION

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## MODELING VI

Cartoon of Vapor Intrusion (Minnesota Pollution Control Agency)



The finite element method may be used to model various aspects of vapor intrusion. E.g. Yao et. al, "Simulating the effect of slab features on vapor intrusion of crack entry". Below you see the concentration profile of a contaminant below a residence overlying contaminated groundwater. Red indicates high levels of contaminant and blue indicate low levels of contaminant.



## BEST VI SAMPLING PRACTICE?

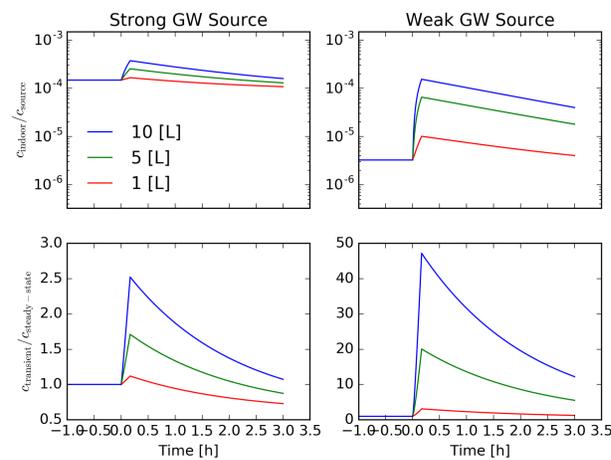
How do we develop best practices for vapor intrusion sampling? Do we focus on capturing...

- Long term, low average levels of exposure?
- Short term, higher levels of exposure?

Houses in Utah & Indianapolis have given insight into these questions.

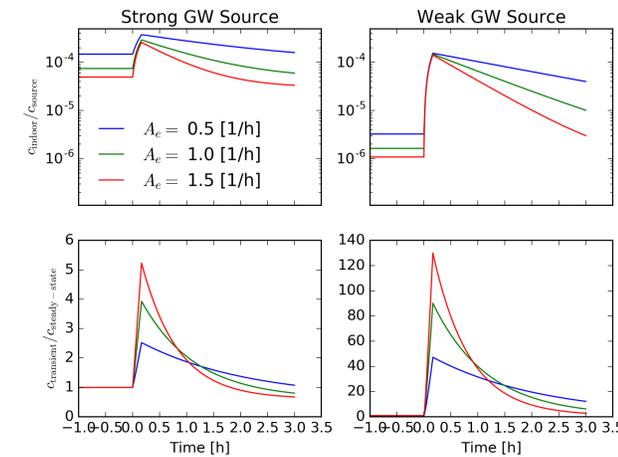
## IMPACT OF INJECTION VOLUME

Indoor air concentration vs. sub-slab contaminated air injection volume

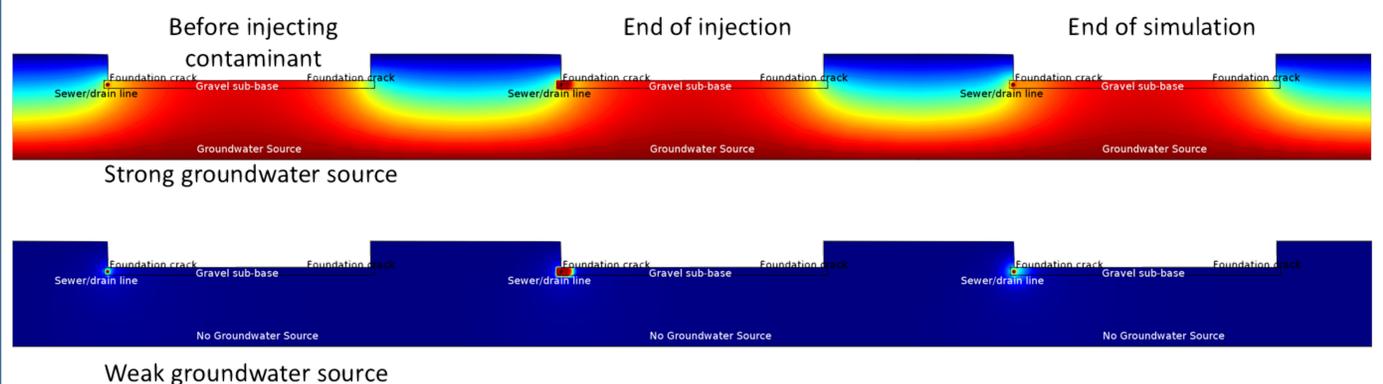


## IMPACT OF AIR EXCHANGE RATE

Indoor air concentration vs. air exchange rate (10 L injected)



## TRANSIENT SOIL CONCENTRATIONS PROFILES [MOL/M<sup>3</sup>]



Weak groundwater source