Chapter 1

Conclusions and Future Work

1.1 Summary of Results

In this work a framework for creating numerical models of vapor intrusion (VI) scenarios has been presented. These models are able to simulate contaminant transport from a source into a building through soils, while taking site specific characteristics, soil moisture, and heterogenous soils into account. Sorption effects, biodegradation, and other phenomena, at both steady state and in time dependent simulations can also be taken into consideration.

These models have been used to explore the temporal and spatial variability that has been observed at VI sites, and in particular the variability associated with preferential pathways like that at the ASU house site. It was demonstrated that preferential pathways may contribute significantly to temporal variation of indoor contaminant concentration, and VI in general, by greatly enhancing the role of advective contaminant transport into a building. This in turn required that three conditions to be satisfied:

1. A ready source of air must be supplied.
2. Likewise, a preferential source of contaminant vapors must be supplied.
3. A permeable zone, e.g. a gravel layer, between the preferential pathway and indoors must exist to facilitate transport.

With the revelation that significant temporal variability of indoor contaminant concentration being associated with advective transport of vapors into a building, we explored the potential various soils to support sufficient airflow rates for advection to dominate. Twelve different soil types were considered, and compared for a house featuring a basement, and on that had a slab-on-grade type foundation. Regardless of foundation type, only sand type soils can be expected to be permeable enough to support airflow for advective transport to dominate. Thus, various site specific characteristics, such as preferential pathways (but not necessarily limited to these) are likely conduits for the elevated airflow rates required for advection to dominate.

It is important to consider if advective or diffusive transport dominates at a site, as the association between building pressurization and contaminant entry are very different at the two. For sites characterized by advection, this association is likely to be strong, and weak at diffusion dominated sites. Consequently, the application of VI investigation techniques like the controlled pressure method are likely to only be effective at advection dominated sites.

Another consequence is that for advection sites, building pressurization can be used as an effective metric for determining when indoor contaminant concentrations are likely to be the highest. We also showed that building pressurization in turn can be predicted relatively easily based on indoor/outdoor temperature differences and wind effects. As the indoor/outdoor temperature differences increases, i.e. it is warmer inside than outside, a building is increasingly depressurized; which is likely why for many sites indoor contaminant concentration are higher during winter.

The trichloroethylene (TCE) sorption capacity of a variety of common materials was measured at relevant contaminant concentration, finding that some of these can contain significant amounts of TCE; with cinderblock being able hold up to almost 41,000 times more contaminant than a comparable TCE contaminated air volume. These sorptive data were then used to explore the role of sorption in some modeled VI scenarios. The modeling showed the significant retarding effect on contaminant transport, due to the increased residence time in the soil pores, that soil sorption can have.

It was also shown that significant amounts of contaminants can be sorbed in the indoor environment, and in some cases maintain a pseudo steady-state, where contaminant vapors are sorbed or desorbed with changing indoor contaminant concentrations. In a situation where a VI site has been effectively mitigated, i.e. contaminant entry into the building completely stopped, the contaminant desorption from indoor materials can maintain significant indoor contaminant concentrations even weeks after the mitigation system has been implemented.

1.2 Suggestions for Future Research

1.2.1 Advective Transport and Specific Site Characteristics

It has been shown that most soils are not permeable enough to provide enough airflow for advective transport of contaminant vapor from the subsurface into building to dominate, and such conditions are most likely to arise to some site specific characteristic, such as a preferential pathway. However, more of these site specific characteristics needs to be explored to gain a more holistic view of which one's are important to discover during a VI site investigation. Some examples of cases to consider if the existence of such a site specific characteristic can significantly increase airflow through the soil into the indoor environment:

- Gravel backfills around a building
- French drains (or similar)
- Disturbed or unpacked soil
- Air pulled through a permeable layer that connects two adjacent buildings, i.e. can one building use another as a preferential air source?

1.2.2 Preferential Pathways

More types of sewer connected preferential pathways should be considered. For instance, at the EPA duplex, it is likely that the sewer line there leaked a few meters away from the edge of the duplex, and such a lateral separation of a leaky preferential pathway should be considered.

1.2.3 Sorption and Vapor Intrusion

Sorption is a relatively unexplored phenomena in VI, but has been shown to potentially have significant consequences, in particular with regards to mitigation of VI at a building. More work is needed to collect sorptive capacities of more materials, considering a greater variety of VI contaminant (at relevant vapor concentrations).

1.2.4 Modeling and Design of Mitigation Systems

Mitigating VI at a site is obviously an important task, but it is not always clear what type of mitigation system design is most appropriate for a given site. Modeling may here offer insights on optimizing a mitigation system design. A mitigation system was installed at the EPA duplex during the latter of that study, and its rich dataset offers an excellent opportunity to examine the efficacy of various designs using modeling.

1.2.5 Model Effects of Weather and Seasons on Vapor Intrusion

In this work, we considered how temperature and wind pressurizes a building relative to ambient, which help explain some of the seasonal trends observed at some VI sites. This work should be expanded to consider other weather phenomena, such as rainfall, snow coverage, or other, to gain a more holistic view of how VI and weather are related.