Understanding the Dynamics of Vapor Intrusion Processes

By

Jonathan Gustaf Viking Ström

A Dissertation Submitted in Partial Fulfillment of the Requirements for the Degree

of

Doctor of Philosophy in the School of Engineering at Brown University

Providence, Rhode Island

May 2020

This dissertation by Jonathan G. V. Ström is accepted in its present form by the School of Engineering as satisfying the dissertation requirement for the degree of Doctor of Philosophy

Date________________ ____________________________________

Eric M. Suuberg, Advisor

Recommended to the Graduate Council

Date________________ ____________________________________

C. Franklin Goldsmith, Reader

Date________________ ____________________________________

Brenda M. Rubenstein, Reader

Approved by the Graduate Council

Date________________ ____________________________________

Andrew G. Campbell, Dean of the Graduate School

Abstract of Understanding the Dynamics of Vapor Intrusion Processes, by Jonathan G. V. Ström, Ph.D., Brown University, May 2020.

Vapor intrusion (VI) investigations, the effort to determine the exposure and associated human health-risk at a VI impacted building, are often complicated by significant spatial and temporal variability in concentrations of contaminants of concern. Over the years there have been efforts to develop new techniques and methodologies that aim to reduce the uncertainties associated with these variabilities. The goal is to simplify and improve the robustness of VI site investigations. The development of the controlled pressure method (CPM), where the pressurization of a building is controlled in an effort to increase or decrease contaminant entry into the building, is one such example. Another approach is to use indicators, tracers, and surrogates (ITS) to help guide when to conduct site investigations, ideally increasing the likelihood of determining the maximum indoor contaminant concentrations.

Both of these approaches rely on a quasi-deterministic relationship between some external variable, such as building pressurization, and indoor contaminant concentration. However, site-specific conditions can give rise to very different responses to such an external variable. To effectively use CPM or ITS, a better mechanistic understanding of contaminant transport and exposure is needed.

In this thesis, we develop three-dimensional finite element models of VI impacted buildings from a first principles perspective. These models combined with analysis of field data from VI sites, allows us to explore the physical mechanisms that drive VI. By considering the dominant contaminant transport mechanism at a site, e.g. if advective or diffusive transport dominates, we can explain why a change in building pressurization can lead to differences in contaminant concentration variability at different sites. We can also better understand how the various factors governing VI contribute to the overall variability.

By classifying the dominant contaminant transport mechanism at a site, we can more effectively anticipate how a particular site will respond to some external stimuli. This will in turn reduce the effort required to, and increase the robustness of the techniques used determine the relevant human exposure at a VI site.

We also applied the model to investigate the role of contaminant sorption to and from soils and common materials. Sorptive capacities of these materials were determined experimentally at relevant conditions, and found that some materials, such as cinderblock, can hold up to 41,000 times more contaminant than a comparable contaminated air volume. Sorption and desorption of contaminant can significantly delay changes in contaminant concentration with respect to time, both in the soil-gas and in the indoor environment. This phenomena is particularly relevant after successful implementation of VI mitigation scheme, where contaminant desorption from certain materials may maintain indoor contaminant concentrations for months longer than if there were no sorbed contaminants.