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Estimating VI Exposure Risks: A VI Modeling Approach that Combines the Influence of Wind and Stack Effects on Indoor and Subsurface Environments

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Background/Objectives. Over the past two decades, vapor intrusion (VI) models have been developed to predict vapor transport through the soil into indoor spaces. Most of these models have focused on subsurface transport. To date, a few VI models have been developed to evaluate the effect of wind flow and indoor air temperature on VI. Most of the wind-focused VI models that have investigated how wind flows influence subsurface processes. They have made important advances, but more research is needed to understand how wind flow and temperature collectively influences the VI exposure risks.

In this study, we present results of a newly developed model that combines three different domains: the atmospheric domain (outdoor above-ground), indoor domain, and subsurface domain. Using this new model, we investigate how wind flow above and around a building, as well as stack effects influences 1) the distribution of VOCs in the subsurface, and 2) indoor air pressure which consequently affects the indoor air concentration of contaminant.

Approach/Activities. This research presents a comprehensive VI model that couples a multizone indoor air model with a CFD program that calculates airflow rates at the building interfaces. The CFD model solves the Reynolds Averaged Navier-Stokes equations to calculate the distribution of wind pressure on building surface for the multizone indoor air model simulations. The multizone program solves air mass balance equations to predict the indoor air pressure which is later used as boundary condition in the VI model. The VI model then solves the chemical transport equation coupled with continuity equation allowing for both convective and diffusive transport and calculates contaminant distribution in subsurface and mass entry rate through the building foundation cracks. VI exposure risk is estimated based on the indoor air concentration, which is calculated by solving mass balance equations using the indoor air multizone indoor air model.

Results/Lessons Learned. The results suggest that wind flows can result in an asymmetrical pressure and soil vapor concentration profiles. Asymmetric pressure profiles around buildings can cause infiltration in the windward side and exfiltration on the leeward side of the building which influence on indoor air pressure and the mass entry rate of contaminant. Results indicate that when the wind speed increases the mass entry rate and average contaminant concentration trough the windward side crack increases, while the leeward side cracks shows almost no change. Indoor air concentration of contaminant calculated by mass balance equations in the multizone indoor air model is influenced by the air exchange rate which is a function of combination effect of wind speed/direction and temperature difference. Model results shows that VI exposure risks vary depending on the specifics of different scenarios (e.g., outside temperature, wind speeds, building air exchange rates, as well as building-specific features).