Model Uncertainty Analysis, Field Data Collection and Analysis of Contaminated Vapor Intrusion into Buildings

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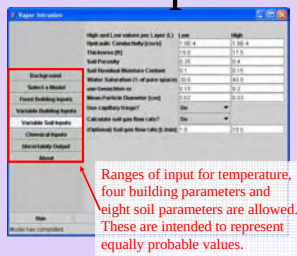
Introduction

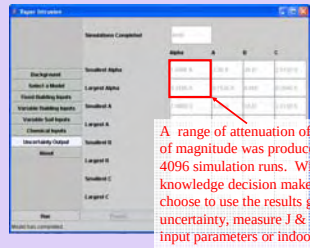
The intrusion of vapors into indoor air from soil and groundwater contaminated by organic compounds is of concern both for the short-term hazard of explosion as well as for longer-term risks associated with lower-level exposures. Volatile organic contaminants (VOCs) are frequently associated with contamination from leaking fuel storage tanks and releases from dry cleaners and industrial facilities. These contaminants may volatilize from soil or ground water and enter homes or businesses through cracks in basement floors or slabs. The Ecosystems Research Division in Athens, Georgia has undertaken an extensive vapor intrusion research program that seeks to address several of the current challenges associated with evaluating the subsurface-to-indoor air pathway. Three of these challenges involve providing vapor-intrusion model users with a full uncertainty analysis given a range of viable model inputs, evaluating the movement of moisture beneath buildings and its effects on vapor intrusion, and using dogs for screening of homes prior to indoor air sampling in order to identify possible indoor sources of contamination. The goal of this program is to provide regulators and other interested parties with practical, cost-effective solutions to challenges in evaluating vapor intrusion.

• Automated Uncertainty Analysis of Vapor Intrusion Models

Numerical models are often used to make decisions as to whether or not a site or particular building at a site has the potential to be impacted by vapor intrusion from the subsurface. A popular model, called the "Johnson and Ettinger Model", is widely used for this application. EPA's Office of Solid Waste and Emergency Response (OSWER) distributes several spreadsheet-versions of the Johnson and Ettinger (J & E) Model for use at RCRA and Superfund sites and uses the model to establish screening-level concentrations in its Draft Guidance for Evaluating the Vapor Intrusion to Indoor Air Pathway. The documentation for the OSWER-distributed model suggests that users run several simulations for differing parameter sets to evaluate uncertainty. However, it is impracticable to run all combinations of inputs by "hand." ORD has developed an automated software system for analysis of model results. When complete this software will be available on the web at http://www.epa.gov/athens/onsite.



Ranges of input for temperature, four building parameters and eight soil parameters are allowed. These are intended to represent equally probable values.



A range of attenuation of one order of magnitude was produced from the 4096 simulation runs. With this knowledge decision makers can choose to use the results given their uncertainty, measure J & E model input parameters or indoor air concentrations.

• Use of Canines for Indoor Source Detection

The ERD program is designed to demonstrate the utility of dogs as a tool in vapor intrusion (VI) investigations with an emphasis on evaluating the cost-effectiveness of employing them, developing quality assurance strategies in support of their use, and protecting the dogs from exposure to harmful levels of chemicals. Benzene, toluene, ethylene, and xylene (BTEX), major constituents of gasoline and frequent culprits related to vapor intrusion into buildings from contaminated groundwater, are the initial set of target compounds that the dogs are trained to detect.

Initial tests indicate that air concentrations of BTEX components can be identified by the dogs down to 1.0 ppb. The dogs discriminate easily between target and nontarget compounds (e.g., acetone, methanol, acetic acid) and detect target compounds in the presence of conflicting scents (e.g. acetone) at much higher (100x) concentrations. A moderate size room or office area (200 sq ft) can be searched with the dogs in a matter of 2 – 3 minutes.

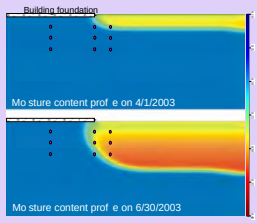
Sammy examines the foundation of a building for target scents.

Sammy is trained to sit as an alert when he identifies a target compound.

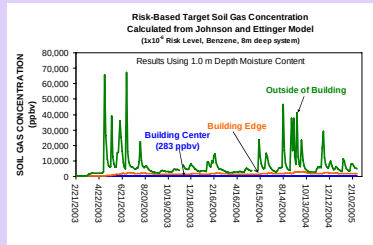
• Investigation of Vapor Intrusion Processes

The Johnson and Ettinger vapor intrusion model is widely used for evaluating which contaminated sites may pose unacceptable risk for vapor intrusion to overlying structures. This model incorporates diffusion from the contaminant source to the overlying building slab, with advection and diffusion of vapors through the slab into the building. As a one-dimensional solution, the Johnson and Ettinger model assumes lateral constancy of parameters. The effective diffusion coefficient required in the model is often computed using the Millington and Quirk relation. This relation is very sensitive to porosity, moisture and air-filled porosity values. The lower the moisture content, the more vapors will migrate towards a building. Site-specific VI pathway assessment may include modeling that utilizes site-measured subsurface moisture content. However, little information is available regarding the movement of water beneath and around structures and the subsequent effect on vapor transport to a building.

A building was constructed on-site at EPA-Athens and outfitted with instruments to measure moisture content and soil gas pressure at several depths beneath and outside the footprint of the structure.



The unsaturated-zone flow and transport model HYDRUS-2d was used with two-years of daily precipitation data to simulate infiltration beneath and near the structure.



Moisture content results were used in the Johnson and Ettinger vapor intrusion model to predict allowable soil gas concentrations over time for a hypothetical benzene contamination at the site. Results show concentrations at a location outside the building slab as high as 230 times concentrations predicted using center-slab concentrations.

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