Evaluating the Sensitivity of Screening Level Vapor Intrusion Models

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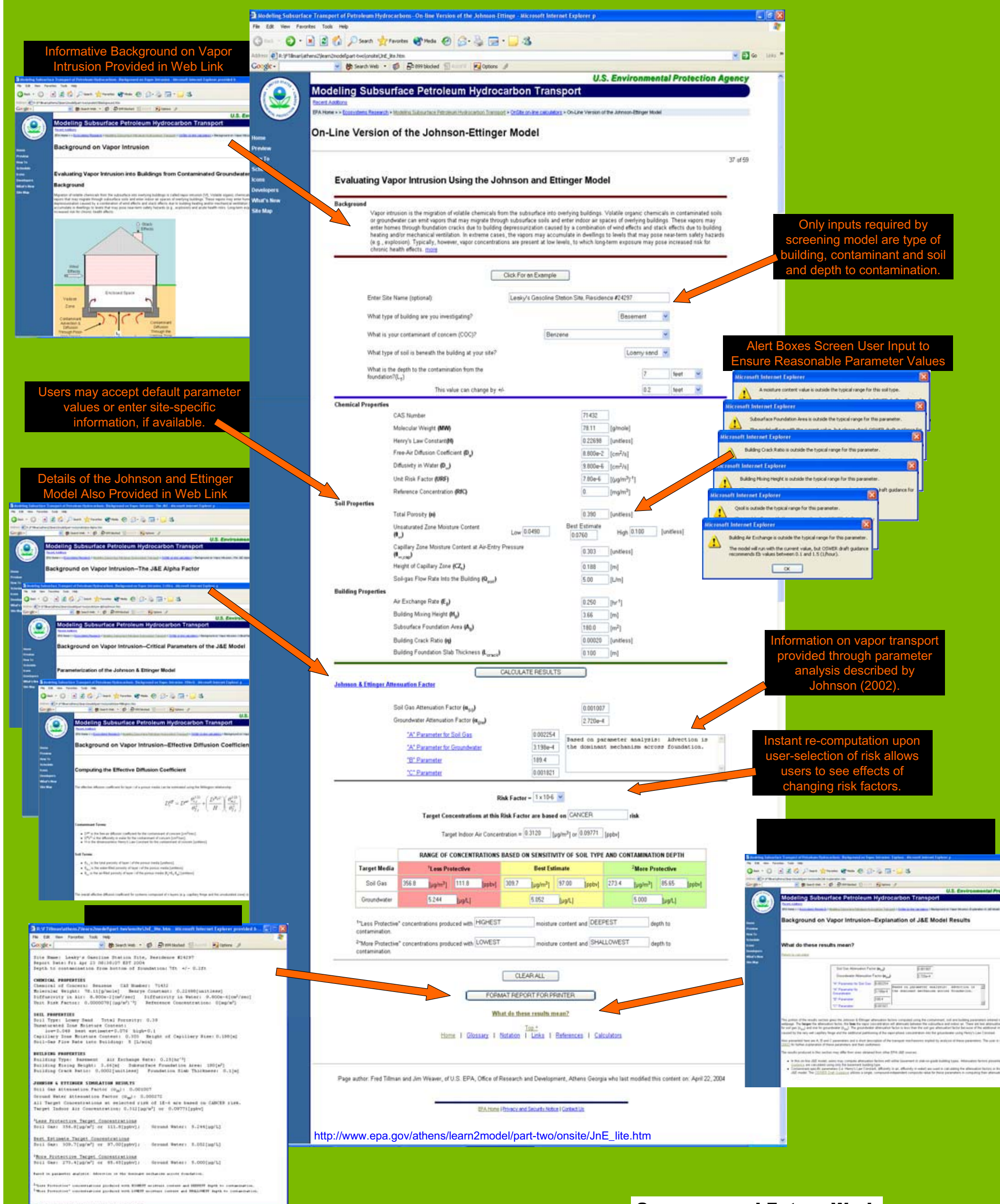
Introduction

Migration of volatile chemicals from the subsurface into overlying buildings is called vapor intrusion (VI). Volatile organic chemicals (VOCs) in contaminated soils or groundwater can emit vapors that may migrate through subsurface soils and enter indoor air spaces of overlying buildings. These vapors may enter homes through foundation cracks due to a combination of wind and building heating and/or mechanical ventilation. Long-term exposure to low levels of VOC vapors may pose increased risk for chronic health effects.

EPA has developed a set of on-line calculators for performing various site assessment calculations (www.epa.gov/athens/onsite). To extend the capabilities of the website to include sites with potential for vapor intrusion, a calculator has been developed to implement the Johnson and Ettinger (J&E) (Johnson and Ettinger, 1991) simplified vapor intrusion model. The J&E model has become increasingly popular with regulators and consultants as a first-tier screening tool to identify sites needing further assessment. The J&E model is a one-dimensional analytical solution that incorporates both advection and diffusion transport mechanisms to produce a unitless "attenuation factor". This attenuation factor is a measure of how soil and building properties limit the intrusion of vapors into overlying buildings. The larger the attenuation factor produced by the model, the greater the intrusion of vapors into indoor air. The on-line vapor intrusion model first calculates an acceptable indoor air concentration of the contaminant of concern based on user-defined risk level. A range of target soil-gas and groundwater concentrations is then produced using the semi-site specific J&E attenuation factor and uncertainty information on two important parameters: depth to the contamination and moisture content in the soil. If target concentrations are greater than field-measured soil-gas and groundwater concentrations then residences near the sample-collection locations do not require further assessment. However, if field measurements exceed target concentrations, then more detailed data must be collected.



Example Use of Model

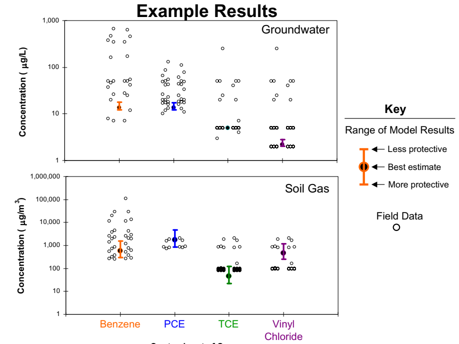
To demonstrate the use of the on-line Johnson & Ettinger model, input data from a contaminated field site in the eastern United States was obtained. A gasoline station was found to have a leaking underground storage tank (UST) which discharged gasoline into the subsurface, contaminating both soil and groundwater. In characterizing the gasoline contamination, it was discovered that a nearby dry cleaner had also contaminated the groundwater with dry cleaning solvents. This gasoline and solvent-contaminated groundwater is flowing under a residential area. Which residences located above the plume might be impacted by vapors from the contaminated groundwater?

Approaches to answering this question include measuring indoor air concentrations (which involve issues of access and indoor sources of contamination) and estimating indoor air concentrations using models.

gasoline & solvent- contaminated groundwater

The on-line vapor intrusion model was run with a depth to contamination of 15 ft (obtained from well data at the site) with a potential variability of this depth of +/- 5.69 ft (obtained from historical well data from a USGS well nearby). Soil type was estimated to be Sandy Loam. The model was used to investigate exposure to two gasoline compounds (benzene and MTBE) and three chlorinated solvents (PCE, TCE and vinyl chloride) using a cancer risk level of $1x10^{-6}$ and a target hazard index of 1. Model results are compared with field data in the chart below.

Example Results



Groundwater

General results for groundwater contamination reveal that computed target concentrations are relatively insensitive to the range of residual moisture contents and depth to contamination. Results for benzene indicated that 21 of the groundwater samples collected at the site were higher than acceptable concentrations for the entire sensitivity range. No groundwater samples containing MTBE were found to violate the model-predicted safe range. For the chlorinated solvents, PCE concentrations were in exceedance of "less protective" target concentrations in 27 samples and in exceedance of 33 samples using "more protective" numbers. TCE and vinyl chloride results indicated 95 and 163 samples, respectively, exceeding target concentrations for the entire sensitivity range.

Soil Gas

Target concentrations for soil gas showed greater sensitivity than for groundwater. The range of model results for soil gas target media indicated from 17 to 28 exceedances of benzene vapor, no exceedances of MTBE, from 0 to 5 exceedances of PCE, from 9 to 50 exceedances of TCE and from 3 to 8 exceedances of vinyl chloride.

Conclusions

The model results show possible impacts to several homes from benzene, PCE, TCE and vinyl chloride. The number of potentially impacted homes depends upon whether the decision-maker uses "more protective" or "less protective" model results. Groundwater results do not vary widely over the sensitivity range, giving decision-makers confidence of the screening levels. Soil gas results do vary somewhat over the range of input values selected, providing decision-makers with valuable information about how choices of parameter values affect screening levels and, subsequently, the number of potentially affected houses.

Summary and Future Work

Migration of volatile chemicals from the subsurface into overlying residences is an area of increasing concern to both regulators and impacted communities. This on-line implementation of the Johnson and Ettinger vapor intrusion model allows users from a wide range of skill levels to screen homes for the vapor intrusion pathway. Basic information about the site is entered in the model using pull-down menus and text boxes. Default parameter values automatically populate the model input fields. Users may accept these default values or provide site-specific values, if available, which are screened based on EPA recommended ranges. Model results are target groundwater and soil-gas concentrations that are considered to produce no un-safe impact on indoor air at the user specified risk level. Information is also provided on the sensitivity of these target concentrations to the important parameters of moisture content and contamination depth.

An important question that remains concerning the use of the Johnson and Ettinger model is: are the results sufficient for decision making? The simplified model does not include all transport phenomena (e.g., no biodegradation), all inputs to the model are not routinely measured, and there is no data on how many "false negatives" (false determinations of no vapor intrusion) may occur. Future work in the area of vapor intrusion will include additional sensitivity analyses of vapor intrusion models, development of approaches for incorporating biodegradation of gasoline hydrocarbons into vapor transport modeling and collection of field data (sub-slab and soil vapor concentrations, moisture content, indoor air concentrations) to answer basic questions about subslab vapor transport.

Citations

Johnson, P.C., 2002. Identification of Critical Parameters for the Johnson and Ettinger (1991) Vapor Intrusion Model. American Petroleum Institute Technical Bulletin Number 17, 38 pgs.

Johnson, P.C. and Ettinger, R.A., 1991. Heuristic Model for Predicting the Intrusion Rate of Contaminant Vapors into Buildings. Environmental Science and Technology, 25(8): 1445-1452.

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