In the Air

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A Practitioner's Perspective on Vapor Intrusion

by Robert Ettinger and Todd McAlary, GeoSyntec Consultants, Inc.

The subsurface vapor migration to indoor air pathway is now being considered more commonly and in more detail during risk-based site evaluations at contaminated sites. The USEPA issued Draft Guidance for Evaluating the Vapor Intrusion to Indoor Air Pathway from Groundwater and Soils (November 2002) and many states also have recent or forthcoming guidance documents. This article provides a practitioner's perspective on the complexities and challenges inherent in evaluating the vapor intrusion pathway and suggests strategies for minimizing the cost of characterization while obtaining technically defensible results.

Conceptual Model

The key to assessment of the vapor intrusion pathway is to identify the processes and mechanisms contributing to vapor intrusion and attenuation and collect data strategically to quantify each important mechanism or process in sufficient detail for a defensible assessment of potential inhalation risks. The framework for this approach is the Site Conceptual Model (SCM). The most common conceptual model is upward diffusion through soil gas from soil or groundwater, with convection into the building and dilution within the building. This conceptual model forms the basis of the commonly applied Johnson and Ettinger (1991) mathematical model (the J&E Model) for calculating the ratio of indoor air vapor concentrations to soil vapor concentrations at a specified depth (i.e., the attenuation factor).

Other processes and conditions that are not considered in the J&E Model may be important in certain circumstances. These include lateral vapor diffusion through the vadose zone, barometric pumping, migration through preferential pathways, biodegradation, pressurized buildings, passively-ventilated crawl spaces, wet basements, the fresh water lens, and perched groundwater layers. Depending on the relative importance of any of these processes and conditions, the common SCM may not be relevant or appropriate.

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Todd McAlary studied subsurface vapor transport at the University of Waterloo, and has been the Technical Director of one of the world's largest assessments of subsurface vapor intrusion at a site in the United Kingdom for the past 6 years, and has consulted at numerous sites throughout the United States. He was a co-author of the draft RCRA Vapor Intrusion Guidance, and was the only non-regulator on the Steering Committee for the EPA Vapor Intrusion Seminars.

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Generalized Evaluation Approach

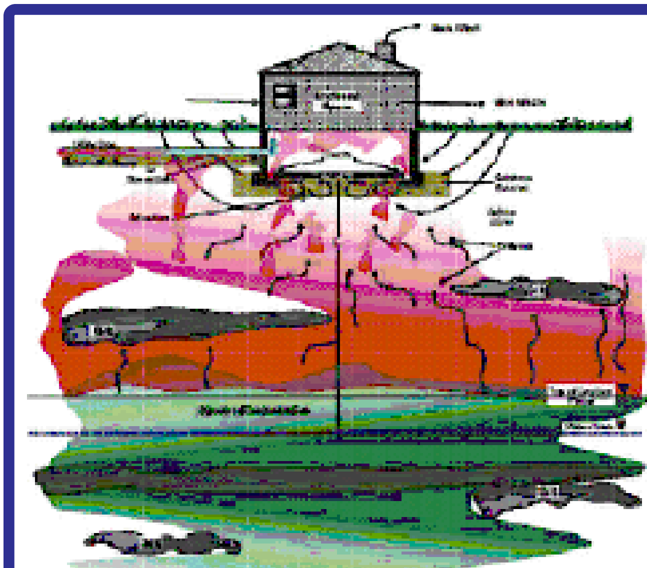
Approaches to assess this pathway commonly follow a tiered system. The evaluation typically begins with a review of potential imminent hazards (explosions, acute health risks). If VOCs are present that are sufficiently volatile and toxic to pose a potential inhalation risk, measured groundwater and/or soil gas concentrations are compared to generic screening values derived using simple one-dimensional modeling and conservative model input values.

The strategic approach to site evaluation is to assess the range of potential impacts considering the expected variability in the important processes and conditions, supported by a combination of model predictions and measurements. Measurements will often be needed in a representative number of locations and time-periods to establish spatial and temporal trends. It is generally better to assess site conditions in a selected few representative locations using a variety of techniques than to rely on a single technique applied more extensively. For example, in cases where VOCs in groundwater have migrated under multiple occupied buildings, it is generally not necessary to conduct exhaustive studies of each and every building.

Modeling

An appropriately-formulated mathematical model is always a useful tool for assessing the sensitivity of various components of the SCM. Screening-level modeling can be initiated at the outset of any assessment to identify the components that contribute most to variability and uncertainty. The field data collection activities can then be selected strategically to provide the most relevant information. An iterative process of data collection and model refinement will often provide the most cost-effective assessment.

The J&E Model is a screening level model that predicts indoor air concentrations from subsurface vapor concentrations, often within approximately one order of magnitude. The inherent variability in subsurface vapor and indoor air concentrations is also often about one order of magnitude; therefore, it is best to compare model results with multiple measurements to address data variability.



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Models other than the J&E Model have been developed that can be used to evaluate vadose-zone biodegradation and/or two and three-dimensional transport.

Data Collection

A compounding challenge in evaluating vapor intrusion is the diversity of opinions on appropriate technical approaches to be used. Typical investigative techniques include sampling and analysis of groundwater, soil gas, indoor air, and outdoor (or ambient) air. For soil gas and groundwater data, it may be important to assess the vertical profile of concentrations via depth-discrete sampling. Target indoor air, soil gas and groundwater concentrations for vapor intrusion assessments are typically very low. To date, limited guidance documents have been published to help meet the data quality objectives necessary at these low concentration levels, although there is work in progress on this topic.

Sampling and analysis of indoor air itself may appear to be the most direct way to assess exposure; however, several complicating factors can confound efforts to accurately quantify subsurface vapor contributions to indoor air. First, target indoor air concentrations for some compounds are lower than typical laboratory detection limits. Second, indoor air usually contains dozens of detectable compounds attributable to building materials and consumer products in addition to any potential contributions from vapor intrusion. Third, even outdoor air quality in some locations can exceed target cleanup concentrations for some compounds. Finally, indoor air quality varies between buildings because of differences in design, construction, thermal efficiency and ventilation, and even within a single building over time because of changes in barometric pressure, wind, temperature, HVAC operation, and the occupant's activities. Therefore, it is difficult to assess the vapor intrusion pathway with indoor air sampling and analysis alone.

Cases that Demonstrate the Strategic Approach

Sometimes a single important factor dominates the vapor intrusion pathway assessment, and a focused study will demonstrate the impact of this factor in sufficient detail to provide a robust decision. A few examples from the authors' experiences are presented in brief below to demonstrate this.

A site in Massachusetts has trichloroethene (TCE) in groundwater at concentrations above 10,000 mg/L at a depth of only 30 feet beneath a residential neighborhood with basements. However, the rate of infiltration of rainfall, lawn watering and snowmelt is sufficient to form a blanket of fresh water about 5 feet thick at the water table that acts as a vapor barrier and prevents off-gassing of TCE from the groundwater. Focused data collection to demonstrate this included depth discrete groundwater sampling using the Waterloo Profiler ™ method, and selected soil gas and indoor air sampling.

A site in Florida has a former industrial building that has been redeveloped into mixed commercial and industrial uses. TCE is present in groundwater beneath the site at concentrations above 10,000 mg/L. The building shields the groundwater from recharge, so there is not likely to be any fresh water lens. However, the building is air-conditioned year-round by about 100 rooftop units that cool atmospheric air and blow it into the building. The flows are balanced to provide 20% new air, which maintains a slight positive pressure to inhibit subsurface vapor intrusion, plus sufficient ventilation to dilute any vapors potentially entering by diffusion to well below concentrations of concern.

A site with residences built on layered geologic materials in a humid climate had a series of fine-textured layers impeding infiltration sufficiently to create saturated layers that act as a vapor barrier. Vapor monitoring wells were installed and sealed at different depths and a pneumatic pumping test was performed, which showed that the different intervals can be pneumatically isolated by the function of the fine-textured layers as vapor barriers.

In all of these cases, the key to understanding the vapor intrusion and attenuation processes required unique data in addition to conventional groundwater, soil gas, indoor air and outdoor air data. Together with the conventional data and mathematical models, the assessments provide multiple lines of evidence to support their conclusions. High quality data is essential, because if any one line of evidence has a systematic bias, the various lines of evidence may not be mutually supportive.

In areas where unacceptable vapor intrusion is not easily refuted, it may be preferable to install a sub-slab depressurization system (e.g. radon mitigation system) to protect indoor air quality proactively. These systems are effective and can often be installed for less than the cost of a detailed site investigation.

Conclusion

The keys to successful vapor intrusion evaluations are selecting the tools and scope of investigation sufficient for protection of human health and regulatory compliance and communicating the findings logically and clearly to all stakeholders. High quality data is essential to decision-making and to maintaining professional credibility throughout the process. The knowledge base for vapor intrusion continues to expand and efforts are underway to compile and share the data being collected at an increasing number of sites. It is clear that the vapor intrusion pathway evaluations will be required at many sites and effective and efficient methods to assess this pathway are needed. The strategic approach described above will focus the assessment scope and methods to the most important processes and conditions, thereby providing a cost-effective and technically defensible outcome.

The preceding article has been condensed from its original format. For the full text, please visit us at www.airtoxics.com.

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Partnering for Success: *A Laboratory Perspective*

The vapor intrusion investigator is responsible for ***"selecting the tools and scope of investigation sufficient for protection of human health and regulatory compliance…"***. To do this, the investigator must invest in a partnership with an analytical laboratory who understands the technical challenges associated with vapor intrusion, delivers results that are technically defensible, and provides high quality data that can aid in the assessment of a vapor intrusion pathway. This article will discuss how this partnership, through effective communication, technical understanding, and commitment to quality will deliver the required results.

Effective Project Communication

Assessment of the vapor intrusion pathway may involve the analysis of soil vapor, indoor air, and outdoor air for the chemicals of concern. Soil vapor samples, which may be 5 to 6 orders of magnitude higher in concentration than outdoor air, should be approached differently than ambient level samples. By effectively communicating the reporting limit requirements for the type of sample being collected, the data set will be improved and overall project costs will be lowered. Examples of this are given below.

Method TO-15 SIM versus Full Scan

The reporting limit for a sample will determine the approach that the laboratory takes to generate the analytical result. A quadrupole mass spectrometer can be operated in two modes often referred to as ***full scan*** and ***selected ion monitoring*** (SIM). In full scan mode, the mass spectrometer sweeps through a range of atomic mass units (amu) which typically range from 35 to 350 amu. The mass spectrometer is capable of scanning through these 315 masses about 2 times per second. Running in full scan mode is beneficial because a detectable target analyte at the appropriate retention time will be complemented by a complete mass spectrum of the target analyte. The target analyte spectrum can be further confirmed by comparison with reference spectra from a commercially available spectral database library. Standard Method TO-15 analysis requirements can be achieved by operating the mass spectrometer in full scan mode. The reporting limit of 0.5 parts per billion by volume (ppbv) using this method is more than sufficient for the analysis of soil vapor.

When investigating ambient samples at the 10^{-6} cancer risk levels, the mass spectrometer must detect reporting limits that achieve single digit parts per trillion by volume (pptv). To improve the sensitivity of a quadrupole mass spectrometer, the instrument is operated in the SIM mode. In SIM mode, the chemist creates a method to monitor two or three ions at the approximate retention time of the target analyte. The increased dwell time for the selected ions improves the sensitivity of detection up to one hundredfold versus operating the mass spectrometer in the full scan mode. One drawback of operating in the selected ion monitor mode is that the target analyte lacks the complementary full mass spectrum that is provided by the full scan mode.

Analyzing a sample by SIM requires additional method development by the laboratory. Since target analytes differ for each vapor intrusion project, SIM methods require modifications depending on the specific target analyte list for the project. The laboratory must be aware of potential coeluting analytes or matrix interferences that would result in the reporting of a false positive for the target analyte. From a cost perspective, the additional method development and the specialized expertise required for SIM analysis makes it more expensive than full scan mode analysis. The limited spectral information provided by the SIM method makes this a poor technique for screening data when not supported by

> ***"effective communication, technical understanding, and commitment to quality"***

modeling, survey, or prior full scan screening evidence. The vapor intrusion investigator should work with the laboratory to determine proper application of the SIM method.

Sampling Media Used for Investigating the Vapor Intrusion Pathway

Whether collecting soil vapor samples or ambient air samples, usually the media of choice is a Summa® canister. Soil vapor samples can be collected in a tedlar bag, but the hold time is limited to 72 hours from sample collection. Therefore, large-scale soil gas sampling events collected in tedlar bags must be coordinated carefully with the laboratory. Ambient air samples should never be collected in tedlar bags due to residual VOC contamination as high as 50 ppbv.

The laboratory is responsible for delivering evacuated and uncontaminated Summa® canisters for the project. Method TO-15 specifies that the laboratory must demonstrate that they can deliver media cleaned to a level of 0.2 ppbv for target analytes. Air Toxics Ltd. (ATL) maintains a canister certification program and database to track the potential for false hits due to contaminated media. For the calendar year 2003, ATL had 1 hit for benzene above the reporting limit for over 2700 canisters certified.

Method TO-15 does not address certification requirements for pptv analysis. When ATL certified a random set of 100 canisters at pptv levels, every canister had a hit for benzene, with an average concentration of 14 pptv. When performing pptv analysis, every canister must be certified for target analytes by GC/MS at or preferably below the target analyte reporting limit. Not every cleaned canister will pass for a given project's reporting limit requirements and failed canisters are not utilized for pptv analysis. Therefore, SIM certified canisters cost about twice as much standard Summa® canisters to produce for a project.

Ensuring the Defensibility of Data

Data defensibility is defined as data that is both relevant and reliable. The relevancy of the data is established by using an analytical method appropriate to the analysis of volatile organic compounds in the respective sample, either soil vapor or ambient air. To achieve 10^{-6} cancer risk levels for ambient air samples, Method TO-15 is modified for SIM acquisition. The laboratory's method development activity, analytical expertise, and well documented quality standards provide the data user with confidence in the laboratory's ability to generate relevant and reliable data at low pptv levels.

Another step in ensuring a reliable data set is to use a laboratory certified under the National Environmental Laboratory Accreditation Program (NELAP). NELAP is based on ISO standards 17025 requiring laboratories to use a systems approach for achieving data quality, documentation, and reporting. A laboratory undergoes a full NELAP audit biennially by the sponsoring State authority.

Conclusion

These are just a few considerations that go into the successful investigation of a vapor intrusion pathway. Communication with the laboratory on reporting limit requirements for the various samples collected from soil vapor or ambient air will provide a more relevant data set and may lower the analytical project cost. Using a NELAP-certified laboratory will ensure the data user that the quality systems are in place to meet the highest degree of nationally recognized quality standards. Lastly, a strong, technically competent partnership between the vapor intrusion investigator and the laboratory is key to a project's success.

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Air Toxics Ltd. is committed to understanding the needs of clients working with vapor intrusion projects. For more information on low level VOC sampling and vapor intrusion, or to request a specialized seminar at your office, please contact Nathan Shafer at 800-985-5955 or via email at n.shafer@airtoxics.com.

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VAPOR INTRUSION CAPABILITIES

ATL's dedicated Vapor Intrusion Team

By focusing on vapor phase samples, Air Toxics Ltd. (ATL) has become the nation's leading environmental testing facility for the analysis of ambient air. ATL maintains its leadership in pptv analysis by continually investing in analytical systems and developing new technologies to meet the demanding requirements of the vapor intrusion investigation. In 2003, ATL supported several large vapor intrusion projects and, for example, were able to deliver 580 SIM-certified canisters and 24-hour flow controllers in just a one week period of time.

We also maintain the highest level of data defensibility. ATL has a laboratory team specifically trained for the demanding requirements of ultra-low level VOC analysis. This team has put systems and standard operating procedures in place to maintain the integrity of the sample and provide reliable results for VOC analysis at pptv levels.

Please call ATL at 1-800-985-5955 to discuss your next vapor intrusion project. At ATL, we want to be your partner in success.

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Air Toxics Ltd. (ATL) is one of the nation's leading testing facilities for the analysis of environmental air samples. Our level of experience, data integrity, technical expertise, analytical capacity and dedicated service make us uniquely qualified to support even the most rigorous project requirements.

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