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Beginning with the Environmental Protection Agency's 2002 guidance on vapor intrusion, observers have noted an increasing interest in the subject, both at the federal and state level. Potentially responsible parties are now on notice that EPA expects vapor intrusion to be addressed in the superfund cleanup process, while a growing number of states are also devising their own vapor intrusion regulations.

Stressing the importance of site-specific data, and potential background sources, attorneys Gregory A. Bibler and Elizabeth F. Mason in this article discuss the reasons for increased attention to vapor intrusion, and propose a number of steps that PRPs can take to shape risk-exposure estimates.

Increased Scrutiny of Indoor Air Pathway Shifts Investigation & Cleanup Standards

By Gregory A. Bibler &
Elizabeth F. Mason

Recent technical guidance from the U.S. Environmental Protection Agency and emerging new standards and regulations from state environmental agencies target inhalation of vapors migrating from contaminated soil and ground water into buildings as an exposure pathway that must be addressed in risk assessments and cleanup plans. This increased regulatory attention to the potential for particular chemicals, volatile organic compounds (VOCs), detected in the subsurface to migrate into buildings poses the prospect for more rigorous cleanup standards for soil and ground water, and for additional monitoring and controls for indoor air.

In its five-year reviews of Superfund sites where VOCs remain in concentrations above levels that allow for unlimited use and unrestricted exposure, in fact, EPA is reevaluating remedies to determine whether vapor intrusion poses an unacceptable risk to human health.

Companies charged with managing the investigation and cleanup of sites that have VOCs in soil or ground water not only need to be aware that agencies may demand data demonstrating that the indoor air pathway has been adequately addressed; they also should take steps early in the assessment process to control both the measurement and the perception of this potential exposure. A thoughtful conceptual model must be developed for characterizing the potential interaction between subsurface conditions—including geology, utility corridors, depth to ground water surface, and chemical concentrations in soil and ground water—and existing or future structures on the surface. Based on that model, information should be collected in a logical se-

quence calculated to control both the costs of the investigation and the impact of any data collected on public perception, including that of workers, tenants, and adjoining landowners.

In scoping the investigation of a site where vapor intrusion may be an issue, companies should be mindful that mathematical models and regulatory standards which EPA and state agencies now use to measure risk depend heavily on conservative default values. Initially, these models and standards may be used as a screening tool to determine whether site conditions warrant closer examination. Where these screening levels are exceeded, collecting additional soil vapor or indoor air data to substitute for regulatory default values, and conducting a more rigorous risk assessment using site-specific data, typically will produce more representative and reliable calculations of exposures, risks, and remedial objectives.

Basics of Vapor Intrusion

Because VOCs are present in a host of commonly used substances, including chlorinated solvents, chemical feedstocks, and gasoline and other petroleum products, they are among the chemicals most often detected in soil and ground water. VOCs can volatilize from soil or ground water into pore spaces between soil particles and, in the form of soil gas, move up through the soil to the surface. Where this occurs beneath a building, the vapors can enter the indoor air space of the building through utility openings or cracks in the building's walls or foundation. In addition, vapors can travel through preferential pathways in the subsurface, including sewers and underground utility lines, to buildings located at some distance from the historical source(s) of contamination.

Vapor intrusion, in turn, may result in the accumulation of low levels of volatilized chemicals in a building's indoor air. Whether and to what extent chemicals may accumulate will depend on a variety of factors, including the concentration and rate of chemicals intruding, the design and condition of the building, the design and operating effectiveness of the building's ventilation system, and the intensity and patterns of use within the building. Where present in sufficient concentration and in areas regularly frequented by workers or homeowners, inhalation of chemicals in indoor air may pose a long-term risk of chronic health effects.

The inhalation exposure pathway from vapor intrusion differs from other pathways, such as ingestion of or dermal contact with soil or ground water, for several reasons. First, health effects data and regulatory values are substantially more developed for the ingestion and dermal contact pathways than for the pathway from the subsurface, into buildings, and through inhalation to workers, residents, and children. Second, evaluating the potential exposure itself can be more complicated. It typically requires the application of predictive computer modeling to site-specific data, including the results of indoor air, soil gas, and ground water monitoring. Third, it is often difficult to differentiate contributions from background sources, including VOC-emitting consumer and household products such as cleaners, solvents and gasoline, from vapors migrating through the subsurface.

Increased Attention to Vapor Intrusion

EPA is signaling strongly that it expects responsible parties to start evaluating exposures and risks presented by the vapor intrusion pathway during the remedial investigation and risk assessment phase of the superfund process, and to address this pathway where it may pose a risk, even if that risk is first identified after remedy selection and implementation. The technical guidance that EPA issued in November 2002, *Draft Guidance for Evaluating the Vapor Intrusion to Indoor Air Pathway From Ground water and Soils*, outlines a three-tiered evaluative process for determining whether the vapor intrusion pathway at a site is complete—that is, whether humans are being exposed indoors to chemical vapors originating from site contamination outdoors—and, if so, whether there may be an unacceptable risk to human health as a result of this exposure.

Many states are issuing their own regulations, policies and guidance documents. For example, Massachusetts, which was one of the first states to address vapor intrusion in its promulgated regulations, recently proposed to make its regulations more stringent. New Jersey presently is in the process of writing its own regulations governing assessment and response actions necessary to address potential risks from vapor intrusion. And in Colorado, where a jury recently awarded $1 million in damages to plaintiffs bringing claims relating to vapor intrusion, state regulators in August 2004 finalized an interim state policy outlining a risk evaluation and management approach for trichloroethylene (TCE) that appears to establish the most stringent screening level nationally for TCE in indoor air.

Prompted in part by the issuance of EPA's vapor intrusion guidance, there are growing concerns about the reliability of EPA's mathematical models for estimating indoor air concentrations and associated health risks from vapor intrusion into buildings. These models—which the EPA guidance incorporates—are based on the widely used Johnson and Ettinger model, which provides an estimated attenuation coefficient that relates the vapor concentration in the indoor air to the vapor concentration at the source of contamination. Although environmentalists and other critics have asserted that EPA models may underestimate the risks from vapor intrusion, it is clear that these models are more likely to *over predict* indoor air concentrations resulting from vapor intrusion.

Risk assessment professionals point to two major sources for potential error in EPA's new guidance. First, the Johnson and Ettinger model was developed for use as a screening-level model and, as a result, is based on a hypothetical set of assumptions regarding contaminant distribution and occurrence, subsurface characteristics, transport mechanisms, and building construction which are, by default, conservative. Second, in developing its own models, EPA modified the Johnson and Ettinger model into a series of easy-to-use spreadsheets that allow the user to rely on conservative pre-defined input values for such critical soil-dependent parameters as soil moisture and permeability, and building-related parameters as building air exchange rate and crack width and ratio. This reliance on generalizing assumptions and default values, while making EPA's models appropriate for use as a screening tool, also renders their results more conservative than would the use of site-specific data.

Parties investigating whether vapor intrusion may pose an unacceptable risk at their sites should be careful not to misinterpret the purpose and the results of

  TXLR ISSN 0887-7394

EPA's new guidance. The guidance compares measured or reasonably estimated contaminant concentrations in the ground water, soil gas or indoor air at a given site to generic, media-specific ''target'' concentrations. These generic target contaminant concentrations are intended to correspond to indoor air concentrations that, according to EPA, are associated with a specific incremental lifetime cancer risk of 10^{-4}, 10^{-5} or 10^{-6}, or a hazard quotient greater than 1, whichever is more restrictive. The guidance gives the user the option of factoring in limited site-specific information, such as soil type and depth to contamination, in order to select generic target concentrations that are more representative of the conditions at the user's site; however, use of such target concentrations still may lead to less representative and reliable results, as they are based on EPA's vapor intrusion models and therefore reflect the use of EPA's model default values.

EPA's reassessment of inhalation risks at sites affected by releases of VOCs is the result, in part, of its new toxicity assessment for TCE. Combining EPA's vapor intrusion guidance with its new TCE risk assessment has the potential to create an even greater overestimate of risk. The revised assessment does not provide a single cancer slope factor for use in risk assessments, as the previous assessment did, but rather identifies a range of slope factors, without any guidance for selecting the most appropriate factor from this range. In addition, the revised assessment slope factors describe the risk from TCE in terms of oral exposure rather than inhalation exposure, thus requiring the application of one of several available oral-to-inhalation extrapolation methods to calculate the potential risk from the inhalation exposure pathway. If a risk assessor selects the revised assessment's upper-bound cancer slope factor for TCE and applies the default method for oral-to-inhalation extrapolation from EPA's vapor intrusion model, the result will be the calculation of an unacceptable indoor air risk at a site even when TCE concentrations in ground water meet the MCL.[1]

EPA has undertaken a nationwide survey of National Priorities List sites where TCE is a contaminant of concern, in order to determine whether there is an inhalation exposure pathway from vapor intrusion that was not evaluated when remedial investigations were performed at these sites. As of January 2003, according to the Agency for Toxic Substances and Disease Registry, about 875 of the then approximately 1,300 sites on the NPL had TCE contamination in any environmental medium, and about 700 of these 875 had TCE in ground water. EPA's new risk assessment for TCE may have an impact on the remedy selected, or on five-year reviews of remedies previously selected, at all of these sites.

Strategic Considerations for Responsible Parties

There are several strategic steps that responsible parties can take at sites where the presence of VOCs in soil or ground water poses the potential for indoor air contamination through vapor intrusion:

- ***Undertake appropriate planning to address the vapor intrusion pathway in the remedial investigation.*** One of the key components of a remedial investigation is the development of a conceptual site model. This model is intended to provide a three-dimensional picture of site conditions and includes the known and suspected sources of contamination, the types of contaminants, the affected media, the known and potential routes of contaminant migration, and the known and potential human and ecological receptors. Conceptual site models have historically focused on soil and ground water as the primary affected media at a site, and on such exposure pathways to human receptors as direct contact with surface soil or ingestion of ground water through its future use as a drinking water source.

  Now, EPA and states are expecting responsible parties to investigate the possible infiltration of occupied buildings by contaminants that have volatilized from contaminated soil or ground water and migrated through cracks in foundations or preferential pathways such as utility corridors into indoor air. It is critical that consultants engaged to undertake remedial investigations understand the technical complexities involved in properly evaluating the vapor intrusion pathway, and appropriately scope and sequence their site characterization activities. A carefully planned investigation that is focused on collecting appropriate site-specific data can save time and money while determining with a greater degree of accuracy whether there is in fact an unacceptable risk to human health from vapor intrusion at the site.

- ***Collect sufficient site-specific data to be able to avoid using EPA-developed default values to the extent possible.*** As noted above, there are significant concerns that relying solely on mathematical models, whether EPA's or others, may lead to overly conservative results and indicate the need for remedial action even where such action may not be necessary. While such mathematical models may be used initially as screening tools to determine whether site conditions require further investigation, instituting a field program to collect soil vapor or indoor air data, and conducting a site specific risk assessment employing that data, typically will yield more reliable results. Moreover, given the importance of the risk assessment in determining remediation endpoints, it is important that the risk assessor be made part of the team early in the process for developing the site conceptual model and defining a step-by-step assessment plan.

- ***Determine whether the migration of volatilized contaminants from the subsurface to indoor air is occurring, not just whether contaminants of concern are present in indoor air.*** EPA's technical guidance recommends the collection of indoor air data if the model's user cannot conclude, after completing a screening evaluation, that the vapor intrusion pathway is incomplete, that is, that there is no unacceptable human exposure to contaminants in indoor air that volatilized from the subsurface. This approach to site characterization and risk assessment, however, is fraught with peril. VOCs are found in dozens of commercial and consumer products and, as a result, are ubiquitous in ''background concentrations'' in both ambient and indoor air. As one commentator has noted, background concentrations of VOCs such as TCE and benzene can be from one to three orders of magnitude higher than a risk-based target indoor air concentration corresponding to a one in one million (10^{-6}) incremental cancer risk.[2]

  Falsely connecting VOCs measured in indoor air to VOCs present in soil or ground water can mask the true source of the chemicals, misdirect remedial resources, and give rise to a host of other problems, including potential lawsuits. To avoid this, it is important: (i) to collect adequate ground water, soil and soil gas data to support a valid assessment of the potential for subsurface concentrations

[1] *See* Manu Sharma, ''Vapor Intrusion—EPA Vapor Intrusion Model Reliability and Role of Background Concentrations in Risk Assessments,'' *Risk Policy Report*, Vol. 11, No. 8 (8/31/04).

[2] *Id.*

to mobilize into buildings; (ii) to collect data on background levels of VOCs in indoor and ambient air on the site and from the literature; (iii) complete an inventory of all potential sources of VOCs in buildings; and (iv) tailor indoor air sampling methods, locations and conditions to measure the flux of VOCs into the building from subsurface sources, apart from contributions from other background sources.

- ***Even if a site has an approved remedy in place, be prepared to respond to requests for reassessments***. As noted above, EPA is reevaluating remedies at those NPL sites where TCE is a contaminant of concern, to determine whether there are any risks from vapor intrusion that warrant reopening signed records of decision or otherwise taking action to address those risks. Similarly, the agency is now using the five-year review as an opportunity to revisit remedial decisions at sites where there are VOCs in soil or ground water. Parties responsible for sites at which reassessments are likely should reacquaint themselves with the terms and procedures of consent decrees and other instruments under which they completed approved remedial measures. They also should consider developing a legal strategy and technical response should the governing environmental agency seek to reopen the previously approved remedy.
- ***If vapor intrusion is identified as an issue at your site, consider all your remedial options***. EPA suggests in its vapor intrusion guidance that the most appropriate response action for addressing vapor intrusion is likely to be ventilation, rather than, for example, removing, treating, or controlling source material in soil or ground water. Ventilation, however, can be expensive, not only because of the capital costs incurred at installation, but also because it requires operation and maintenance over time. Other options for addressing vapor intrusion include: (i) installing sub-slab depressurization systems similar to those used in conventional radon abatement systems; (ii) sealing the building envelope or installing vapor barriers (e.g., placing impermeable geotextile membranes beneath the building, or spraying on a rubberized asphalt emulsion gas vapor membrane); (iii) installing active or passive gas venting systems; (iv) modifying the building foundation; (v) installing an active site remediation technology such as soil vapor extraction; or (vi) installing indoor air purifiers or adsorption systems such as carbon filtration. Again, a focused remedial investigation and robust risk assessment will result in more representative and reliable calculations of the exposures, risks, and remedial objectives at a site, which in turn will enable the selection of a remedial option, if necessary, that is most appropriately tailored to the actual conditions at the site.
- ***Before you begin, establish a plan for communicating sampling results***. Regardless of the results, the mere prospect of indoor air testing has the potential to set off public concern or, worse, symptoms of ''sick building syndrome,'' whether real or imagined. Before instituting any indoor air sampling, therefore, parties should draft a plan for communicating the purpose and the results of sampling. Where appropriate, parties may need to consult with local health and other government officials, citizen groups, union stewards, and leaders of other organizations likely to voice reaction to any results. It is also important to note that, under federal and state worker health and safety laws, notice of the results of indoor air testing may need to be posted in the workplace or otherwise communicated to workers.

Conclusion

Migration of volatilized compounds from below the ground surface into occupied buildings is difficult to measure and model. Emerging regulatory programs for addressing this potential pathway can overestimate the magnitude and the risk of exposure and underestimate contributions from other sources.

Absent a thoroughly documented conceptual model that takes into account site-specific soil vapor and ground water data, together with full information on potential background sources, the results of indoor air monitoring will tend to exaggerate the connection between subsurface contamination and indoor air. Careful planning is important to frame the investigation, control the creation and evaluation of the data, and establish realistic objectives and methods for effectuating a truly risk-based remediation program.

  TXLR ISSN 0887-7394