Vapor Intrusion Basics

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So your client thinks that it has no more worries with its remediated site? Not so fast. There's a new factor to consider—vapor intrusion.

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THE PAST DECADE witnessed a huge transformation in the way that contaminated properties have been cleaned up. The EPA and most state brownfield programs adopted risk-based cleanup approaches that permitted residual contamination to remain at a site depending on the nature of the land use and allowed the use of institutional controls to prevent exposure to the residual contamination.

These developments stimulated the reuse of contaminated properties by expediting remediation and reducing cleanup costs. However, owners of these sites may now find themselves subject to additional cleanup because the potential for vapor intrusion may not have been evaluated when the cleanup was completed. For example, the New York State Department of Environmental Conservation ("NYSDEC")

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recently announced that it would re-examine approximately 430 sites contaminated with chlorinated solvents that had been remediated before 2004.

Like the NYSDEC, the EPA and many state environmental agencies have been increasingly focusing on vapor intrusion in the investigation and remediation of contaminated sites. Because the science behind vapor intrusion is rapidly evolving and the preferred technical approaches for addressing the issue vary considerably from state to state, owners and operators of contaminated sites are finding themselves subject to costly delays and much uncertainty as they try to satisfy the ever-changing regulatory requirements. In addition, responsible parties who thought they had completed remediation at sites and received "no further action" letters are now finding themselves subject to additional investigation and remedial obligations. Moreover, the potential for vapor intrusion is creating potential exposure for third-party claims for personal injury and property damage.

Vapor intrusion may present new terms and technical concepts that may be unfamiliar even to experienced environmental lawyers. This article is intended to acquaint the practitioner with the key concepts and issues and the relevant regulatory background.

KEY CONCEPTS AND ISSUES • Contamination is usually expressed in terms of mass (e.g., parts per million, parts per billion). For vapor intrusion, the key measurement will be contamination per volume of air, which is expressed in terms of micrograms per cubic meter (mcg/m^3). Some of the key issues that lawyers must be prepared when addressing vapor intrusion are as follows:

- How to determine if there is a potential for vapor intrusion;
- How to investigate the extent of a potential vapor intrusion issue;
- How to determine the appropriate action level (for example, OSHA versus state health-based standard);
- When to proceed with further investigation or when to simply implement mitigation;
- How to determine if mitigation is sufficient or if more extensive remediation is necessary;
- When and how to communicate with occupants and adjacent property owners or operators about potential vapor intrusion issues;
- How to evaluate if the current or proposed mitigation system is adequately designed to protect the health of building occupants; and
- What kind of long-term operation and maintenance systems should be established.

REGULATORY BACKGROUND • Until recently, federal and state remedial programs have focused on identifying and addressing contaminant concentrations in soil and groundwater. The upward migration of contaminated vapors from soil or groundwater into indoor air was generally not considered to be a significant potential exposure pathway. As a result, cleanup remedies usually focused on reducing soil or groundwater contamination or at least eliminating the pathways of exposure to the contaminated media. The exception to this rule was radon gas in certain parts of the country, gasoline vapors associated with large fuel leaks, or migration and accumulation of explosive levels of methane gas from former landfills.

Risk-Based Corrective Action

Vapor intrusion began to attract some attention with the introduction of risk-based corrective action ("RBCA"), in which cleanup levels are based on the actual (not theoretical) risks posed by contaminants. Because petroleum compounds biodegrade fairly rapidly, the common belief was that effects from sub-surface petroleum contamination would wear off before reaching buildings within proximity of the contamination. The RBCA practice issued by the American Society for Testing and Materials ("ASTM") in 1994, E 1739–95, *Standard Guide for Risk-Based Corrective Action Applied at Petroleum Release Sites,* did provide for estimating indoor air concentrations of volatile compounds found in soil or groundwater. This practice used a form of the Johnson & Ettinger model (the "J&E Model"). *See* Paul C. Johnson and Robert A. Ettinger, 1991 *Heuristic Model for Predicting the Intrusion Rate of Contaminant Vapors into Buildings*. 25 Envtl. Sci. & Tech. 1445 (1991).

Many states and the EPA adopted this approach and allowed responsible parties to simply model the vapor intrusion pathway instead of collecting indoor air samples even for contamination involving chlorinated solvents. For example, the EPA's 1996 Guidance establishing generic soil screening levels for volatile organic compounds ("VOCs") set forth specific equations for evaluating the groundwater to indoor air pathway. *Soil Screening Guidance: User's Guide* (EPA540/R-96/018 July 1996), available at www.epa.gov/superfund/resources/soil/ssg496.pdf. The EPA also referred to vapor intrusion in supplemental guidance for its Human Exposure Environmental Indicators ("EIs") determination for measuring progress under the Resource Conservation and Recovery Act ("RCRA") corrective action program. The states that did evaluate vapor intrusion usually predicted potential indoor air concentrations based on groundwater concentrations. If groundwater was below 15 feet in depth, evaluation of the vapor pathway was generally not required.

Regulatory Revision

The regulatory landscape changed after significant levels of chlorinated solvents in the form of dichloroethylene ("DCE") were found in homes near the Colorado Department of Transportation Materials Testing Laboratory site (also known as the Redfield Rifle Field Scopes Site) in Denver, Colorado in 2000. The elevated levels were detected even though the EPA model had predicted little or no contamination. This discovery led the EPA and state agencies to re-examine their policies toward vapor intrusion. In December 2001, the EPA issued supplemental EI guidance. *See RCRA Draft Supplemental Guidance for Evaluating the Vapor Intrusion To Indoor Air Pathway* (December 2001), available at www.epa.gov/epaoswer/hazwaste/ca/eis/vapor/vapor.pdf. The agency then issued draft technical guidance in November 2002 that was designed to provide regulators and responsible parties with procedures for screening sites to determine if the vapor intrusion pathway was complete and assessing if the pathway presented an unacceptable risk to human health. *Draft Guidance For Evaluating the Vapor Intrusion To Indoor Air Pathway From Groundwater And Soils (Subsurface Vapor Intrusion Guidance)*, 67 Fed. Reg. 71,169 (November 29, 2002)("Draft Guidance"). The Draft Guidance was not intended as a tool for evaluating the extent of the risk or for eliminating the risk. The EPA also recommended that this guidance be used not just for the RCRA corrective action program but also for Superfund and brownfield sites. For underground storage tank ("UST") sites, the EPA recommended that regulators and responsible parties continue to use the agency's RBCA guidance. *See* OSWER Directive 9610.17: *Use of Risk-Based Decision Making in UST Corrective Action Programs,* available at www.epa.gov/swerust1/directiv/od961017.htm. Dozens of states have revised or are in the process of revamping their remedial programs to address vapor intrusion.

Revised Exposure Limits

In addition to revising its technical guidance, the EPA also tightened the acceptable exposure limits for trichloroethylene ("TCE"). Many states have adopted their own indoor action levels that can vary significantly from state to state and within a state depending on the regulatory agency that is supervising the cleanup. Often, the disparity is a due to different inhalation cancer slope factors or exposure assumptions.

WHAT IS VAPOR INTRUSION? • Vapor intrusion refers to the transport of vapors from subsurface soils or groundwater into buildings through the natural exchange of air or mechanical ventilation systems. To develop a vapor intrusion problem, there must be a source of contamination and a pathway for entry of the contaminants into a building.

The source of the vapors can be from contamination in the soil, dissolved in groundwater, or that exists as a separate phase with the groundwater known as a non-aqueous phase liquid ("NAPL"), such as gasoline floating on the top of the water table. Once these contaminants are introduced into the subsurface, they may move as a vapor through the soil and into building structures.

In general, contaminated vapors want to move from areas of high concentration (e.g., groundwater) to areas of low concentration (building interiors). Buildings will generally be more prone to vapor intrusion when there is:

- Porous fill material or soil beneath the building;
- High concentrations of contamination; and
- Either shallow contaminated groundwater or contaminated soil just below the building foundation or slab.

However, the factors that influence the movement of vapors from the subsurface soil or groundwater into buildings can be very complex. As a result, the potential for vapor intrusion is highly site-specific and will depend on such variables as:

- Type of contaminant;
- Concentration of the contaminant;
- Depth and location of the contamination;
- Nature of the soil;
- The pathway of exposure; and
- Building design.

Common Chemicals Of Concern

The contamination source can be natural (such as radon gas) or from human activity (such as releases or spills of certain types of hazardous materials). For a vapor intrusion problem to occur, the contaminants must readily volatize into gas at normal atmospheric pressure and temperature, and present health risks at low concentrations.

The EPA has identified 107 compounds that potentially present unacceptable inhalation risk, but the principal contaminants of concern tend to be chlorinated solvents such as:

- DCE;
- TCE;
- Tetrachloroethylene ("PCE" or "PERC");
- Carbon tetrachloride; and
- Vinyl chloride.

Fuel constituents also pose a vapor intrusion risk, including:

- Benzene;
- Toluene;
- Ethylbenzene; and
- Xylene

(The above are collectively referred to as "BTEX".)

Other contaminants that are not as volatile but can still cause concerns at low concentrations include:

- Mercury;
- Polychlorinated biphenyls ("PCBs"); and
- Certain semi-volatile organic compounds ("SVOCs") associated with diesel fuel and heating oil.

Contamination Levels

In general, contamination levels will significantly reduce as they move from one media to another, such as from groundwater to soil. Thus, contamination that is dissolved in groundwater must be present at higher concentrations to present a potential for vapor intrusion than contamination in soil. The potential for vapor intrusion may also vary by season. For example, contaminants will be more volatile when temperatures are warmer.

Proximity

Likewise, the deeper the contamination is located, the less likely it is to present a potential for vapor intrusion. Until recently, the conventional thinking was that contamination deeper than 15 feet would not likely present a significant risk of vapor intrusion. However, the new EPA guidance suggests that regulators and responsible parties evaluate the vapor intrusion pathway when the contamination is within 100 feet of a structure.

Geology

The nature of the geology beneath a building can also influence the potential for vapor intrusion. Vapors can migrate through porous, sandy soil much easier than through clay soil. Likewise, there is a greater potential vapor intrusion when the bedrock below a building is fractured.

Vapor Pathways

The contamination can vaporize from soil and groundwater directly beneath a building or migrate from a preferential pathway such as sewer or utility conduit. The vapors can move through the pore spaces in the soil and then infiltrate buildings through cracks in walls or foundations and through open windows or doors. Buildings with dirt floors or crawl spaces, stone foundations, and basements will have a higher potential for vapor intrusion because the below-grade spaces create greater surface area for vapors to infiltrate and may be closer to the subsurface source of the contamination. Foundations and subsurface walls constructed from cement blocks may be more prone to vapor intrusion because of cracks around mortar that can allow subsurface vapors to enter the building. A single-pour cement foundation may be more resistant to vapor intrusion than foundations with separately poured footers and floors because of the potential for cracks along stress lines. Buildings with sumps, or with gaps around piping or utility lines, may also have a higher potential for vapor intrusion.

A building's mechanical ventilation system can also create a negative air pressure that can draw contaminated vapors from the subsurface into the building. The use of fireplaces, heaters, open windows, air conditioners, or wind can also result in building depressurization. Newer buildings that have "tight" building design for energy efficiency have a greater potential for accumulation of vapors than older buildings that may have greater exchange rates with the outside air. Moreover, during winter months when fresh air exchange is reduced, the temperature differential between the indoor air of building and the air in the soil can cause a "stack effect" that can draw vapors into a building much like a fireplace draws air from a room. Fortunately, building an air-handling system can also be used to mitigate these effects by increasing the air exchange or creating a positive air pressure gradient on the ground floor.

Hazards

Once inside a building, the principal concern is exposure to occupants through inhalation. In some extreme cases, vapors may accumulate to levels that can pose short-term safety hazards (such as the risk of explosion), acute health effects, or aesthetic problems such as odors (for example, methane or gasoline). Often though, vapors associated with TCE or PCE may accumulate at low levels that are below odor thresholds. In such situations, the principal concern is the potential for chronic health effects from long-term exposure to the low concentrations.

EPA GUIDANCE • The EPA Draft Guidance uses a tiered approach to evaluating vapor intrusion. The document is organized in the form of "questions" that lead the user through up to three tiers of evaluation.

Tier 1 Analysis

The first tier establishes whether compounds of sufficient volatility and toxicity are present in soil or groundwater within 100 feet of inhabited buildings using modeling. If the Tier 1 analysis indicates that chemicals of concern are not present, then the vapor intrusion pathway is considered to be not "complete" and no further exposure assessment is required. If the chemicals are present, the user must proceed to the second tier.

Tier 2 Analysis

The second tier compares groundwater and soil vapor concentrations at the site to generic screening levels that are based on 10^{-4}, 10^{-5}, and 10^{-6} risk levels. (The Draft Guidance sets the screening level at the maximum contaminant levels ("MCLs") established under the Safe Drinking Water Act for compounds where the screening level would set a level below the MCL.) The regulatory agency has the discretion to choose which risk level to use should be appropriate for determining if further action is required. For example, the 10^{-4} risk factor may be appropriate for commercial settings, whereas the 10^{-6} may be used when the affected property is used for residential purposes. The generic screening levels employ assumed "attenuation factors" or decreases in vapor concentration as the vapor moves from the groundwater to soils immediately below the building and then into the indoor air.

Tier 3 Analysis

Finally, if the screening levels are exceeded, the third tier of evaluation requires more site-specific investigation. If Tier 3 models indicate a potential for exposure at levels above the applicable criteria, additional data gathering (for example, sub-slab sampling or indoor air monitoring) or remediation may be needed to meet the human health environmental indicator.

KEY TECHNICAL ISSUES • Attorneys and their clients should be aware of several key technical issues that could significantly affect the reliability of data, whether mitigation is required, and projected costs of mitigation.

Modeling

There is considerable controversy about whether numeric models such as the J&E Model can accurately extrapolate indoor air concentrations from groundwater or soil vapor concentrations. In the case of petroleum contaminants, there is some evidence to suggest that the model is too conservative (predicts higher concentrations than are actually present) but there is other literature that indicates that the models under-predict potential levels of chlorinated solvents. Recent data suggests that newer versions of the model may better predict the potential for vapor intrusion from contaminants that do not degrade (such as the chlorinated solvents) as opposed to those that do degrade (such as petroleum hydrocarbons). There are also other scenarios (for example, buildings constructed over bedrock) in which there is less confidence in the model results. Another area of concern is the use of samples collected from outside a building footprint. There is some evidence that suggests the moisture and oxygen levels may be different below building structures and therefore not accurately predict the potential for vapor intrusion. As a result of the questions about modeling, some states do not allow any modeling at all and require actual indoor air sampling.

Sampling And Background Concentrations

It should be noted that the indoor air action levels for chlorinated solvents involve very low levels that push the limits of most laboratory equipment. Thus, special laboratory tests are often necessary to achieve the very low detection limits required by many chlorinated solvent indoor air action levels. In addition, sampling protocols are not well established and samples can easily become contaminated. Because of the very low detection limits, sampling devices such as canisters should be cleaned and tested before use to ensure that residual contamination from prior tests do not affect test results and result in false positives.

Other Indoor Sources Of VOCs

Another complicating factor is that many household products such as household cleaners, polishes, adhesives, furniture, carpets, textiles, sealants, glues, paints, waxes, lubricants, heating systems (i.e., fuels), cooking vapors, and personal care products contain VOCs that can be identical to the subsurface contaminants and be present in concentrations that exceed indoor air action levels. In addition, many household materials such as wallboard, ceiling tile, carpet, and upholstery can absorb VOCs during high-concentration periods and then release or "off-gas" the compounds when the indoor air VOC concentration decrease of because of changes in temperature or other environmental factors.

Thus, simply detecting VOCs in indoor air may not serve as conclusive evidence that source of the VOCs is the subsurface contamination. Unless the background levels can be identified and distinguished from the actual impacts from subsurface contamination, regulators may require additional testing programs that will go well beyond the affected area.

Investigation And Mitigation

The costs to evaluate vapor intrusion potential can become significant. Unless the regulatory agency allows the use of groundwater or soil vapor data to evaluate the potential for indoor air effects, indoor air tests are likely to be required. This will not only increase the costs of the remediation and delay work but could also unduly alarm occupants and nearby property owners when the responsible party comes knocking at their door to request permission to install a carbon canister in their home or office building.

Mitigation Techniques For Buildings

Depending on the results of the site investigation, mitigation may be required to eliminate the potential to exposure to contamination by vapor intrusion. Mitigation techniques can include relatively inexpensive passive systems such as selective placement of buildings, installing piping without fans, and filters. Active mitigation systems can range from the radon-type sub-slab depressurization systems with installation of vapor barriers or sealing of floors and foundations to soil vapor extraction systems and adjustments to the mechanical ventilation systems. In many cases, carefully installed standard radon venting systems will reduce indoor air concentrations below action levels. These systems can cost of approximately $1,200 to $1,500 for typical residential homes and approximately two dollars per square foot of area requiring remediation for larger commercial buildings.

In some cases, it may be more cost-effective to simply retrofit an existing structure with a vapor mitigation system than to conduct comprehensive indoor air sampling. Building owners or developers who suspect that vapor intrusion may be a problem should consider implementing a mitigation system into the design of a new buildings or an older building undergoing renovation because it can be substantially cheaper than retrofitting a completed building.

Soil And Groundwater Mitigation

In some cases, the only way to address the vapor intrusion problem may be soil or groundwater remediation. Ordinarily, soil and groundwater cleanup standards are based only on the effects to soil or groundwater. If a cap can prevent exposure to contaminated soil, or if groundwater is not being used for drinking water purposes, a property owner may be allowed to leave residual contamination in place at a site. However, because the indoor action levels may be so low, a property owner may be required to perform a more extensive cleanup to prevent the migration of vapors that would result in concentrations above the indoor air action levels. Indeed, in some instances, owners may find themselves forced to remediate groundwater below the MCLs established for drinking water. For example, the MCL for TCE is 5 parts per billion. However, depending on site conditions, in some states concentrations of TCE at the MCL could result in vapor levels above the state action level. In addition to cleanup costs, vapor intrusion can also result in significant indirect costs such as labor and electrical costs for maintaining operation and maintenance systems. Building owners may also be required to adjust the operation of mechanical air systems to minimize vapor intrusion but that could result in these systems operating less efficiently.

CONCLUSION • Because the science of vapor intrusion is still in its infancy and regulators are still being trained how to evaluate this pathway, there is significant potential for misintepretation and misapplication by regulators, consultants, and lawyers. When in doubt, regulators will often adopt the most conservative assumptions and procedures. To prevent unduly burdensome requirements, responsible parties and their lawyers should try to remain in control of the process. This means that attorneys must understand the vapor intrusion pathway, the technological approaches for evaluating the pathway, the status of controversial issues, and how these might affect decisions at the site in question. Responsible parties should identify risks in advance, reduce these risks through pre-emptive actions, and propose reasonable scopes of work to regulatory agencies if required.

PRACTICE CHECKLIST FOR

Vapor Intrusion Basics

The discovery that some environmental problems remained with sites thought to have been remediated has led to concerns about vapor intrusion. But what is the vapor intrusion problem all about and what can your client do about it?

• The basic risk-based corrective action ("RBCA"), in which cleanup levels are based on the actual (not theoretical) risks posed by contaminants, began after the EPA issued the *Draft RCRA EI Supplemental Guidance for Evaluating the Vapor Intrusion To Indoor Air Pathway* (December 2001) and the *Draft Guidance For Evaluating the Vapor Intrusion To Indoor Air Pathway From Groundwater And Soils (Subsurface Vapor Intrusion Guidance)*, 67 Fed. Reg. 71,169 (November 29, 2002)("Draft Guidance").

• "Vapor intrusion" refers to the transport of vapors from subsurface soils or groundwater into buildings through the natural exchange of air or mechanical ventilation systems. To develop a vapor intrusion problem, there must be a source of contamination and a pathway for entry of the contaminants into a building. In general, contaminated vapors want to move from areas of high concentration (e.g., groundwater) to areas of low concentration (building interiors). Accordingly, the vapor intrusion problem depends on the:

__ Type of contaminant;

__ Concentration of the contaminant;

__ Depth and location of the contamination;

__ Nature of the soil;

__ The pathway of exposure; and

__ Building design.

• The EPA has identified 107 compounds that potentially present unacceptable inhalation risk, but the principal contaminants of concern tend to be chlorinated solvents such as:

__ Dichloroethylene ("DCE");

__ Trichloroethylene ("TCE");

__ Tetrachloroethylene ("PCE" or "PERC");

__ Carbon tetrachloride; and

__ Vinyl chloride.

• Fuel constituents also pose a vapor intrusion risk, including:

__ Benzene;

__ Toluene;

__ Ethylbenzene; and

__ Xylene

• Other contaminants that are not as volatile but can still cause concerns at low concentrations include:

__ Mercury;

__ Polychlorinated biphenyls ("PCBs"); and

__ Certain semi-volatile organic compounds ("SVOCs") associated with diesel fuel and heating oil.

• Until recently, the conventional thinking was that contamination deeper than 15 feet would not likely present a significant risk of vapor intrusion. However, the new EPA guidance suggests that regulators and responsible parties evaluate the vapor intrusion pathway when the contamination is within 100 feet of a structure.

• The extent of vapor intrusion into a building is affected by architecture. If there are pathways from the soil or groundwater into a building, there could be a vapor intrusion problem. These pathways can include:

__ Sewer or utility conduits;

__ Cracks in walls or foundations;

__ Open windows or doors;

__ Dirt floors or crawl spaces, stone foundations, and basements;

__ Foundations with separately poured footers and floors;

__ Gaps around piping or utility lines;

__ Ventilation systems that create a negative air pressure that draws contaminated vapors from the subsurface into the building. (This can include the use of fireplaces, heaters, open windows, air conditioners or wind);

__ Modern "tight" energy efficient designs that can lead to accumulations of vapor intrusion, owing to diminished exchange rates with the outside air.

• The EPA Draft Guidance uses a tiered approach to evaluating vapor intrusion. The document is organized in the form of "questions" that lead the user through up to three tiers of evaluation:

_ The first tier establishes whether compounds of sufficient volatility and toxicity are present in soil or groundwater within 100 feet of inhabited buildings using modeling. If the Tier 1 analysis indicates that chemicals of concern are not present, then the vapor intrusion pathway is considered to be not "complete" and no further exposure assessment is required. If the chemicals are present, the user must proceed to the second tier;

__ The second tier compares groundwater and soil vapor concentrations at the site to generic screening levels that are based on 10^{-4}, 10^{-5}, and 10^{-6} risk levels. The regulatory agency has the discretion to choose which risk level to use should be appropriate for determining if further action is required;

__ Finally, if the screening levels are exceeded, the third tier of evaluation requires more site-specific investigation If Tier 3 models indicate a potential for exposure at levels above the applicable criteria, additional data gathering (for example, sub-slab sampling or indoor air monitoring) or remediation may be needed to meet the human health environmental indicator.

• There is considerable controversy whether numeric models can accurately extrapolate indoor air concentrations from groundwater or soil vapor concentrations. As a result of the questions about modeling, some states do not allow any modeling at all and require actual indoor air sampling.

• Mitigation techniques include relatively inexpensive passive systems such as selective placement of buildings, installing piping without fans, and filters. Active mitigation systems can range from the radon-type sub-slab depressurization systems with installation of vapor barriers or sealing of floors and foundations to soil vapor extraction systems and adjustments to the mechanical ventilation systems. In many cases, carefully installed standard radon venting systems will reduce indoor air concentrations below action levels.

• In some cases, the only way to address the vapor intrusion problem may be soil or groundwater remediation.