CPEO Brownfields Briefs

Brownfields and Vapor Intrusion

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Vapor intrusion, the emerging pathway now being investigated at sites across the country, is one of the most significant obstacles to the safe use of contaminated property. The science and regulatory framework for vapor intrusion has been developed for existing structures. Only recently has anyone begun to address redevelopment at sites likely to experience vapor intrusion.

Vapor intrusion is usually defined as the vertical migration of volatile subsurface contamination into buildings above. Where indoor toxic concentrations exceed health standards as well as ambient (outdoor) levels, mitigation is quickly put into place because the inhalation pathway is complete. It's not practical for residents, workers, or other building users to breathe substitute air.

Since the *Denver Post* ran a major series on vapor intrusion in January, 2002, regulatory agencies, responsible parties, affected communities, and all their consultants have been taking the vapor intrusion pathway seriously. Agencies have adopted protocols for predicting and measuring indoor air contamination. Mitigation systems, such as subslab ventilation, have been installed in hundreds, probably thousands of homes. At some sites, remedial programs have been altered to reduce or eliminate the sources responsible for indoor contamination.

A few state regulatory guidance documents now mention vapor intrusion and future development, but no agency—to our knowledge—has yet established a comprehensive approach as to where, when, and how to develop on property with shallow volatile contamination in groundwater or soil. Developers and property owners, as well as local officials, prospective residents, and other property users, face significant uncertainty.

Rising to the Surface

Volatile compounds in groundwater or soil exist as both liquids and vapors. The vapors fill microscopic pores in the soil, and their concentrations can be measured through soil-gas sampling. While groundwater contamination generally moves with the groundwater, forming elongated plumes, vapor-phase contamination spreads radially from the source, which can be the original contamination within the soil or an elongated plume of groundwater contamination.

Soil gas tends to rise, and if the contamination is near the surface, some of it is likely to be released at the surface. Many factors influence that process, including the type and concentration of the contamination, the make-up of the soil, and the presence of uncontaminated water near the surface. Organisms such as bacteria may break down the contaminants—particularly petroleum products—as they approach the surface.

Surface structures, including buildings and pavement, can influence the quantity and rate of vapor migration, by influencing both biodegradation and creating updrafts that pull the contamination up. Vertical vapor migration is often greater under structures than under open space.

Furthermore, like the air escaping from the puncture in a tire, soil vapor releases "find" holes—cracks in slabs, utility trenches, openings around pipes, etc.—in surface structures. As long as there is a negative pressure differential, the gases trapped beneath the entire structure will rise through such preferential pathways.*

To predict concentrations of indoor air contamination resulting from vapor intrusion, scientists have developed mathematical models, the most widely known of which is the Johnson-Ettinger model. The models attempt to calculate "alpha," of the attenuation factor, named for the Greek letter α in the models' mathematical formulas. Alpha represents the ratio of the concentration of indoor air contamination (due only to vapor intrusion) to the concentration of vapors in the soil below. Alpha is calculated from a number of variables, some of which can be measured at the site. These include soil types, depth to groundwater, and the physical properties of the specific volatile compounds. Alpha usually turns out to be about one one-thousandth (.001). That is, contaminants in indoor air are usually found somewhere around one one-thousandth the concentration of the same vapors in the soil beneath.

Where there are existing structures, those conducting vapor intrusion investigations generally use soil gas measurements to determine if and where to test the indoor air. They also use them to help distinguish between vapor intrusion and the same contaminants from other sources, such at outdoor air or household or commercial products. Residents and environmental activists are often concerned that investigators rely too much on the models; they are unwilling to accept that the air inside is clean unless it is actually sampled.

For redevelopment sites, there is usually no indoor air to test. If there are existing structures that are slated for demolition, sampling inside might give an indication of potential vapor intrusion for replacement structures, but that too is subject to significant variability. Therefore, the only way to evaluate the potential for vapor intrusion at most redevelopment sites, such as brownfields, is to measure as many of the variables in the Johnson-Ettinger (or similar) model as practical, and then use alpha to predict where, and how much vapor intrusion is likely to occur.

Most vapor intrusion sites with existing structures lie above shallow plumes of contaminated groundwater, which have migrated beneath the building in the years since the original release of contamination. However, at brownfields sites (including those recently redeveloped) the structures may be proposed to be built (or already sit) above source areas, areas of soil contamination that were polluted as the contamination originally leaked out and down through the soil. Thus, at redevelopment sites, vapor intrusion investigations must

* Conversely, as long as a structure maintains a positive pressure, gasses trapped beneath will not enter the structure. While this is an expensive way to solve a vapor intrusion problem alone, it often makes sense in commercial structures where positive pressure is used to conserve energy.

carefully determine the location of any such release and determine whether it has been cleaned up.

Since soil contamination and groundwater contamination often occur in the same areas, it sometimes takes additional investigation to determine whether soil gas concentrations result primarily from soil pollution or contaminants in the underlying groundwater. One approach is to measure the compound's soil gas concentrations at different depths. If the concentrations at a location are higher nearer the surface, that suggests that the location is an original source area. If the concentrations are lower nearer the surface, it's likely that the source is deeper—probably contaminated groundwater.

Decisions, Decisions

Continuing exposure to volatile organic compounds in the air we breathe poses a long-term health threat. There is a major scientific debate going on today (see below) over what levels pose a significant risk, but rarely do the levels of exposure found in vapor intrusion scenarios pose an acute—that is, immediate—risk.

Still, there is no established process for deciding when to build homes, schools, workplaces, or other structures above shallow sub-surface contamination. One of the reasons is that the environmental regulatory agencies—U.S. EPA and its state, territorial, and tribal counterparts—that normally supervise or even conduct major hazardous waste cleanups are not the entities that must approve development proposals. The regulators may impose, as part of a cleanup remedy subject to their jurisdiction, land use controls that limit what can be built or what types of additional design features are necessary for safe use of the new buildings. But because vapor intrusion is such a new concern, there is little history of such controls.

Usually, it's up to local governments to approve new construction, and their normal operations don't provide the tools to review the vapor intrusion potential. That is, the zoning, subdivision, site plan and architectural review, and building permit processes do not ask the vapor intrusion question. Only those jurisdictions where environmental review is required have an institutionalized way to evaluate and place conditions on development because of vapor intrusion concerns. For example, Mountain View, California used the California Environmental Quality Act to impose conditions on new housing construction on a parcel near an active vapor intrusion site.

Furthermore, most local governments lack the expertise to evaluate potential vapor intrusion construction proposals. That normally isn't their job. Again, Mountain View solved this problem by partnering with experts from U.S. EPA. EPA analyzed the developers' environmental data and documents for city officials.

Yet there are two important reasons why the potential for vapor intrusion should be evaluated early in the redevelopment process. First, it is easier to conduct subsurface sampling, to install remediation systems, or to implement mitigation before or during construction than conducting such responses after the fact. Second, once people move into the new development, many will respond to any toxic surprise, such as vapor intrusion, by contacting lawyers.

Five Steps

CPEO therefore recommends the following steps be incorporated into the approval process for any property known or suspected to contain volatile organic compounds in the shallow subsurface. To trigger this process, **environmental regulatory agencies**

should notify local planning jurisdictions of any such sites being addressed under their authority, and **developers who discover shallow contamination during environmental site assessment should report it**, both to local government and environmental regulatory agencies.

1. The potential for vapor intrusion should be fully evaluated before development is approved.

2. Cleanup remedies should be in place before construction begins.

3. Either accelerated remediation methods should be approved or the development should be moved or delayed.

4. Engineering controls should be required as a condition of development

5. Future property users should be notified of the vapor intrusion investigation and its results.

1. The potential for vapor intrusion should be fully evaluated before development is approved. While this may seem obvious, most of the local planning jurisdictions that review proposed developments are not even aware of the vapor intrusion pathway, let along the various tiered approaches for evaluating it. In addition to existing contamination on the property, the potential for inward migration of contaminated groundwater should be considered.

2. If, in the absence of engineering controls, vapor intrusion at unhealthy levels is likely to occur, then cleanup remedies should be in place before construction begins. Such remedies should be protected by institutional controls. That is, neither construction nor the new use should interfere with remedial progress. The key point here is the recognition that engineering controls are not as robust as removal or degradation of the pollutants.

3. Where necessary, engineering controls such as impermeable membranes, subslab ventilation systems, and positive air pressure (for commercial buildings) should be required as a condition of development. Evidence from the field suggests that such measures usually work in the short run, but not always. Therefore sampling is necessary to confirm that they are working as designed. Also, many such measures are susceptible to breakdown, so regular monitoring and contingency plans should accompany any engineering controls. Those requirements should be backed up by enforceable institutional controls**.** Since developers don't like to encumber their properties in this way, this provides an additional incentive for remediation.

Other design features may also be used to limit exposures. For example, agencies may require that there be no living space on the ground floor. However, one should be careful not to replace the risk of vapor intrusion with the release of contaminants from garages built directly under homes.

4. If engineering controls are likely to fail before cleanup remedies reduce residual contamination to a level at which vapor intrusion will not pose an unacceptable risk, then either accelerated remediation methods should be approved or the development should be moved or delayed. Where public health requires serious limits on development, regulators and local governments should resist the political and economic pressure to sweep vapor intrusion risks under the rug. But compromises are possible. There may be ways to significantly reduce risk simply by changing the footprint of the proposed development. Note that in most cases, the vapor intrusion air standards for industrial and commercial structures are only about three times higher (less stringent) than for residential or unrestricted use, so simply restricting residential uses might not provide adequate protection.

5. Future owners, tenants, employees, students, and visitors should be notified of the vapor intrusion investigation and its results. Some states provide residential property buyers with notice of local contamination sites in the midst of the sale closure process. That's too late. Property users should receive enough notice so they can make informed decisions. For example, Mountain View recently required that *marketing* materials for new homes adjacent to a vapor intrusion site should include vapor intrusion warnings. If accurate warning is provided, then developers will have an additional reason to accelerate and intensify cleanup.

It's important, in devising any disclosure scheme, not to undermine the privacy of the owners or other residents and users of affected property. That is, property-specific notice should be given only when it helps a prospective buyer, employee, resident, etc. make judgments about the safety of buying or using the property.

Re-Openers

Disclosure that homes or other properties suffer vapor intrusion, or even that the vapor intrusion problem is suppressed with engineering controls, prompts immediate, intense concern among property owners. They face a double-whammy: potentially serious health problems if exposed to the contaminants; and a likely reduction (or diminished increase) in property value. Some people, more concerned about re-sale value, try to keep the bad news quiet. This is an argument, of course, for publicizing vapor intrusion threats before property transactions occur.

Still, there are many new homes and other buildings where developers completed projects based upon comfort letters or other assurances that no further cleanup would be required. Now—in New York, for example—regulators are re-visiting many such sites, requiring further investigation at supposedly finished sites. In such cases, the agencies that provided assurance need to check the fine print. If indeed, they gave overbroad assurances, then they need to seek funds elsewhere to re-investigate the site. CPEO firmly believes, however, that the public should not be subject to continuing vapor exposures—or even conditions which might lead to future exposures—simply because assurances were given. And if such promises were not made, then the developer unfortunately has to eat the additional expenses, unless it can recover costs from the responsible parties. To cushion the impact on developers yet ensure that residents are protected, CPEO believes that legislators and agencies should consider providing low-interest cleanup loans at sites where remediation is re-opened due to vapor intrusion,.

Health Standards

It should be recognized there is significant uncertainty—or at least an argument between major polluters and environmental and public health advocates—about what constitutes an unacceptable level of exposure to volatile organic compounds in air. In 2001, U.S. EPA completed a draft Human Health Risk Assessment for TCE, one of the most common intruding vapors. That Assessment, if adopted, would translate into a health standard of .02 micrograms of TCE per cubic meter of air. Because in most urban areas, TCE in ambient air is about ten times that, somewhere around .2 $\mu g/m^3$, the de facto cleanup objective at most sites would be somewhere around that level (because outdoor air would recontaminate indoor air cleansed to a more stringent standard).

However, other federal agencies—the Energy and Defense Departments and NASA—as well as private polluters, objected to EPA's findings, so the four federal agencies sent the question of TCE toxicity to the National Academy of Sciences for re-review. It will be years before there is a new federal standard. If that new standard is protective for vulnerable populations such as young children—as the 2001 study suggested—then it is likely that the safety thresholds for other common volatile organic compounds, such as perchloroethylene and trichloroethane, will eventually be reduced as well. Meanwhile, most EPA regions and states with vapor intrusion programs are using 1 $\mu g/m^3$ or a higher number as their interim action level for TCE in residential air.

Developers, communities, and agencies are all faced with substantial uncertainty. CPEO believes vapor intrusion investigations should be conducted based upon the more protective numbers, using detection limits of about .02 $\mu g/m^3$. That way, if EPA's 2001 findings are upheld, there will be no need to re-open the investigations. Unless prohibitively expensive, cleanup targets should approach background air concentrations, to avoid the prospect of having to come back and re-remediate sites.

Finally, well conducted vapor intrusion investigations distinguish indoor sources—such as household products—from vapor intrusion. Neither developers nor responsible parties are expected to remove from the air contaminants released from household products or active industrial processes. However, since volatile organic compounds such as TCE and PCE do not occur naturally, it's important to determine if ambient levels are present due to vapor migration from the subsurface. While it might not be possible to clean indoor air below outdoor air levels, it may be possible, through additional source remediation over a wide area, to reduce the concentrations in outdoor air.

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