A Stakeholder's Guide to New Construction at Vapor Intrusion Sites

By Lenny Siegel

December, 2016

The people and institutions in communities where vapor intrusion occurs have a stake in how vapor intrusion is addressed, as well as important roles to play in conducting the response. This document was prepared for non-governmental community stakeholders and local government officials to explain how residents, developers, and local governments can safely cooperate with regulatory agencies to build homes, schools, and businesses at construction sites where vapor intrusion is likely.

What Is Vapor Intrusion, and How Is it Addressed?

Every year in the United States, thousands of buildings are built on property contaminated by past industrial activity, poor waste and materials management, and fires and accidents. The use of consumer and building products, such as asbestos, lead-based paint, and petroleum products may have left contamination on residential and commercial property as well as industrial sites.

Townhomes under construction at the MEW Superfund Study Area, Mountain View, CA

Where that contamination consists of solvents or other vapor-forming toxic substances in underlying or nearby soil, soil gas, groundwater, or conduits such as sewers and utility vaults, the toxic substances complicate the development process and pose a potential threat to future building occupants. The threat is vapor intrusion (VI), the physical process in which buildings suck up and accumulate toxic vapors from the subsurface in the indoor air. Vapor intrusion is a potential concern wherever buildings or other enclosed structures are located near an underground source of vapor-forming contamination.

Over the past two decades, the federal government, state environmental regulators, and private financial institutions have established practices to enable and even encourage the development of contaminated property safely. In many cases, those practices—environmental site assessments, voluntary cleanup programs, brownfields funding, etc.—have led to good projects which provide the protection people expect. But more needs to be done if everyone is to be protected against vapor intrusion in new developments.

If implemented properly the technical response to the vapor intrusion threat, particularly in new structures, is protective, reliable, and cost-effective.[1] But the regulatory process often fails to serve the dual needs of development and environmental protection, largely because the environmental agencies responsible for protecting the public from toxic exposures are not the jurisdictions that approve development.

While subsurface cleanup is the long-term solution to the threat of vapor intrusion, reducing subsurface contamination to safe levels often takes decades or longer. The more immediate, routine protection against vapor intrusion is known as **mitigation**, largely based upon decades of experience protecting building occupants from the intrusion of naturally occurring radon. Common solutions include systems that depressurize the subsurface and plastic or rubber-like vapor barriers, which can be implemented in existing and new buildings. A wider array of approaches and technical options is typically available to mitigate or avoid vapor intrusion at new buildings, compared to existing buildings. These options potentially include the choice of building location and opportunities to modify the building design and construction (*e.g.,* building designs that separate living and work spaces from the threat of soil gas intrusion).

Because mitigation is designed into new buildings, implementing it has usually become the responsibility of building developers. Thus, vapor mitigation has often become a **brownfields** issue, even at many sites where subsurface remediation is carried out under the Superfund law and its state counterparts. Furthermore, developers intending to avoid construction delays may actually conduct subsurface remediation, under regulatory oversight, perhaps hoping to recover costs later from responsible parties.

In January 2014, after four decades of environmental activism during which I learned about the technical and regulatory aspects of contaminated site cleanup, I was elected as a City Council member in Mountain View, California, in the heart of Silicon Valley. Over the past two years I have voted to approve a succession of new residential and commercial developments on properties contaminated with chlorinated volatile organic compounds, such as trichloroethylene (TCE) and tetrachloroethylene (PCE), the two compounds most often found to intrude into buildings at levels that can pose immediate and long-term health threats. In my new role, I routinely explain from the Council dais that the sites have been investigated, and that the city has cooperated with environmental regulators to ensure that occupants will be safe. With the help of U.S. EPA, Mountain View has figured it out.

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[1] For background, see Lenny Siegel, "A Stakeholder's Guide to Vapor Intrusion: Update," CPEO, November, 2015, at http://www.cpeo.org/pubs/SGVIU.html .

Is There a Human Health Problem? Is There a Risk of Unacceptable Vapor Intrusion?

Vapor intrusion is one of many potential ways that people may come into contact with hazardous vapors while performing their day-to-day indoor activities. Depending upon building- and site-specific circumstances, concentrations of chemical vapors arising in structures from vapor intrusion may threaten human health or safety.

Historically, regulatory agencies screen for vapor intrusion potential in existing buildings by sampling several different media, including shallow groundwater, soil, soil gas, indoor air, and outdoor air to identify sources, exposure pathways, and potential control strategies. This is termed "multiple lines of evidence." While all such data may be valuable, there is growing consensus among experts that indoor air sampling is the most direct way to measure human exposure arising from toxic vapor intrusion, and there are numerous ways to determine whether substances measured inside have actually intruded from the subsurface.

Offices being built over the heart of the MEW TCE plume, Mountain View, CA

Where there is no building, the presence of vapor-forming chemicals in the subsurface suggests the potential for vapor intrusion. However, there is no way to conduct indoor air sampling if there is no building yet. California's *Vapor Intrusion Mitigation Advisory* actually suggests the construction of test homes in multi-building developments,[2] but I've never run across a site where this was done. Where the new construction is actually the remodel of or an addition to an existing building, it may be possible to sample the existing structure to help understand the risk of vapor intrusion, but it's important to remember that renovations can dramatically alter the amounts of soil gas that intrude and/or are retained in indoor air.

To determine whether there is any potential for vapor intrusion at a yet-to-be-constructed building, one must review information available about the subsurface on the development property as well as adjacent properties. In many communities, such as Mountain View, decades of environmental investigation have identified large industrial groundwater plumes, such as the "Regional Plume" at the MEW Superfund Study Area, and small former dry-cleaning sites as well as current or former gasoline stations. But even if properties are not on the lists of U.S. EPA, state regulatory agencies, and local oversight agencies, most commercial, government, and multi-family residential property transactions are subject to Phase I Environmental Sites Assessments. Where such assessments are not mandated by law, they are often required by lenders and insurance companies.

Conducted under ASTM's E-1527 Standard in accordance with U.S. EPA's All Appropriate Inquiries Rule, Phase I Assessments are essentially desktop screening exercises designed to determine if there is a likelihood of environmental contamination (termed a "recognized environmental condition" or REC) based on readily available information such as past property use. ASTM's E-2600 Vapor Encroachment Screening Guide provides the tools for incorporating specific criteria pertinent to vapor intrusion. If the Phase I Assessment shows that there is insufficient data to determine whether there is vapor intrusion potential or any other recognized environmental conditions, a Phase II Environmental Site Assessment (E-1903) is conducted. This means "intrusive" subsurface sampling is carried out.

Properly conducted Phase II investigations, as well as studies conducted pursuant to environmental protection statutes, generate information about the depth and flow of shallow groundwater, concentrations of toxic substances in groundwater, soil, and soil vapor, and other soil characteristics—particularly the permeability. Because both subsurface contamination and indoor air pollution can vary significantly over time and space, usually a great deal of sampling is necessary to rule out unacceptable exposures, particularly for TCE. Regulatory agency scientists have concluded that on the wrong day a spike of inhaled TCE vapors during the first trimester of pregnancy heightens the risk of a woman bearing a child with a cardiac birth defect.[3]

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[2] California Department of Toxic Substance Control, *Vapor Intrusion Mitigation Advisory (VIMA),* October, 2011 at https://www.dtsc.ca.gov/SiteCleanup/upload/VIMA_Final_Oct_20111.pdf; page 53 of PDF

[3] See, for example, Gerald Hiatt and Daniel Stralka, "EPA Region 9 Interim Action Levels and Response Recommendations to Address Potential Developmental Hazards Arising from Inhalation Exposures to TCE in Indoor Air from Subsurface Vapor Intrusion," U.S. EPA Region 9, June 30, 2014, https://yosemite.epa.gov/r9/sfund/r9sfdocw.nsf/3dc283e6c5d6056f88257426007417a2/6a24ed351efe25b888257d16007659e8/$FILE/R9%20TCE%20Action%20Levels%20and%20Recs%20Memo%207_14.pdf

What Can Developers and Municipalities Do
When Subsurface Vapor-Forming Contamination is Found?

In some cases, development projects are abandoned when subsurface contamination with vapor-forming chemicals is found. Sometimes stakeholders fear that it is too difficult to make new buildings safe. Or developers may decide that an acceptable response is too costly, or they are uncertain about the liability implications. Or perhaps there is another, similar property available without similar contamination.

However, there are three ways to move forward based on an understanding of the levels, fate, and transport of subsurface vapor-forming contamination:
1) Consider the existing data and likelihood of vapor intrusion.
2) Err on the side of caution. Where volatile compounds are found in the subsurface on or near a site, assume that vapor intrusion is possible and develop and implement a mitigation plan.
3) Conduct further analysis in the hope of ruling out vapor intrusion as a risk.

These are explained in more detail below.

The Mott Haven school campus, Bronx, New York has built-in vapor mitigation.

1. Shallow groundwater data is often the only or first information available about contamination, so most regulatory agencies initiate vapor intrusion investigations based on the spread of groundwater plumes. However, since soil vapor concentrations can be a better indication of likely indoor air concentrations than are groundwater sampling results, most jurisdictions sample soil gas to determine the likelihood of vapor intrusion. Pennsylvania's recent guide highlights the important of sampling throughout the proposed building's footprint:

> If an as-yet undeveloped area is being evaluated, then there will need to be enough near-source soil gas points to encompass future building construction. Because petroleum hydrocarbons tend to pose a relatively low risk for [Vapor Intrusion] owing to bioattenuation, [the Department of Environmental Protection] regards chlorinated VOCs as a greater concern for potential under-sampling.[4]

[4]Pennsylvania Department of Environmental Protection, "Land Recycling Program Technical Guidance Manual for

Regulatory agencies set soil gas screening levels to help answer the question whether mitigation is necessary. It's a complicated two-step process. I expect that most stakeholders will have to take time to understand it, but it's important, because these calculations often determine whether buildings are constructed protectively. If one can't take the time, it's essential to find a trusted technical advisor.[5]

How Soil Gas Screening Levels Are Calculated

First agencies adopt indoor air targets—that is, what levels of indoor air exposure are acceptable given the building's expected occupancy. Residential targets are more protective than those for commercial buildings, because individuals may be inside most or all of the time, while people are expected to be in commercial buildings no more than 40 or 50 hours a week.[6]

For TCE in a residential setting, the indoor target is usually around 0.5 micrograms per cubic meter ($\mu g/m^3$) in jurisdictions where the excess lifetime cancer risk (ELCR) goal is one in a million (10^{-6}) and around 2 $\mu g/m^3$ where the cancer goal is less protective. The latter is based on the risk of birth defects. In most of the country, the PCE residential target is around 11 $\mu g/m^3$ where the ELCR goal 10^{-6}, and ten or 100 times higher where the ELCR goal is less protective. However, in California—which does its own toxicological assessments—the cancer-based PCE target is around 0.5 $\mu g/m^3$, the same as TCE.[7]

To calculate the soil gas screening level, the indoor air target is divided by an assumed attenuation factor, the expected ratio of the indoor air concentration to the soil gas concentration for a generic building. EPA and states that follow EPA's *Technical Guide* use a default attenuation factor of 0.03 for samples from "sub-slab" or "near-source" soil gas (*i.e.,* from immediately beneath a building's foundation, or from a short distance from the subsurface vapor

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Vapor Intrusion into Buildings from Groundwater and Soil under Act 2," Document #261-0300-101, November 17, 2016 at http://www.elibrary.dep.state.pa.us/dsweb/Get/Document-115613/261-0300-101.pdf , page 31 of PDF

[5]In many cases communities feel comfortable relying on regulatory agencies experts for technical advice, and local governments are often in a position to hire experts. Furthermore, there are also a number of state and federal programs that provide independent technical assistance to community groups. It's important, however, to find advisors with direct experience evaluating vapor intrusion response. CPEO currently provides such assistance to community groups at brownfield sites.

[6]Commercial indoor air targets are typically calculated anywhere from 3.5 to 4.5 times the corresponding residential number.

[7]I focus on the two chlorinated solvents, TCE and PCE, which are responsible for most vapor intrusion sites requiring mitigation. Petroleum hydrocarbons can also cause vapor intrusion, but at most small sites—such as former gasoline stations—the vapor intrusion risks are considered very low because the vapors degrade as they rise and come into contact with atmospheric oxygen. Larger petroleum sites and sites with high concentrations of methane, which poses a risk of explosion, pose greater risks. Both U.S. EPA and the Interstate Technology Regulatory Council have technical guides explaining how to screen for petroleum vapor intrusion. See U.S. EPA Office of Underground Storage Tanks, *Technical Guide For Addressing Petroleum Vapor Intrusion At Leaking Underground Storage Tank Sites,* EPA 510-R-15-001, June, 2015 at https://www.epa.gov/sites/production/files/2015-06/documents/pvi-guide-final-6-10-15.pdf and Interstate Technology & Regulatory Council (ITRC), "Petroleum Vapor Intrusion: Fundamentals of Screening, Investigation, and Management," October, 2014 at http://www.itrcweb.org/PetroleumVI-Guidance/ .

source).[8] For either of these sample types the soil gas screening level associated with an indoor air target of 2 µg/m^3 is about 70 µg/m^3. The indoor air target of 0.5 calculates to a screening level of 16 µg/m^3.

California, despite its reliance on some of the most protective indoor air targets for PCE and TCE, uses less protective attenuation factors than EPA. For future residential buildings, the default attenuation favor is 0.001; for future non-residential buildings, it's even lower: 0.0005. So California's default future-building scenario residential soil gas screening levels for PCE and TCE are 460 µg/m^3 and 480 µg/m^3 respectively. Using these levels to decide whether to mitigate will likely exempt many projects from preemptive action, and the screening concentrations are high enough that they may fail to trigger a response at some number of sites where unacceptable risks may then be found after the construction is completed—if indoor air sampling is conducted after construction.

2. Erring on the side of caution is called preemptive mitigation. Most of the community groups with which I work prefer this approach. New York State's Vapor Intrusion Guidance captures the logic:

> In many cases, installation of mitigation systems on new buildings may be a prudent, proactive action. The costs associated with installing a system at the time of a building's construction are often considerably less than the costs associated with retrofitting a system to the building after construction is completed. Furthermore, in many parts of New York State, the mitigation system would also address concerns about human exposures to radon.[9]

3. When an intrusive investigation such as a Phase II indicates that there is a risk of vapor intrusion, but there are too many uncertainties in the data, a full-scale site investigation should take place to determine whether mitigation is necessary. In some jurisdictions this is called a remedial investigation, and if the data determine there is a risk, it is followed by a feasibility study. Some jurisdictions, such as New York, call this a remedial action work plan.

Recognizing that conditions vary significantly from site to site, some jurisdictions allow developers' consultants to calculate site-specific attenuation factors based upon the permeability of the soil and the depths at which soil gas is measured. If soil is tight (moist) clay or the soil vapor must travel further upwards to reach buildings on or near the surface, one might expect lower levels of vapor intrusion. One should note, however, that when jurisdictions allow this, the results may be unprotective. For example, in California I have reviewed documents claiming attenuation factors one tenth or even one hundredth of the default, leading to extremely

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[8] U.S. Environmental Protection Agency Office of Solid Waste and Emergency Response, *OSWER Technical Guide for Assessing and Mitigating the Vapor Intrusion Pathway from Subsurface Vapor Sources to Indoor Air,* OSWER Publication 9200.2-154, June, 2015 at https://www.epa.gov/sites/production/files/2015-09/documents/oswer-vapor-intrusion-technical-guide-final.pdf. See page 132 of PDF.

[9] New York State Department of Health, "Guidance for Evaluating Soil Vapor Intrusion in the State of New York," October, 2006 at http://www.health.ny.gov/environmental/investigations/soil_gas/svi_guidance/docs/svig_final2006_complete.pdf page 17 of PDF

unprotective soil gas screening levels. I have expressed my concern that developers are able to tweak mathematical formulas—usually the Johnson-Ettinger Model—to avoid spending time and money protecting future building occupants.

A mixed-use development is planned for the contaminated Hoover site, North Canton, OH.

In addition to the general shortcoming of reliance of modeling, often those using models make un-provable assumptions. For example, they may assume that all the soil at the site is low permeability clay. Indeed, if all the soil is undisturbed clay, then a lower (less protective) attenuation factor may be appropriate. But if there is undetected soil disturbance or if sub-surface sand channels are present, then the clay-based attenuation factor may seriously underestimate the risk. The Massachusetts Department of Environmental Protection explains, “The MCP [Massachusetts Contingency Plan] does not allow the use of site-specific models to estimate EPCs in indoor air in buildings that have yet to be constructed (310 CMR 40.0926(7)(b)).”[10]

Mitigating Against Vapor Intrusion

In the long run, remediation—the removal or degradation of subsurface contamination—is the solution to vapor intrusion, but for chlorinated solvents the cleanup of groundwater and soil gas is generally slow, expensive, and difficult. Fortunately, based upon decades of

[10] Massachusetts Department of Environmental Protection, “Vapor Intrusion Guidance: Site Assessment, Mitigation and Closure,” Policy #WSC-16-435, October 14, 2016, http://www.mass.gov/eea/docs/dep/cleanup/vapor-intrusion-guidance-10-14-2016.pdf, page 49 of the PDF. An earlier version of the guidance explained further, “The agency does not support, however, use of site-specific modeling inputs. Such site-specific modeling has not been found to be sufficiently predictive of indoor air concentrations and should not, under most circumstances, be relied upon as the sole determinant of potential exposure. This is especially the case with future buildings where the site-specific modeling results cannot be validated through direct measurements under actual conditions. Reliance upon modeling with site-specific inputs alone to evaluate exposures associated with future buildings provides future developers/owners/occupants no real assurance that the site conditions are protective.” Massachusetts Department of Environmental Protection, “Interim Final Vapor Intrusion Guidance” (WSC#-11- 435), December, 2011 at http://www.mass.gov/eea/docs/dep/cleanup/laws/vifin.pdf , page 91 of PDF.

experience with the intrusion of naturally occurring radon from the subsurface, there are inexpensive engineering controls that, if implemented properly, reliably protect building occupants from toxic vapor intrusion while the source remains. This family of responses is called "mitigation," because they protect building occupants without fully eliminating the problem.

Leaking sewer pipes were responsible for TCE contamination at this development site at the MEW Superfund Study Area in Mountain View.

The most common form of mitigation in existing buildings is active sub-structure (sub-slab or sub-membrane, if there is no slab) depressurization. Most buildings operate at a negative pressure relative to the subsurface. So even the smallest pathway, such as a crack in the concrete slab or an unsealed plumbing opening in the floor, can allow vapors just below the surface to enter the building. Active mitigation systems use fans connected to perforated piping under buildings to lower the subsurface vapor pressure below the interior air pressure. If there's a pathway between the subsurface and basement or interior, vapors are drawn downward, preventing vapor intrusion.

In new buildings, however, passive venting is often selected as the mitigation remedy. Piping and other features encouraging sub-structure air flow are installed during construction, along with vapor barriers. Vent risers connect the subsurface piping to the atmosphere above the building. Then, once the building is completed—and hopefully before occupancy—indoor air is sampled to see if the passive system is preventing vapor intrusion. If not, fans are installed in the risers, converting the system to active depressurization. Installing piping and other passive features is much less expensive during construction than after buildings are complete.

This is the new-building remedy selected by U.S. EPA Region 9 at the MEW Superfund Study Area in Mountain View.

> The selected remedy for all future buildings is Passive Sub-slab Ventilation with Vapor Barrier (and Ability to Convert to Active), Monitoring, and ICs. Although Active Subslab/Sub-membrane Ventilation is considered to have a better long-term effectiveness than Passive Sub-slab Ventilation systems, areas with lower groundwater VOC [Volatile Organic Compound] concentrations are considered to have a lower potential for vapor intrusion at levels exceeding the Site indoor air cleanup levels, and therefore the passive option is more cost-effective in meeting the indoor air cleanup levels.[11]

Each site may have unique characteristics, so other strategies may be considered. U.S. EPA's *Vapor Intrusion Technical Guide* lists several, which I cite below:

> At some sites, contaminated areas most likely to produce unacceptable vapor intrusion exposures can be avoided and designated for another purpose, such as recreational space or undeveloped landscape.[12]

This approach makes sense, but it must be applied protectively. California's Department of Toxic Substances Control (DTSC) initially approved this approach at Stanford University's University Terrace Housing project, under construction at a former industrial site in the Stanford Research Park. However, it accepted a fifty-foot buffer between homes and known hotspots, despite inadequate sampling between those hotspots and proposed building footprints as well as evidence that contamination had migrated at least three hundred feet.[13] When neighbors protested, the Palo Alto City Council required mitigation, because the buffers were not adequate. The Council's decision was made easier by Stanford's admission that the cost of mitigation, when designed into construction, was minimal.

EPA also suggests that HVAC (heating, ventilation, and air conditioning) systems can provide mitigation. Commercial HVAC systems can reduce indoor air contamination both by raising the indoor air pressure above the subsurface vapor pressure and by increasing building ventilation. However, systems must be managed to provide mitigation. Normal temperature management may not meet mitigation needs, as EPA's *Vapor Intrusion Guide* notes:

> Mitigation needs can also be considered in the selection of heating and cooling systems, which are normally selected based only on economics, aesthetics, preference, and custom. A system design that avoids creating under-pressurization inside the structure and maintains over-pressurization inside the structure may be effective in mitigating vapor intrusion.[14]

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[11] U.S. EPA Region 9, "Record of Decision Amendment for the Vapor Intrusion Pathway—Middlefield-Ellis-Whisman (MEW) Superfund Study Area," August 16, 2010 42 of PDF at https://yosemite.epa.gov/r9/sfund/r9sfdocw.nsf/3dc283e6c5d6056f88257426007417a2/6c373a69325cd99f882577820077b04b/$FILE/MEW%20VI%20ROD%20Amendment%20and%20RS%20-%20Aug%2016%202010.pdf , page.
[12] *OSWER Technical Guide,* page 172 of PDF.
[13] See Lenny Siegel, "Avoiding Vapor Mitigation at Stanford Research Park Housing," April, 2016 at http://www.cpeo.org/pubs/SRP.pdf /.
[14] *OSWER Technical Guide,* page 172 of PDF

University Terrace faculty housing project, Stanford Research Park, Palo Alto, CA

In fact, at a Google building within the MEW Superfund Area, EPA required installation of active depressurization systems because the HVAC system was not effective in reducing contaminants below health risk levels.

EPA and other regulators also recognize the limited value of passive barriers:

> Passive barriers, such as a low-permeability membrane, can be more readily installed between the soil and the building during new building construction. Passive barriers are intended to reduce vapor intrusion by limiting openings for soil gas entry. However, passive barriers as stand-alone technologies may not adequately reduce vapor intrusion owing to difficulties in their installation and the potential for perforations of the barrier during or after installation. They are commonly combined with ADT [active depressurization technology] systems or with sub-membrane ventilation systems to help improve their efficiency.[15]

To enhance the effectiveness of both active and passive venting, regulators acknowledge the value of venting layers for the successful operation of active depressurization systems, noting that is easier to install porous media during new construction. EPA appears to also endorse the use of constructed voids:

> Constructed sub-slab ventilation systems typically consist of: a venting layer (e.g., filled with porous media such as sand or pea gravel; or suitably fabricated with continuous voids) below a floor slab to allow soil gas to move laterally to a collection piping system for discharge to the atmosphere; and a sub-slab liner that is installed on top of the venting layer to reduce entry points for vapor intrusion. These and other sub-slab ventilation systems function by drawing outside air into and through the sub-slab area, which dilutes and reduces concentrations of vapor-forming chemicals, and provides a route for soil gas to vent to the atmosphere or migrate outside the building footprint, rather than into a building.[16]

[15] *ibid*.
[16] *ibid*.

Finally, mitigation can be incorporated into building design. EPA wrote, "New buildings may be designed to include a highly ventilated, low-occupancy area at ground level, such as an open parking garage."[17] California's Vapor Intrusion Mitigation Advisory suggests that using such podium-style buildings to mitigate against vapor intrusion is not always simple.

> The risk from VI may be greatly reduced by a building design that utilizes an open-air first floor, stilts, or an appropriately ventilated first floor space. An example of such a building design is a well-ventilated ground level parking structure. However, all potential vapor conduits to upper floors of the building (particularly utility lines, elevator shafts, and ventilation systems) must be engineered and sealed in a manner that reduces the risk of VI. Such provisions may include construction of the elevator on an exterior wall of the building (rather than having an interior, central entrance), sealing the base of the elevator, possible venting, and increased ventilation of the elevator. If used as an enclosed parking area, additional consideration is needed to achieve ventilation flow rates required to ensure acceptable levels of carbon monoxide and volatile chemical concentration levels. In general, DTSC considers podium-style buildings inappropriate for use with single-family dwellings because of concern that individual homeowners may alter or convert their garages to livable space.[18]

New buildings and their associated infrastructure can also be designed to eliminate preferential pathways for the spread of subsurface contamination. ITRC wrote:

> In the case of undeveloped or redeveloped property, new construction presents an opportunity to deal with one of the more vexing VI problems: mitigating subsurface conduits that may become migration routes for soil gas. For example, sewer, water, underground cable and electrical lines are often placed on porous gravel or soil to maintain good drainage. Yet this practice also fosters inadvertent vapor transport requiring construction provisions that contain barriers to vapor transport, either through the design of the conduit or the use of nonporous materials. Currently, the National Aeronautics and Space Administration (NASA) requires this for new construction at the NASA Research Park, located at Moffett Field in California.[19]

At the former Moffett Naval Air Station in Mountain View, where the MEW Regional TCE Plume merged with Navy releases, an inactive old steam tunnel was found to provide a preferential pathway for vapors to intrude into at least one building from the subsurface.

Post-Construction Management and Monitoring

Any time engineering controls, such as mitigation systems, are implemented to protect the occupants of buildings, new or existing, from vapor intrusion, it is essential that a long-term management plan be developed and carried out.[20] For new structures, the most immediate

[17] *ibid*.
[18] "VIMA," p. 31 of PDF
[19] ITRC, "Vapor Intrusion Pathway: A Practical Guide," January, 2007 at http://itrcweb.org/GuidanceDocuments/VI-1.pdf , page 79 of PDF
[20] See Lenny Siegel, "A Stakeholder's Guide to Long-Term Management at Vapor Intrusion Sites," CPEO, April, 2016 at http://www.cpeo.org/pubs/VILTM.pdf .

requirement is that mitigation systems be inspected and pressure differentials be measured. Ideally, indoor air monitoring should also take place. Such sampling isn't just designed to check that the system was installed properly. Where a passive system has been installed, sampling is necessary to determine whether fans should be added to convert it to active mode.

U.S. EPA lays out a general framework for post-construction monitoring:

> Mitigation monitoring will generally entail two phases: (i) an initial post-construction phase, which is generally more intensive; and (ii) a subsequent phase, which may be comprised of fewer diagnostic tests to be conducted periodically. As with radon mitigation systems, results of indoor air sampling during initial post-construction monitoring may be used to demonstrate that the occupant's exposure to vapor-forming subsurface contaminants has been reduced as anticipated. In addition, pressure field measurements in the subslab region can be used to demonstrate that the system has attained hydraulic control and communication (e.g., depressurization in the case of an ADT system) over the footprint of the building (or portion of a large building, as appropriate, considering the extent of subsurface contamination). Adjustments to the mitigation system and/or additional diagnostic testing may be warranted if the results of such testing do not clearly demonstrate that the system is achieving its intended performance and effectiveness.[21]

EPA recommends that monitoring programs be based upon site-specific information. For example, it suggests that periodic sampling be more frequent where passive venting is the selected mitigation remedy, where subsurface remediation is likely to alter soil gas conditions, or where subsurface concentrations are likely to increase. It refers readers to monitoring scenarios established by regulators in California, New Jersey, and Massachusetts.

Like EPA, Massachusetts requires more for passive systems:

> The recommended sampling approach to demonstrate effectiveness of passive measures depends on the relative groundwater and sub-slab soil gas concentrations, as well as the indoor air concentrations prior to the completion of the passive mitigation measures. More extensive testing is recommended when subsurface and indoor air concentrations are higher.[22]

Once it's clear that systems are operating more protectively, most agencies suggest less frequent monitoring and fewer types of tests. But in the long run, unless subsurface contamination falls to safe levels, the chance of system failure will begin to increase. Slabs may crack. Remodeling may occur. New property owners may unplug fans.

Yet conventional monitoring, in which investigators place and remove Summa™ canisters or passive sorbent devices and send them to labs for analysis, can get expensive if required to continue indefinitely. If developers are required to conduct frequent, ongoing sampling, pre-emptive mitigation may no longer be cost-effective. The costs and benefits must be weighed at each site.

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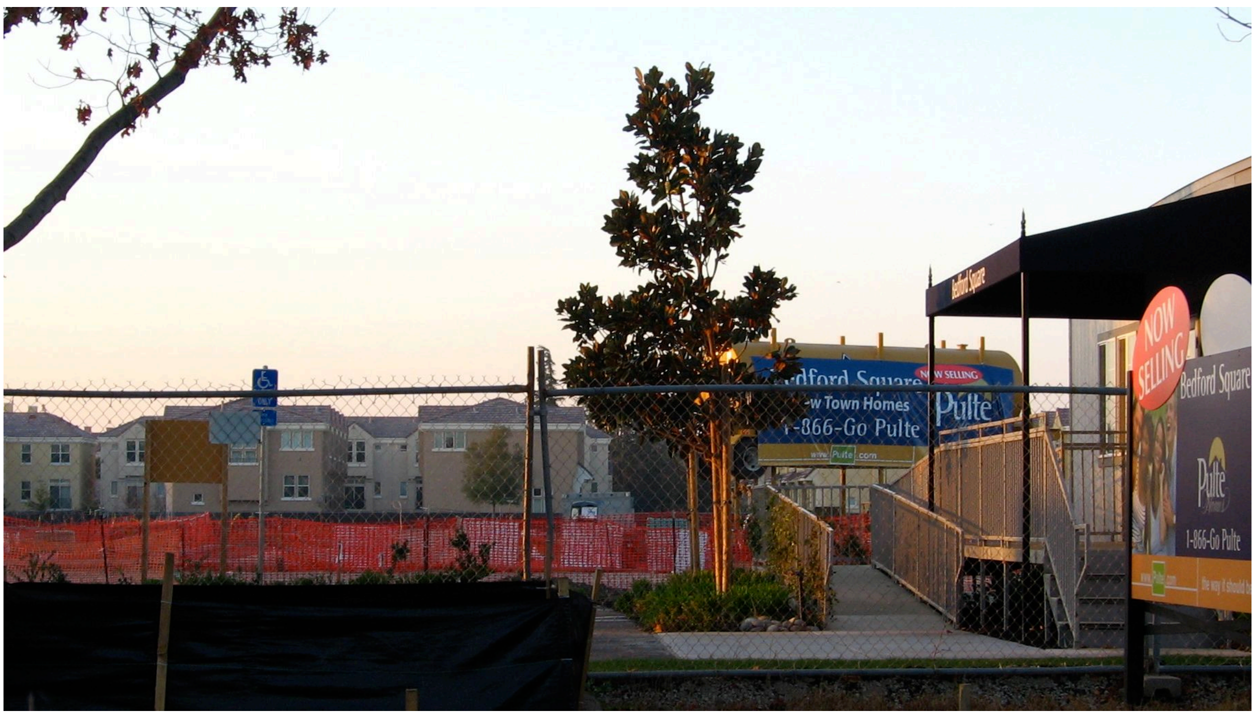
[21] *OSWER Technical Guide,* page 175 of PDF.

[22] Mass DEP, "Vapor Intrusion Guidance: Site Assessment, Mitigation and Closure," page 76 of PDF

Fortunately, remote monitoring can reduce the cost of long-term monitoring. With low-cost Internet or wireless technology available almost everywhere, off-site managers can check to see if fans are operating and pressure differentials are being maintained. Massachusetts requires telemetry to

> alert the owner and operator of the building that is protected by the Active Exposure Pathway Mitigation Measure and the Department immediately upon failure of the system, such as loss of power, mechanical failure or other significant disruption of the effectiveness of the system.[23]

As new sensors are developed to measure low VOC concentrations in near real time, monitoring may take place inexpensively without disturbing residents or other building occupants. Furthermore, near-continuous monitoring should help capture temporal variations in indoor air concentrations. Automated building monitoring systems can screen large buildings or campuses for potential problems at little cost. And such systems can be designed into new buildings so they are invisible to most building occupants.[24]



One of the first Mountain View sites where the city used the California Environmental Quality Act to require mitigation and notification

Monitoring, in itself, is insufficient. There should be contingency plans and a chain of responsibility to fix problems as they are discovered. At sites with continuing regulatory oversight, this is usually routine. But at developments where pre-emptive mitigation is voluntary, similar plans should be made and passed along to whomever is responsible for building management.

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[23] *ibid.,* page 78 of PDF.

[24] See Lenny Siegel, "Emerging Sampling Strategies," CPEO, November, 2015, http://www.cpeo.org/pubs/SGVI/EmergingStrategies.pdf for a slightly longer discussion.

While the primary responsibility for long-term management lies with those entrusted with cleanup—the regulators, responsible parties, and developers—building occupants should be considered part of the long-term management team. Residents and the managers of commercial buildings or schools should be informed about monitoring, maintenance, and the reason for mitigation in the first place. If informed, they can spot problems with mitigation or changes in the building that increase the likelihood of exposure. Their roles may vary, from allowing access to sampling personnel to checking the manometers—built into depressurization systems—that measure the level of depressurization. They need to know *not* to disconnect or damage mitigation pipes and equipment.

Beyond their role in long-term management, new building owners and occupants should be notified about the contamination and the nature of the mitigation. They have a right to know that their homes, workplaces, or schools—this may apply to the parents of occupants—are contaminated sites, even if mitigation is in place. Some may decide to take personal risk management decisions, removing themselves or their children from buildings, even if mitigated, because they are not convinced that they or their families are being adequately protected.

What Works in Mountain View

All in all, we know how to build new buildings and manage them to protect occupants from the threat of vapor intrusion. In a growing number of cases, regulators create institutional controls (ICs)—activity and use limitations (AUL)—to document the need to mitigate or relocate planned buildings at risk of vapor intrusion. These controls inform site developers how to incorporate mitigation into new construction.

But it's easy for even the most routine requirements to slip through the cracks, because the agencies with the responsibility and expertise to manage environmental risk are not the jurisdictions that review and approve new construction. EPA explains:

> Units of local governments, for instance, typically have jurisdiction to implement, maintain, enforce, and terminate certain governmental controls, such as zoning ordinances and building permit conditions. Therefore, it is important to evaluate the capacity (financial, technical, etc.) and willingness of the entity ultimately responsible for taking over IC responsibilities prior to IC selection. Site managers and site attorneys are encouraged to coordinate early with IC stakeholders so that adequate assurances may be acquired and then subsequently maintained as necessary over time.[25]

We have been fortunate in Mountain View. U.S. EPA and the state regulatory agencies have cooperated closely with our planning division, often answering questions at City Council meetings where developments proposed for contaminated areas are considered. Mountain View, the birthplace of most of the commercial semiconductor industry and now the home of well-known tech companies, is experiencing a resurgence of both commercial and residential development, on land checker-boarded with TCE and to a lesser extent PCE contamination in shallow groundwater.

[25] "OSWER Technical Guide," page 185 of PDF

In 2002, EPA initiated a collection of vapor intrusion investigations on Superfund sites and one EPA-led RCRA [Resource Conservation and Recovery Act] Corrective Action site. The latter was by then the site of hundreds of homes, clustered in an award-winning transit-oriented development. As EPA and the responsible party examined the groundwater and indoor air, the city used the California Environmental Quality Act (CEQA) to require that mitigation be built into a newer development on the same property. The city even required that prospective buyers be notified of the environmental conditions at the point of marketing, but I was never able to verify that this took place.

As EPA developed a precedent-setting Record of Decision Amendment addressing vapor intrusion at the nearby MEW Superfund Study Area, it sought the city's help:

> In 2009, EPA published the Proposed Plan for the MEW Study Area that identified EPA's preferred alternatives for the vapor intrusion remedy. The Proposed Plan identified the adoption of a municipal ordinance as EPA's preferred IC, but the City of Mountain View and concerned property owners raised concerns that this was not necessary. Instead, EPA worked with the City of Mountain View, California, to have the City formalize its permitting procedures that apply to future construction. These permitting procedures oblige those proposing new building construction within the MEW Study Area to obtain EPA approval of construction plans to ensure that, where necessary, the appropriate vapor intrusion control system is integrated into building construction.… The City will also implement remedy requirements for projects subject to the California Environmental Quality Act through that law's procedures.… Additionally, EPA selected the use of a tracking service to provide notice when changes are made to properties within the MEW Study Area. Additional controls that will be implemented by the City of Mountain View include creation of a mapping database to help ensure that parties interested in properties within the MEW Study Area are informed of the appropriate construction specifications when making inquiries with the City.[26]

Since the adoption of the Permit Process for the MEW area in 2009, Mountain View has applied the same principles to developments on sites overseen by U.S. EPA, DTSC, and the Regional Water Board. While the city is already aware of most contaminated properties in town, the environmental studies conducted as required by CEQA identify both on-site and nearby subsurface contamination.

The CEQA documents may be labeled Initial Studies or Mitigated Negative Declarations, and larger projects may trigger Environmental Impact Reports. Unlike studies prepared according to CEQA's federal counterpart, the National Environmental Policy Act (NEPA), CEQA documents actually mandate environmental actions. Typically these include compliance with regulatory agency requirements, access for subsurface monitoring or remediation by responsible parties, and sometimes even remediation. Most important, for addressing vapor intrusion, the documents specify vapor mitigation. At a residential development under DTSC supervision along Mora Drive, Mountain View's Mitigated Negative Declaration requires:

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[26]*ibid*., page 186 of PDF

The developer of townhouses along Mora Drive will complete the groundwater cleanup.

> The developer shall complete a Vapor Intrusion Investigation Work Plan. This plan shall include soil vapor sampling in the areas of concern. The developer shall then prepare a Vapor Intrusion Mitigation Plan (VIMP) that reflects the results of the investigation and implement the VIMP, including any long-term operation and maintenance. The VIMP shall use a 10^{-6} cancer risk level and shall use the U.S. EPA residential screening levels to interpret the 10^{-6} cancer risk level. The developer shall provide DTSC's written approval on the Investigation Work Plan and the VIMP to the City.[27]

At a commercial site above the downgradient portion of a Superfund-site TCE plume, where the Water Board is lead downgradient regulator, the Initial Study applies the following among other conditions:

> • VAPOR BARRIER: Installation of a high-quality vapor barrier with an active venting system to protect building occupants from any TCE vapors. This "sub-slab depressurization system" (SSD) will be overlain by a spray-applied membrane. The system will be designed to function by continuously creating a lower pressure directly underneath the building slab relative to the pressure within the building. The resulting sub-slab negative pressure will inhibit soil gases from flowing into the building. The spray-applied membrane will be placed between the foundation of the building and the base materials, effectively sealing penetrations and the sub-slab to create an additional barrier to vapors from permeating through the slab and into the building.[28]

[27] "Mora Drive Residential Project: Initial Study/Draft Mitigated Negative Declaration," City of Mountain View, January 2016, https://mountainview.legistar.com/LegislationDetail.aspx?ID=2559810&GUID=FE44FE38-85B4-4796-9504-B0DAA10177AD&Options=&Search= page 4 of Attachment 1 PDF

[28] "1625 Plymouth Street Office Project: Initial Study of Environmental Significance," City of Mountain View, June 2016, https://mountainview.legistar.com/LegislationDetail.aspx?ID=2762593&GUID=4E57F32A-FCDA-448D-A17E-CE0C1B4DAE95 page 41 of Attachment 1 PDF

Plymouth Street development in Mountain View's North Bayshore area

The use of city-approved documents does not prevent regulators from including additional requirements in their own documents, particularly if the responsible party is involved in the vapor mitigation project. Such mandates may be more detailed than the city's. At a residential development within the MEW Superfund Area, the responsible parties' consultant submitted a "Property-specific Vapor Intrusion Control System Remedial Design." In addition to technical specifications, it includes:

- The treatment units and discharge points will be located away from the new residences, secured, and be congruent with the visual appearance of the development,
- Open common areas within the development are not available for locating the treatment units,
- Noise from the treatment units should not disturb residents,

…

- The SSD system will have minimal impact to occupants and visitors…[29]

In instances, the city has gone beyond requirements imposed by the environmental regulators, insisting that developments *near* potential vapor intrusion sites build passive mitigation into new structures. At a townhouse project down the same street from the MEW Superfund Area, the pre-emptive response proved valuable. Subsequent groundwater investigations found high levels of TCE in groundwater and soil gas, due to an old leaking sewer line, very close to the buildings. When U.S. EPA sampled inside the homes with built-in passive venting, it found the air safe.

[29]Haley & Aldrich, "Property-Specific Vapor Intrusion Control System Remedial Design: 277 Fairchild Drive, Mountain View, California," https://yosemite.epa.gov/r9/sfund/r9sfdocw.nsf/3dc283e6c5d6056f88257426007417a2/ec3201077f354d5088257fa000771e11/$FILE/Draft%20%20Vapor%20Intrusion%20Remedial%20Design%20-%20277%20Fairchild%20Drive%20-%20April%202016.pdf, page 10 of PDF

EPA drills well in front of townhomes with pre-emptive mitigation, Mountain View, CA

More recently, Mountain View approved an office building near the MEW plume and another Superfund TCE plume, on property that is not overseen by any of the regulatory agencies. Once again, however, the city included the following two conditions, among others, in the Mitigated Negative Declaration:

> MM HAZ-2.5: The installation of vapor mitigation system consisting of an impermeable barrier and sub-slab venting shall be required to help protect occupants against potential vapor intrusion of VOCs into the indoor air space of the proposed office building.
>
> MM HAZ-2.7: An as-built report shall be prepared to document the installation and final configuration for the vapor mitigation. The report will include mechanisms for restoring the barrier integrity in the event that future tenant improvements require penetration of the sub-slab vapor barrier, or in the event of any suspected vapor barrier breach or failure.[30]

I have found few other cities that use environmental impact documents to address vapor intrusion. Alhambra, California recently included a one-paragraph requirement in the Draft Mitigated Negative Declaration for the International Extrusion site.[31] New York City's "e"

[30] "580-620 Clyde Avenue Office Project—Initial Study/Mitigated Negative Declaration," City of Mountain View, May 2016, https://mountainview.legistar.com/LegislationDetail.aspx?ID=2741994&GUID=3A9218A5-526A-4C63-B588-0C77FDA2146C&Options=&Search=, page 3 of PDF

[31] "Alhambra Court Commercial Development—Mitigated Negative Declaration and Initial Study," City of Alhambra, http://www.cityofalhambra.org/imagesfile/file/201612/hellman_medical_office_building_mnd_december_2_2016_20161201_152717.pdf ,[sic] page 89 of PDF

designation imposes extra environmental review. And as mentioned above, in response to my testimony and pressure from site neighbors, in early 2016 the city council of Palo Alto voted to place additional mitigation conditions on portions of a Stanford University faculty housing project. However, Palo Alto does not systematically impose such conditions on other contaminated-site development.

A home improvement store and offices are proposed for the International Extrusion Site, Alhambra, California.

Of course, not every state has its own version of CEQA. And in many cities pre-emptive mitigation requirements might be a deal-breaker. Mountain View is fortunate that our developers, for both residential and commercial projects, believe that their properties become more valuable when they incorporate environmental protection and sustainability features into projects. It also makes it easier for me, as a councilmember aware of the risks of toxic exposure, to not only vote to approve these projects, one by one, but to assure the public that steps have been taken to ensure that building occupants will be safe, despite residual contamination in the subsurface.

Ten years ago or so Mountain View pioneered the practice of notifying prospective homebuyers that vapor intrusion was being investigated or mitigated on development properties. This now occurs routinely. In fact, in approving a hotel project above the same plume as the Plymouth Street office project shown above, the City Council voted to require that permanent hotel employees be told that the property is subject to an environmental response under the supervision of the Water Board.

Not every land-use planning jurisdiction has the tools, economic conditions, and will to supplement regulatory oversight with local oversight, but I believe that other communities can learn from Mountain View's example and perhaps adapt some of our approach. Once one understands that it is much safer and cost-effective to build vapor protection into new buildings, it's only a matter of figuring out the best way to do that. It's the duty of local officials in communities with subsurface vapor-forming contamination to learn the fundamentals of vapor intrusion and to figure out how they can cooperate with regulators to protect their residents, workers, students, and other building occupants.