A Stakeholder's Guide to Long-Term Management at Vapor Intrusion Sites[1]

By Lenny Siegel

April, 2016

Vapor intrusion occurs when toxic volatile substances are pulled into overlying buildings from the subsurface. The contamination that causes vapor intrusion, typically chlorinated volatile organic compounds (VOCs) such as TCE (trichloroethylene) and PCE (tetrachloroethylene), tends to persist in the subsurface. In most cases where there have been significant releases, neither natural biological degradation nor conventional treatment reduces contaminant concentrations to acceptable levels in a reasonable amount of time. Therefore, long-term management is necessary to protect the people who might be exposed. This is true, whether a decision is made to mitigate—that is, interrupt the vapor intrusion pathway—or not, and whether an effort is made to accelerate the removal or degradation of the subsurface contamination.

Long-term management may include:

- monitoring of subsurface contamination, in the form of groundwater or soil gas;
- inspecting possible pathways from the subsurface to indoors;
- operation, maintenance, monitoring, and inspection of mitigation systems;
- training building maintenance personnel;
- controlling and monitoring of mitigation system emissions;
- monitoring indoor and outdoor air;
- being prepared to implement contingency plans should indoor air concentrations exceed or even approach target levels;
- establishing institutional controls to limit activities and uses at the site and to ensure continuation of the steps above;
- periodic review of the protectiveness and/or efficiency of the response;
- notifying building occupants and public at large, including prospective purchasers, of site conditions and the current status of the environmental response;
- developing a decision-making process for turning off active mitigation when the vapor intrusion threat has receded;
- preparing reports documenting all of the above.

Particularly at high-profile sites with robust regulatory oversight, best practices have emerged. They are described in U.S. EPA's June, 2015 vapor intrusion *Technical Guide*,[2] as well as numerous guidance documents produced by the states. But at many sites, especially new developments with little of no regulatory oversight, site management activities end after early rounds of sampling or soon after the installation of mitigation systems. To this day, there is no national accounting of the number of buildings that have been evaluated for vapor intrusion, let alone the number of sites subject to future investigation or mitigation.

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[1] This is a supplement to Lenny Siegel, "A Stakeholder's Guide to Vapor Intrusion: Update," Center for Public Environmental Oversight (CPEO), November 2015, http://www.cpeo.org/pubs/SGVIU.html

[2] U.S. EPA, *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, http://www.epa.gov/vaporintrusion/technical-guide-assessing-and-mitigating-vapor-intrusion-pathway-subsurface-vapor .

This guide is designed to help stakeholders, particularly the people who live, work, study, pray, and recreate in buildings potentially susceptible to vapor intrusion, ensure that their sites receive proper long-term attention. And if there is no entity taking long-term responsibility, it provides a template for insisting that an agency or private entity take that responsibility. As with subsurface remediation, public oversight is the central element in making sure things are done right.

Above the IBM Plume, Endicott, New York

The best-known vapor intrusion sites in the U.S. are those that have had continuing regulatory oversight, public meetings, and press coverage. At a number of these sites, responsible parties have developed long-term management plans. These documents have a verity of titles, including workplans, portions of site management plans, and operations and maintenance agreements. This guide builds upon the approaches being used at three sites:

1) The off-site areas at the IBM contamination site in Endicott, New York, where 513 mitigation systems have been installed at 462 primarily residential properties.[3] IBM's environmental response is overseen by the New York State Department of Environmental Conservation (NYS DEC) under the State Inactive Hazardours Waste Sites (State Superfund) program.

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[3] See O'Brien & Gere, "Operation and Maintenance Work Plan of Structure Ventilation Systems," IBM, June 2012, www.cpeo.org/pubs/IBMVentilationWorkplan.pdf and O'Brien & Gere, "Ventilation System Operation & Maintenance 2013 Heating Season," IBM, February 2014, www.cpeo.org/pubs/IBMVentilationReport.pdf posted with permission.

2) Two buildings now occupied by Google at the MEW Superfund Study Area in Mountain View, California.[4] Well over 100 non-residential buildings lie over the MEW Plume. EPA Region 9 oversees the response by several private responsible parties at the MEW area.

3) The Mott Haven secondary school campus in the Bronx, New York, where New York City recently built four schools on a former railyard where off-site VOC contamination had migrated below the footprint of the new schools.[5] NYS DEC oversees the activities of the New York City School Construction Authority and Department of Education there under the state Brownfield Cleanup Program.

Where conditions, such as indoor air sampling results or high subsurface levels of volatile contaminants require mitigation, most communities want robust operation, maintenance, and monitoring to ensure that the mitigation is effective. But at a growing number of sites, responsible parties and builders are installing mitigation systems *before* there is compelling evidence that they are necessary. This approach, called Preemptive Mitigation (PEM) or Early Action, can be quicker, more protective, and even less expensive than the sampling option. At redevelopment sites, such as brownfields, early action may help accelerate construction while providing developers with the certainty they need about the environmental aspects of their projects. This is particularly true where the contamination has migrated from a source area to the development property.

Pre-emptive systems can be passive venting—consisting of vapor barriers, perforated subsurface piping, and vertical vent pipes—or active depressurization, including blower fans as well. If builders install passive venting systems under new buildings, they can switch them to active depressurization by installing blower fans if post-construction indoor air monitoring shows unacceptable concentrations of toxic compounds in indoor air.

However, robust repetitive sampling may discourage developers and other cleanup volunteers from agreeing to preemptive mitigation in the first place, if they are required to spend as much time and money on post-mitigation monitoring as they would have, had they not agreed

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[4] See Geosyntec Consultants, *Building-Specific Long-Term Vapor Intrusion Operations, Maintenance, and Monitoring Workplan,* Schlumberger Technology Corporation, October 2013, http://yosemite.epa.gov/r9/sfund/r9sfdocw.nsf/3dc283e6c5d6056f88257426007417a2/a64d883b289c1b4488257f45007402cc/$FILE/Draft%20SSD%20OMM%20Plan%20369-379%20N%20Whisman%20Rd%20-%20MEW%20Superfund%20-%20Oct%202013.pdf and Weiss Associates, "2015 Annual Sub-Slab Depressurization System Operation, Maintenance, and Monitoring Report," Schlumberger Technology Corporation, January 28, 2016, http://yosemite.epa.gov/r9/sfund/r9sfdocw.nsf/3dc283e6c5d6056f88257426007417a2/b95bce419de7b42288257f4a0003c3ea/$FILE/2015%20Annual%20SSD%20Operation,%20Maintenance%20&%20Monitoring%20Rpt%20-%20369%20&%20379%20N%20Whisman%20(Bldgs%207%20&%206).pdf .

[5] See Shaw Environmental, *Former Metro-North Property (Mott Haven) Final Site Management Plan,* New York City School Construction Authority, November 2008, Part 1, www.cpeo.org/pubs/MottHavenSMP.pdf and ATC Associates, "Revised Annual Site Management Report, Mott Haven Campus-X790," New York City Department of Education, September 30, 2011, www.cpeo.org/pubs/MottHavenASMR.pdf . See also Peter Strauss and Lenny Siegel, "Community Guide to Long-Term Management, Mott Haven Campus, Bronx, New York," CPEO, June 2010, http://www.cpeo.org/pubs/MottHavenGuide.pdf .

to mitigate. In its vapor intrusion *Technical Guide,* "EPA generally recommends that decision-making about PEM include a consideration of the O&M [Operation and Maintenance] and monitoring obligations." However, EPA also notes, "Passive systems are generally less predictable and less efficient at preventing vapor intrusion than active systems and, therefore, typically warrant more intensive monitoring, all else being equal."[6]

Long-term monitoring requirements at vapor intrusion sites are evolving, and in many cases they are determined on a site-specific basis. Generally, consultants recommend and/or regulators require careful monitoring soon after mitigation systems are installed. If systems prove effective, they reduce inspection and monitoring frequencies over time.

The problem is that elements of the mitigation systems such as vapor barriers and other seals, as well as the basic construction of a building, such as concrete slabs, are more likely to leak as time progresses. Over time, building occupants and owners may alter structures, unintentionally weakening the pull of depressurization systems. Thus, even buildings with mitigation systems that appear to be working may end up needing operation, maintenance, and monitoring in future years. Furthermore, changing climatic conditions may limit the effectiveness of systems that work well in the conditions for which they were designed. Therefore, continuing operation and regular maintenance and monitoring of mitigation systems need to be incorporated into building maintenance regimes. However, since few sites have addressed volatile-compound vapor intrusion longer than a dozen years, no one really knows when more sampling will be necessary.

Establishing Requirements

The first step in the long-term management of vapor intrusion sites is the preparation of a site-specific management plan. Though there are a variety of guidance documents and model workplans in place, the scope, timing, and even the strategy for mitigation varies is based on the magnitude and nature of the contamination, the number and types of structures, and the concerns of the owners and occupants of the buildings. Despite their differences, each workplan should address all of the other components of long-term management. It may also repeat site history, document site contamination, and describe anticipated or implemented remedial action and mitigation.

Workplans may be prepared by responsible parties, regulatory agencies, developers, or property owners. In fact, one of the key elements of the workplan is establishing who is responsible for conducting long-term management as well as which agency, if any, is responsible, for overseeing it. In the workplan, the responsible entity should demonstrate or even set aside the funding necessary to implement long-term management for as long as contamination poses a risk, and it should list the individuals responsible for implementing the various aspects of the workplan. Finally, it should list specific requirements for record-keeping, reporting to oversight agencies, and communicating with the public.

[6] EPA, *Technical Guide,* pages 157 and 175 of the PDF.

Where there is no workplan, that's an indication that no one is planning to do the work. In that case, **concerned stakeholders need to press those that have installed mitigation systems to get them to do the necessary follow-up**. While the stakeholders most directly affected are building occupants and owners, others—such as insurance companies, banks, and local governments—may also have an interest. At development projects with little regulatory oversight, once the original environmental consultant goes off contract, there may be nobody around who knows anything about the vapor intrusion response.

A workplan may apply to a small number of buildings, such as the two Google buildings in Mountain View. Or it may apply to an entire plume or operable unit. The IBM workplan covers hundreds of homes. At the Mott Haven campus the vapor intrusion long-term management workplan was incorporated into a site management plan that addresses other long-term management needs at the site, such as soil covers.

MEW Superfund Area, Mountain View, California

Ideally, those conducting cleanup will start preparing the long-term management plan while they are still designing the remedial action and mitigation systems. Understanding the ongoing costs and challenges may lead them to invest more up front in the removal or treatment of site contamination. If new construction is contemplated, they may adjust the footprint or design of the buildings. At Mott Haven, the community groups with which I was working actually went to court to insist successfully that the Site Management Plan be developed earlier in the process.

It's important that the geographic scope of the plan, or collection of plans, consider every building at risk of vapor intrusion, as well as property where buildings may be built in the future. When mitigation is installed as part of development above a downgradient off-site plume from a contamination site, it should be clear whether the property owner or the responsible party is responsible for long-term management. At the Mott Haven site, New York school authorities developed a Site Management Plan for the entire site, even though only one corner of the property was covered by a state-regulated Brownfields Cleanup Plan. It took persistent pressure from the community to get the Department of Environmental Conservation to review the entire Site Management Plan.

Subsurface Monitoring

While long-term management at vapor intrusion projects is generally focused on buildings where mitigation is in place, at many sites there are buildings that have not had systems installed. Continuing monitoring of soil gas and groundwater may be necessary to determine if contamination levels are increasing, or simply if they were missed. Where the purpose of site characterization is to identify buildings at risk of vapor intrusion, as opposed to threats to production wells some distance away, denser sampling is often required. For example, at the MEW site in Mountain View, not far from the two Google buildings mentioned above, U.S. EPA conducted additional groundwater sampling to tighten up delineation of the shallow TCE plume. In 2012, three decades after the main plume was first discovered, it found two new groundwater hotspots beyond the historic plume boundary. That triggered additional indoor air sampling in dozens of homes and the addition of at least two residential mitigation systems.[7]

Inspection of Potential Pathways

One of the best protections against vapor intrusion is an intact slab or floor. Though some vapors may penetrate a typical foundation or floor, any crack or hole can form a preferential pathway, allowing greater upward flow. At the Google buildings, the slab was "trenched" for the installation of underground cable. Thus, visible elements of buildings' intrinsic vapor barriers should be checked routinely for new openings, as well as after construction, extreme weather, or other natural disasters. Buildings with maintenance staff can create tiered schedules. Maintenance personnel, such as custodians, can be trained to incorporate inspection into their routines, while outside specialists can make less frequent visits.

EPA's *Technical Guide* suggests smoke tests or quantitative tracer tests as means of detecting leaks, but it reports that small cracks may release too little smoke for visual detection and that large cracks may be detected in other ways. At Mott Haven, the Site Management Plan called for smoke tests, but the schools' contractor didn't conduct them. When my colleague and I questioned that omission, the state regulator explained that such tests were only planned for

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[7] Lenny Siegel, "Mountain View, California's Mystery TCE Hotspots," CPEO, November 18, 2013, http://www.cpeo.org/pubs/MVHotspots.pdf . Since publication of this report, EPA confirmed that a sewage lines that leaked in the early 1960s was the source of the four hotspots.

"locations where cracks or penetrations were observed during the visual inspection of the slab." And then she concluded that the state did not have a methodology for such tests, and that in this instance it would be impractical.[8] This minor dispute demonstrates the importance of not promising any monitoring techniques in the vapor workplan that cannot be carried out. Rather, reliable, established methods should be agreed upon up front.

Operation and Maintenance of Mitigation Systems

Mitigation systems, such as sub-slab depressurization systems, are a proven way to prevent subsurface vapors from intruding into overlying structures. But they work only as long as they work. For residential structures, those installing the systems should brief owners and tenants on the fundamentals of the system. For commercial and institutional buildings, such as schools, the consultants should provide maintenance personnel, such as custodians, site-specific operation and maintenance training, complete with explanations why smooth, reliable functioning of mitigation systems is essential for the health of building occupants.

Inspection

The simplest element of mitigation system maintenance is inspection. Building management personnel or building occupants need to routinely check visible system components, both passive and active, to check that they are undamaged, and that the system has not been modified. If the systems are active—that is, they rely on a blower fan to depressurize the subsurface—it's necessary to ensure that the fan remains plugged in, turned on, and properly functioning for whatever schedule is called for in the workplan. For both active and passive systems, it's also important to check that piping is intact and not plugged—by ice, for example. If, as in the case of some large commercial buildings, emission controls are applied to vent pipes, those "scrubber" units must be maintained as well, and the releases from those systems should be monitored according to a pre-established protocol and schedule.

Routine inspections should also ensure that the pressure differential between the indoors and the subsurface meets system design criteria, using a manometer or a similar device—typically installed as part of the systems. This can be done on the same schedule as inspection for pathways. Particularly in homes, residents may be irritated by fan noise or unhappy about paying for the extra electricity—if that's the arrangement. Some have turned off their systems, not realizing the potential impact. So it's important to make sure that they understand why and when the system needs to operate.

As with pathway inspection (above), for larger buildings it often makes sense to established tiered inspection protocols. Building maintenance personnel can incorporate basic inspection into their daily routines, while skilled professionals can schedule less frequent visits. For example, consultants may periodically measure flow rates in the vent risers and check for changes in the building's other ventilation systems.

Auto-Reporting and Telemetry

[8] Letter from Sondra Martinkat, New York State Department of Environmental Conservation to CPEO, September 30, 2013.

Many active systems are designed to announce when the fan fails. Historically, this has been done with an audible alarm or an auto-dialer. The former is designed to get the attention of a building occupant or maintenance personnel, so they can phone in the problem. The latter simple calls the project management team directly. These days, however, continuous telemetry is inexpensive, nearly universal, and reliable using Internet or wireless technology. So system failures can be instantly reported.

Mott Haven Campus, Bronx, New York

For example, at the two Google buildings, an automated transmitter is programmed to contact project engineers if blower fans lose power or otherwise fail. Elsewhere, a service called VaporTrac "transmits air-flow, pressure (vacuum), power, and device temperature measurements continuously via cellular or WiFi communication networks." Ideally, a continuous or near-continuous signal would confirm that the system is functioning properly. This would eliminate the risk that a problem would be missed because the reporting device failed as well.

Some mitigation practitioners use telemetry to collect data from pressure sensors on the buildings being mitigated. If the pressure differential goes below an agreed-upon standard, the project manager is automatically notified. This approach is used to quickly identify other system failures, such as vent pipe blockage, fan failures, or even the insufficiency of fan power to overcome the influence of cold weather. Beyond that, one can structure remote sensing systems, using pressure differentials, to turn adjust blower fans or even turn them on and off as needed.

These systems are designed to conserve energy and extend fan life while preventing vapor intrusion.[9]

Teamed with other sensors—ambient temperature, for example—telemetric systems can also generate and send continuous reports, not just to project engineers, but to regulators, building owners, and even the public, describing site conditions and the effectiveness of mitigation.

In addition, system operators may use other data to manage mitigation systems. For the new mitigation systems at the Google buildings, the consultant programmed blower shutdowns to occur whenever the temperature inside equipment enclosures exceeded 140 degrees Fahrenheit, to protect the equipment. In 2015 there were numerous interruptions due to direct sunlight on the enclosure, but each time the system restarted when the temperature fell.

Fan Replacement

The blower fan is perhaps the most vulnerable component of a typical mitigation system, because it is the primary moving part. Some projects wait for them to fail before replacing them, while others also replace them on a fixed timetable. Large projects—that is, with multiple fans—keep spare fans and parts handy to facilitate rapid repair or replacement.

Emission Controls

While mitigation systems on single-family homes rarely vent enough VOCs to be a concern, large systems on commercial buildings may release enough contaminant to concern air regulators. In these cases, emission controls such as vapor-phase carbon absorption may be used to extract the target compounds from the off-gas. This is good thing, but it creates another opportunity for failure, not just of off-gas treatment, but sub-slab depressurization itself. At one of the Google buildings, particulate blockage of a carbon filter reduced the differential pressure below design requirements, so the consultants shook it and later replaced it.

HVAC Systems

In commercial buildings (including schools), heating, ventilation, and air conditioning (HVAC) systems can protect against vapor intrusion by pressurizing the interior and by maintaining a high ventilation rate. However, this may require that they be operated longer or more intensely than if only programmed to maintain desirable temperatures. So an operations plan must be developed and tested against indoor air measurements. If HVAC operation is considered to be protective against vapor intrusion, then its operation and maintenance should be incorporated into the long-term management plan.

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[9] See, for example, Thomas E. Hatton & Daniel J. Nuzzetti, "The Effects of Weather-Induced Variables on Large Building Vapor Intrusion Mitigation Systems," Paper # 49 Presented at the Vapor Intrusion, Remediation, and Site Closure Conference, September 10-11, 2014, Cherry Hill, NJ, www.cpeo.org/pubs/Hatton-Weather.pdf , posted with permission.

Even after operational parameters are set, air monitoring should be conducted periodically to ensure effectiveness. It was only through indoor air sampling (showing exceedances of TCE screening levels) that it was discovered that the two Google buildings were operating under negative pressure. Modifications had been made to the HVAC systems; they were under manual, not automatic operations; and one of the systems was reporting erroneous pressure readings. This is what led to the installation of the sub-slab depressurization system and the preparation of the Operations, Maintenance, and Monitoring Plan.

Air Monitoring

The best measure of whether indoor air meets regulatory standards is to measure indoor air, and in my experience community stakeholders prefer this over indirect measurements. One consultant wrote:

> Regarding remediation performance monitoring associated with mitigation systems, [EPA's] guidance barely mentions the importance of collecting appropriate chemical information to confirm that reduction in exposure objectives have been met. Instead, the focus is aimed at evaluation of the pressure field and whether or not mechanical components are operational. On the basis of the interactions with people exposed or potentially exposed to toxic and explosive conditions in and around their homes and businesses, citizens are primarily concerned about harmful levels they are being exposed to. Determining whether a fan is operational is of secondary importance.[10]

Historically the best practice for measuring indoor air concentrations has been to conduct at least two sampling events, at least one of which took place during worse case conditions, presumed to be winter. This applied whether the purpose was to determine whether mitigation was necessary or to check that it was working. However, not many building managers, responsible parties, or regulators choose to conduct more indoor sampling. Not only are they concerned that indoor sources may generate false positives, but arranging to enter homes twice for each event—to emplace and remove sampling devices—is burdensome and takes a significant time commitment when multiple buildings are involved. Indeed, simply getting the property owner to sign an access agreement may be difficult and time-consuming, but such agreements are essential if anything is to be done of the property.

Still, research showing significant temporal (over time) variability—by weather, time of day, and season—has called that practice into question, particularly where the chemical of concern is believed to pose a short-term health risk.[11] EPA and other regulatory agencies believe that if pregnant women are exposed to low levels of TCE for periods as short as one day to three weeks, there is an unacceptable risk that their children will be born with cardiac birth defects. Sampling once or twice a year, one could miss the elevated levels that pose that risk.

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[10] Mark Kram, "The Emperor's Old Clothes: An Inconvenient Truth About Currently Accepted Vapor Intrusion Assessment Methods," *Groundwater Monitoring & Remediation,* Fall 2015, http://onlinelibrary.wiley.com/doi/10.1111/gwmr.12140/full , page 3.

[11] For background, see "Temporal Variability," CPEO, November 2015, http://www.cpeo.org/pubs/SGVI/Time.pdf .

When deciding whether to mitigate, some investigators have worked to overcome that by generating an artificial worst case, depressurizing the building to see if indoor air levels are likely to rise during a "perfect storm" of atmospheric and building conditions. This approach is gradually gaining acceptance, but it won't work once mitigation is in place. It would require turning off sub-structure depressurization systems, so it could not be used to see how those systems are working.

The solution is continuous or near-continuous monitoring at low detection levels, but historically continuous or near-real-time sampling of indoor air at the concentrations typical of vapor intrusion has been expensive and difficult. This is changing, as research teams compete to bring inexpensive, accurate near-real-time sampling equipment to market. Cheap compact devices are still in development, but according to one practitioner:

> The good news is that many types of continuous monitoring methods are commercially available. These methods are not only capable of determining worst case exposure concentrations, but also yield critical information about what might be causing potential fluctuations so that these can be appropriately addressed. As such, they are also ideal for verifying when risks are not present and for avoiding false-positive conclusions as well.[12]

Near-continuous monitoring can also be used to measure the impact of routine weather patterns that may affect barometric pressures. For example, at a site in Southern California consultants observed large increases in indoor concentrations during the middle of the day, when buildings were occupied. Conventional 24-hour sampling would have understated exposure levels for workers, including pregnant women.

Near-continuous remote monitoring has been called the "gold standard" of vapor intrusion sampling, and I believe it may soon be routinely available. However, it is important to develop the tools to know how to respond to the anticipated deluge of new data. For example, at each site, decision-makers will have to agree in advance how much of a spike in indoor air measurements should trigger a site visit and possibly alteration of the mitigation system.

Any time indoor air sampling is conducted, whether it's during an initial investigation or while mitigation systems are operating, it's also important to sample outdoor air to help determine whether the VOCs inside have entered from below or from doors and windows. By now most regulators have agreed that reference tables on outdoor background levels are unreliable. While it's unusual to find TCE in outdoor air at levels comparable to unacceptable vapor intrusion, its presence is a sign that either there is an industrial source nearby or the compound is volatilizing from surface water such as a spring or creek. Note that EPA now considers the evaluation of such outdoor releases to be a part of vapor intrusion investigation. In dense urban areas with many dry cleaners, it's not uncommon to find PCE outside at levels of concern. In the unusual case where petroleum compounds are considered a vapor intrusion threat, outdoor emissions from gasoline or auto exhaust can easily reach the levels rising from the subsurface.

[12] Kram, page 4.

We are currently in a "chicken vs. egg" situation. Regulatory agencies are reluctant to use or require continuous monitoring because the equipment is not widely available at affordable prices, and developers are slow to bring new products to market because regulators seem comfortable with the conventional approach to monitoring.

Where regulators are unwilling or unable to conduct or require indoor air testing, building occupants have another option. Reliable mail-order sampling kits are now available that test for suspected vapor intrusion compounds for less than $200.00.

Long-Term Monitoring Frequency

Most guidance on post-mitigation monitoring frequency, particularly as it applies to indoor air sampling, suggests that confirmation sampling be conducted after mitigation is installed or a new building is completed, with less frequent sampling over time. The theory is that once a system is proven, there is less need to sample.

In its *Technical Guide,* EPA explains:

> For example, it may be acceptable to reduce inspection or maintenance frequency once efficient system operation has been demonstrated for at least an initial year, with triggers for additional, unscheduled inspections following alarms (from warning devices) and floods, earthquakes, and building modifications, if any.[13]

But site-specific factors may influence the monitoring schedule. EPA suggests that older buildings, passive venting systems, migrating groundwater plumes, and the application of new subsurface remedies may trigger the need for additional monitoring.

Moreover, the likelihood that system elements, be they vapor seals or active blowers, will fail increases over time. Most guidances say that building modifications or natural disasters, such as earthquakes, should trigger new sampling, but many events that could re-open vapor pathways may go unnoticed. So unless there is evidence that treatment or natural degradation are eliminating the subsurface source of volatile compounds, one could argue that monitoring should be conducted more often over time.

On the other hand, when encouraging developers and others to carry out pre-emptive mitigation, as an alternative to recurring sampling to determine whether to mitigate, I and others have argued that mitigation is less expensive and time-consuming than sampling. If they are required to do a large amount of post-mitigation sampling, that incentive disappears. So it's important to seek balance. Since mitigation is more protective than just sampling, the long-term monitoring program should be designed so it's not too burdensome, yet it can catch system failures.

Using conventional monitoring techniques such as Summa™ canisters or passive samplers, it is possible, on a site-specific basis, to compare the cost of various sampling timetables as well as pre-emptive mitigation. Other assumptions, such as the number of locations

[13] EPA, *Technical Guide,* page 173 of PDF.

sampled for each building, also affect monitoring costs. But if one accepts that TCE exposure poses a serious risk to unborn children, in many cases it's hard to come up with a long-term monitoring program that is at once fully protective and cost-effective.

The solution, once again, lies in automated systems for continuous monitoring. Today, as new mitigation systems are installed, it should be a standard practice for the remote monitoring of mitigation systems—fan operation, pressure differentials, etc. As continuous indoor air monitoring becomes more practical, it too should be required.

> Some options include tracking of general parameters (e.g., total volatile organic compounds) while others are analyte-specific (e.g., TCE, PCE, benzene, methane, oxygen). Some rely on sensors while others exploit innovative multiplexing components that allow for laboratory grade chromatographic analyses using a system that can draw and analyze samples from multiple locations, much like what is currently performed in hospital settings.[14]

Monitoring systems that more completely collect concentration data over space and time open new opportunities for displaying and analyzing information. That is, plugged back into the conceptual site model, sampling data should make it easier to understand where toxic vapors are coming from as well as where building occupants might encounter them.

While it is possible that air monitoring may occasionally detect elevated levels of volatile organic compounds due to indoor or even outdoor sources, those detections should not just be seen as false-positives. They represent increased health risks for building occupants. The data from the continuous sampling could be used to help residents, employees, etc., to find and eliminate those source or in some cases, avoid the contaminated areas.

Contingency Plans

Contingency planning is an important, but often neglected component of long-term management. At the Mott Haven site, my colleague and I recommended:

> First, the SCA and DEC should specify contingency plans or at least a contingency process for addressing monitoring results that show that unacceptable exposures are occurring. This applies not only to the cap, but to the hydraulic barriers and subslab depressurization system. A contingency plan would describe how SCA and regulatory agencies plan to address foreseeable problems, including routine, long-term contingencies and uncontrollable events (e.g., severe flooding) that could affect the stability of the proposed remedy. Potential contingencies can be divided into Technical Contingencies (e.g., failure of a hydraulic barrier, an increase in contaminant detections in groundwater, or increases in vapor concentrations), Logistical Contingencies (e.g., changes in personnel, funding, or land or building use), and Regulatory Contingencies (e.g., significant changes in regulatory standards or redefinition of the roles and responsibilities of the different responding agencies).[15]

[14] Kram, page 4.

[15] Lenny Siegel and Peter Strauss, "Independent Review of the Cleanup of the Mott Haven Complex, Bronx, New York," CPEO, January 24, 2007, page 12, http://cpeo.org/pubs/Mott-Haven.pdf .

We were disappointed when the Site Management Plan included little more than emergency contact information.

The MEW OM&M plan for the two Google buildings, on the other hand, established clear contingency measures up front, so stakeholders have the opportunity to know if problems are addressed properly. For example, if indoor air concentrations after mitigation startup exceeded EPA action levels, the responsible parties were to measure pressure differential and modify the system if necessary. If indoor air levels remained high, the responsible party had a checklist of activities that included checking for potential indoor sources and preferential pathways and asking the property owner and tenant about building modifications.

Institutional Controls

Institutional controls are legal requirements designed to support physical cleanup. They include a variety of written measures, such as land use covenants, deed restrictions, and local ordinances. At vapor intrusion sites they can be used to restrict activities and uses, and they typically require building owners and operators to report any change in ownership or use. They frequently mandate the operation and maintenance of mitigation systems. And they can also be employed to guarantee timely access for responsible parties, regulators, and their consultants. Where mitigation is conducted without regulatory oversight, it's rare to find any institutional controls.

In their simplest form, institutional controls restrict what can be done on a specific piece of property. For example, they can be used to prevent construction of any building where there are high concentrations of VOCs in the subsurface. Or because exposure standards are more protective for residences than commercial buildings—because people may be at home longer than they are at work—they can simply outlaw housing.

Stanford University is building housing on a toxic site in Palo Alto, California, and the state Department of Toxic Substances Control (DTSC) expects to establish a land use covenant that will restrict exactly where those homes can be placed. Ironically, the issuance of the land use covenant may be the neighbors' only opportunity to submit to DTSC formal comments on the planned site response.

It is good when developers design vapor mitigation into buildings with a potential for vapor intrusion or responsible parties voluntarily offer mitigation to homes and other structures above groundwater contamination, but there is often no requirement that they operate, inspect, maintain, and monitor the mitigation systems. Stakeholders should explore mechanisms for establishing such requirements. And even when mitigation is described in regulator-approved workplans, there is no guarantee that regulators will still be paying attention once a project is completed.

In my community, Mountain View, the city identifies projects with known VOC contamination when developers seek city approval. Where there is regulator involvement, the city insists on regulator approval of both remediation and mitigation. The city also uses the

California Environmental Quality Act (CEQA) to impose requirements. The following is from a recently approved CEQA Mitigated Negative Declaration at a Mountain View housing development:

> The developer shall install vapor intrusion mitigation systems beneath all buildings to effectively eliminate vapor intrusion. The mitigation system shall either be an active or passive sub-slab depressurization system. The developer shall also provide measures in the VIMP [Vapor Intrusion Mitigation Plan] to confirm the vapor intrusion mitigation system works as designed. The developer shall provide financial assurances of adequate funds for long-term operation and maintenance, if required by the VIMP.[16]

The Declaration also mandates that the VIMP include long-term operation and maintenance. The Council also voted to include notice requirements for prospective homebuyers. Unfortunately, few communities have the experience or expertise to include such specifications in their environmental reviews.

To my knowledge, however, Mountain View has only applied such CEQA language to properties on or near sites with state or federal environmental regulatory oversight, so the city has been in a position of reinforcing an approach that has been developed by government officials with knowledge and experience with vapor intrusion.

To apply local oversight to properties where there is no state or federal involvement, three things are necessary:

1. A statute that gives the city or other local planning jurisdiction the authority to establish and enforce environmental requirements.

2. A model set of requirements that each jurisdiction can adapt to its own situation.

3. Technical assistance, since most local governments lack the capacity to evaluate the data generated in vapor intrusion investigations.[17]

It is essential that institutional controls "run with the land." That is, if restrictions are applied to a current landowner, they should also be binding on future landowners. This seems obvious on private property, such as the Google buildings, but it also applies to governmental agencies. A key element of the Mott Have Site Management Plan was that the controls accepted by the New York City School Construction Authority would apply to the City's Department of Education, which took over the site once construction was complete.

Finally, even where new construction is not expected, institutional controls can be used to flag and prevent activities that would open up pathways from the subsurface or weaken mitigation systems. For example, when a building owner or contractor seeks a permit to modify

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[16] "Mora Drive Residential Project, Initial Study/Draft Mitigated Negative Declaration," City of Mountain View," January 2014, page 4.
[17] Within the next several months, I plan to elaborate on this in a "Stakeholder's Guide to New Construction at Vapor Intrusion Sites."

plumbing or electrical systems, local governments should be able to check to see if any restrictions apply to the property. If those restrictions were designed to combat vapor intrusion, the government entity can place conditions on the utility work. Once again, however, few local governments have the capacity to determine exactly where, when, and how such care must be taken.

Periodic Review

While operation, maintenance, and monitoring should be conducted frequently, if not nearly continuously, there is a need for periodic review to check to see that those are being carried out properly. The federal Superfund law (CERCLA), as well as a number of state statutes, prescribes that such reviews be conducted at least every five years. The review, which provides for stakeholder input, is designed to determine whether the remedy—in this case, mitigation—remains protective.

However, many sites are not subject to periodic review, but as long as the subsurface contamination poses a threat of vapor intrusion there should be some type of oversight. And that oversight should be conduct by an entity, perhaps a governmental unit such as a county health department, that expects to be around and accessible to the public indefinitely. Stakeholders will have to work hard up front to ensure that a proper level of oversight remains in place as long as the contamination.

Notice

People have a right to know that the buildings that they buy, rent, or otherwise occupy might be subject to vapor intrusion, and they should also be informed what has been done to protect them. Fully informed, they may choose to make their own risk management decisions. For example, knowing vaguely about the risk to their fetuses, some pregnant Google employees chose to work from home rather than be exposed to TCE vapors in their workplace.

Fully notifying building users has other benefits. Occupants who understand the risks of contamination as well as the steps designed to address it can become partners in the site management effort, making sure that the mitigation systems in their homes are operating properly or that those in their workplaces have not failed. Of course, notice is essential where those maintaining and monitoring systems need access agreements to enter buildings to carry out their duties.

The simplest form of disclosure is for the sale of homes. Most states require some form of notification, but that is rarely effective. In some jurisdictions, sellers routinely avoid disclosure. In New York State they can just pay a small fine. In many places, buyers learn about hazardous waste contamination in the area roughly halfway through the laborious real-estate document-signing process. Mountain View however, has begun routinely requiring, as part of development approval, notification of prospective buyers at the point of marketing.

IBM has a particularly robust notification system for buildings that qualify for mitigation at its Endicott, New York site. Not only do its representatives check on all the buildings with mitigation systems in place, but each year they contact all other property owners within its "blanket" response zone. One of the objectives of its *Operation and Maintenance Work Plan of Structure Ventilation Systems* is to "Track and annually re-offer ventilation systems to property owners that originally declined systems, had unsafe or other conditions such that design and installation was not practical, or were unresponsive to IBM's repeated attempts at communication."[18]

Initially, however, tenants in apartment buildings within the IBM mitigation area did not receive notice of the investigation, so Assemblywoman Donna Lupardo led a multi-year effort that culminated in the enactment of a state law requiring that tenants be told of sampling results associated with an indoor air investigation. It also require disclosure of mitigation:

> For real property for which an engineering control is in place to mitigate indoor air contamination, or if the real property is subject to ongoing monitoring pursuant to an ongoing remedial program, the owner or owner's agent of real property to whom indoor air contamination test results have been provided by an issuer shall provide, or cause to be provided, fact sheets, and upon request any test results, or closure letter received by such owner or owner's agent to any prospective tenant prior to the signing of a binding lease or rental agreement.[19]

Non-residential buildings pose their own notification challenges. In Santa Ana, California, the Orange County Health Care Agency issued a release, pursuant to the state's Proposition 65 program, explaining that indoor TCE levels exceed EPA's accelerated response levels. This is a former plating shop that now hosts a "storefront" church.[20] I have not yet determined whether churchgoers, who are likely Spanish-speaking, understand the risk associated with their exposures. Google notified its employees about the elevated TCE levels in its buildings, but at least some of the employees—pregnant women who contacted me—felt they needed more information. At 2350 Fifth Avenue, in Harlem, New York City, building occupants observed remediation and mitigation work on the premises, but they were not told what was going on.[21]

At a series of New York City school sites, my colleague and I recommended low-key warning signs at entrances. School authorities and regulators repeatedly ignored this suggestion. Nevertheless, we continue to believe that people who enter buildings subject to a vapor intrusion response have a right to know about it. Here's what we recommended at the Mott Haven site:

> Plaques or signs at all entrances to the property should notify the public that the site is subject to a site management plan. The signs should be clearly visible, but non-obtrusive. They should be designed to direct people to the repositories or a web

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[18] IBM Workplan, page 5.

[19] New York State Assembly Bill 10952, May 8, 2008, http://assembly.state.ny.us/leg/?default_fld=&bn=A10952&term=2007&Summary=Y&Text=Y .

[20] "Trichloroethylene Detected in Indoor Air Samples at Santa Ana Site," News Release, Orange County (California) Health Care Agency, February 9, 2016, http://us4.campaign-archive2.com/?u=2f2593b644c191a74f2a4d25a&id=07cc9c5970&e=7d32448a0d .

[21] Lenny Siegel, "Harlem: Learning about Vapor Exposures the Hard Way and Doing Something About It," CPEO, August, 2012, http://www.cpeo.org/pubs/2350FifthExposures.pdf

> address, in such a way that they may request to be added to the contact list…. They should be worded carefully to avoid causing unnecessary fear. We suggest language such as, "This property is subject to an environmental site management plan. For more information…"[22]

Furthermore, a growing number of people routinely search the Internet for information when they hear reports of rumors of contamination in their neighborhoods, buildings they use or visit, or properties they are considering for purchase. There should be a Web site that is easy to find, up to date, and targeted to lay readers that both explains the conditions and risk profile for each site and also provides links to resource documents and experts.

Failure to provide notice breeds mistrust. I recall the anger expressed by the father of a student at the Manhattan Center for Science and Mathematics, on New York's Upper East Site. He and his daughter had carefully searched the web to choose that school but they learned nothing about site contamination until he attended his first meeting of the Parents' Association. Similarly, parents at two middle schools in Winston-Salem, North Carolina successfully demanded that the schools be closed when they learned that their children had been attending class above subsurface VOC contamination, even though there was no evidence of unacceptable exposure.[23] Perhaps the worse case of failure to communication was at the Bronx New School. There the New York City Department of Education DOE discovered high levels of TCE inside as early as January 2011, received a recommendation to ventilate from consultants in May, and notified parents and teachers in August when they announced plans not to re-open the building after the summer break. Hundreds of angry parents attended a subsequent meeting, where DOE Chancellor Dennis Walcott offered a public apology.[24]

Beyond general notice, it's standard practice to mark mitigation systems, describing the various components, and to attach placards containing instructions. Service manuals are provided to homeowners or building maintenance personnel. Perhaps most important, there should be a sign directing people to a reachable, responsible point of contact. For buildings for which there is no responsible point of contact, it would be useful to point people to a generic source of information, such as a web site.

Exit Strategy

Thus far, the deliberate termination of active mitigation has been considered at only a handful of sites across the United States, because removing volatile organic compounds from the subsurface is slow and difficult. (Of course, if a building is demolished mitigation is necessarily terminated.) Termination criteria, such as "numeric cleanup levels for each site-specific

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[22] Lenny Siegel and Peter Strauss, "Independent Review of the Draft Site Management Plan for the Mott Haven Schools Complex, Bronx, New York," CPEO, March 25, 2008, page 17, http://www.cpeo.org/pubs/MottHavenSMP.pdf .

[23] Lenny Siegel, "Vapor Anxiety at the Hanes-Lowrance Middle School Campus, Winston-Salem, North Carolina," CPEO, June, 2015, http://www.cpeo.org/pubs/HaLo.pdf .

[24] Lenny Siegel, "Vapor Intrusion at the Old and New Bronx New School Campuses," CPEO, November 2011, http://www.cpeo.org/pubs/PS51xVaporIntrusion.pdf

contaminant and narrative cleanup objectives that are to be attained by the response actions," should be established as early as possibly in the vapor intrusion response. EPA states:

> EPA recommends that these termination criteria be recorded in decision documents, in any other planning reports, and in monitoring reports. EPA generally recommends also developing and documenting an exit strategy, which clarifies how it will be determined that the termination criteria have been attained (e.g., monitoring data and associated statistics that will be used to demonstrate attainment). This document could be developed in conjunction with the O&M plan and monitoring program so that all stakeholders are provided with a clear and comprehensive set of termination criteria for the remediation and mitigation systems and ICs. If site conditions (e.g., building usage, vapor flux) change during the cleanup activities, it may become necessary to modify the termination criteria and/or strategy.[25]

Those evaluating termination should consider the past, current, and future levels of subsurface contamination, with "attainment monitoring" conducted after systems are shut down to make sure there is no rebound in contamination. At the Google buildings in Mountain View, the responsible party's consultant has proposed a multi-stage process, beginning with measurement of all VOCs at extraction points. If those levels fall below the target for three successive samples, they next propose subslab soil gas sampling. It soil gas levels meet screening levels, they propose a temporary shutdown of the mitigation system. If three tests show acceptable levels in soil gas, they propose a permanent shutdown followed by indoor air testing.

Where parties other than building owners or occupants have been maintaining active mitigation systems, the occupants or owners should be given the opportunity to continue their operation to address other soil gas risks, such as radon.

There should also be well-defined criteria for termination of each element of the long-term management workplan, especially inspection, monitoring, and institutional controls.

Regular Reporting

In most cases, those responsible for implementing long-term management workplans at contamination sites, including vapor intrusion responses, submit annual reports to the relevant regulatory agencies. Those reports cover all of the elements of the site management workplan, and they should be organized so regulators and stakeholders can evaluate site management against the promises or requirements included in the workplan.

In Endicott, IBM's annual report documents its inspections of each building. It lists and counts the specific improvements and repairs, such as addressing fan noise or replacing circuit breakers, vent stacks, or fans. But, like most other vapor intrusion site documents, it redacts individual addresses to protect the privacy of the owners and residents.

Ideally annual reports are delivered (in electronic or hardcopy form) to other interested parties, including building occupants. Where they are not, stakeholders need to keep track of due

[25] EPA, *Technical Guide,* page 189 of PDF.

dates for those reports, not just to receive copies, but to make sure that the reports are indeed completed on schedule. At Mott Haven school authorities delayed the first annual report without explanation to the community.

At Mott Haven, serving as a technical consultant to the local community, my colleague and I prepared a "report card" so community members could evaluate the first annual Site Management Report. We listed activities agreed to by school authorities in the Final Site Management Plan as well as other activities we recommended. We also described long-term management activities that would need to be implemented by other parties. While this exercise proved educational for the community, the actual grades ended up serving as a vehicle for the communication of community distrust of school authorities and regulators.

In Summary

In most cases, the mitigation of vapor intrusion can protect building occupants and sustain the value of affected properties, but it has to be done right for the life of the contamination. Stakeholders, including property owners, other residents, students, employees, and other have a key role to play in 1) making sure there is an institution responsible for long-term site management; 2) insisting that the long-term management workplan or site management plan be developed as soon as possible; and 3) checking to see that those responsible for long-term management are doing their jobs. Fulfilling those roles requires basic knowledge of vapor intrusion and the technologies for addressing it, but if stakeholders start with this guide and the more general guide (See footnote 1), it's not too hard for them to learn what they need to know.