by Henry Schuver
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A General (Evidence-Based) Framework for Assessing the

Vapor Intrusion Pathway

This article follows on from some of the concepts discussed during the vapor intrusion screening levels panel at A&WMA's Vapor Intrusion Specialty Conference, held September 2010 in Chicago. It describes a general conceptual approach for assessing the subsurface contaminant vapor intrusion (VI) into indoor air pathway for exposure.

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Although each site is unique, the proposed approach can serve as both a framework for conducting a site investigation and as a vehicle for meaningful public involvement. Note that the approach described below is primarily geared for sites with potential off-site residential impacts and a more streamlined approach may be possible at sites that are primarily commercial/industrial or that have relatively few potentially impacted buildings.

Proposed Site Evaluation Approach

The overall objective of the VI site evaluation process is to identify and take actions to address VI-related exposures (or potential exposures) in the indoor air at all structures that exceed specified decision criteria. The proposed approach essentially follows the scientific method (i.e., hypothesis and testing) to achieve that objective. Data collected during the course of the investigation are used to formulate and refine a conceptual site model (CSM). Hypotheses regarding the nature and extent of contamination, the pathway that the contaminants follow as they move from the source toward a structure, and the impacts of the contaminants on the indoor air of structures at the terminus of the pathway, spring from the model and are tested during an iterative series of data acquisition phases.

Engaging Stakeholders

Because VI may directly impact the well-being of building occupants and because the VI evaluation process ultimately requires the participation of those occupants, it is essential that all stakeholders, including the general public, are included as early as possible in the evaluation process and at key points during the evaluation. Experience has shown that the public's opportunity to understand and be actively involved in the course of the investigation from the beginning increases the ease with which the investigation will proceed, and the likelihood of public acceptance of its outcome.

The nature of VI-related exposures presents a unique challenge to both those conducting the evaluation and to the public. In most cases, the presence of VI-related contaminants (e.g., volatile organic contaminants) in the indoor air is not readily discernable without testing the air. In addition, there is often a substantial period of time between the point at which a structure is identified as being potentially impacted by VI and the point at which an exposure is either confirmed or ruled out. During that time, building inhabitants are in the difficult position of not knowing whether they are being exposed, and not having any practical alternatives to avoid exposures if they are occurring. For that reason, it is imperative that the public has a clear understanding of the existing evidence regarding the potential for VI exposures and a clear view of how the evaluation process will proceed and how long it will take. Those responsible for the evaluation should also provide the public with information regarding the possible health impacts that may be associated with these exposures (which are currently typically considered to be of a chronic nature).

In addition to concerns about the impacts of VI on their health, many residents worry about its financial impacts as well. For many people, their home is the single most important asset they have. The possibility that the value of their home will be substantially diminished as a result of the environmental contamination heightens their level of frustration and adds to their feeling of being locked into a situation in which both their health and financial well-being are suffering through no fault of their own. It is not unusual for people in that situation to avoid participating in a structure (i.e., indoor air and/or sub-slab) sampling program in the hope that this will help protect the value of their home, or to consider litigation as their only option to correct the perceived injustice that has been visited upon them. Although these considerations don't typically come to mind when one thinks about a CSM, empathy for the potentially impacted residents, and consideration of possible actions to address their financial concerns (e.g., a "home value protection program") should not be overlooked.

VI Evaluation

The evaluation approach described in this article is illustrated in Figure 1. The process is one in which historical and new data are used to build and refine the CSM. The CSM is the vehicle that serves to integrate and compare lines of evidence, identify data gaps and the next steps in closing them, and communicate with stakeholders. Typically, the first phases of a VI evaluation involve establishing the

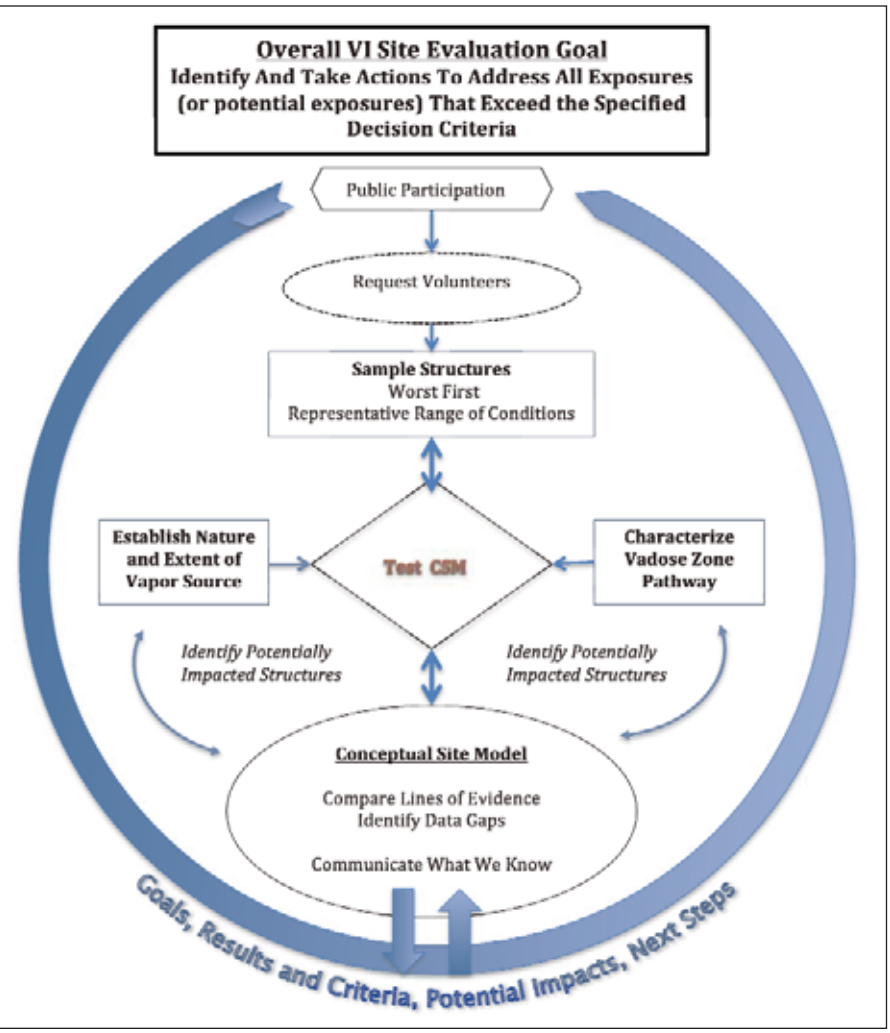

Figure 1. *Proposed VI evaluation approach.*

nature and extent of the contaminant source and an area where structures could be potentially impacted by VI. At the start of that process, the goals of the investigation, the criteria that will be used in making decisions and the overall approach to the evaluation should be developed in conjunction with the appropriate regulatory authorities.

As soon as practical thereafter, the reasons for undertaking the VI evaluation, the results to date, and the likely next steps in the investigation should be shared with local government officials and with the public. The public's response to the information and their suggestions to improve the evaluation process should be considered and adjustments to the program should be made where practicable. Periodically thereafter, and whenever a critical milestone in the evaluation is reached, there should be other rounds of communication with the public to ensure that they understand how the evaluation is proceeding and are apprised of any significant changes in the CSM that could possibly affect them.

Typically, once the nature and extent of the vapor "source" has been reasonably well established, characterization of the vadose (unsaturated) zone pathway is used to test and enhance the CSM. For example, deep and shallow soil gas samples, geologic and physical characterization of the vadose zone, and identification of anthropogenic features that could affect contaminant vapor migration would be used to further refine the expected areal extent of potentially impacted structures. In the case of degradable vapor forming compounds (e.g., in petroleum), an appropriate vadose zone characterization program may be sufficient to document the impacts of biodegradation on the distribution of those compounds and to eliminate the need for structure samples.

Evaluations where recalcitrant (e.g., chlorinated) vapor-forming compounds are the contaminants of concern will usually involve collection of a "representative" suite of structure samples to observe whether VI is taking place in the tested buildings, and if it is, to identify all buildings that require actions to address VI-related exposures. Ultimately, due to the variability in individual buildings (e.g., due to varying location, orientation, design, construction, condition, appliances, operations, and occupants), all potentially impacted structures may need to be sampled unless an area-wide or purely preemptive mitigation approach is offered in lieu of sampling.

Communication

Prior to undertaking (interior) structure sampling, it is absolutely critical that the public, especially the potentially impacted building owners and occupants, understand why the sampling is taking place and the outcomes that will follow the sampling results, that is (1) no further action, (2) further sampling to resolve uncertainty (e.g., due to spatial and temporal variability and/or confounding 'background' sources), or (3) vapor controls/mitigation and/or source remediation.

Figures and maps illustrating the nature and extent of the groundwater or soil vapor source "plume,"

the distribution of compounds of concern in the vadose zone (soil gas), and the area where structure sampling will likely take place should be a standard part of any communication package. For example, a map view of the proposed "vapor source area" could be combined with or supplemented by a map illustrating the estimated potential for vapor migration through the subsurface (vadose zone) materials above the "vapor source area."

To help the public better understand the information, the figures could include identification of areas with relatively high, moderate, and low subsurface "vapor migration potential." In addition, charts that compare the reasonably likely range of potential VI-related indoor air concentrations that could be expected, the applicable regulatory health-risk screening levels, and the typical background indoor air concentration ranges for the chemical contaminants of concern, as well as other possible soil-gas contaminants, such as naturally occurring radon, are all useful for putting the risks associated with potential VI exposures into perspective.

Volunteers

Because the process of identifying property owners who are interested in being sampled can be quite cumbersome, seeking potential volunteers during the course of a public meeting may be a good technique for identifying those most interested in being sampled and expediting that process. The interested public could also be invited to comment on and/or request additional sampling to test the proposed extent (e.g., samples from areas not previously measured). Not uncommonly, a reasonably small number of quality assurance (QA) samples (e.g., 10%) are collected in most sampling efforts and perhaps that QA sample concept could be expanded to include additional community-requested samples. Such hypothesis testing could help ensure that the investigation has both properly identified the full "vapor source" area (with a potential for unacceptable VI) and accurately delineated the surrounding areas without vapor sources.

Improved transparency can help the potentially-affected community members become more actively involved and able to contribute their knowledge of local conditions and concerns that can lead to better hypothesis testing and more defensible conclusions.

As the investigation proceeds, the figures should be periodically updated to illustrate the current status of the investigation. Plots of the indoor air results from the sampled buildings, could be used to illustrate the observed effects (if any) of VI on indoor air quality and to compare these with the previously estimated potentials for VI in those areas. These comparisons could be used to suggest the potential for VI in other (still untested) buildings, in the particular site setting (and at the specific time of sampling). When charts are added to illustrate the observed and expected range of temporal variation in indoor air impacts due to VI in tested buildings the public could have a fuller appreciation of the nature of the potential for VI into (their) indoor air.

Summary

The framework depicted in this article is not meant to prescribe a "one-size-fits-all" process for conducting an evaluation. Although we do believe that it is important to develop and test hypotheses regarding the nature and distribution of contaminants along the VI pathway, and that the overall goal for all sites should be the same (see Figure 1), we recognize that each site is unique.

The course of the investigation will be influenced by both the data that are developed during the investigative process and by the resource allocation choices that the investigative team makes. More often than not, multiple rounds of groundwater and vadose zone characterization and structure sampling may be necessary before completing an evaluation of all but the smallest sites. At some sites, investigators may perform highly detailed environmental characterizations with the hopes of minimizing the need for structure sampling. At other sites, the team's approach might be to use structure samples as the primary method for completing the evaluation. At all sites, you should expect surprises! em