Douglas, Michigan: Proposed Development over a TCE Plume

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The tools for evaluating, mitigating, and remediating vapor intrusion—the upward migration of toxic vapors from the subsurface—at sites with existing buildings are well proven and relatively easy to learn about. Nationally, however, much less thought has gone into determining when and where it is appropriate to develop or redevelop properties with underlying contamination with volatile compounds. In my visits to development sites with potential vapor intrusion, I have made four recurring observations:

1) Most communities—including local government officials as well as grassroots residents—know little about the vapor intrusion pathway or how it is successfully addressed.
2) While some states and EPA regions have extensive experience investigating and responding to vapor intrusion, others have limited experience or outdated policies or guidance.
3) It is less expensive and more effective to investigate, remediate, and mitigate vapor intrusion before or during construction, rather than after the fact.
4) Plume contour maps that have been drawn to address potential drinking water contamination may not be precise enough to make judgments about the potential for vapor intrusion.

On February 12, 2007 I visited the Village of Douglas, Michigan, a small community located between Kalamazoo Lake and Lake Michigan, southwest of Grand Rapids. I spoke at an event sponsored by the Douglas Lakeshore Homeowners Association. A small number of City Councilors and Planning Commissioners were in the audience.

West Shore Golf course, with Clubhouse on right and Wick's Creek on left

A developer plans to build 64 single-family homes and 78 triplex units on about 15 acres of the former West Shore Golf course. A plume of TCE and other pollutants flows from the former Chase Manufacturing plant, just to the southeast, to Wick's creek, a tributary of Kalamazoo Lake that bisects the development parcel.

In 2003 and 2005, the Michigan Department of Community Health conducted health consultations on the property. It reported TCE concentrations in the shallow-most aquifer as high as 23,000 parts per billion. The author, a Department toxicologist, concluded, "There is no apparent current public health hazard via inhalation of indoor air, however the hazard is indeterminate for the future." The 2005 Health Consultation noted, "Future construction activities in the area near and above the plume, however, could result in preferential vapor pathways leading toward structures."

In downplaying the potential for unacceptable vapor intrusion, the 2005 Health Consultation relied upon the Department's Groundwater Volatilization to Indoor Air Inhalation Criterion (GVIIC). It found, "The maximum TCE concentration found (23,000 ppb) is less than twice the Residential/Commercial I GVIIC of 15,000 ppb. Because the magnitude of the exceedance is not significant and because a site-specific criterion could be greater than 23,000 ppb, it is unlikely that any vapors currently originating from the TCE in the groundwater would accumulate in indoor air to a degree that would cause health effects. However, future underground construction could lead to preferential pathways along which vapors could easily migrate."

In my experience, however, any time there is a proposal to build above a shallow groundwater plume of TCE where contamination levels are measured in parts per million (thousands of parts per billion), there is cause for caution. At least, there is cause for additional investigation. But the residents and officials of Douglas do not have the experience with vapor intrusion to question, or even utilize the Department of Community Health's findings.

Former Chase Manufacturing plant—the source of TCE

Finding the Health Department's study useful, but its general conclusion unprotective, I've attempted to deconstruct the GVIIC. I'm sorry about all the calculations, but that's the approach that most regulatory jurisdictions take: Figure out how much pollution is likely to cause unacceptable risk, and then allow exposures up to that point.

For starters, it's important to recognize that there is a weak quantitative correlation between groundwater sampling results and vapor intrusion. Most guidances on the subject call for active soil gas sampling to predict indoor air concentrations from subsurface sources. (In Douglas, there was extensive passive soil gas sampling, useful in some ways, but as the Community Health Department recognizes, not sufficient to model vapor intrusion.)

In the absence of soil gas data, California's vapor intrusion guidance projects soil gas concentrations by multiplying the groundwater concentration by the Henry's law constant for the compound in question, and then multiplying by a unit conversion factor. Henry's Law describes how a volatile compound partitions into vapor and aqueous phases. I looked up the Henry's law constant for TCE, and at the reference temperature it's .0091. Thus, 1000 ppb of TCE in groundwater corresponds to a soil gas concentration of 9100 micrograms per cubic meter ($\mu g/m^3$).

Michigan, where average groundwater concentrations are colder, divides that number in half. So in Michigan, 1000 ppb of TCE in groundwater corresponds to a soil gas concentration of 4550 $\mu g/m^3$.

To get from soil gas to indoor air, Michigan applied an old version of the well-regarded Johnson-Ettinger Model. J & E plugs in a number of site-specific factors, or defaults where data in unavailable for some measurements, into a formula to calculate alpha (α), the attenuation factor. The attenuation factor represents the indoor air concentration of a contaminant (or at least, that portion originating in the subsurface) divided by the concentration in soil gas, beneath or near the building.

In my experience, α typically varies from .02 to .001 (from 1/50 to 1/1000). Applied to the 4550 $\mu g/m^3$ calculated soil-gas concentration, that means the indoor air concentration for a site with 1000 ppb TCE in groundwater would normally be between 91 $\mu g/m^3$ and 4.55 $\mu g/m^3$. As the health consultation points out, specific conditions such as dirt basements or open sumps might lead to greater levels. More important, risk management decisions should be based upon the more conservative assumption—that occupants would be exposed to 91 $\mu g/m^3$—unless additional data shows otherwise.

Michigan apparently has no health standard or screening level for TCE in indoor air. A 2003 Health Consultation for the West Shore property claims that EPA's reference concentration for TCE is 40 $\mu g/m^3$. I believe that a more realistic cleanup objective would be the 1 $\mu g/m^3$ action level used in residential settings by California, Connecticut, U.S. EPA Region 9, and now New York State. (New York actually uses a matrix, but in most cases action would be taken at 1 $\mu g/m^3$.) Note that this action level does not fully take into account EPA's 2001 risk assessment finding that TCE was 5 to 65 times as hazardous as previously believed. EPA officials withdrew the risk assessment in 2003.

Thus, a 1000 ppb shallow groundwater measurement would suggest an indoor air concentration 91 times higher than the acceptable level with standard residential construction. Calculated in reverse, a 1 $\mu g/m^3$ indoor air threshold implies a soil gas screening level of 50 $\mu g/m^3$ in the absence of site-specific data suggesting that greater attenuation will take place. In turn, that implies a groundwater screening level of 11 ppb in locations with cold groundwater, not 15,000 ppb.

Much of the proposed construction site appears to have TCE in groundwater above 11 ppb, but it's hard to know which proposed buildings are likely to be at risk. The rule of thumb for vapor intrusion potential is that buildings or building sites laterally within 100 feet of subsurface contamination should be evaluated. In the field, however, this may be confusing. The West Shore site has a TCE contour map. Soil, groundwater, and surface water have been sampled with sufficient density to protect potential drinking water, but in my opinion there are not enough monitoring wells to delineate areas with serious vapor intrusion potential. In fact, there's one isolated sample, near where Wick's Creek enters Kalamazoo Lake, where the TCE level is 140 ppb, surrounded by contours suggesting 5 ppb. Further testing is necessary to determine whether that reading was indeed accurate, and if so, why it's there.

Furthermore, though there is a pump-and-treat system installed at the source area, I have seen no evidence that the plume will not spread further. High levels (1600 ppb) of TCE in Wick's Creek, at the head of the plume, suggest a continuing flow from the source. If the plume moves laterally, more areas will be at risk of vapor intrusion.

Existing housing, near or above the TCE plume

Recommendations

Based upon my visit to Douglas, I cannot say for sure that the new buildings, if constructed, will have unacceptable levels of vapor intrusion. I have concluded, however, that there is enough of a problem to conduct further investigation. I recommend the following:

- Additional monitoring wells should map the full extent of the TCE plume over time.

- Active soil gas sampling should be conducted at each proposed home site.

- Target indoor air concentrations of TCE should be no higher that 1 $\mu g/m^3$.

- The footprint for the proposed development should be altered to move residential units away from higher concentrations of TCE in the subsurface. If a protective site plan cannot be designed, then the development should be rejected.

- All structures should be built with vapor membranes and subslab depressurization systems. The latter may be operated in passive mode if subslab soil gas does not exceed levels corresponding to the indoor air screening level.

- After construction, but before occupancy, each unit should be tested, including measurements of subslab soil gas, indoor air, and ambient nearby (outdoor) air. As long as soil gas contamination at any structure remains above levels corresponding to the indoor air targets, such sampling should continue periodically.

- Institutional controls should warn building occupants of potential exposure, prevent construction above the highest levels of groundwater contamination, forbid perforation of vapor barriers, and require periodic monitoring for perforation caused either by natural or human activity.

Michigan should develop more realistic tools for evaluating vapor intrusion risk. All government agencies with jurisdiction over development and vapor intrusion decisions where buildings are proposed above plumes of volatile pollutants should adopt an approach that incorporates the type of recommendations I have made for Douglas.