Environmental Health Technical Brief

Vapor Intrusion of VOCs

Evaluating the Risks to Buildings in Your Town

Environmental & Occupational Health Assessment Program

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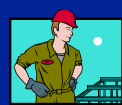
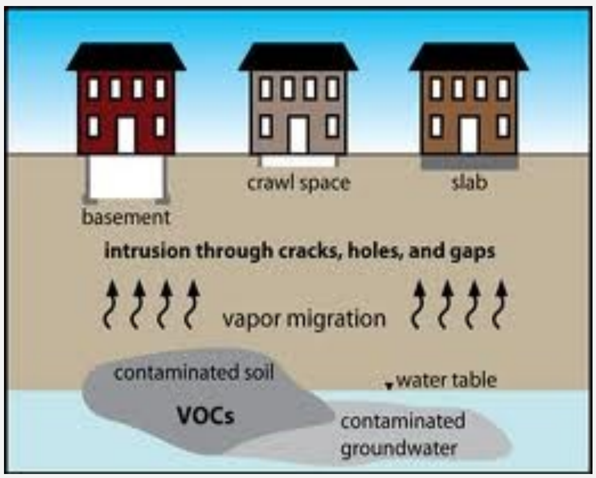


The intrusion of soil gas into homes, schools and businesses is a threat to indoor air quality and the health of building occupants. Nationally and in Connecticut there have been numerous homes, workplaces and schools affected by vapor intrusion.



The extreme case is when a building actually explodes because of an intrusion of methane from a nearby landfill, as occurred in Pittsburgh PA in 1987 and Akron OH in 1984 (ATSDR, 2001). While rare, these cases point out that gases can migrate from a source and build up inside nearby structures to a dangerous level. More common is the case where the vapors are not an immediate hazard but lead to a chronic health risk for building occupants. A good example is radon gas. It is emitted by uranium in bedrock and migrates into homes, to present an increased cancer risk. This soil gas issue is widely tested for during home inspections. Yet little thought is given during property development or transfer to the potential for other soil gases, namely VOCs, to migrate into buildings. The good news is that when this is discovered simple measures can be taken to prevent exposure and protect occupant health and property values.

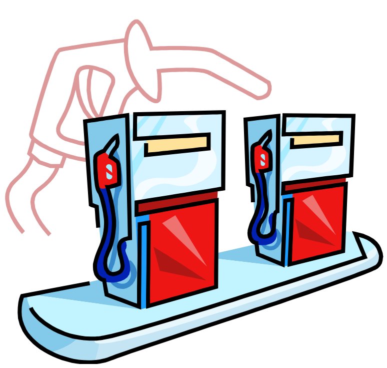
What are VOCs?

Volatile organic chemicals (VOCs) is the general term for a range of industrial chemicals that can migrate from the groundwater as a vapor (gas) into the air spaces between soil particles and then enter buildings through foundation cracks and utility corridors. Town officials can help ensure that VOCs do not threaten indoor air quality by understanding the sources of VOCs in their town relative to the location of planned or existing homes and businesses. The following table lists the most common VOC contaminants of soil and groundwater and their source.

Which VOCs are of Greatest Concern for Vapor Intrusion?

VOC	Health Effect	Major Source	Type of Release
Benzene	Leukemia	Gasoline	Gas station tank leak
Toluene	Affects nervous system	Gasoline	Gas station tank leak
Ethylbenzene	Reproductive risk	Gasoline	Gas station tank leak
Xylene	Affects nervous system	Gasoline	Gas station tank leak
MTBE	Kidney damage, possible carcinogen	Gasoline	Gas station tank leak
Naphthalene	Respiratory effects, possible carcinogen	Home heating oil	Oil tank spill
Trichloroethylene (TCE)	Carcinogen, birth defects	Solvent used by industry to clean parts, degreasing agent	Historic industrial releases
Perchloroethylene (PERC)	Carcinogen, kidney toxicity	Dry cleaning solvent	Spill or discharge from dry cleaner
Dichloroethylene	Liver toxicity, nervous system	Industrial solvent and cleaner	Historic industrial releases
Vinyl chloride	Carcinogen	Formed from breakdown of PERC and TCE	Historic industrial releases
Methane, sulfides, industrial solvents, fuel-related VOCs	Odors, explosive risks, various health endpoints	Municipal landfills	Leaching from landfill to groundwater

VOCs can persist for decades after a release as there is little oxygen or bacteria in groundwater to break them down. The contamination site does not have to be directly adjacent to a building because groundwater can deliver contaminants to distant locations. Groundwater generally flows from high to low topography but this is often hard to predict based on the ground surface. Groundwater test wells are usually needed to define the groundwater flow path. VOCs released from an old factory, gas station or landfill spread out in the direction of groundwater flow encompassing an area of contamination called the plume. It may take years for the plume to reach down gradient buildings depending upon their distance from the source.

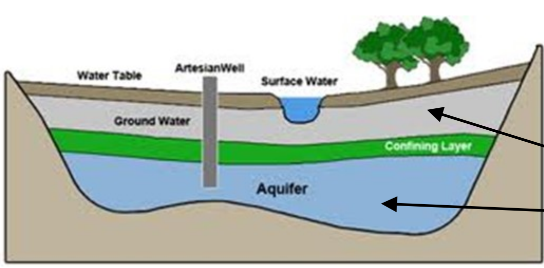


How Close is Too Close to a VOC Source?

Your town will likely have a number of potential VOC sources. As shown in the chart , gas stations, auto garages, factories, landfills, former industrial or waste sites and dry cleaners represent potential sources of VOCs to groundwater and ultimately indoor air. The safe distance for a building to not be affected is dependent upon initial VOC concentrations at the source and how much the plume becomes diluted as it migrates towards buildings. Generally, sources more than ¼ mile from a building are a low risk to that building. The soil type makes a difference with sandy soils more vulnerable due to large pore spaces between the soil particles, while clay soils are the most resistant. These and other building vulnerability factors are summarized below:

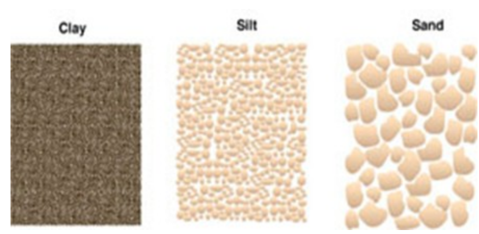
Factor	High Vulnerability	Low Vulnerability
Distance from source	Closer is more vulnerable	>¼ mile
Direction of GW flow	Towards building	Away from building
Soil type	Sandy	Clay
Depth to groundwater below foundation	Shallow	Deep (> 15 feet)
Type of foundation	Basement	Slab or crawl space
Occupied level	Basement	Upper floors (but depends on how heating/cooling systems circulate air)

This above chart provides very general guidance. The principles need to be applied on a site-specific basis to determine whether a particular location is at risk for vapor intrusion. For example, a new housing development across the street from an existing gas station may not appear to be at risk based upon groundwater flow (flows away from the development). However, since it is so close to the source, the vapors from the gas station may be able to reach the new buildings by transport through soil pores without the need for transport via groundwater. The Connecticut Department of Energy and Environmental Protection (CTDEEP) and the Connecticut Department of Public Health (CTDPH) can assist you in evaluating the vulnerability of new or existing buildings to VOC intrusion.

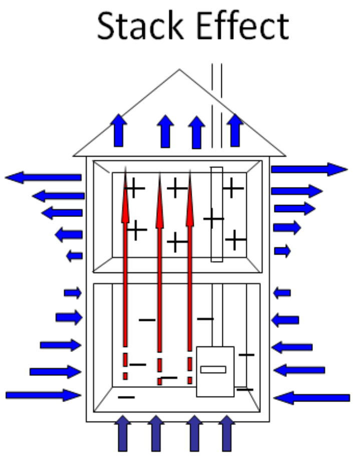


Is the contamination shallow or deep?

Soil type matters: Larger particles (e.g., sand) means more pore space and easier migration of soil vapors.



Why Do VOCs Head Towards a Building?



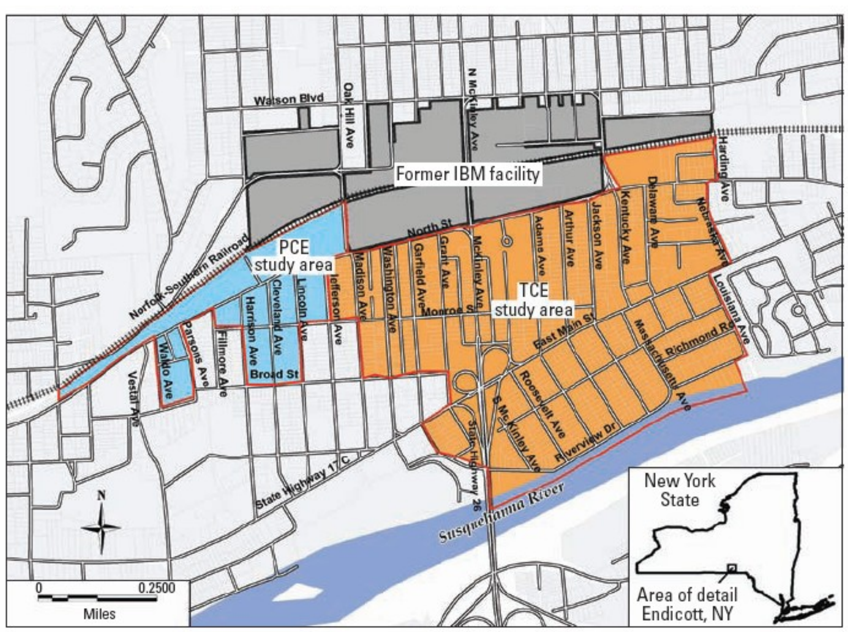
Rising air causes negative pressure in basement, pulling air in from soil gas.

Underground vapors such as VOCs and radon gas do not travel randomly but follow pressure gradients that can bring them up into a basement (Little et al. 1992). VOCs target basements in cold weather because of two forces: 1) the furnace requires make up oxygen and so draws air from the basement; this creates a void or area of lower pressure; the soil gas will be at higher pressure and thus drawn in via cracks or breaches in the foundation; 2) stack effect: warm air in a building rises towards the upper floors and eventually exits via the roof; this draws air up from the basement and in turn, the basement finds its replacement air from the soil gas. These processes can bring substantial amounts of soil gas into buildings, with this being at a maximum under winter conditions. Even in warm weather, the operation of hot water heaters and other equipment can cause some basement depressurization and vapor intrusion.

Where has Vapor Intrusion Been a Problem?

A recent example that received national attention was in Newark, Ohio where TCE released to the soil decades ago by a state maintenance garage formed a groundwater plume that has now reached eight homes (Columbus Dispatch, 10/16/2012). These homes are being taken over by the state for demolition because of health risks from TCE volatilization and entry into these homes. Fortunately, in most cases homes can be retro-fitted with radon-style sub-surface depressurization systems to prevent the vapors from entering the home without the need for demolition (see next page).

A health study of a TCE/PERC plume in Endicott, NY found associations between vapor intrusion and increased risk for birth defects and other adverse reproductive outcomes (Forand et al. 2012). The affected area extended approximately one half mile from the industrial pollution source, involving a neighborhood of over 3,000 residents. The health study focused on the period prior to 2002 as many of the homes were retro-fitted with depressurization systems in 2002. This study highlights the importance of vapor intrusion as an exposure pathway that can produce adverse health outcomes.



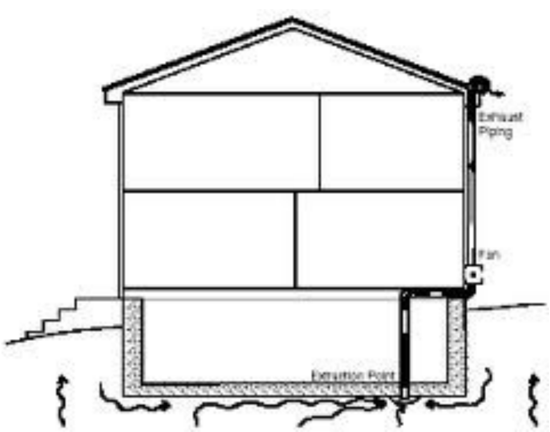
Endicott NY Study Area, Forand et al. 2012

In Connecticut, vapor intrusion has affected indoor air quality in a number of towns including Brookfield, Durham, Milford, Stratford, Southington and Stonington. The largest case was in 2004 and involved the former Raymark site in Stratford; 106 homes required depressurization systems to prevent intrusion of TCE and related VOCs. These homes are in the Ferry Boulevard neighborhood, which is approximately 0.3 miles from the industrial release.

Solutions

The best solution to prevent vapor intrusion is to stop the VOC source from reaching occupied buildings. This could involve interception and treatment of a groundwater plume or collecting gases at a landfill for flaring and energy generation so that they do not move offsite. CTDEEP and the U.S. Environmental Protection Agency (USEPA) endeavor to identify and cleanup VOCs before they impact drinking water or indoor air. Further, the CTDEEP regulatory program requires responsible parties to remediate groundwater pollution they are responsible for (see next section). However, groundwater remediation is not always possible and buildings may need to be protected from VOC intrusion by the installation of a sub-surface depressurization system.

Sub-surface depressurization systems are commonly used to mitigate radon in buildings and can be used for other types of soil gas as well (USEPA 2001). They work by intercepting soil gas prior to its entry across the building foundation and directing it above ground to the outdoor air. Perforated pipes are placed under the basement to collect soil gas. An exhaust fan pulls air through these pipes and vents it above ground to the atmosphere. Cracks and penetrations in the building foundation must be sealed for the system to be effective. These systems are relatively inexpensive to install and maintain although in large industrial buildings they are not always practical. Refer to the diagram and picture below. More information on vapor protection of buildings can be found at USEPA (2001).



Sub-Surface Depressurization to Vent Soil Gas Under a Building

Depressurization System Vent Pipe Outside Home

Regulatory Approaches

Regulatory Approaches

USEPA and the CTDEEP recognize vapor intrusion as a key pathway for human exposure to VOCs. CTDEEP's Remediation Standard Regulations (RSRs) have Volatilization Criteria based upon a model of the flux of VOCs from groundwater into soil gas and then into buildings, and sets the criteria to make sure that indoor VOC concentrations will remain below health-based targets set by CT DPH. The volatilization model and overall approach used by CTDEEP are consistent with national vapor intrusion guidance established by USEPA.

Evaluating Vapor Intrusion in Your Town

Being on the lookout for subsurface VOC contamination is prudent because of possible impacts to both drinking water and indoor air. The following resources can help determine the vulnerability of a particular location to vapor intrusion:

1. Areas of known contamination: sources of information can include CTDEEP soil or groundwater investigations and data on public or private well detections.
2. Areas of potential contamination: the sources listed in the table on page 2 (e.g., gas stations, automotive repair shops, industrial operations, dry cleaners, waste sites, landfills) can be noted along with the DEEP contaminated sites list. This list indicates addresses in your town which have been investigated historically due to a chemical release. CTDEEP can inform you if VOCs were released to soil or groundwater at specific addresses in the database.

Town Planning & Zoning meetings are a good forum for vapor intrusion concerns at new developments.

When new homes, schools, day cares, or businesses are being planned, their vulnerability to VOC sources can be understood from evaluating their proximity to areas of known or potential contamination. If there is a concern, soil gas monitoring could be conducted prior to construction, or the homes could be outfitted with a sub-surface depressurization system to ensure their safety. These systems are much less expensive to install as the structure is being built compared to a retro-fit. If there are health complaints or odors in existing buildings, an assessment of VOC vulnerability can help determine whether vapor intrusion is a likely cause.

Additional Resources

If you become aware of VOC spills or subsurface contamination in your town, immediately contact CTDEEP at 860-424-3338 (spills) or 860-424-3705 (remediation program). You can contact the DEEP district coordinator for your area directly. They will assist you in investigating the release and understanding its implications for nearby drinking water and indoor air.

Contact CTDPH's Environmental and Occupational Health Assessment Program (860-509-7740) to discuss the health effects of released contaminants and their potential to impact indoor air. Contact CTDPH's Drinking Water Section (860-509-7333) to further evaluate the potential impact to public supplies and our Private Well program (860-509-7296) for information on private drinking water supplies.

References

- Agency for Toxic Substances and Disease Registry (ATSDR) Landfill Gas Primer, 2001.
- Columbus Dispatch Sept. 23, 2012 - Danger in the land | Toxic plume spreads under Newark; 8 families must leave.
- Forand SP, Lewis-Michl EL, Gomez MI. (2012) Adverse birth outcomes and maternal exposure to trichloroethylene and tetrachloroethylene through soil vapor intrusion in New York State. Environ Health Perspect 120: 616-21.
- Little Daisey and Nazaroff (1992) Transport of subsurface contaminants into buildings: an exposure pathway for volatile organics. Environ Sci & Technol 26: 2058-2066.
- USEPA (2001) Building Radon Out. A Step-By-Step Guide on How to Build Radon-Resistant Homes.