VAPOR INTRUSION

An Emerging Indoor Air Issue

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VAPOR INTRUSION (VI):

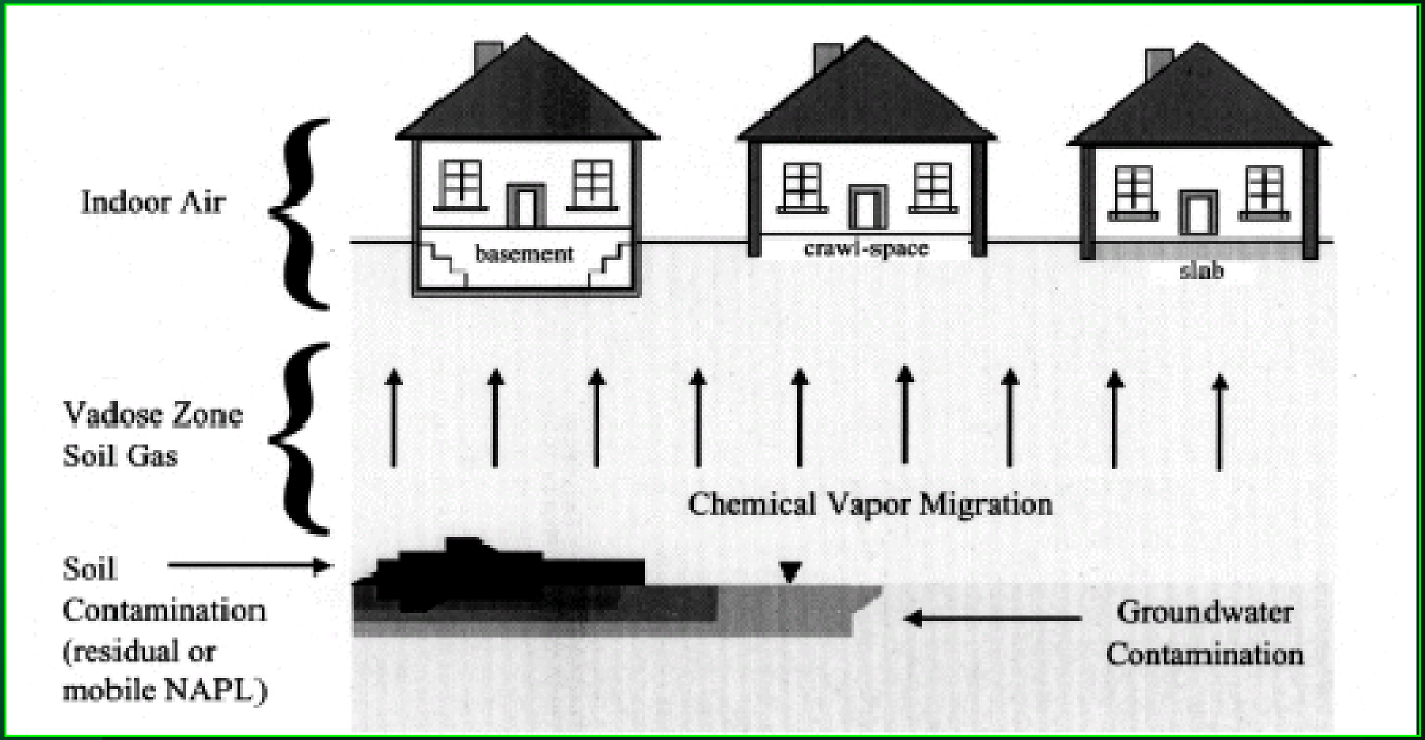
WHAT IS IT?

Vapor intrusion is the migration of volatile chemicals from the subsurface into overlying buildings.

HOW DOES IT HAPPEN?

Volatile chemicals in buried wastes and/or contaminated groundwater emit vapors that migrate through subsurface soils and into indoor air spaces of overlying buildings in ways similar to that of radon gas.

ILLUSTRATION OF VAPOR INTRUSION



VAPOR INTRUSION:
STATEMENT OF THE ISSUE

- "No one anticipated that old spills of common industrial solvents could slowly create toxic plumes with the power to spread underground for miles before snaking up through pipes, foundation cracks, or porous materials to fill indoor air with carcinogens and other toxic substances." (AWMA 2007 VI Report)

SITES WITH THE POTENTIAL FOR VI

Any site with volatile chemicals!

- Manufacturing sites (especially those with chlorinated solvents)
- Dry cleaners using perchloroethylene
- Gas stations and tank farms (with fuel spills)
- Landfills
- Brownfield sites

NEWS REPORTS:
VI CASES IN U.S.

Mercury at New Jersey Day Care Center

The discovery of toxic mercury vapors in a day care center built on the site of a former thermometer factory is just the latest in a series of toxic scandals to rock New Jersey. More than 30 children were exposed to toxic mercury vapors at the Kiddie Kollege day care center in Franklinville, New Jersey.

(www.PEER.org, August 2006)

NEWS REPORTS:
VI CASES IN U.S.

Toxic Gases in West Coast Homes

More than 4,900 people in a 5-state federal study suffered strokes, anemia, and urinary tract disorders at rates double or triple the national average. One man suffered an inoperable brain tumor and his mother died of liver cancer. All these people lived in homes polluted with toxic gas from underground contamination.

(*Denver Post*, January 6, 2002; AIHCE 2009 Workshop)

PREDOMINANT CONTAMINANTS

The April 2010 AIHA *Synergist* reported that according ot the EPA Indoor Air Vapor Intrusion Database, the predominant vapors found in indoor air at vapor intrusion sites are chlorinated hydrocarbons and petroleum hydrocarbons. See http://iavi.rti.org/

VI: A UNIQUE KIND OF INDOOR AIR ISSUE

- Source of contaminants is underground
- Much less experience to draw upon when assessing the risk
- Evaluating the risk of VI from chemicals underground is complicated by the presence of those same chemicals from other indoor air emission sources or occupant activities.

VI: ADDRESSING THE PROBLEM

Requires Multi-disciplinary Approach with a Team of Experts:

- Risk assessment and modeling
- Soil and groundwater measurements
- Indoor and ambient air measurements
- Building engineers

VI MEASUREMENTS

Involve multiple locations and matrices:

- Groundwater
- Subslab soil vapor, near slab soil vapor
- Indoor air
- Outdoor air

With considerations of site-specific conditions related to building structure, geology, groundwater, other chemical sources inside the building, etc.

U.S. EPA PROTOCOL FOR VI STUDIES

www.epa.gov

VI GUIDANCE DOCUMENTS
U.S. EPA

- U.S. EPA's OSWER has issued *Draft Guidance for Evaluating the Vapor Intrusion to Indoor Air Pathway from Groundwater and Soils* *(November 2002)*
- This document is available online at www.epa.gov. Search using "*vapor intrusion guidance.*"

VI GUIDANCE DOCUMENTS UPDATE

- In December 2009, the Office of Inspector General issued a report faulting EPA for not updating and finalizing this 2002 draft guidance document.
- EPA is moving forward with this directive. Consult the EPA website as this issue continues to evolve.

GETTING STARTED ON A VI PROJECT

First Step:

- Develop a Conceptual Site Model (CSM) that presents a narrative and visual representation of the site conditions.
- Describe historical uses of the site, suspected contaminant sources, vapor transport pathways, building/land use, and potential human exposures.

CSM: AN ESSENTIAL MANAGEMENT TOOL

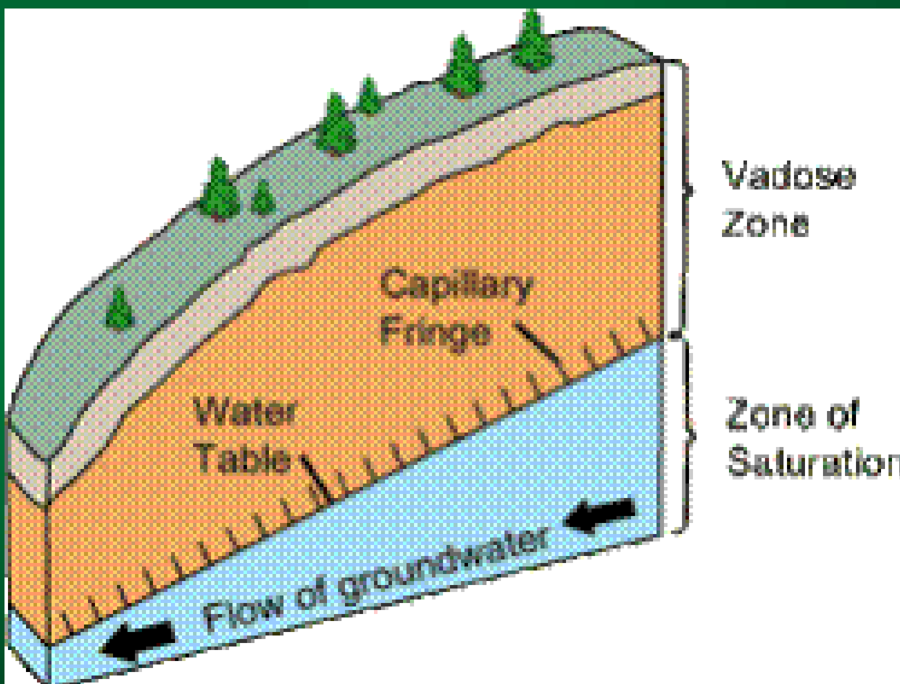
- Site maps
- Historical records of land use and site activity
- Published data on local soil and groundwater conditions
- Data from previous site studies
- Suspected nature and extent of contamination
- Individuals at risk particularly sensitive populations

NEXT STEP: ASSESSING THE RISK

U.S. EPA Tiered Approach:

- Tier 1 Primary Screening-Identify potential contaminants and determine VI potential based on general knowledge of the site and chemicals known/suspected to be present.
- Tier 2 Secondary Screening-Conduct a basic site evaluation with collection of limited site-specific data on target chemicals in various matrices.
- Tier 3 Site-specific Pathway Assessment-Collect detailed site-specific data including subslab and indoor air measurements.

TIPS ON TERMINOLOGY: DOWN IN THE DIRT



- The EPA guidance document discusses the *unsaturated or vadose zone* of soil.
- This is the region extending from the soil surface to the top of the principal water table.

TIER 1-SCREENING PROCESS

Primary Screening-Question #1:

- Are chemicals present in the subsurface that are VOLATILE enough to result in

  VI and TOXIC enough to pose a significant health risk?
- Table 1 of the EPA document provides a list of chemicals and yes/no information on toxicity and volatility questions.

TIER 1-SCREENING PROCESS

Primary Screening-Question #2:

- Are there (potentially) inhabited buildings *near* (within 100 ft laterally or vertically) subsurface contaminants?
- Consider migration of the contaminant plume if the source of contamination is groundwater.
- Consider “significant preferential pathways” that may enhance VI.

SIGNIFICANT PREFERENTIAL PATHWAYS

- Defined as a naturally occurring or man-made condition that is expected to enhance gas permeability and influence VI into the building
- These buildings should be evaluated for VI even if they are further than 100 ft from the contamination.

EXAMPLES:

- Cracks in foundations
- Gaps around piping or utility lines
- Subsurface drains that intersect vapor sources
- Fractures or macropores in the soil

TIER 1-SCREENING PROCESS

Primary Screening-Question #3:

- Is there evidence to suggest IMMEDIATE action may be warranted to mitigate imminent risks?

INDICATORS OF IMMINENT RISK

1. Chemical odors by occupants
2. Health problems reported by occupants
3. Wet basements in areas where chemicals are known to be in the groundwater
4. Explosive or acutely toxic vapor levels in the building

Immediate steps should be taken to verify and eliminate imminent risks. Otherwise, continue to Tier 2 secondary screening if VI could not be ruled out in Tier 1 primary screening.

VAPOR INTRUSION AND METHANE

- Reported cases of homes that were built on former landfills exploding
- Produced by anaerobic decomposition of organic matter
- Flammable in air and a simple asphyxiant

TRIGGER LEVELS FOR METHANE

- Local landfill control programs in the U.S. typically use a methane trigger level of 500 ppm over ambient at the surface of the landfill to reduce safety hazards from methane itself.
- A methane trigger level of 50 ppm is often used to reduce health hazards from the toxic constituents of landfill gas.

See *U.S. EPA Guidance for Evaluating Landfill Gas Emissions from Closed or Abandoned Facilities* (p. 4-11) at www.epa.gov.

TIER 2-SCREENING PROCESS

Secondary Screening:

- In this basic evaluation step, limited site-specific data is collected in a sequential process to obtain information on the contamination source and subsurface conditions.
- Concentrations of target compounds are obtained along with the depth of contamination and soil type/conditions.

SEQUENTIAL PROCESS
FOR DATA COLLECTION

DON'T START WITH INDOOR AIR!

- Start with the source of vapors and consider if there is any contamination in the groundwater or soil.
- If so, collect soil vapor samples above the contamination source.
- Then move upward to the exposure point and collect samples of the subslab vapors.
- Finally, evaluate indoor air if warranted.

SEQUENTIAL PROCESS FOR DATA COLLECTION??

- The collection of indoor air data WITHOUT evidence to support VI from the subsurface can lead to confounding results.
- Indoor air sampling should only be done for chemicals that are found in subsurface sources of contamination.
- Make sure the detection limits of the measurement methods are below the target screening levels in guidance documents.

TIER 2-SCREENING PROCESS

Secondary Screening-Question #4:

- Is indoor air quality data available?

EPA does not recommend that you start a VI project with the collection of indoor air data. But, if you already have existing indoor air data available, EPA recommends that it be evaluated at this time.

TIER 2-SCREENING PROCESS

If YES, indoor air data is available:

- Compare indoor air contaminant levels to generic screening levels listed in EPA Table 2.
- If levels exceed screening values, initiate a Tier 3 detailed site-specific assessment.
- If levels do not exceed screening values, use professional judgment to determine if the indoor air data is sufficient to rule out the possibility of VI or not.

TIER 2-SCREENING PROCESS

If indoor air data is inconclusive or unavailable:

- Obtain measurements or determine “reasonably estimated concentrations” of target compounds in groundwater and soil vapors and compare contaminant levels to screening levels in EPA Table 2.

Indoor measurements are not done in Tier 2 Screening.

SCREENING LEVELS

- In addition to the screening levels listed in the federal EPA Guidance Document, many U.S. states also have published their own target concentrations.
- Minimal Risk Levels developed by the Agency for Toxic Substances & Disease Registry (ATSDR) are often used as the basis of target concentrations for indoor air.

MINIMAL RISK LEVELS (MRLs)

- Defined as an estimate of the daily human exposure to a hazardous substance that is likely to be without appreciable risk of adverse *noncancer* health effects over a specified duration of exposure.
- Originally developed to serve as screening levels for chemicals found at hazardous waste sites.
- See www.atsdr.cdc.gov/mrls/index.html

TIER 3-SITE-SPECIFIC ASSESSMENT

If the Tier 2 evaluation can not rule out the possibility of VI, more detailed site-specific investigations should be performed including:

1. Direct measurement of subslab or crawl space vapor concentrations
2. Removal of all possible sources of indoor air emissions
3. Direct measurement of indoor air coupled with a home survey and measurement of ambient air

TIER 3-SITE-SPECIFIC ASSESSMENT

- At this level, professionals should develop a comprehensive project plan that includes a data quality assurance program.
- Direct samples may be complemented by site-specific modeling.
- Also, background/ambient sources of contamination must be addressed.

AIR MEASUREMENTS FOR VI STUDIES

SOIL GAS SAMPLING: AVAILABLE OPTIONS

- Reference ASTM D5314-92, *Standard Guide for Soil Gas Monitoring in the Vadose Zone* (www.astm.org)
- Soil gas sampling options:

(a) collection by a whole air or sorbent method

(b) collection of a bulk soil or water sample for subsequent sampling of the headspace.

SOIL GAS SAMPLING: HEADSPACE ANALYSIS

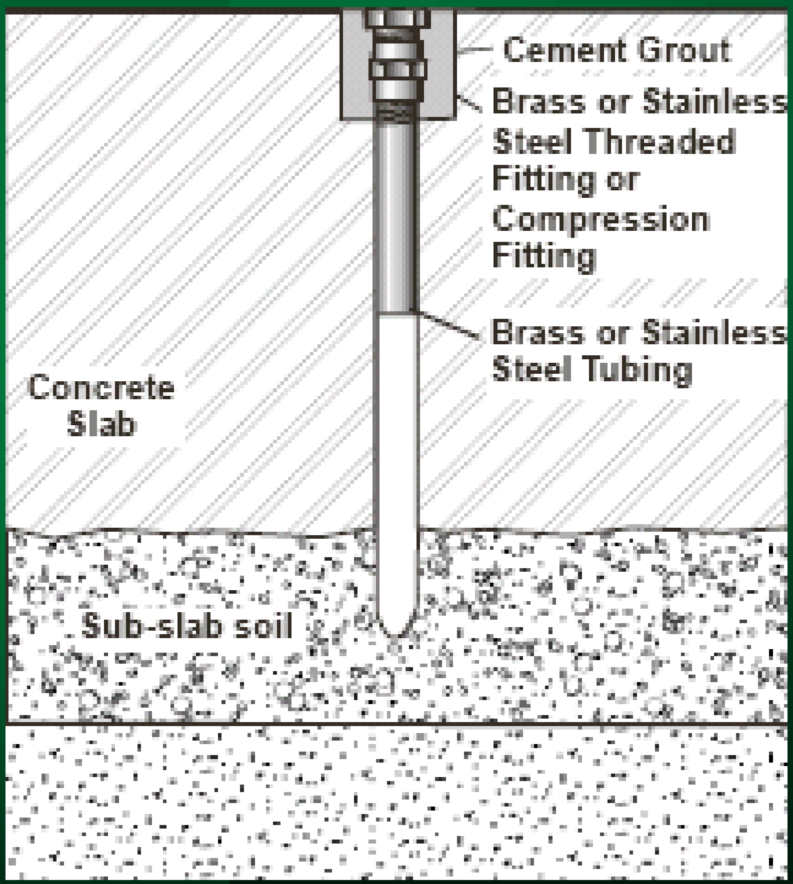
Per the ASTM standard, Option B using headspace analysis has significant disadvantages.

- The headspace atmosphere is not true soil gas, but is an artificial atmosphere formed above the soil sample. Contained atmospheres are not representative of the true vadose zone.
- It is a poor method for determining more volatile compounds.
- Whole air or sorbent method is preferable.

SOIL GAS SAMPLING:
SUBSLAB COLLECTION

- With either method, samples are collected via holes drilled through the flooring as close to the center of the floor space as possible or outside via holes drilled under the foundation

SOIL GAS SAMPLING:
SUBSLAB COLLECTION



- A stainless steel probe is inserted into the hole, the hole is sealed around the top of the probe, and an air sample is drawn through the probe into a sample collection device for analysis.

SOIL GAS SAMPLING:
WHOLE AIR METHOD

- The ASTM standard states that “whole air samples can be contained in any device that conveniently satisfies survey, handling, transport, and analytical requirements.”
- The sample collection device selected should remain the same throughout the survey to avoid bias.

SOIL GAS SAMPLING:
WHOLE AIR METHOD

The collection of soil gas samples into evacuated stainless steel canisters is commonly performed followed by GC/MS analysis using U.S. EPA Method TO-15.

6 liters

1 liter

CANISTER SAMPLING-THE BASICS

- "SUMMA" canisters refer to a proprietary electropolishing process used to make the steel chemically inert.
- Some canister manufacturers use newer electropolishing procedures, i.e. Silcosteel® treatment, and report enhanced collection for even reactive compounds such as sulfur-containing compounds.

CANISTER SAMPLING-THE BASICS

- Most canister sampling is done “passively” using a canister that has been evacuated to a specified vacuum level.
- Prior to sample collection, a qualified laboratory should clean and certify the canister, evacuate the canister to the desired level, and provide sample identification.
- All of this information may be needed for chain of custody documentation.

CANISTER SAMPLING-THE BASICS

The canister sampling train includes:

- Stainless steel sampling inlet
- Particle filter
- Critical orifice
- Flow controller

A vacuum gauge is used to visually monitor canister status during sampling.

Source: www.restekcorp.com

SOIL GAS SAMPLING: WHOLE AIR METHOD

SKC Cat. No. 231-939

- U.S. EPA SOP# 2042 describes the use of 1-liter sample bags for soil gas using negative pressure collection with a rigid container such as the SKC Vac-U-Chamber.

NOTES ON BAG SAMPLING

- Users should consider detection limits and storage stability before using bags for vapor intrusion studies.
- Also note that Tedlar® film is no longer available from DuPont™ for sample bags.
- When current supplies of Tedlar bags are depleted, users will need to consider other bag materials.
- SKC now offers a SamplePro ® FlexFilm bag that offers equivalent or improved storage stability for VOCs studied by SKC chemists.

SOIL GAS SAMPLING:
SORBENT METHOD

- Soil gas is drawn through the probe onto sorbent tubes designed for thermal desorption and GC/MS analysis.

- EPA Method TO-17 provides guidance on the choice of suitable sorbents for the collection of designated VOCs and on important considerations for analysis.

ASTM GUIDANCE ON SORBENT TUBE SAMPLING

- Sorbent sampling is well suited to sites where the soil is permeable to vapor and where site concentrations are below the detection limits for whole air samples.
- Humidity greater than 60% (common in soil) can reduce the capacity of the sorbent by 50%. If you see water in the tube, consider the sample suspect.

CRAWL SPACE SAMPLING
NOTES FROM THE FIELD

- Air inside crawl spaces is NOT typically sampled because crawl spaces have air vents to the outside that dilute contaminants.
- If the crawl space has a concrete floor or is sealed inside a building and is accessed regularly by personnel, you could collect a sample using subslab soil gas or indoor air methodologies.

INDOOR AIR SAMPLING: INITIAL ACTIVITIES

- Walk-through Inspection-To obtain a chemical inventory and to look for any *preferential pathways* such as cracks in the foundation.
- Occupant Survey-To identify any emission sources or activities that could generate airborne exposures of the target compounds.

INDOOR AIR SAMPLING: INITIAL ACTIVITIES

48 hours prior to sampling, provide instructions to occupants on their activities :

- Do not use wood stoves, fireplaces, auxiliary heating equipment, or clothes dryers.
- Do not open windows or keep doors open.
- Operate the furnace or AC as usual.
- Do not smoke indoors.

INDOOR AIR SAMPLING:
LOGISTICS

-Collect 24-hour samples within the breathing zone (2 to 5 ft above the floor) on the lowest inhabited area.

-Collect 24-hour samples in the basement (the probable place of highest concentration).

-Collect side-by-side samples at multiple locations.

-Collect an outdoor air sample for comparisons.

INDOOR AIR SAMPLING:
ANALYTICAL CONSIDERATIONS

- Vapor intrusion sampling methodology must meet or exceed the performance criteria as specified in EPA Methods TO-15 for canisters and TO-17 for sorbent-based samples.
- U.S. EPA states that the method detection limits must be below 0.5 ppb.

INDOOR AIR SAMPLING:
AVAILABLE OPTIONS

- Stainless Steel Canisters
- Sorbent Tubes for Thermal Desorption
- Passive Samplers for Thermal Desorption

CANISTERS
ADVANTAGES & DISADVANTAGES

- Considered the reference method
- Documentation of reliability
- Validated U.S. EPA methods
- Sensitive
- Accurate

- Must be cleaned, evacuated, and certified before each use
- Bulky to transport
- Expensive to ship
- Cannot be used for collection of semi-volatile compounds

THERMAL DESORPTION TUBES

ADVANTAGES & DISADVANTAGES

- Methodology has been documented in U.S. EPA Method TO-17
- Tubes with multi-sorbent beds enhance collection
- Tubes with backup section
- Collect volatile and semi-volatiles
- High sensitivity

- Require sorbent purging by qualified lab prior to sample collection
- Analysis may be a “single shot”
- Sample time is limited to avoid overloading the analytical system.
- Require additional purchase of pump and calibrator

INDOOR AIR SAMPLING
DIFFUSIVE SORBENT SAMPLERS

- Ease and convenience of passive sampling
- High sensitivity of thermal desorption
- Side-by-side studies with canisters show good correlation with proper sorbent selection and considerations for low face velocity.

SKC ULTRA®

INDOOR AIR SAMPLING
PASSIVE SORBENT SAMPLERS

ULTRA I SAMPLER

- ULTRA I samplers are pre-filled with sorbent that has been thermally purged.
- U.S. EPA recommends purged sorbent be used within a month to ensure sorbent cleanliness.

SKC Cat. Nos. 590-100, 102,103, 200

INDOOR AIR SAMPLING
PASSIVE SORBENT SAMPLERS

ULTRA II SAMPLER

- ULTRA II samplers are sold empty and are user-filled with purged sorbent upon use.
- The analytical lab can purge and ship the sorbent to users in vials that attach directly to the sampler for sorbent transfer.

Sampler housings and sorbent material are reusable. See EPA Method TO-17, Section 10.1.2.2 for guidance on sorbent reusability.

SORBENTS FOR THERMAL DESORPTION

Options Include:

- Anasorb® GCB1
- Carbopack X
- Chromosorb ® 106
- Tenax® TA

Note that although Tenax is commonly used for thermal desorption, it is a weak sorbent prone to reverse diffusion when sampling 24 hours or more.

FIELD STUDIES

SAMPLING OPTIONS FOR VAPOR INTRUSION

INDOOR AIR STUDIES
CANISTERS VS ULTRA PASSIVE SAMPLERS

- Homes in New York were investigated for possible VI by collecting side-by-side samples using canisters and ULTRA passive samplers .
- Target compounds were VOCs in contaminated groundwater from a dry cleaner and gas station.
- Samples were collected at multiple locations in each home with sample times of 24 hours.

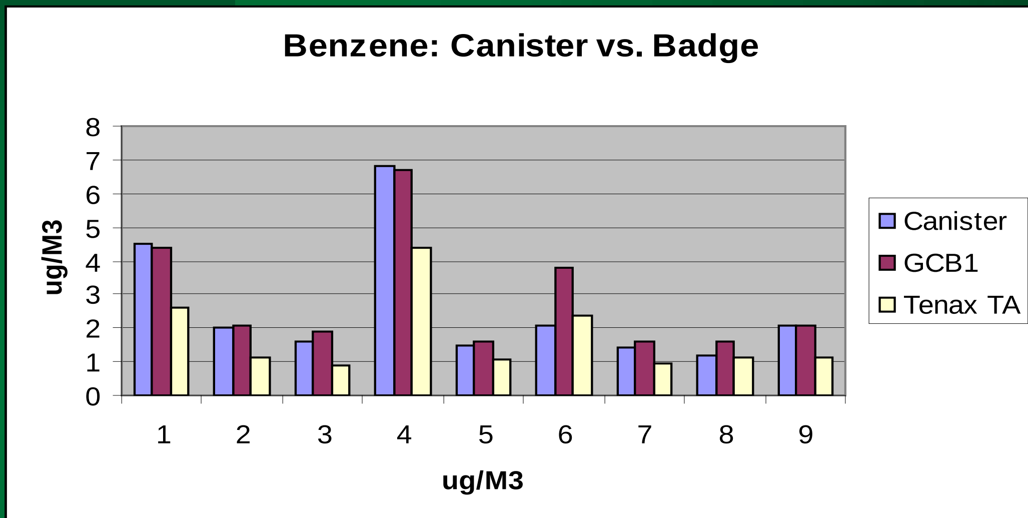
NOTE ON LOW FACE VELOCITIES

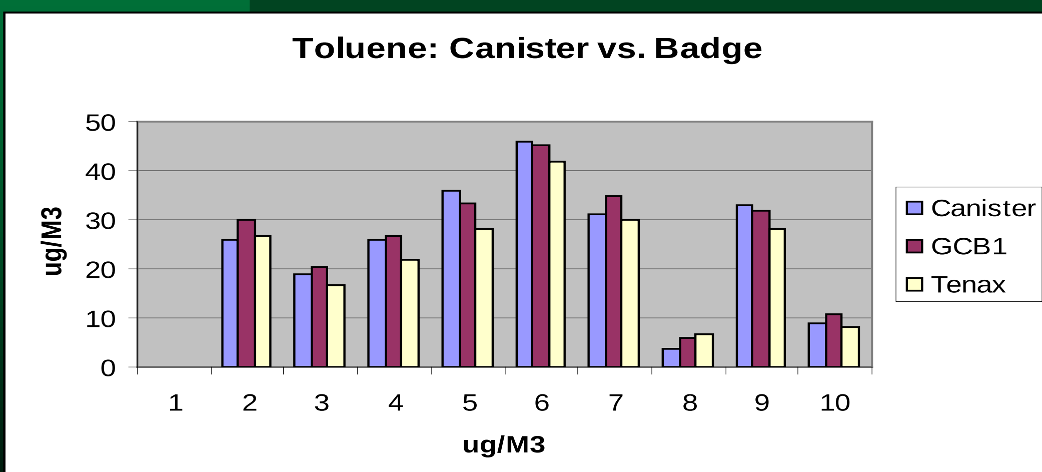
- In the field study, the air velocities in the homes measured were 0 to 2 ft/min.
- Laboratory validation studies were performed to measure uptake (sampling) rate of the ULTRA samplers under these conditions.
- Data indicated that the sampling rates at low face velocities were 60% of the rates generated in the original validation studies.

NOTE ON LOW FACE VELOCITIES

- The revised sampling rates at low face velocities were used in this study.
- Another option for addressing the low face velocities with passive samplers is to use a rotating stand to mount the passive samplers.

INDOOR AIR STUDIES
RESULTS





Benzene data showed correlation coefficients of 0.953 and 0.944 for Anasorb GCB1 and Tenax TA, respectively. In nearly all cases, Anasorb GCB1 gave higher results than those with Tenax TA since Anasorb GCB1 has better adsorptive properties.

SOIL GAS STUDIES

CANISTERS VS THERMAL DESORPTION TUBES

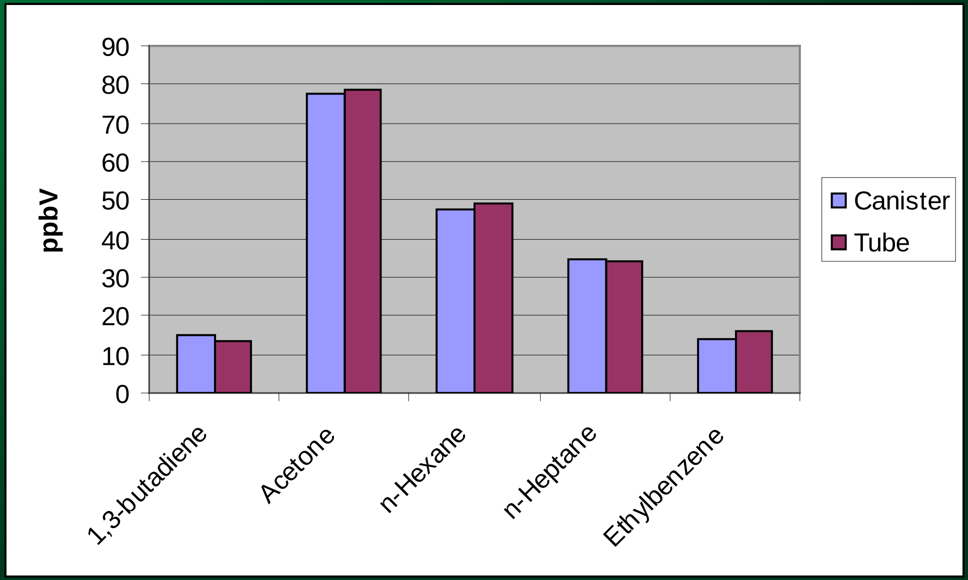
- Another field study was conducted in Southern California in an area where the soil had been contaminated by both chlorinated VOCs and petroleum hydrocarbons.
- A canister and a sorbent tube sampling train were connected to the same soil gas probe in the monitoring wells through a manifold assembly .

SOIL GAS STUDIES

CANISTERS VS THERMAL DESORPTION TUBES

- Multi-bed sorbent tubes were used containing both Anasorb GCB1 and Anasorb CMS (SKC Cat. No. 226-349) for analysis following EPA Method TO-17.
- A preliminary study was performed to verify acceptable recoveries under high moisture conditions of soil.

SOIL GAS STUDIES
RESULTS



Overall, the data indicated very good correlation between the canister and tube samples for the compounds studied with correlation coefficients of 0.9987 to 0.9992.

FOR MORE INFORMATION

- See the publication by SKC and American Analytics entitled Vapor Intrusion Sampling Options: Performance Data for Canisters, Badges, and Sorbent Tubes for VOCs.
- Go to www.skcinc.com and search using "*vapor intrusion*."

ONGOING RESEARCH

- Currently, SKC is evaluating the reliability of passive sampling for ppb-level determinations over extended periods of 7 to 30 days using the ULTRA sampler.
- This could have application for indoor and ambient air sampling.

VI CONTROLS:
THE FINAL STEP

- Seal cracks and gaps in foundation and floors.
- Cover sump pits.
- Install a vapor barrier.
- Pressurize the building through the HVAC system.
- Install a soil vapor extraction system.
- Install a subsurface depressurization system.

(AIHA *Synergist*, February 2007)

THANK YOU FOR YOUR ATTENTION

SKC

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