United States
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Agency

OSWER Draft Guidance for Evaluating the Vapor Intrusion to Indoor Air Pathway from Groundwater and Soils (Subsurface Vapor Intrusion Guidance)

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DRAFT GUIDANCE
FOR
EVALUATING THE VAPOR INTRUSION TO INDOOR AIR PATHWAY FROM GROUNDWATER AND SOILS
(Subsurface Vapor Intrusion Guidance)

I. INTRODUCTION

A. General

One of the primary objectives of the Office of Solid Waste and Emergency Response (OSWER) under EPA's Strategic Plan is stated as:

> "By 2005, EPA and its state, tribal and local partners will reduce or control the risk to human health and the environment at more than 374,000 contaminated Superfund, RCRA, underground storage tank (UST), brownfields and oil sites, and have the planning and preparedness capabilities to respond successfully to all known emergencies to reduce the risk to human health and the environment."

In order to effectively "reduce or control the risk to human health and the environment," it is necessary to determine if specific exposure pathways exist. If an exposure pathway exists, we need to evaluate the site to determine whether contamination is present at levels that may pose a significant risk to human health or the environment.

B. What Is The Intent Of This Guidance?

This draft guidance specifically addresses the evaluation of a single exposure pathway – the "vapor intrusion pathway." The intent of this draft guidance is to provide a tool to help the user conduct a screening evaluation as to whether or not the vapor intrusion exposure pathway is complete and, if so, whether it poses an unacceptable risk to human health. A complete pathway means that humans are exposed to vapors originating from site contamination. The approach suggested in this draft guidance begins with simple and generally reasonable conservative screening approaches and gradually progresses toward a more complex assessment involving increasingly greater use of site-specific data. For those sites determined to have an *incomplete* vapor intrusion pathway, EPA generally recommends that further consideration of the current site situation is not needed. For those sites determined to have a *complete* pathway, recommendations are provided on how to evaluate whether the pathway does or does not pose a potential significant risk to human health.

This guidance is not intended to provide recommendations on how to delineate the extent of risk or how to eliminate the risk, only to determine if there is a potential for an unacceptable risk. We generally recommend that a reevaluation of a screened-out site be carried out if site conditions or building/facility uses change in a way that might change the screening-out decision or other new information suggests greater conservatism is warranted in assessing this exposure pathway.

Please recognize that this is a guidance document, not a regulation. This document presents current technical and policy recommendations of the Office of Solid Waste and Emergency Response, based on our current understanding of the phenomenon of subsurface vapor intrusion. EPA personnel (and of course, states) are free to use and accept other technically sound approaches, either on their own initiative, or at the suggestion of responsible parties or other interested parties. In addition, personnel who use this guidance document are free to modify the approach recommended in this guidance. This guidance document does not impose any requirements or obligations on EPA, states, or the regulated community. Rather, the sources of authority and requirements for addressing subsurface vapor intrusion are the relevant statutes and regulations (e.g., RCRA, CERCLA and the NCP).

C. At What Sites Are We Currently Suggesting You Use This Guidance?

The draft guidance is suggested for use at RCRA Corrective Action, CERCLA (National Priorities List and Superfund Alternative Sites), and Brownfields sites, but is not recommended for use at Subtitle I Underground Storage Tank (UST) sites at this time. The draft guidance recommends certain conservative assumptions that may not be appropriate at a majority of the current 145,000 petroleum releases from USTs. As such, the draft guidance is unlikely to provide an appropriate mechanism for screening the vapor pathway at UST sites.

We recommend that State and Regional UST corrective action programs continue to use a risk based decision making approach as described in OSWER Directive 9610.17: *Use of Risk-Based Decision Making in UST Corrective Action Program* to address this pathway. A majority of State programs are successfully implementing this directive at their UST cleanups and use the recommended approaches where appropriate, to prioritize and remediate their sites, including risk associated with vapor migration to indoor air in a manner that is protective of human health and the environment.

EPA also acknowledges that there are many unique issues specific to petroleum releases from underground storage tanks. EPA is forming an EPA-State working group to further study the behavior of petroleum and petroleum products in the subsurface associated with the vapor intrusion pathway.

D. What Is The Scope Of The Guidance?

This draft guidance is intended to address the incremental increases in exposures and risks from subsurface contaminants that may be intruding into indoor air. The approaches suggested in this draft guidance are primarily designed to ensure protection of the public in residential settings but may be adjusted for other land uses (e.g., commercial/industrial, recreational), so that human exposures in non-residential settings may also be considered under this guidance, as described below.

1) Occupational settings where persons are in a working situation.

There may be occupational settings where persons present are employees and hazardous constituents may be intruding into the air space from the vapor intrusion pathway. Such settings could include workplaces where workers are handling hazardous chemicals (e.g., manufacturing facilities) similar to or different from those in the subsurface contamination, as well as other workplaces, such as administrative and other office buildings where chemicals are not routinely handled in daily activities. OSHA and EPA have agreed that OSHA generally will take the lead role in addressing occupational exposures. Workers will generally understand the workplace (e.g., Occupational Safety and Health Administration, OSHA) regulations (and monitoring, as needed) that already apply and provide for their protection. For example, workplaces are subject to a written Hazard Communication and Monitoring Plan.

In general, therefore, EPA does not expect this guidance be used for settings that are primarily occupational.[1] However, employees and their employers may not be aware of subsurface contaminants that may be contributing to the indoor air environment of their workplaces, particularly since vapor intrusion may include constituents that are no longer or were never used in a particular workplace, may originate from elsewhere, or be modified by bio-degradation or other subsurface transformation processes. Therefore, we recommend that regional or State authorities notify the facility of the potential for this exposure pathway to cause a hazard or be recognized as a hazard and suggest that they consider any potential risk that may result. Any change in the future use of the building/facility might suggest a need to reevaluate the indoor air pathway.

2) Non-residential settings where persons are in a non-working situation.

Non-residential buildings may need to be evaluated where people (typically non-workers – see above) may be exposed to hazardous constituents entering into the air space from the subsurface. This would include for example buildings where the general public may be present, e.g., schools, libraries, hospitals, hotels, and stores. EPA recommends the appropriate environmental (public health protection) screening levels be applied to these situations.

The recommendations in this guidance may be appropriate for such situations, although we recommend adjustments appropriate for non-residential exposure durations, the building specific air volumes and air exchange rates, as well as other relevant factors be considered. The model used in this guidance accommodates the inclusion of these kinds of variables and for comparison of computed values with the recommended numerical criteria in Tables 2 and 3.

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[1] It should be noted that at CERCLA sites, the cleanup levels are generally determined either by ARARs or risk range considerations; the OSHA standards are not ARARs under the CERCLA statute and regulations. Therefore, there may be instances (under CERCLA and other cleanup programs) where standards other than the OSHA standards are used to determine whether the exposure pathway presents a risk to human health.

E. Will This Guidance Supersede Existing Guidance?

This draft guidance supersedes the draft RCRA EI Supplemental Guidance for Evaluating the Vapor Intrusion to Indoor Air Pathway (December 2001). It does not supersede State guidance. However, we believe that States will find this guidance useful and States will consider this guidance in making Current Human Exposures Under Control EI determinations. Additionally, the lead regulatory authority for a site may determine that criteria other than those recommended herein are more appropriate for the specific site or area. For example, site-specific indoor air criteria may differ from the generic indoor air criteria generally recommended in this guidance and, consequently, the corresponding soil gas or groundwater screening levels may differ. Also, the site-specific relationship between indoor air concentrations and subsurface soil gas or groundwater concentrations may differ from that assumed in developing this guidance. Therefore, we suggest that the first step generally be to consult with the lead regulatory authority to identify the most appropriate approach for evaluation of any potential vapor intrusion to indoor air pathway.

F. Will We Continue To Evaluate Data And Revise This Document Accordingly?

Vapor intrusion is a rapidly developing field of science and policy and this draft guidance is intended to aid in evaluating the potential for human exposure via this pathway given the state-of-the-science at this time. EPA will continue to explore this area and improve our understanding of this complex exposure pathway. As our understanding improves, this guidance will be revised as appropriate. EPA and State site managers are encouraged to provide OSWER with relevant site information that can be added to the OSWER database to facilitate EPA's efforts (for more information see Site-Specific Investigations).

II. EXPLANATION OF VAPOR INTRUSION

Vapor Intrusion is the migration of volatile chemicals from the subsurface into overlying buildings. Volatile chemicals in buried wastes and/or contaminated groundwater can emit vapors that may migrate through subsurface soils and into indoor air spaces of overlying buildings in ways similar to that of radon gas seeping into homes, as shown in Figure 1. (However, this guidance is not intended for evaluation of intrusion of radon gas.) As the figure illustrates, this vapor intrusion pathway may be important for buildings both with and without a basement.

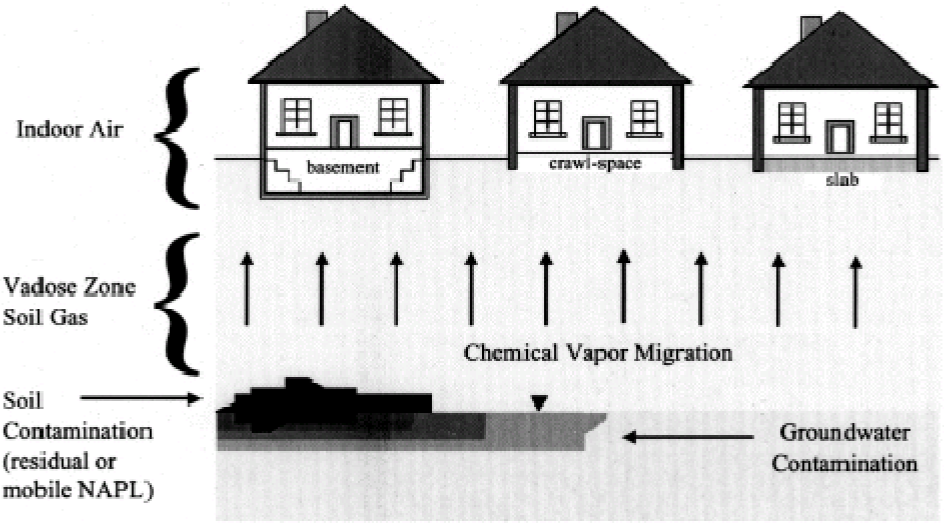

Figure 1: Generalized schematic of the pathway for subsurface vapor intrusion into indoor air.

A. Why Should You Be Concerned With This Pathway?

In extreme cases, the vapors may accumulate in dwellings or occupied buildings to levels that may pose near-term safety hazards (e.g., explosion), acute health effects, or aesthetic problems (e.g., odors). Typically however, the chemical concentration levels are low or, depending on site-specific conditions, vapors may not be present at detectable concentrations. In residences with low concentrations, the main concern is whether the chemicals may pose an unacceptable risk of chronic health effects due to long-term exposure to these low levels. A complicating factor in evaluating the potential chronic risk from vapor intrusion is the potential presence of some of the same chemicals at or above background concentrations (from the ambient (outdoor) air and/or emission sources in the building e.g., household solvents, gasoline, cleaners) that may pose, separately or in combination with vapor intrusion, a significant human health risk.

B. How Is This Exposure Pathway Different From Other Pathways?

The inhalation exposure pathway from vapor intrusion differs from other pathways in several respects. First, there is much less experience for risk assessors to draw upon when assessing the subsurface vapor to indoor air pathway than there is for the assessment of other pathways (e.g., groundwater ingestion and direct exposure to contaminated soils). Consequently, the key issues and technical challenges are not as fully understood. Second, response options will typically be different. For example, where groundwater used as drinking water is found to be highly contaminated, the groundwater plume may be cleaned up or its volume/concentration reduced, or people may drink bottled water, or they can be connected to other potable sources. In the case of significant vapor intrusion, ventilation is likely the most appropriate approach. Third, assessing the vapor intrusion pathway can be more complex than assessing other pathways because it typically involves the use of indirect measurements and modeling (e.g., using soil gas or groundwater data) to assess the potential for indoor inhalation risks. Fourth, it is our judgment that indoor air sampling results can be misleading because it is difficult and sometimes impossible to eliminate or adequately account for contributions from "background" sources.

III. SUMMARY OF DRAFT GUIDANCE

This draft guidance employs a tiered approach to assist the user in determining whether the exposure pathway is complete (i.e., subsurface vapors intrude into indoor air spaces); and, if so, whether the vapors are present at levels that may pose an unacceptable exposure risk. Although vapors may be present in soils beneath a building, the vapors may or may not pose a risk to human health. It may also be predicted that a plume would reach a development or that future construction may occur over a plume that would result in a potential for exposure via this pathway. Estimating human health risk from indoor air exposure depends upon human exposure to the vapors. If contaminant vapors do not enter the building, the exposure pathway from the source of contamination to a person (receptor) is not "complete," and in such circumstances the person cannot be considered to be at risk from indoor air exposure due to vapor intrusion. In other situations, vapors may enter the building, but be present at such low levels that the risk is considered negligible. However, in some cases, vapors may seep into a building and accumulate at levels that may pose an unacceptable risk to human health.

A. How Should You Use This Draft Guidance?

The overall approach presented here is similar to that used in the February 5, 1999, RCRA Corrective Action Current Human Exposures Under Control EI Guidance. Record sheets containing a series of questions guide users through a recommended series of analytical steps to help determine if the subsurface vapor intrusion into indoor air pathway is complete and may present unacceptable risks. The record sheets encourage documentation of the facts and considerations that typically drive responses. Documentation is important to ensure clarity and transparency of the decisions. We recommend those who use this guidance consider the technical objectives, apply professional judgment, and attempt to assess the completeness of the vapor intrusion pathway in a technically defensible fashion. Users may find the discussions included in the attached Appendices to be useful in applying professional judgment to the evaluation of the vapor intrusion pathway.

B. How Do I Start And What Are The Different Tiers?

OSWER's fundamental approach to evaluating contaminated sites uses ***Guidance for the Data Quality Objectives (DQO) Process, EPA QA/G-4*** (EPA/600/R-96/055;August 2000); (URL = http://www.epa.gov/quality/qs-docs/g4-final.pdf) which calls for proceeding in a careful stepwise fashion. We recommend that site investigators use the specific sequential approach outlined in the DQO process to adequately determine the nature and extent of contamination, and identify potential exposure pathways and receptors that may be at risk (see Appendix A for more information). The first step in the

DQO process is to develop a Conceptual Site Model (CSM). A CSM is a three-dimensional "picture" of site conditions illustrating the contaminant sources, their movement of contaminants in the environment, their exposure pathways and the potential receptors (see Appendix B for more information).

The flowchart presented in Figure 2 summarizes the evaluation approach presented in this draft guidance. There are three tiers of assessment that involve increasing levels of complexity and specificity.

- Tier 1 - Primary Screening is designed to be used with general knowledge of a site and the chemicals known or reasonably suspected to be present in the subsurface; it does not call for specific media concentration measurements for each constituent of concern;
- Tier 2 - Secondary Screening is designed to be used with some limited site-specific information about the contamination source and subsurface conditions (e.g., measured or reasonably estimated concentrations of target chemicals in groundwater or soil gas, and depth of contamination and soil type); and
- Tier 3 - Site-Specific Pathway Assessment involves collecting more detailed site-specific information and conducting confirmatory subslab and/or indoor air sampling.

The evaluation process shown in Figure 2 presents a logical and linear progression designed to screen out sites ordinarily not needing further consideration and focuses attention on those sites that generally need further consideration of the vapor intrusion pathway or action. We suggest that a user of this guidance start at tier 1. However, the user does not need to begin with tier 1 and may proceed directly to tier 2 or 3 if they so choose. In addition, as noted earlier, the user may use other technically sound approaches in evaluating the vapor intrusion pathway.

C. What Are The Steps Associated With Each Tier And How Do I Use Them?

Tier 1 - Primary Screening: This step is designed to help quickly identify whether or not a potential exists at a specific site for subsurface vapor intrusion, and, if so, whether immediate action may be warranted. Criteria recommended for making these determinations under the guidance are presented in Questions 1 through 3, which focus on identifying:

a) if chemicals of sufficient volatility and toxicity are present or reasonably suspected to be present (Question 1);
b) if inhabited buildings are located (or will be constructed under future development scenarios – except for Environmental Indicator determinations, see section IV.C below) above or in close proximity to subsurface contamination (Question 2); and
c) if current conditions warrant immediate action (Question 3).

If the Primary Screening does not support a conclusion that the pathway is incomplete, or that immediate action is warranted to mitigate risks, we recommend the user proceed to Secondary Screening.

Tier 2 - Secondary Screening: This analysis involves comparing measured or reasonably estimated concentrations of target chemicals in various media (groundwater, soil gas, and/or indoor air) to recommended numerical criteria identified in Questions 4 and 5. These "generic criteria" reflect generally reasonable worst-case conditions. Question 4 provides a conservative first-pass screening of groundwater and soil gas data. Question 5 (based on a mathematical model) considers the relationship (if any) between groundwater and soil gas target criteria to such site-specific conditions as depth of contamination and soil type. Under the guidance, the site risk manager may choose to select media-specific target concentrations for screening at three cancer risk levels: 10^{-4}, 10^{-5}, and 10^{-6}, or a hazard quotient of 1 for non-cancer risk, whichever is appropriate. When results from secondary screening do not support a determination that the pathway is incomplete, we recommend the user proceed to the Site-Specific Pathway Assessment.

Tier 3 - Site-Specific Pathway Assessment: This tier specifically examines vapor migration and potential exposures in more detail (Question 6). At this level of assessment, the guidance generally recommends direct measurement of foundation air and/or indoor air concentrations from a subset of the potentially affected buildings and complementary site-specific mathematical modeling as appropriate. Modeling is considered to be useful for determining which combination of complex factors (e.g., soil type, depth to groundwater, building characteristics, etc.) lead to the greatest impact and, consequently, aid in the selection of buildings to be sampled. It is recommended that sampling of subslab or crawlspace vapor concentrations and/or sampling of indoor air concentrations be conducted before a regulator makes a final decision that there is not a potential problem with respect to vapor intrusion. When indoor air sampling is conducted to determine if a significant risk exists, we recommend that it be conducted more than once and the sampling program be designed to identify ambient (outdoor) and indoor air emission sources of contaminants.

IV. USE OF THIS GUIDANCE

A. Under What Conditions Do We Recommend You Consider This Pathway/Guidance?

We recommend that you consider the possibility of exposure by this pathway if you have or suspect the presence, in soil or groundwater, of volatile chemicals (Henry's Law Constant > 10^{-5} atm m^3/mol) at your site as follows:

- located 100 ft or less in depth or
- located in close proximity to existing buildings or future buildings (see Primary Screening Question #2 for definition of close proximity) or
- To the expected footprint of potential future buildings (for non-EI determinations).

B. Does This Guidance Address Setting Risk Management Goals?

No. The tiered approach to evaluating the vapor intrusion pathway described in this guidance uses computed target media-specific concentrations generally based on consensus toxicity values, where available, to aid in determining whether an unacceptable inhalation exposure risk is posed by the site contamination. The tables in this guidance provide target media-specific concentrations that may be used (where appropriate) for those contaminants for which a determination has been made that a pathway is complete. An adequate site evaluation demands careful consideration of all relevant chemical and site-specific factors as well as appropriate application of professional judgment. Risk management action decisions may need to consider other factors depending on the regulatory program that applies and/or site-specific circumstances. We recommend that the lead regulatory authority select the most appropriate value to consider for site evaluation purposes.

C. How Is The Guidance To Be Used In Making Current Human Exposures Under Control Environmental Indicator (EI) Determinations?

We recommend that the approaches suggested in this guidance be used, where appropriate, to support Current Human Exposures Under Control EI determinations. However, we do not believe that confirmatory sampling will generally be necessary in that context. Current Human Exposures Under Control EI determinations are intended to reflect a reasonable conclusion by EPA or the State that current human exposures are under control with regard to the vapor intrusion pathway and current land use conditions. We believe that not recommending confirmatory sampling is appropriate because of the conservative nature of the assumptions made. Additionally, the recommended approaches are designed to help site decision makers to differentiate those sites for which there is more likely to be unacceptable vapor intrusion from those where unacceptable vapor intrusion exposures are less likely.

Finally, this guidance provides targeted indoor air concentrations set at 10^{-4}, 10^{-5}, and 10^{-6} (incremental individual lifetime cancer risk) levels and a Hazard Quotient (HQ) of 1 for non-cancer risk. For the purposes of making Current Human Exposures Under Control EI determinations with respect to vapor intrusion under RCRA and CERCLA, EPA generally recommends the use of 10^{-5} values. This level, in EPA's view, serves as a generally reasonable screening mechanism for the vapor intrusion pathway. Additionally, it takes into account practical issues associated with the analytical difficulties in taking air measurements and the possible presence of many constituents of concern due to contributions from "background" sources, including ambient (outdoor) air and/or emitted from indoor sources.

D. How Will This Guidance Be Used In The RCRA And CERCLA (Superfund) Programs?

We recommend that this draft guidance be used in making Current Human Exposures Under Control EI determinations at RCRA and NPL sites, as well as in CERCLA remedial investigations and RCRA facility investigations. It is not designed to help the site decision makers conduct a more detailed (e.g., site-specific) assessment of current and future risks at NPL sites and it does not address cumulative risk that includes other exposure pathways.[2] Likewise, this draft guidance is not designated to be used during the process for determining whether, and to what extent, cleanup action is warranted at these sites.

E. What Has Changed From Previous Guidance Related To Vapor Intrusion That I Should Be Aware Of?

This draft guidance provides improved methodologies designed to be used at any site evaluation involving a potential vapor intrusion pathway. Much work has been done to improve methodologies and coordinate various cleanup programmatic interests, especially the major OSWER regulatory programs, in developing this vapor intrusion guidance. EPA believes that this guidance should prove useful and beneficial to these programs as well as to others by providing the most up-to-date recommended approach for use in evaluating potential exposures via the vapor intrusion pathway. Specifically, it should be noted that:

- The Johnson and Ettinger Model (1991) is used in Questions 5 and 6 of this draft guidance. EPA/OSWER re-evaluated the strengths and limitations of the model which led to revisions of the previous spreadsheets developed by the Superfund Program in 1997. The revisions include new default parameters that EPA generally recommends be used in vapor intrusion pathway evaluations. The new spreadsheets are available on the following website at: http://www.epa.gov/superfund/programs/risk/airmodel/johnson_ettinger.htm

- EPA is also issuing *Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites* (SG) (OSWER 9355.4-24) which updates the 1996 Soil Screening Guidance and includes non-residential exposure scenarios. The site-specific methodologies and tools presented in the SG are consistent with this vapor intrusion guidance.

- As further improvements in practice are developed, for example sampling techniques described in Appendix E, they will be further evaluated and considered for updating of this vapor intrusion guidance and notification on the OSWER website.

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[2] The draft guidance does not specifically address the issue of "additive risk." At sites where there are a limited number of constituents in the subsurface environment, this likely is not an issue. However, at those sites where a number of contaminants are identified in the subsurface environment, the Regions and states may want to consider the additively of these contaminants. For further guidance on additively, you could review Section 2.1.1 of the Soil Screening Guidance: Technical Background Document, EPA/540/R-95/128, May 1996.

F. If I Have Indoor Air Measurements Do I Need To Follow All The Steps Described In This Guidance?

We do not recommend that indoor air quality monitoring be conducted prior to going through the steps recommended in this guidance. In those cases where indoor air quality data are available at the beginning of the evaluation, however, we generally recommend that these data be considered. We recommend that a site-specific evaluation be performed simultaneously with the subsurface assessment if indoor air concentrations exceed target levels. In some cases, the responsible party or others may decide to proactively eliminate exposures through avoidance or mechanical systems as a cost-effective approach. This option may be appropriate at any time in the assessment.

In addition, there may be circumstances in which a lead authority or a responsible party elects to initiate indoor air quality monitoring to determine whether there are any potential risks rather than pursue assessment of the pathway via the steps recommended in this guidance. If a responsible party decides to initiate indoor air monitoring, coordination and approval of air monitoring plans with the lead regulatory authority is recommended.[3]

G. What Else Might I Consider If I Have Indoor Air Concentrations Data?

Using other information in conducting a screening evaluation of the vapor intrusion pathway beyond the guidance presented in this document may be appropriate and would be consistent with the need to consider all relevant data/information in screening and/or assessing vapor intrusion to a building. For example, in some cases, a building may be positively pressurized as an inherent design of the heating, ventilation, and air conditioning system. It may be possible to show that the pathway, in this case, is incomplete, at the current time, by demonstrating a significant pressure differential from the building to the subsurface.

H. How Should "Background" Be Considered In Evaluating The Contribution Of Subsurface Contamination To Indoor Air Contamination?

We believe that it is critical to consider the presence of background concentrations in assessing the vapor intrusion pathway. Background concentrations may be impacted by volatile chemicals commonly found in the home or found in local atmospheric emissions. For example, in urban areas air quality is often affected by multiple atmospheric emission sources. In addition, human activities (e.g., smoking, craft hobbies) or consumer products (e.g., cleaners, paints, and glues) typically found in the home provide additional indoor vapor emission sources that can contribute to increased indoor air concentrations of some chemicals. In fact, there may be dozens of detectable chemicals in indoor air even absent subsurface contribution. These two types of sources can contribute to background indoor air levels of VOCs, and we recommend they be considered in

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[3] While proactive indoor air monitoring may be initiated at any time, EPA recommends that it is generally not necessary if the pathway can be confirmed to be incomplete considering other site-specific data and factors.

evaluating the contribution of subsurface contamination to indoor air contamination in dwellings at a cleanup site. Additionally, we recommend that: 1) an inspection be conducted of the residence, 2) an occupant survey be completed to adequately identify the presence of (or occupant activities that could generate) any possible indoor air emissions of target VOCs in the dwelling (see appendices E, H and I), 3) all possible indoor air emission sources be removed, and 4) ambient (outdoor) air samples be collected in conjunction with any indoor air samples. We recommend the evaluation of existing indoor air data focus on constituents (and any potential degradation products) present in subsurface sources of contamination. We recommend the relative contributions of background sources be carefully considered (see Appendix I) in order to properly assess the potential inhalation exposure risks that can be attributed to the vapor intrusion pathway.

It may be a challenge to distinguish "background" (ambient outdoor and indoor air) sources of vapors from site-related contamination. However, we recommend vapors attributable to background sources be accounted for during the "Site Specific Assessment" to properly assess the potential risk posed by exposures via the vapor intrusion pathway. To the extent practicable, we recommend that background sources of contamination be removed or excluded from the site dwellings or occupied buildings selected for sampling before any indoor air sampling is conducted. If this is not possible, then we recommend the contribution from these sources be carefully considered when evaluating any indoor air sampling results. (See Site-Specific Question # 6)

Compile Site Information

- Develop Data Quality Objectives
- Develop Conceptual Site Model

Tier 1 - Primary Screening

- Determine if volatile and toxic chemicals are present (see Table 1).
- Determine if inhabited buildings are, or in the future could potentially be, located near subsurface contaminants.
  - If toxic volatile chemicals are present and current, or future, human exposure is suspected, proceed with screening.
- Determine if potential risks warrant immediate action.
  - If immediate action does not appear to be necessary, proceed to secondary screening.

Tier 2 - Secondary Screening

Question 4

- If indoor air data are available, compare to appropriate target concentration (Table 2a, b, or c).
  - If indoor air data exceed the target concentration proceed to Question 6.
- Determine if there is any potential for contamination of soils in the unsaturated zone.
  - If contamination of the unsaturated zone is suspected, assess soil gas data.
  - If contamination of the unsaturated zone is not suspected, assess groundwater data.
- Compare soil gas or groundwater data to appropriate target concentration (Table 2a, b, or c).
  - If groundwater data exceed the target concentration, assess soil gas data.
  - If soil gas data exceed the target concentration proceed to Question 5.
- Determine if data are adequate to characterize the site and support an assessment.
  - If adequate data are not available, develop a sampling and analysis plan that satisfies the established data quality objectives.
- Determine if site conditions, or data limitations, would preclude the use of generic attenuation factors used in Tables 2a, b, and c.
- If appropriate data do not exceed target media concentration, pathway is considered to be incomplete.

Question 5

- Determine if there is any potential for contamination of soils in the unsaturated zone.
  - If contamination of the unsaturated zone is suspected, assess soil gas data.
  - If contamination of the unsaturated zone is not suspected, assess groundwater data.
- Compare soil gas or groundwater data to appropriate target concentration (Table 3a, b, or c).
  - If groundwater data exceed the target concentration, assess soil gas data.
  - If soil gas data exceed the target concentration proceed to Question 6.
- If adequate data are not available, develop a sampling and analysis plan that satisfies the established data quality objectives.
- Determine if site conditions, or data limitations, would preclude the use of scenario-specific attenuation factors used in Tables 3a, b, and c.
- If appropriate data do not exceed target media concentration, pathway is considered to be incomplete.

Tier 3 - Site Specific Pathway Assessment

Question 6

- Determine if the nature and extent of contamination has been adequately characterized to identify the buildings that are most likely to be impacted.
  - If no, develop a sampling and analysis plan that satisfies the data quality objectives.
- Compare sub-slab soil gas or indoor air data to appropriate target concentration.
  - If sub-slab data exceed target concentration, assess indoor air data.
- Determine whether or not site data meet data quality objectives and background/ambient sources have been adequately accounted for.
- Determine if exposure pathway is complete.

Figure 2. Schematic flow diagram: evaluation process recommended in guidance.

IV. TIER 1 - Primary Screening

Primary Screening is designed to help quickly screen out sites at which the vapor intrusion pathway does not ordinarily need further consideration, and point out the sites that do typically need further consideration. This evaluation involves determining whether any potential exists at a specific site for vapor intrusion to result in unacceptable indoor inhalation risks and, if so, whether immediate action may be warranted. Recommended criteria for making these determinations are presented in Questions 1 through 3, which focus on identifying:

a) if chemicals of sufficient volatility and toxicity are present or reasonably suspected to be present (Question 1);
b) if inhabited buildings are located (or will be constructed under future development scenarios – except for Environmental Indicator determinations, see section IV.C below) above or in close proximity to subsurface contamination (Question 2); and
c) if current conditions warrant immediate action (Question 3).

This primary screening process is illustrated in a flow diagram included in Appendix C.

A. Primary Screening – Question #1

Q1: Are chemicals of sufficient volatility and toxicity known or reasonably suspected to be present in the subsurface (e.g., in unsaturated soils, soil gas, or the uppermost portions of the ground water and/or capillary fringe – see Table 1)? (We recommend this consideration involve DQOs (see Appendix A) used in acquiring the site data as well as an appropriately scaled Conceptual Site Model (CSM) for vapor intrusion (see Appendix B).)

_____ If **YES** - check here, check off the relevant chemicals on Table 1, and continue with Question 2. The chemicals identified here (and any degradation products) are evaluated as constituents of potential concern in subsequent questions.

_____ If **NO** - check here, provide the rationale and references below, and then go to the Summary Page to document that the subsurface vapor to indoor air pathway is incomplete (i.e., no further consideration of this pathway is needed); or

_____ If sufficient data are not available, go to the Summary Page and document the need for more information. After collecting the necessary data, Question 1 can then be revisited with the newly collected data to re-evaluate the completeness of the vapor intrusion pathway.

1. What is the goal of this question?

This question is designed to help quickly screen out sites at which the vapor intrusion pathway generally does not need further consideration. This evaluation involves determining whether or not any potential exists at a specific site for the vapor intrusion pathway to result in unacceptable indoor air inhalation risks. Table 1 lists chemicals that may be found at hazardous waste sites and indicates whether, in our judgment, they are sufficiently volatile (Henry's Law Constant > 10^{-5} atm m^3/mol) to result in potentially significant vapor intrusion and sufficiently toxic (either an incremental lifetime cancer risk greater than 10^{-6} or a non-cancer hazard index greater than 1, or in some cases both) to result in potentially unacceptable indoor air inhalation risks. The approach used to develop Table 1 is documented in Appendix D and can be used, where appropriate, to evaluate volatile chemicals not included in the Table. We recommend that if any of the chemicals listed in Table 1 that are sufficiently volatile and toxic are present at a site, those chemicals become constituents of potential concern for the vapor intrusion pathway and are evaluated in subsequent questions in this guidance. If the chemicals listed in Table 1 are not present at a site, and no other volatile chemicals are present, we suggest that the vapor intrusion pathway be considered incomplete and no further consideration of this pathway is needed.

2. *What should you keep in mind?*

In evaluating the available site data, we recommend the DQOs used in collecting the data be reviewed to ensure those objectives are consistent with the DQOs for the vapor intrusion pathway (see Appendix A). We recommend the detection limits associated with the available groundwater data be reviewed to ensure they are not too high to detect volatile contaminants of potential concern. Also, we suggest that the adequacy of the definition of the nature and extent of contamination in groundwater and/or the vadose zone be assessed to ensure that all contaminants of concern and areas of contamination have been identified. Additionally, we recommend groundwater concentrations be measured or reasonably estimated using samples collected from wells screened at, or across the top of the water table. We recommend users read Appendices B (Conceptual Site Model for the Vapor Intrusion Pathway) and E (Relevant Methods and Techniques) to obtain a greater understanding of the important considerations in evaluating data for use in screening assessments of the vapor intrusion pathway.

3. *Rationale and References:*

B. Primary Screening – Question #2

Q2: Are currently (or potentially) inhabited buildings or areas of concern under future development scenarios located *near* (see discussion below) subsurface contaminants found in Table 1?

_____ If **YES** – check here, identify buildings and/or areas of concern below, and document on the Summary Page whether the potential for impacts from the vapor intrusion pathway applies to currently inhabited buildings or areas of concern under reasonably anticipated future development scenarios, or both. (Note that for EI considerations, we recommend only current risks be evaluated.) Then proceed with Question 3.

_____ If **NO** – check here, describe the rationale below, and then go to the Summary Page to document that there is no potential for the vapor intrusion pathway to impact either currently inhabited buildings or areas of concern under future development scenarios (i.e., no further evaluation of this pathway is needed). (Note that for EI considerations, only current risks are evaluated.); or

_____ If sufficient data are not available – check here and document the need for more information on the Summary Page. After collecting the necessary data, Question 2 can then be revisited with the newly collected data to re-evaluate the completeness of the vapor intrusion pathway.

1. What is the goal of this question?

The goal of this question is to help determine whether inhabited buildings currently are located (or may be reasonably expected to be located under future development scenarios) above or in close proximity to subsurface contamination that potentially could result in unacceptable indoor air inhalation risks. If inhabited buildings and/or future development are not located "near" the area of concern, we suggest that the vapor intrusion pathway be considered incomplete and no further consideration of the pathway should be needed.

For the purposes of this question, **"inhabited buildings"** are structures with enclosed air space that are designed for human occupancy. Table 1, discussed above in Question 1, lists the **"subsurface contaminants demonstrating sufficient volatility and toxicity"** to potentially pose an inhalation risk. We recommend that an inhabited building generally be considered **"near"** subsurface contaminants if it is located within approximately 100 ft laterally or vertically of known or interpolated soil gas or groundwater contaminants listed in Table 1 (or others not included in table 1 – see Question 1) and the contamination occurs in the unsaturated zone and/or the uppermost saturated zone. If the source of contamination is groundwater, we recommend migration of the contaminant plume be considered when evaluating the potential for future risks. The distance suggested above (100 feet) may not be appropriate for all sites (or contaminants) and, consequently, we recommend that professional judgment be used when evaluating the potential for vertical and horizontal vapor migration.

2. How did we develop the suggested distance?

The recommended distance is designed to allow for the assessment to focus on buildings (or areas with the potential to be developed for human habitation) most likely to have a complete vapor intrusion pathway. Vapor concentrations generally decrease with increasing distance from a subsurface vapor source, and eventually at some distance the concentrations become negligible. The distance at which concentrations are negligible is a function of the mobility, toxicity and persistence of the chemical, as well as the geometry of the source, subsurface materials, and characteristics of the buildings of concern. Available information suggests that 100 feet laterally and vertically is a reasonable criterion when considering vapor migration fundamentals, typical sampling density, and uncertainty in defining the actual contaminant spatial distribution. The recommended lateral distance is supported by empirical data from Colorado sites where the vapor intrusion pathway has been evaluated. At these sites, no significant indoor air concentrations have been found in residences at a distance greater than one house lot (approximately 100 feet) from the interpolated edge of ground water plumes. Considering the nature of diffusive vapor transport and the typical anisotropy in soil permeability, in our judgment a similar criterion of 100 feet for vertical transport is generally conservative. These recommended distances will be re-evaluated and, if necessary, adjusted by EPA as additional empirical data are compiled.

3. What should you keep in mind when evaluating this criterion?

It is important to consider whether **significant preferential pathways** could allow vapors to migrate more than 100 feet laterally. For the purposes of this guidance, a “significant” preferential pathway is a naturally occurring or anthropogenic subsurface pathway that is expected to have a high gas permeability and be of sufficient volume and proximity to a building so that it may be reasonably anticipated to influence vapor intrusion into the building. Examples include fractures, macropores, utility conduits, and subsurface drains that intersect vapor sources or vapor migration pathways. Note that naturally occurring fractures and macropores may serve as preferential pathways for either vertical or horizontal vapor migration, whereas anthropogenic features such as utility conduits are relatively shallow features and would likely serve only as a preferential pathway for horizontal migration. In either case, we recommend that buildings with significant preferential pathways be evaluated even if they are further than 100 ft from the contamination.

We also recommend that the potential for mobile “vapor clouds” (gas plumes) emanating from near-surface sources of contamination into the subsurface be considered when evaluating site data. Examples of such mobile “vapor clouds” include: 1) those originating in landfills where methane may serve as a carrier gas; and 2) those originating in commercial/industrial settings (such as dry cleaning facilities) where vapor can be released within an enclosed space and the density of the chemicals’ vapor may result in significant advective transport of the vapors downward through cracks/openings in floors and into the vadose zone. In these cases, diffusive transport of vapors is usually overridden by advective transport, and the vapors may be transported in the vadose zone several hundred feet from the source of contamination.

Finally, this guidance is intended to be applied to existing groundwater plumes as they are currently defined (e.g., MCLs, State Standards, or Risk-Based Concentrations). However, it is very important to recognize that some non-potable aquifers may have plumes that have been defined by threshold concentrations significantly higher than drinking-water concentrations. In these cases, contamination that is not technically considered part of the plume may still pose significant risks via the vapor intrusion pathway and, consequently, the plume definition may need to be expanded. Similarly, we recommend evaluating the technologies used to obtain soil gas and indoor air concentrations to determine if appropriate methods were used to ensure adequate data quality at the time analyses were conducted.

4. Identify Inhabited Buildings (or Areas With Potential for Future Residential Development) Within Distances of Possible Concern:

C. Primary Screening Stage–– Question #3

Q3: Does evidence suggest immediate action may be warranted to mitigate current risks?

_____ If **YES** – check here and proceed with appropriate actions to verify or eliminate imminent risks. Some examples of actions may include but are not limited to indoor air quality monitoring, engineered containment or ventilation systems, or relocation of people. The action(s) should be appropriate for the site-specific situation.

_____ If **NO** – check here and continue with Question 4.

1. What is the goal of this question?

This question is intended to help determine whether immediate action may be warranted for those buildings identified in Question 2 as located within the areas of concern. For the purposes of this guidance, "immediate action" means such action is necessary to verify or abate imminent and substantial threats to human health.

2. What are the qualitative criteria generally considered sufficient to indicate a need for immediate actions?

Odors reported by occupants, particularly if described as "chemical," or "solvent," or "gasoline." The presence of odors does not necessarily correspond to adverse health and/or safety impacts and the odors could be the result of indoor vapor sources; however, we believe it is generally prudent to investigate any reports of odors as the odor threshold for some chemicals exceeds their respective acceptable target breathing zone concentrations.

Physiological effects reported by occupants (dizziness, nausea, vomiting, confusion, etc.) may, or may not be due to subsurface vapor intrusion or even other indoor vapor sources, but, should generally be evaluated.

Wet basements, in areas **where chemicals of sufficient volatility and toxicity** (see Table 1) **are known to be present in groundwater and the water table is shallow enough that the basements are prone to groundwater intrusion or flooding.** This has been proven to be especially important where there is evidence of light, non-aqueous phase liquids (LNAPLs) floating on the water table directly below the building, and/or any direct evidence of contamination (liquid chemical or dissolved in water) inside the building.

Short-term safety concerns are known, or are reasonably suspected to exist, including: a) measured or likely explosive or acutely toxic concentrations of vapors in the building or connected utility conduits, sumps, or other subsurface drains directly connected to the building and b) measured or likely vapor concentrations that may be flammable/combustible, corrosive, or chemically reactive.

3. Rationale and Reference(s):

V. TIER 2 - SECONDARY SCREENING

The vapor intrusion pathway is complex and, consequently, we recommend that a comprehensive assessment of this pathway using all available lines of evidence be conducted before drawing conclusions about the risks posed by this pathway. Users are encouraged to consider the evidence for vapor intrusion in sequential steps, starting with the source of vapors (contaminated groundwater or unsaturated soils), proceeding to soil gas in the unsaturated zone above the source, and upward to the exposure point (e.g., subslab or crawlspace vapor). Then, if indicated by the results of previous steps, collect and evaluate indoor air data. In our judgment, this sequential evaluation of independent lines of evidence provides a logical and cost-effective approach for identifying whether or not subsurface vapor intrusion is likely to contribute significantly to unacceptable indoor air quality. However, in those cases where indoor air quality data are available at the beginning of an evaluation, this guidance recognizes these data will generally be considered early in the process.

Collection of indoor air quality data without evidence to support the potential for vapor intrusion from subsurface sources can lead to confounding results. Indoor air quality can be influenced by ‘background’ levels of volatile chemicals. For example, consumer products typically found in the home (e.g., cleaners, paints, and glues) or occupant activities (e.g., craft hobbies, smoking) may serve as contributory sources of indoor air contaminants. Additionally, ambient (outdoor) air in urban areas often contains detectable concentrations of many volatile chemicals. In either case, the resulting indoor air concentrations can be similar to or higher than levels that are calculated to pose an unacceptable chronic inhalation risk in screening calculations. In fact, there may be dozens of detectable chemicals in indoor air even absent subsurface contributions. Thus, we recommend focusing the evaluation of existing indoor air data on constituents (and any potential degradation products) present in subsurface sources of contamination. We recommend considering the relative contributions of background sources (see Appendices E and I) in order to properly assess the potential inhalation exposure risks that can be attributed to the subsurface vapor intrusion pathway.

Using a sequential approach, the secondary screening suggested in this guidance involves comparing available measured or reasonably estimated concentrations of constituents of potential concern (identified in Question 1) in groundwater and/or soil gas to target concentrations identified in Questions 4 and 5. More detailed studies, including foundation and/or indoor air sampling and vapor intrusion modeling, are generally conducted in the site-specific assessment in Question 6. The sequential evaluation approach is illustrated in flow diagrams included in Appendix C. Question 4 uses conservative “generic” attenuation factors that reflect generally reasonable worst-case conditions for a first-pass screening of groundwater and soil gas data. Question 5 uses attenuation factors (based on a generally conservative use of the Johnson-Ettinger mathematical model) that relate groundwater and soil gas target concentrations to such site-specific conditions as depth of contamination and soil type. In performing the secondary screening assessment, the user will need to identify whether the contamination (source of vapors) occurs in groundwater or in the unsaturated zone. In our judgment, if there is a contaminant source in the unsaturated zone, soil gas data are needed to evaluate the vapor intrusion pathway in the vicinity of the unsaturated zone source. However, we recommend that groundwater data still be evaluated, particularly if the plume extends beyond an unsaturated zone source of vapors, but only in conjunction with soil gas data. If the secondary screening indicates the vapor intrusion pathway is complete, the guidance recommends the user perform a site-specific assessment following the guidelines in Question 6. If the secondary screening indicates this pathway is incomplete and/or does not pose an unacceptable risk to human health, then no further assessment of the pathway is recommended, unless conditions change.

The media-specific target concentrations used in Questions 4 and 5 were developed considering a generic conceptual model for vapor intrusion consisting of a groundwater and/or vadose zone source of volatile vapors that diffuse upwards through unsaturated soils towards the surface. Under the model, the soil in the vadose zone is considered to be relatively homogeneous and isotropic, though horizontal layers of soil types can be accommodated. The receptors at the surface used in the model are residents in homes with poured concrete foundations (e.g., basement or slab on grade foundations or crawlspace homes with a liner or other vapor barrier). The underlying assumption for this generic model is that site-specific subsurface characteristics will tend to reduce or attenuate vapor concentrations as vapors migrate upward from the source and into structures. Thus, application of the secondary screening target concentrations necessitates at least rudimentary knowledge of the contamination source, subsurface conditions (e.g., measured or reasonably estimated concentrations of target chemicals in soil or groundwater, and depth of contamination and soil type), and building construction at the site (e.g., foundation type). Specific factors that may result in unattenuated or enhanced transport of vapors towards a receptor, and consequently are likely to render the use of the secondary screening target concentrations inappropriate, are discussed in each question below. Factors such as biodegradation that can result in accelerated attenuation of vapors are not considered in the conceptual model. In general, it is recommended that the user consider whether the assumptions underlying the generic conceptual model are applicable at each site, and use professional judgment to make whatever adjustments (including not considering the model at all) are appropriate.

A. **Secondary Screening – Question #4:** Generic Screening

Q4(a): Are indoor air quality data available? (Collection of indoor air quality data without evidence to indicate the potential for vapor intrusion from subsurface sources is not recommended at this level of screening, but if such data are available, we recommend they be evaluated along with the available subsurface data.)

_____ If **YES** - check here and proceed to **Question 4(b).**

_____ If **NO** – check here and proceed to **Subsurface Source Identification - Question 4(c**).

Q4(b): Do measured indoor air concentrations of constituents of potential concern identified in Question 1 (and any degradation products) exceed the target concentrations given in Tables 2(a), 2(b), or 2(c)?

_____ If **YES** - check here, document representative indoor air concentrations on Table 2, and **initiate a site-specific assessment** following the guidelines in Question 6. (We recommend the user also proceed with the subsurface evaluation to evaluate whether there is sufficient evidence to indicate the elevated indoor concentrations are due to vapor intrusion from subsurface sources, and not from background or other sources)

_____ If **NO** – check here and proceed to **Subsurface Source Identification - Question 4(c).** (Here, the recommendation to proceed with the subsurface evaluation is based on the assumption that only limited indoor air data are available and, therefore, the available subsurface data need to be evaluated to ensure that all possible areas potentially affected by the vapor intrusion pathway are evaluated. However, in our judgment, if the site has been adequately characterized and sufficient indoor air data are available (see Question 6 for a discussion of data needs), the **pathway is incomplete** and/or does not pose an unacceptable risk to human health, and no further assessment of the pathway is recommended. Document the finding as described in Question 6.)

Subsurface Source Identification:

Q4(c): Is there any potential contamination (source of vapors) in the unsaturated zone soil at any depth above the water table? (In our judgment, if there is a contaminant source in the unsaturated zone, soil gas data are needed to evaluate the vapor intrusion pathway in the vicinity of the source and, consequently, use of the groundwater target concentrations may be inappropriate. However, we recommend that groundwater data still be evaluated, particularly if a contaminant plume extends beyond the unsaturated zone source, but that the evaluation be performed only in conjunction with an evaluation of soil gas data. Other vapor sources that typically make the use of groundwater target concentrations inappropriate include: 1) those originating in landfills where methane may serve as a carrier gas; 2) those originating in commercial/industrial settings (such as dry cleaning facilities) where vapor can be released within an enclosed space and the density of the chemicals' vapor may result in significant advective transport of the vapors downward through cracks/openings in floors and into the vadose zone; and 3) leaking vapors from underground storage tanks. In these cases, diffusive transport of vapors is often overridden by advective transport and the vapors may be transported in the vadose zone several hundred feet from the source of contamination.)

_____ If **YES**-check here and skip to **Soil Gas Assessment - Question 4 (g)** below.

_____ If **NO**- check here and continue with **Groundwater Assessment - Question 4(d)** below.

Groundwater Assessment:

Q4(d): Do measured or reasonably estimated groundwater concentrations exceed the generic target media-specific concentrations given in Tables 2(a), 2(b), or 2(c)? (For more information on the use of data for this part, please see the sections below entitled "How should data be used in this question?" and "How do you know you have unusable data?".)

_____ If **YES** (or if the detection limit for any constituents of potential concern is above the target concentration) - check here and document representative groundwater concentrations on Table 2. If **soil gas data are available**, proceed to **Soil Gas Assessment - Question 4(g)** below, **otherwise** proceed to **Question 5.**

_____ If **NO** – check here and **proceed to Question 4(e).**

Q4(e): Is the **nature and extent of groundwater contamination adequately characterized** (see Appendices B & E) in areas with inhabited buildings (or areas with the potential for future development of inhabited buildings)?

_____ If **YES** - check here and continue with **Question 4(f)** below.

_____ If **NO** - check here, go to Summary Page and document that more information is needed. We recommend the next step be expeditious collection of the needed data in accordance with proper DQOs. Question 4 can then be revisited with the newly collected data to re-evaluate the completeness of the vapor intrusion pathway.

Q4(f): Are there site conditions and/or data limitations that make the use of the recommended generic groundwater attenuation factors inappropriate? We recommend this consideration involve comparison of the generic conceptual model to an appropriately scaled and updated Conceptual Site Model (CSM) for vapor intrusion (see Appendix B), as well as the proper DQOs (see Appendix A). We also recommend evaluation of the generic attenuation factors used to develop the media-specific attenuation factors (see the section below titled "What is in Tables 2(a), 2(b), and 2(c) and how did we develop them?" and Appendix F.)

Factors that, in our judgment, typically make the use of generic groundwater attenuation factors inappropriate include:

- ☐ Very shallow groundwater sources (e.g., depths to water less than 5 ft below foundation level); or
- ☐ Relatively shallow groundwater sources (e.g., depths to water less than 15 ft below foundation), and one or more of the following:

- buildings with significant openings to the subsurface (e.g., sumps, unlined crawlspaces, earthen floors), or
- significant preferential pathways, either naturally-occurring and/or anthropogenic (see discussion below under "What Should I Keep in Mind When Evaluating Data"), or
- buildings with very low air exchange rates (e.g., < 0.25/hr) or very high sustained indoor/outdoor pressure differentials (e.g., > 10 Pascals).

_____ If **YES** - check here, briefly document the issues below, and proceed to **Site-Specific Assessment - Question 6**.

_____ If **NO** - check here, briefly document the rationale below and document on the Summary Page that the groundwater data indicate the **pathway is incomplete** and/or does not pose an unacceptable risk to human health. In order to increase confidence in the assessment that the pathway is incomplete, we recommend that soil gas data **also** be evaluated (**Question 4(g)**).

_____ If sufficient data (of acceptable quality) are not available - check here, go to Summary Page and document that more information is needed. We recommend the next step be expeditious collection of the needed data in accord with proper DQOs. Question 4 can then be revisited with the newly collected data to re-evaluate the completeness of the vapor intrusion pathway.

Soil Gas Assessment:

Q4(g): Do measured or reasonably estimated soil gas concentrations exceed the generic target media-specific concentrations given in Tables 2(a), 2(b), or 2(c) (see Appendix D)? For more information on the use of data for this part, please see the section below entitled "How should data be used in this question?"

_____ If **YES** (or if the detection limit for any constituents of potential concern is above the target concentration) - check here. Document representative soil gas concentrations on Table 2 and proceed to **Question 5**.

_____ If **NO** – check here and proceed to **Question 4(h)**.

Q4(h): Is the **nature and extent of soil contamination adequately characterized** and has an adequate demonstration been made to show that the **soil gas sampling techniques used could reasonably detect an elevated concentration of vapors** if they were present in the site setting?

_____ If **YES** - check here and continue with **Question 4(i)** below.

_____ If **NO** - check here. Skip to Summary Page and document that more information is needed. We recommend the next step be expeditious collection of the needed data in accord with proper DQOs. Question 4 can then be revisited with the newly collected data to re-evaluate the completeness of the vapor intrusion pathway.

Q4(i): Are there site conditions and/or data limitations that may make the use of generic soil gas attenuation factors inappropriate? (We recommend that this consideration involve an appropriately scaled and updated Conceptual Site Model (CSM) for vapor intrusion (see Appendix B), as well as the proper DQOs (see Appendix A). We also recommend evaluation of the generic attenuation factors used to develop the media-specific attenuation factors (see the section below titled "What is in Tables 2(a), 2(b), and 2(c) and how did we develop them?" and Appendix F.))

Factors that, in our judgment, typically make the use of generic soil gas attenuation factors inappropriate include:

- Shallow soil contamination vapor sources (e.g., less than 15 ft below foundation level), and one or more of the following:
  - buildings with significant openings to the subsurface (e.g., sumps, unlined crawlspaces, earthen floors), or
  - significant preferential pathways, either naturally-occurring and/or anthropogenic (see discussion below under "What Should I Keep in Mind When Evaluating Data"), or
  - buildings with very low air exchange rates (e.g., < 0.25/hr) or very high sustained indoor/outdoor pressure differentials (e.g., > 10 Pascals).

_____ If **YES** - check here, briefly document the issues below, and proceed to **Site-Specific Assessment** - **Question 6**.

_____ If **NO** - check here, briefly document the rationale below and document on the Summary Page that the soil gas data indicate the **pathway is incomplete** and/or does not pose an unacceptable risk to human health. In this case, no further assessment of the vapor intrusion pathway is recommended.

_____ If sufficient data (of acceptable quality) are not available - check here, go to Summary Page and document that more information is needed. We recommend the next step be expeditious collection of the needed data in accord with proper DQOs or proceed to **Question 5**. When additional data are collected, Question 4 can then be revisited with the newly collected data to re-evaluate the completeness of the vapor intrusion pathway.

1. What is the goal of this question?

Question 4 is intended to allow a rapid screening of available site data using measured or reasonably estimated groundwater and/or soil gas concentrations. The term "measured or reasonably estimated" is used above (and throughout this document) in recognition of the fact that measurements adjacent to or in all buildings of concern may not be practical or necessary. For example, groundwater concentrations beneath buildings are commonly estimated from concentrations collected in wells distributed about a larger area of interest.

2. How should data be used in this question?

Question 4 calls for comparison of site data with generic target media-specific concentrations given in Tables 2(a), 2(b), and 2(c). These target media-specific concentrations correspond to indoor air concentrations associated with a specific incremental lifetime cancer risk of (a) 10^{-4}, (b) 10^{-5}, (c) 10^{-6} or a hazard quotient greater than 1 (whichever is more restrictive). Under this question, the user selects the appropriate screening risk level for the site and compares the soil gas and/or groundwater concentrations observed at the site to the corresponding target media concentrations in the table. If the detection limit for any constituent of potential concern is above its target screening level, we recommend the user continue the evaluation as though the target level is exceeded.

In order to select the appropriate target media concentrations for comparison, it is important to identify whether a source of vapors in an area occurs in the unsaturated zone (contaminated soil). This allows the site data to be segregated into two categories: a) data representing areas where contaminated groundwater is the only source of contaminant vapors, and b) data representing areas where the underlying unsaturated zone soil contains a source of vapors. In case (a) either the groundwater or soil gas target concentrations in Tables 2(a), 2(b), or 2(c) are generally appropriate to use. In case (b), we recommend that only soil gas target concentrations and soil gas samples collected above the vapor source zone be used. This is because the groundwater target concentrations have been derived assuming no other vapor sources exist between the water table and the building foundation. However, we recommend that groundwater data still be evaluated, particularly if a contaminant plume extends beyond the unsaturated zone source, but the evaluation be performed only in conjunction with an evaluation of soil gas data. In either case, because of the complexity of the vapor intrusion pathway, we recommend that professional judgment be used when applying the target concentrations.

This screening approach is based on a conceptual model that assumes diffusive transport of vapors in the unsaturated zone. Consequently, we recommend the target concentrations used in this secondary screening not be applied to data from sites in which advection significantly influences vapor transport. Thus, the exclusionary criteria listed above in Questions 4(f) and 4(i) are designed to identify those situations in which advective vapor transport may result in unattenuated or enhanced vapor intrusion (e.g., shallow vapor sources at depths less than 15 ft below foundation level and buildings with significant openings to the subsurface, or very high sustained pressure differentials, or significant vertical preferential pathways).

3. *What is in Tables 2(a), 2(b), and 2(c) and how did we develop them?*

Tables 2(a), 2(b), or 2(c) contain generally recommended target concentrations for indoor air, soil gas, and groundwater for each chemical listed. A separate table is provided for each of the three cancer risk levels considered (a) 10^{-4}, (b) 10^{-5}, and (c) 10^{-6} including non-cancer risk values where applicable for Hazard Quotient = 1. Details regarding the derivation of Tables 2(a), 2(b), and 2(c) are provided in Appendix D. The tabulated indoor air concentrations are risk-based screening levels calculated following an approach consistent with EPA's ***Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites*** (EPA, 2002). These recommended target indoor air concentrations were calculated using toxicity information current as of the date indicated on the tables. The user is encouraged to visit the EPA web-page to determine whether updated tables are available.

The soil gas and groundwater target concentrations were calculated to correspond to the target indoor air concentrations using media-specific attenuation factors. Shallow soil gas (e.g., subslab gas and soil gas measured at 5 feet or less from the base of the foundation) is conservatively assumed to intrude into indoor spaces with an attenuation factor of 0.1. Note that in general samples taken less than 5 feet below the building foundation are not recommended unless the sample was taken from directly under the foundation slab or repeated sampling is performed to ensure a representative soil gas value. For deep soil gas (e.g., soil gas samples taken at depths greater than approximately 5 feet below the foundation level), an attenuation factor of 0.01 (generally considered reasonably conservative) is used to calculate target concentrations. For groundwater, an attenuation factor of 0.001 (generally considered reasonably conservative) is used in combination with the conservative assumption that the partitioning of chemicals between groundwater and soil vapor is assumed to obey Henry's Law. (Note that if the risk-based concentration calculated for groundwater falls below the chemical's MCL, the MCL is recommended as the target concentrations.) EPA generally considers the attenuation factors used in this guidance to be reasonable upper bound values based on data from sites where paired indoor air, soil gas and groundwater samples were available (see Appendix F), and also theoretical considerations.

4. *How do you know if you have usable data?*

In comparing available site data to the target media-specific target concentrations in Table 2, we recommend that DQOs used in collecting the data be consistent with DQOs for the vapor intrusion pathway and that the sampling issues specific to evaluating this pathway be considered (see Appendices A and E). Some examples of sampling issues that we recommend be considered are: 1) groundwater samples be taken from wells screened (preferably over short intervals) across the top of the water table (only volatile contaminants in the uppermost portions of an aquifer, including the capillary fringe, are likely to volatilize into the vadose zone and potentially migrate into indoor air spaces); 2) fluctuations in water table elevation can lead to elevated source vapor concentrations and thus, we recommend soil gas samples be considered in these areas; 3) we recommend soil gas samples be taken as close to the areas of interest as possible and preferably from directly underneath the building structure; and 4) as vapors are likely to migrate upward through the coarsest and/or driest material, we recommend that soil gas samples be collected from these materials. More detail regarding considerations for using groundwater and soil gas data to evaluate the vapor intrusion pathway are provided in Appendix E.

5. What should I keep in mind when evaluating data?

It is important to consider whether **significant preferential pathways** could allow vapors to migrate farther and at greater concentrations than expected. For purposes of this guidance, a preferential pathway is a naturally-occurring and/or anthropogenic subsurface 'pathway' that is expected to have a high intrinsic gas permeability (vadose zone) or high conductivity (saturated zone) and thus influence the flow or migration of contaminated vapors or groundwater. A preferential pathway is likely to have a significant influence on vapor intrusion if it is of sufficient volume and proximity to a currently occupied building so that it may be reasonably anticipated to influence the migration of contaminants to, or into, the building. Significant vertical preferential pathways may result in higher than anticipated concentrations in the overlying near surface soils, whereas significant horizontal preferential pathways may result in elevated concentrations in areas on the periphery of subsurface contamination. Naturally occurring preferential pathways may include fractured vadose zone geology or very permeable soils located between a relatively shallow source of contamination and a building. Anthropogenic preferential pathways may include utility conduits or subsurface drains that are directly connected to a building and a source of vapors. In highly developed residential areas, extensive networks of subsurface utility conduits could significantly influence the migration of contaminants. EPA recommends that buildings with significant preferential pathways be evaluated closely even if they are further than 100 feet from the contamination.

6. What if I have bulk soil data?

Soil (as opposed to soil gas) sampling and analysis is not currently recommended for assessing whether or not the vapor intrusion pathway is complete. This is because of the large uncertainties associated with measuring concentrations of volatile contaminants introduced during soil sampling, preservation, and chemical analysis, as well as the uncertainties associated with soil partitioning calculations. Thus, bulk soil target concentrations were not derived and the use of bulk soil target concentration is not generally recommended. Note however, if a NAPL source is suspected, a soil sample may be necessary to determine whether a NAPL source is present. Also, bulk soil concentration data could be used in a qualitative sense for delineation of sources, where appropriate. For example, high soil concentrations would indicate impacted soils; unfortunately, the converse is not always true and it is our judgment that non-detect analytical results can not be interpreted to indicate the absence of a vapor source.

7. Rationale and Reference(s):

Document Risk Level Used (Circle One): 10^{-4}, (b) 10^{-5}, or (c) 10^{-6}

B. Secondary Screening – Question #5: Semi-Site Specific Screening

Q5(a): Do groundwater and/or soil gas concentrations for any constituents of potential concern exceed target media-specific concentrations by a factor greater than 50? (Evaluation of limited site data in Question 5 allows the user to potentially screen sites using target concentrations that are higher by a factor of up to 50 times greater than the generic target concentrations used in Question 4. If observed concentrations are greater than 50 times the generic target concentrations, we recommend expeditious site-specific evaluation.)

_____ If **YES** - check here and briefly document the issues below and go to **Site-Specific Assessment - Question 6.**

_____ If **NO** - check here and continue with **Question 5(b)**.

Q5(b): Are there site conditions and/or data limitations under which we would not recommend the use of semi-site specific attenuation factors (based on the Johnson-Ettinger Model)? (To determine whether use of the Johnson-Ettinger model is appropriate, we recommend the user consider an appropriately scaled and updated Conceptual Site Model (CSM) for vapor intrusion (see Appendix B) and DQOs (see Appendix A). We also recommend users refer to Appendix G, which lists the limitations of the Johnson-Ettinger Model.)

Factors that, in our judgment, typically make the use of semi-site specific attenuation factors inappropriate include:

- ☐ Very shallow vapor sources (e.g., depths less than 5 ft below foundation level); or
- ☐ Relatively shallow vapor sources (e.g., depths less than 15 ft below foundation level), and one or more of the following:
  - buildings with significant openings to the subsurface (e.g., sumps, unlined crawlspaces, earthen floors), or
  - significant preferential pathways, either naturally-occurring and/or anthropogenic (see discussion in Question 4), or
  - buildings with very low air exchange rates (e.g., < 0.25/hr) or very high sustained indoor/outdoor pressure differentials (e.g., > 10 Pascals), or
  - soil types outside the range shown in Table 4, or
- ☐ Any other situation for which the Johnson-Ettinger Model is deemed inappropriate.

_____ If **YES** - check here and briefly document the issues below and go to **Site-Specific Assessment - Question 6.**

_____ If **NO** - check here and continue with **Question 5(c)**.

_____ If sufficient data (of acceptable quality) are not available - check here and skip to Summary Page and document that more information is needed. We recommend that the next step be expeditious collection of the needed data in accord with proper DQOs. Question 5 can then be revisited with the newly collected data to re-evaluate the completeness of the vapor intrusion pathway.

Q5(c): Are the **depth to vapor source and the overlying unsaturated zone soil type adequately characterized** in areas with inhabited buildings (or areas with the potential for future development of inhabited buildings)?

_____ If **YES** - check here and continue with **Question 5(d)** below.

_____ If **NO** - check here, go to Summary Page and document that more information is needed. We recommend the next step be expeditious collection of the needed data in accord with proper DQOs. Question 5 can then be revisited with the newly collected data to re-evaluate the completeness of the vapor intrusion pathway.

<u>Subsurface Source Identification</u>

Q5(d):Is there any potential contamination (source of vapors) in the unsaturated zone soil at any depth above the water table? (In our judgment, if there is a contaminant source in the unsaturated zone, soil gas data are needed to evaluate the vapor intrusion pathway in the vicinity of the source and, consequently, use of the groundwater target concentrations may be inappropriate. However, we recommend that groundwater data still be evaluated, particularly if a contaminant plume extends beyond the unsaturated zone source, but that the evaluation be performed only in conjunction with an evaluation of soil gas data. Other vapor sources that we believe typically make the use of groundwater target concentrations inappropriate include: 1) those originating in landfills where methane may serve as a carrier gas; 2) those originating in commercial/industrial settings (such as dry cleaning facilities) where vapor can be released within an enclosed space and the density of the chemicals' vapor may result in significant advective transport of the vapors downward through cracks/openings in floors and into the vadose zone; and 3) leaking vapors from underground storage tanks. In these cases, diffusive transport of vapors is often overridden by advective transport and the vapors may be transported in the vadose zone several hundred feet from the source of contamination.)

_____ If **YES** - check here and skip to **Soil Gas Assessment – Question 5(f)** below.

_____ If **NO** - check here and continue with Groundwater Assessment - **Question 5(e)** below.

Groundwater Assessment:

Q5(e):Do measured or reasonably estimated groundwater concentrations exceed the target media-specific concentrations given in Tables 3(a), 3(b), or 3(c) for the appropriate attenuation factor (given that the conditions listed above in 5(b) are not present and that sampling issues described Appendix E have been considered)?

_____ If **YES** - check here, document the soil type, depth to groundwater and attenuation factor used in the assessment on the summary page, and document the representative groundwater concentrations on Table 3. If **soil gas data are available**, proceed to **Soil Gas Assessment - Question 5(f)** below**, otherwise** proceed to **Site Specific Assessment - Question 6**.

_____ If **NO** – check here and document that the groundwater data indicate that the **pathway is incomplete** and/or does not pose an unacceptable risk to human health on the Summary Page. In order to increase confidence in the assessment that the pathway is incomplete, EPA recommends that soil gas data also be evaluated following the soil gas assessment guidelines below (**Question 5(f)**).

Soil Gas Assessment:

Q5(f): Do measured or reasonably estimated soil gas concentrations exceed the target media-specific concentrations given in Tables 3(a), 3(b), or 3(c) for the appropriate attenuation factor (given that the conditions listed above in 5(b) are not present, or that other site specific factors make consideration of this analysis inappropriate, and that sampling issues described in Appendix E have been considered)?

_____ If **YES** - check here, document the soil type, depth to source and attenuation factor used in the assessment on the summary page, document representative soil gas concentrations on Table 3 and proceed to **Site Specific Assessment - Question 6**.

_____ If **NO** – check here and document that the subsurface vapor to indoor air **pathway is incomplete** and/or does not pose an unacceptable risk to human health on the Summary Page. In this case, we recommend no further assessment of the vapor intrusion pathway.

1. What is the goal of this question?

The goal of this question is to provide a means of evaluating the vapor intrusion pathway using tables of generally recommended target media-specific concentrations that incorporate limited site-specific information. Specifically, Question 5 factors in consideration of soil type and depth to source in screening the available groundwater and soil gas data. Soil gas- and groundwater-to-indoor air attenuation factors generally depend (as described in Appendix G) on building characteristics, chemical type, soil type, and depth of the source (which is defined as either a measured soil gas concentration at the specified sample collection depth below the building, or the ground water concentration at the depth of the water table). By using the Johnson and Ettinger Model (1991) and keeping all factors besides source depth and soil type constant (and reasonably conservative), a set of attenuation factors can be derived that allows for the selection of semi-site specific target media concentrations that are more representative of the user's site. The semi-site-specific target values provided in Question 5 are less conservative (higher by a factor of 2 to 50 times, depending on soil type and depth to source) than the generic screening values used in Question 4. The increase in target concentrations corresponds to a decrease in the calculated attenuation factors as depth to source increases and soil type becomes finer grained (see Figures 3(a) and (b) and Section 3 below). In our judgment, if observed concentrations are greater than 50 times the generic target concentrations provided in Question 4, there is no benefit in using the criteria in Question 5 and we recommend expeditious site-specific evaluation.

2. How do you use the Graphs and the Tables?

The user selects a representative attenuation factor for soil gas from Figure 3(a) and for groundwater from Figure 3(b) based on measured site-specific information about soil type and depth to source. The selected attenuation factors are then rounded up to the nearest attenuation factor shown in Figure 3. Then, the columns in Tables 3(a), 3(b), and 3(c) corresponding to the attenuation factors selected from Figure 3(a) or 3(b) can be used to determine the appropriate target media concentrations for this level of screening. The values in Tables 3(a), 3(b), and 3(c) were derived as discussed in Appendix D.

3. How did we develop the media-specific target concentrations?

The Johnson and Ettinger (1991) Model was used as described in Appendix G to calculate the attenuation factors shown in Figures 3(a) and 3(b). Generally reasonable building characteristics were selected and held constant in these calculations and the chemicals were assumed not to degrade. To capture the effect of changes in soil properties, the U.S. Soil Conservation Service (SCS) soil texture classifications were considered, and a subset of these was selected. This subset was chosen so that their relevant properties (porosity and moisture content) would collectively span the range of conditions most commonly encountered in the field. Then, plots of attenuation factor versus depth were calculated, and these results are presented in Figures 3(a) and 3(b). The two graphs are different because the soil gas attenuation factors (Figure 3(a)) do not have to account for transport across the capillary fringe whereas the groundwater attenuation factors (Figure 3(b)) do. Details of the input parameters and calculations used to derive the graphs are included in Appendix G.

4. What should you keep in mind when using the graphs?

The generally recommended depth to source used to select a scenario-specific attenuation factor is: 1) the vertical separation between the soil gas sampling point and the building foundation for use of Figure 3(a), or 2) the vertical separation between the water table and the building foundation for use of Figure 3(b). Note that we recommend that groundwater or soil gas samples collected at depths less than 5 feet (1.5 m) below the building foundation not be evaluated with these graphs. If contaminated groundwater is within 5 feet of the foundation level, or if the only soil gas samples available for screening were obtained from depths less than 5 feet below foundation level and the soil gas concentrations are greater than target levels, we recommend the user perform a site specific assessment. If the depth to source across the site varies, we recommend that the minimum depth be used in this assessment.

We recommend that the soil type used to select a scenario-specific attenuation factor represent the material most permeable to vapors between the building foundation and the contaminant source (e.g., the coarsest and/or driest soils). The graphs below use the U.S. Soil Conservation Service system of soil classification, in which the soil texture classes are based on the proportionate distribution of sand, silt and clay sized particles in soil. The generally preferred method for determining the SCS soil class is to use lithological information combined with the results of grain size distribution tests on selected soil samples. Table 4 below has been developed to assist users in selecting an appropriate SCS soil type in cases where lithological and grain size information is limited. Note that in Table 4 there is no soil texture class represented as consisting primarily of clay. Exclusion of clay was deliberate since homogenous unfractured clay deposits are rare.

Table 4. Guidance for selection of soil type curves in Figures 3(a) and 3(b).

If your boring log indicates that the following materials are the predominant soil types …	Then we recommend the following texture classification when obtaining the attenuation factor.
Sand or Gravel or Sand and Gravel, with less than about 12 % fines, where "fines" are smaller than 0.075 mm in size.	Sand
Sand or Silty Sand, with about 12 % to 25 % fines	Loamy Sand
Silty Sand, with about 25 % to 50 % fines	Sandy Loam
Silt and Sand or Silty Sand or Clayey, Silty Sand or Sandy Silt or Clayey, Sandy Silt, with about 50 to 85 % fines	Loam

5. *Rationale for Selecting Semi-Site Specific Attenuation Factor and Reference(s):*

Document Risk Level Used (Circle One): 10^{-4}, (b) 10^{-5}, or (c) 10^{-6}

Figure 3a- DRAFT
Vapor Attenuation Factors - Soil Vapor to Indoor Air Pathway
Basement Foundations

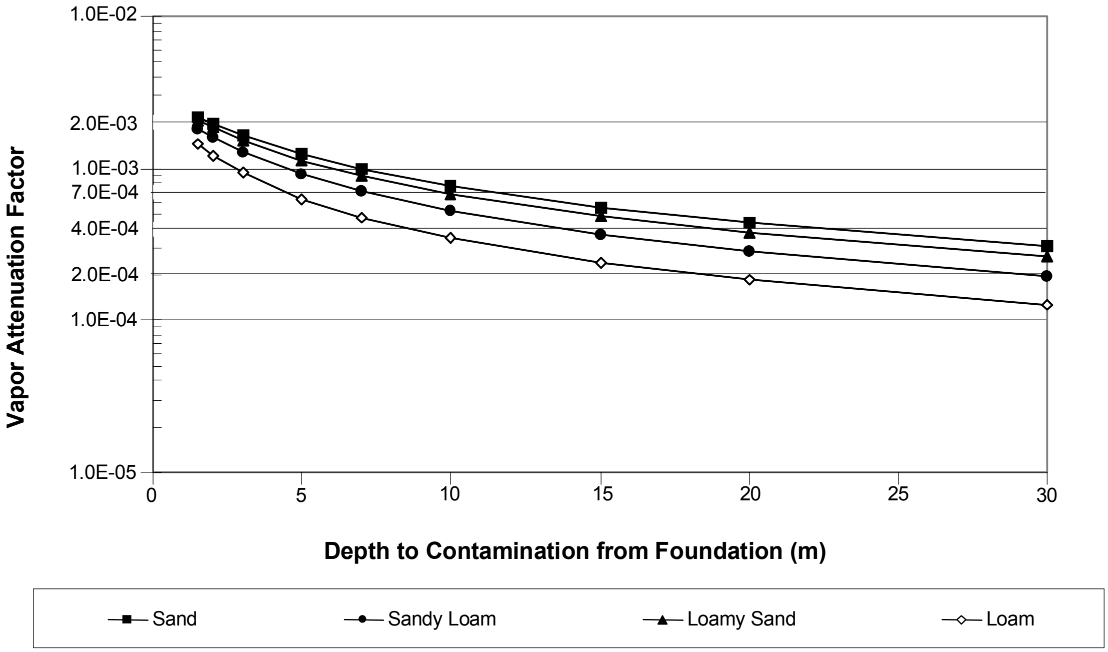
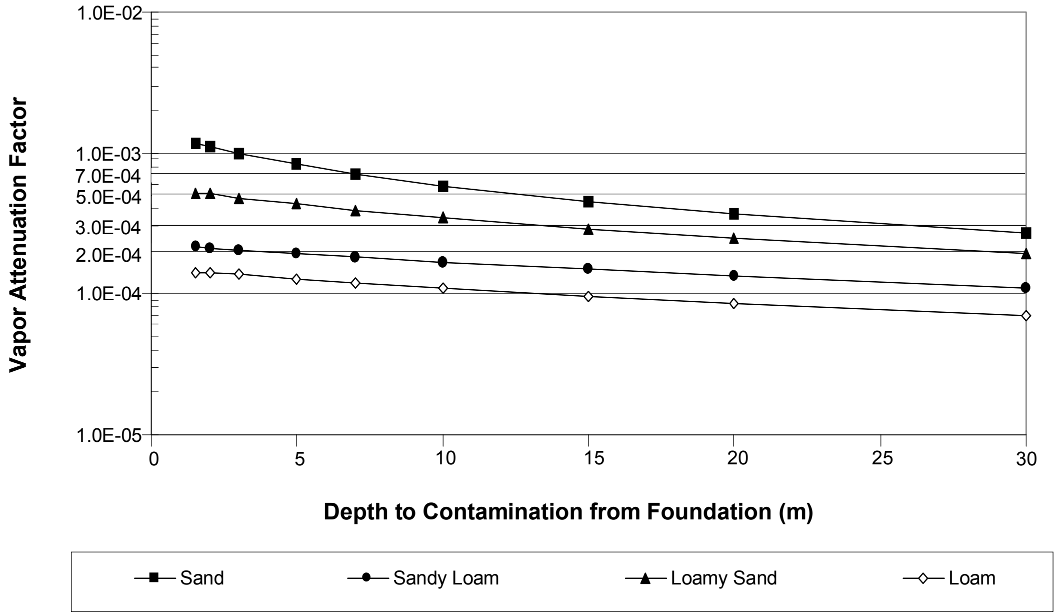


Figure 3b- DRAFT
Vapor Attenuation Factors - Ground Water to Indoor Air Pathway
Basement Foundations



VI. Tier 3 - Site-Specific Assessment

If primary and secondary screening results do not assist in excluding the existence of a vapor intrusion pathway, we recommend a site-specific assessment. In this case, this guidance recommends: (1) direct measurement of foundation air concentrations before any indoor air measurements; (2) direct measurement of indoor air concentrations coupled with a home survey (see Appendix H) and sampling to identify background sources of vapor in ambient (outdoor) and/or indoor air; 3) removal of all indoor air sources before sampling indoors; and (4) complementary site-specific mathematical modeling as appropriate. The sampling of foundation air (e.g., subslab and /or crawlspace air) and ambient (outdoor) air in conjunction with indoor air is intended to distinguish the exposures that originate from subsurface contaminant vapor intrusion from those due to background sources.

The recommended site-specific modeling is intended to be complementary to the more direct building-related measurements collected from a selected subset of the potentially impacted buildings. Considering the complexities involved in evaluating the vapor intrusion pathway (due to the sensitivity of attenuation factors to soil type, depth to source, and building characteristics), mathematical modeling may be useful in determining which combination of factors leads to the greatest impact and, consequently, aid in identifying appropriate buildings to be sampled. However, if an appropriate model is not available or cannot be modified to represent the conceptual site model, the only available option may be a site-specific assessment that relies entirely on direct measures of potential exposures.

We recommend that since site-specific assessments are based on direct evidence (confirmatory sampling of subslab or crawlspace vapor concentrations and/or indoor air concentrations), decisions made that “no further action with respect to vapor intrusion is needed”, are likely to be “final decisions.” Additionally, we recommend that the approaches suggested in the site-specific assessment be used, where appropriate, to support Current Human Exposures Under Control EI determinations. However, we do not believe that confirmatory sampling will generally be necessary in that context. Current Human Exposures Under Control EI determinations are intended to reflect a reasonable conclusion by EPA or the State that current human exposures are under control with regard to the vapor intrusion pathway and current land use conditions. We believe that not recommending confirmatory sampling to support Current Human Exposures Under Control EI determinations is appropriate because of the conservative nature of the assumptions made.

If buildings are not available or not appropriate for sampling, for example in cases where future potential impacts need to be evaluated, we recommend mathematical modeling be used to evaluate the potential for unacceptable inhalation risks due to the vapor intrusion pathway. Where modeling indicates there is the potential that vapor intrusion may result in unacceptable exposures, other more direct measures of potential impacts, such as emission flux chambers or soil gas surveys, may need to be conducted in areas underlain by subsurface contamination. Alternately, it may be appropriate to reduce potential exposures with a mechanical ventilation system in the event buildings are constructed over subsurface vapor sources. EPA recommends that these sites be reevaluated when they are being developed, as appropriate, and that management decisions be made based on evaluation results at that time.

The data collected during site-specific evaluations of the vapor intrusion pathway can also serve to increase the level of understanding about key issues and important factors in the assessment of this pathway. Because the Agency is interested in improving the understanding of the modeling approach to evaluate the vapor intrusion pathway, EPA requests that the relevant data collected in site specific assessments be submitted electronically to an EPA repository that will be established by OSWER. EPA plans to develop a database structure specific to vapor intrusion evaluations to facilitate electronic entry of the relevant data and electronic submission to the repository. Once developed, EPA plans to make the database structure accessible through OERR's and OSW's web sites.

EPA plans to review and analyze these submitted data on an ongoing basis and consider appropriately refining this draft guidance for assessing the vapor intrusion pathway. EPA plans to post any revisions/addenda on the OSWER's website.

A. Site Specific Assessment – Question 6

Q6(a): Have the **nature and extent of contaminated soil vapor, unsaturated soil, and/or groundwater as well as potential preferential pathways and overlying building characteristics been adequately characterized to identify the most-likely-to-be-impacted buildings?** (Consider an appropriately-scaled Conceptual Site Model (CSM) for vapor intrusion (see Appendix B) and DQOs (see Appendix A)).

_____ If **YES** - check here, briefly document the basis below and **proceed to Question 6(b).** If a model was used, we recommend it be an appropriate and applicable model that represents the conceptual site model. If other means were used, document how you determined the potentially most impacted areas to sample.

_____ If **NO**, or if insufficient data (of acceptable quality) are available - check here, briefly **document the needed data** below, and skip to the Summary Page and document that more information is needed. After collecting the additional data, you can return to this question. However**, if indoor air data are available go to Question 6(e)**.

Q6(b): Are you conducting an EI determination and are you using an appropriate and applicable model?

_____ If **YES** - check here and continue with **Question 6(c)** below.

_____ If **NO** - check here and continue with **Question 6(d)**.

Q6(c): Does the model predict an unacceptable risk? (EPA recommends that predictive modeling can be used to support Current Human Exposures Under Control EI determinations without confirmatory sampling to support this determination. Current Human Exposures Under Control EI determinations are intended to reflect a reasonable conclusion by EPA or the State that current human exposures are under control with regard to the vapor intrusion pathway and current land use conditions.)

_____ If **YES** - check here and continue with **Question 6(d)** below.

_____ If **NO** - check here and document that the **Pathway is Incomplete** and/or does not pose an unacceptable risk to human health for EI determinations. However, this determination does not necessarily reflect a final decision that the site is clean without confirmatory sampling.

Q6(d): Are subslab soil gas data available?

_____ If **YES** - check here and continue with **Question 6(e)** below.

_____ If **NO** - check here and continue with **Question 6(g)**.

Q6(e): Do measured subslab soil gas concentrations exceed the target shallow soil gas concentrations given in Tables 2(a), 2(b), or 2(c)?

_____ If **YES** - check here, document representative subslab soil gas concentrations on Table 2, collect indoor air data and **go to Question 6(g).**

_____ If **NO** – check here and **continue to Question 6(f)**.

Q6(f): Is the subslab sampling data adequate? (We recommend doing subslab sampling before indoor air sampling) Some factors we recommend for consideration in this question include:

- Do analytical results meet the required detection thresholds?
- Do the data account for seasonal and/or temporal transience?
- Do the data account for spatial variability?
- Is there any reason to suspect random (sampling) or systematic (analytical) error?
- How do the data account for the site conceptual model?
- Was "background" ambient (outdoor) air or other vapor sources considered?

_____ If **YES** - check here and document that the **Pathway is Incomplete** and/or does not pose an unacceptable risk to human health.

_____ If **NO** or unsure - check here, briefly document the needed data below, and skip to the Summary Page and document that more information is needed. After collecting the additional data, return to Question 6(e).

Q6(g): Do measured indoor air concentrations exceed the target concentrations given in Tables 2(a), 2(b), or 2(c)? (We recommend that before any indoor air sampling occurs: 1) an inspection of the residence be conducted, 2) an occupant survey be completed to adequately identify the presence of (or occupant activities that could generate) any possible indoor air emissions of target VOCs in the dwelling (see appendix E, H and I), 3) all possible indoor air emission sources be removed, and 4) that the analysis be done only for the constitutes of potential concern found on the site.)

_____ If **YES** - check here, document representative indoor air concentrations on Table 2, and go to Question 6(i).

_____ If **NO** – check here and continue to Question 6(h).

Q6(h): Do the indoor air concentrations adequately account for seasonal variability and represent the most impacted buildings or area (see Appendix E)? Some factors we recommend for consideration in this question include:

- Do analytical results meet the required detection thresholds?
- Do the data account for seasonal and/or temporal transience?
- Do the data account for spatial variability?
- Is there any reason to suspect random (sampling) or systematic (analytical) error?
- How do the data account for the site conceptual model?

_____ If **YES** - check here, document that **Pathway is Incomplete** and/or does not pose an unacceptable risk to human health. If a model was used to predict the indoor air concentrations also document the relationship between the predicted concentrations and the measured concentrations.

_____ If **NO** - check here, go to the summary page and document that more information is needed. If the data do not account for seasonal variability, we recommend designing a sampling plan to account for seasonal variability, resample and return to Question 6(g). If the data do not represent most impacted building or area, skip to the Summary Page and document that more information is needed. After collecting the additional data, you can return to Question 6(g).

Q6(i): Have background sources of vapor in indoor air and ambient (outdoor) air been adequately accounted for?

_____ If **YES** - check here, document results and document that **Pathway is Complete**. If a model was used to predict the indoor air concentrations, also document the relationship between the predicted concentrations and the measured concentrations.

_____ If **NO** - check here, briefly document the needed data below, and skip to the Summary Page and document that more information is needed. After collecting the additional data, you can return to Question 6(g).

1. What is the goal of this question?

The Site-Specific Pathway Assessment is designed to be used where site-specific conditions warrant further consideration prior to concluding either that the pathway is incomplete, or that some form of exposure control may be needed. In general, this final step recommends direct measures of potential impacts (e.g., building-specific foundation vapor concentrations – subslab sampling and/or indoor air concentrations) coupled with site-specific mathematical modeling where an appropriate model is available. However, EPA recommends that predictive modeling can be used to support Current Human Exposures Under Control EI determinations without confirmatory sampling these determination. Current Human Exposures Under Control EI determinations are intended to reflect a reasonable conclusion by EPA or the State that current human exposures are under control with regard to the vapor intrusion pathway and current land use conditions. The purpose of this site-specific approach is to help assess whether or not the vapor intrusion pathway is a likely problem. It is not meant to provide detailed guidance on how to delineate the extent of impacted buildings.

2. How should you complete this evaluation?

We recommend that the first step in conducting the site-specific evaluation be to update the site-specific conceptual site model and determine what additional information (e.g., direct sampling) you may need to determine the most-likely-to-be-impacted buildings (e.g., professional judgment or a model such as the J&E model). Confirmatory subslab/crawlspace and/or indoor air sampling is recommended at a percentage of the buildings at each potentially affected site that you have determined to be the most-likely-to-be-impacted. If sampling confirms that unacceptable inhalation risks due to vapor intrusion do not occur at the site, we recommend that the vapor intrusion pathway be considered incomplete and/or does not pose an unacceptable risk to human health. If sampling confirms that any building is impacted on the site, we recommend that the pathway be considered complete. In such case, we recommend that further analysis be conducted to delineate the extent of the impacted building(s) and that mitigation or avoidance measures be considered for the impacted buildings. These tasks are critically important, but are outside the scope of this guidance.

3. Why do we recommend updating your conceptual site model?

A conceptual model of the site and potential subsurface vapor transport and vapor intrusion mechanisms will be needed to adequately support the Site-Specific Pathway Assessment recommended in this guidance. We recommend that the site-specific conceptual model be developed in the typical source-pathway-receptor framework, and that it identify how the site-specific conceptual model is similar to, and different from, the generic conceptual model used in this guidance (see Introduction and Secondary

Screening). Under the guidance approach, key components of the conceptual model need to be justified with site-specific data, including, but not limited to, the source (chemical constituents, concentrations, mass, phase distribution, depth, and aerial extent), pathway (soil texture, moisture, and layering) and building (building design, construction, and ventilation). Some of the necessary data might already be available from previous site characterization efforts, but if not, we recommend collecting or developing appropriate site-specific data for evaluating the vapor intrusion pathway.

4. *What should you keep in mind when you conduct indoor air or subslab sampling?*

Collection of indoor air quality data without evidence to indicate the potential for vapor intrusion from subsurface sources can lead to confounding results. Indoor air quality can be influenced by 'background' levels of volatile chemicals (e.g., due to indoor and/or outdoor ambient sources). For example, consumer products typically found in the home (e.g., cleaners, fuels, paints, and glues) may serve as ancillary sources of indoor air contaminants. Additionally, ambient outdoor air in urban areas often contains detectable concentrations of many volatile chemicals. In either case, the resulting indoor air concentrations can be similar to or higher than levels that are calculated to pose an unacceptable chronic inhalation risk. Thus, we recommend the evaluation of existing indoor air data focus on constituents (and any potential degradation products) present in subsurface sources of contamination and the relative contributions of background sources be considered (see Appendix I). Additionally, see Appendix E for other items to keep in mind when doing subslab sampling.

5. *What direct measurements should be considered and what do they mean?*

Direct measures of indoor air and building foundation air (e.g., subslab and/or crawlspace concentrations) are recommended to verify whether or not the vapor intrusion pathway is complete. We recommend that the building specific sampling program be designed to identify and account for background sources. Prior to indoor air sampling, it is recommended that an inspection of the residence be conducted and an occupant survey be completed to adequately identify the presence of (or occupant activities that could generate) any possible indoor air emission sources of target VOCs in the dwelling (see discussion above and Appendices E, H & I) and then, if possible remove these sources. The Massachusetts Department of Environmental Protection (MA DEP) has prepared a useful ***Indoor Air Sampling and Evaluation Guide (April 2002)*** which is available at the following URL: http://www.state.ma.us/dep/ors/files/indair.pdf.

In collecting indoor air samples, it is important to recognize that indoor air quality can be influenced by 'background' levels of volatile chemicals (e.g., due to indoor and/or outdoor ambient sources), as discussed in the above section. Thus, we recommend the evaluation of existing indoor air data focus on constituents (and any potential degradation products) present in subsurface sources of contamination and determine the relative contributions of background sources (see Appendix I) in order to properly assess the potential inhalation exposure risks that can be attributed to the subsurface vapor intrusion pathway. Where air concentrations in upper level living spaces are greater than basement levels, intrusion is not likely to have occurred. Indoor air quality data also are subject to homeostatic fluctuations and temporal trends. Thus, to properly evaluate the indoor air data, we recommend that sufficient information be obtained to identify seasonal and spatial variations in indoor air concentrations. Additionally, we recommend careful consideration of subsurface data from the site in order to determine whether the most likely to be impacted structures were sampled.

Sampling of foundation air (e.g., subslab and/or crawlspace air) provides a direct measure of the potential for exposures from vapor intrusion. When collected in conjunction with indoor air sampling, foundation samples can be used to identify the exposures that originate from vapor intrusion and distinguish those due to background sources. Subslab vapor is defined as the soil gas in contact with the building envelope immediately beneath or within the sub-floor construction materials. Subslab samples are recommended to be, but do not need to be, collected via holes through the flooring as close to the center of the floor space as possible. Soil gas sampling using angled or horizontal borings from outside under the foundation also may be effective. Appendix E provides more detailed recommendations on subslab and soil gas sampling methodologies. The recommended attenuation factor for sub-slab soil gas samples in this step is 0.1 (see Appendix F). The recommended attenuation factor to apply for crawl-space air samples is 1.0 (i.e., the same as target indoor air concentrations).

6. Why should you consider using site-specific modeling at this time?

Site-specific modeling is intended to complement the evaluation of samples collected from a subset of the potentially impacted buildings. We recommend that only models appropriate for the site setting be used and that the direct evidence from the sampled buildings be used to verify the accuracy of the model's site-specific predictive capability. Where predictions and direct evidence from the indoor air sampling are consistent, the model can be used to direct the selection of buildings to be sampled. Considering the complex influence of soil type, depth to groundwater, and building characteristics on vapor attenuation factors, the model may help to determine which combination of factors leads to the greatest impact. Additionally, the model may be used to justify the decreased need for more direct evidence from the remaining contaminated area. We recommend that site-specific modeling be performed with inputs derived from direct measurements at the site. This may necessitate the collection of more detailed information regarding subsurface properties, nature and extent of contamination, and building construction characteristics.

EPA has developed a spreadsheet version of the Johnson and Ettinger (JE) Model (1991), which is one of the available screening level models for evaluating the vapor intrusion pathway. As described in Question 5, the JE Model was used to develop conservative attenuation factors linked to soil type and depth to source at a site. This model and documentation for the model are available at the following web site:

URL = http://www.epa.gov/superfund/programs/risk/airmodel/johnson_ettinger.htm

If the JE model is used in a site-specific assessment of the vapor intrusion pathway, we recommend that model inputs and assumptions that are different from the generic assumptions used in Question 5 and described in Appendix G be supported with site-specific information. If a model other than the JE Model is used, EPA recommends model inputs and outputs be identified and appropriately justified.

7. How do you appropriately involve the community when evaluating the vapor intrusion pathway?

Prior to conducting any direct sampling efforts, we recommend appropriately involving the community. It has been our experience that proper community involvement efforts are critical to the effective implementation of this level of screening. We recommend that users refer to the Community Involvement Guidance in Appendix H. Under the approach recommended in this guidance, we recommend the user consider the following: 1) getting to know the neighborhood, key stakeholders and the concerns of the community; 2) informing stakeholders of the situation; 3) developing a community involvement plan that highlights key community concerns; 4) obtaining written permission, and involving the property owner in identifying or removing potential indoor air sources, including inspection of residence and completing an occupant survey: 5) fully communicating sampling results (with visuals, maps etc.); and 6) a commitment to ongoing communications activities throughout site cleanup efforts. Appendix H contains and cites examples of guidance that could be considered for site-specific adaptation for interaction/involvement with building/dwelling occupants prior to indoor air sampling.

8. What do you do if the pathway is found to be complete?

If the pathway is judged to be complete during the Site-Specific Screening, the next recommended step is to identify the impacted buildings or areas of concern. This may result in some buildings or areas being included and some being excluded from the areas of concern. For these areas, we recommend that the pathway be considered to remain complete unless some action is taken to reduce occupants' exposure to the site contamination. Possible actions include:

- engineered containment systems (subslab de-pressurization, soil vacuum extraction, vapor barriers),
- ventilation systems (building pressurization, indoor air purifiers),
- avoidance (temporary or permanent resident relocation), or
- removal actions to reduce the mass and concentrations of subsurface chemicals to acceptable levels (i.e., remediation efforts).

This draft guidance is not intended to provide direction on how to fully delineate the extent of impacted buildings or what action should be taken after the pathway is confirmed. It is intended to be a quick screening process to help guide the user in determining if vapor intrusion is or is not a problem on the site.

9. Rationale and Reference(s):

Document Risk Level Used (Circle One): 10^{-4}, (b) 10^{-5}, or (c) 10^{-6}

VII. VAPOR INTRUSION PATHWAY SUMMARY PAGE

Facility Name: ____

Facility Address: ____

Primary Screening Summary

☐ *Q1: Constituents of concern Identified?*

________ *Yes*

________ *No* (If NO, skip to the conclusion section below and check NO to indicate the pathway is *incomplete.)*

☐ *Q2: Currently inhabited buildings near subsurface contamination?*

________ *Yes*

________ *No*

Areas of future concern near subsurface contamination?

________ *Yes*

________ *No* (If NO, skip to the conclusion section below and check NO to indicate the pathway is *incomplete.)*

☐ *Q3: Immediate Actions Warranted?*

________ *Yes*

________ *No*

Secondary Screening Summary

☐ *Vapor source identified:*

______ *Groundwater*

______ *Soil*

______*Insufficient data*

☐ *Indoor air data available?*

______ *Yes*

______ *No*

☐ *Indoor air concentrations exceed target levels?*

______ *Yes*

______ *No*

☐ *Subsurface data evaluation: (Circle appropriate answers below)*

Medium	**Q4 Levels Exceeded?**	**Q5 Levels Exceeded?**	**Data Indicates Pathway is Complete?**
Groundwater	YES / NO / NA / INS	YES / NO / NA / INS	YES / NO / INS
Soil Gas	YES / NO / NA / INS	YES / NO / NA / INS	YES / NO / INS

NA = not applicable
INS = insufficient data available to make a determination

Site-Specific Summary

☐ *Have the nature and extent of subsurface contamination, potential preferential pathways and overlying building characteristics been adequately characterized to identify the most-likely-to-be-impacted buildings?*

_____ *Yes*

_____ *No*

_____ *N/A*

EPA recommends that if a model was used, it be an appropriate and applicable model that represents the conceptual site model. If other means were used, document how you determined the potentially most impacted areas to sample. EPA recommends that predictive modeling can be used to support Current Human Exposures Under Control EI determinations without confirmatory sampling to support this determination. Current Human Exposures Under Control EI determinations are intended to reflect a reasonable conclusion by EPA or the State that current human exposures are under control with regard to the vapor intrusion pathway and current land use conditions. Therefore, if conducting evaluation for an EI determination, document that the **Pathway is Incomplete** and/or does not pose an unacceptable risk to human health for EI determinations.

☐ *Are you making an EI determination based on modeling and does the model prediction indicate that determination is expected to be adequately protective to support Current Human Exposures Under Control EI determinations?*

_____ *Yes*

_____ *No*

_____ *N/A*

☐ *Do subslab vapor concentrations exceed target levels?*

_____ *Yes*

_____ *No*

_____ *N/A*

☐ *Do indoor air concentrations exceed target levels?*

_____ *Yes*

_____ *No*

Conclusion

Is there a Complete Pathway for subsurface vapor intrusion to indoor air?

Below, check the appropriate conclusion for the Subsurface Vapor to Indoor Air Pathway evaluation and attach supporting documentation as well as a map of the facility.

_____ NO - the "Subsurface Vapor Intrusion to Indoor Air Pathway" has been verified to be incomplete for the ______________________________________ facility, EPA ID #____________, located at _____________________. This determination is based on a review of site information, as suggested in this guidance, check as appropriate:

- _____ for current and reasonably expected conditions, or
- _____ based on performance monitoring evaluations for engineered exposure controls. This determination may be re-evaluated, where appropriate, when the Agency/State becomes aware of any significant changes at the facility.

_____ YES –The "Subsurface Vapor to Indoor Air Pathway" is Complete. Engineered controls, avoidance actions, or removal actions taken include: _____________
____
____

_____ UNKNOWN - More information is needed to make a determination.

Locations where References may be found:

____
____
____
____
____

Contact telephone and e-mail numbers:

(name) __________________________________

(phone #) ________________________________

(e-mail) __________________________________

Reminder: As discussed above, this is a guidance document, not a regulation. Therefore, conclusions reached based on the approaches suggested in this guidance are not binding on EPA or the regulated community. If information suggests that the conclusions reached using the approaches recommend are inappropriate, EPA may (on it's own initiative or at the suggestion of interested parties) choose to act at variance with these conclusions.

References

Burning of Hazardous Waste in Boilers and Industrial Furnaces; Final Rule (58 FR 7135, February 21, 1991)

Draft Exposure Assessment Guidance for RCRA Hazardous Waste Combustions Facilities (April/May 1994)

Guidance for the Data Quality Objectives (DQO) Process, EPA QA/G_4. (EPA/600/R-96/055; August 2000);(URL = http://www.epa.gov/quality/qs_docs/g4_final.pdf)

Johnson and Ettinger (JE) Model (1991)
(URL = http://www.epa.gov/superfund/programs/risk/airmodel/johnson_ettinger.htm)

Massachusetts Department of Environmental Protection (MA DEP) Indoor Air Sampling and Evaluation Guide - WSC Policy#02-430 (April 2002) (URL = http://www.state.ma.us/dep/bwsc/finalpol.htm)

EPA Strategic Plan - Goal 5: Better Waste Management, Restoration of Contaminated Waste Sites, and Emergency Response (p.40-41) (EPA 190-R-00-002); (URL = http://www.epa.gov/ocfo/plan/2000strategicplan.pdf)

RCRA Corrective Action Environmental Indicator (EI) Guidance (Feb 5, 1999)
(URL = http://www.epa.gov/epaoswer/hazwaste/ca/eis/ei_guida.pdf)

RCRA draft Supplemental Guidance for Evaluating the Vapor Intrusion to Indoor Air Pathway (EPA/600/SR-93/140 - Dec 2001)
(URL= http://www.epa.gov/epaoswer/hazwaste/ca/eis/vapor.htm)

Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites
(Peer Review Draft: March 2001) Office of Emergency and Remedial Response/EPA
(URL = http://www.epa.gov/superfund/resources/soil/ssgmarch01.pdf)
[final version will issue concurrently with the *Subsurface Vapor Intrusion Guidance*.]

Use of Risk-Based Decision Making in UST Corrective Action Programs. OSWER **Directive 9610.17 (EPA; Mar 1, 1995);(URL= http://www.epa.gov/swerust1/directiv/od961017.htm)**

Table 1

Table 2

Table 3

Appendix A. Data Quality Assurance Considerations

Appendix B. Development Of Conceptual Site Model (CMS) For Assessment Of The Vapor Intrusion Pathway

Appendix C. Detailed Flow Diagrams Of The Evaluation Approach Used In This Guidance

Appendix D. Development Of Tables 1, 2, And 3

Appendix E. Relevant Methods and Techniques

Appendix F. Empirical Attenuation Factors And Reliability Assessment

Appendix G. Considerations For The Use Of Johnson and Ettinger Vapor Intrusion Model

Appendix H. Community Involvement Guidance

Appendix I. Consideration of Background Indoor Air VOC Levels In Evaluating The Subsurface Vapor Intrusion Pathway

Table 1: Question 1 Summary Sheet.

CAS No.	Chemical	Is Chemical Sufficiently Toxic? [1]	Is Chemical Sufficiently Volatile? [2]	Check Here if Known or Reasonably Suspected To Be Present [3]
83329	Acenaphthene	YES	YES	
75070	Acetaldehyde	YES	YES	
67641	Acetone	YES	YES	
75058	Acetonitrile	YES	YES	
98862	Acetophenone	YES	YES	
107028	Acrolein	YES	YES	
107131	Acrylonitrile	YES	YES	
309002	Aldrin	YES	YES	
319846	alpha-HCH (alpha-BHC)	YES	YES	
62533	Aniline	YES	NO	NA
120127	Anthracene	NO	YES	NA
56553	Benz(a)anthracene	YES	NO	NA
100527	Benzaldehyde	YES	YES	
71432	Benzene	YES	YES	
50328	Benzo(a)pyrene	YES	NO	NA
205992	Benzo(b)fluoranthene	YES	YES	
207089	Benzo(k)fluoranthene	NO	NO	NA
65850	Benzoic Acid	NO	NO	NA
100516	Benzyl alcohol	YES	NO	NA
100447	Benzylchloride	YES	YES	
91587	beta-Chloronaphthalene	YES	YES	
319857	beta-HCH (beta-BHC)	YES	NO	NA
92524	Biphenyl	YES	YES	
111444	Bis(2-chloroethyl)ether	YES	YES	
108601	Bis(2-chloroisopropyl)ether	YES	YES	
117817	Bis(2-ethylhexyl)phthalate	NO	NO	NA
542881	Bis(chloromethyl)ether	YES	YES	
75274	Bromodichloromethane	YES	YES	
75252	Bromoform	YES	YES	
106990	1,3-Butadiene	YES	YES	
71363	Butanol	YES	NO	NA
85687	Butyl benzyl phthalate	NO	NO	NA
86748	Carbazole	YES	NO	NA
75150	Carbon disulfide	YES	YES	
56235	Carbon tetrachloride	YES	YES	
57749	Chlordane	YES	YES	
126998	2-Chloro-1,3-butadiene (chloroprene)	YES	YES	
108907	Chlorobenzene	YES	YES	
109693	1-Chlorobutane	YES	YES	
124481	Chlorodibromomethane	YES	YES	
75456	Chlorodifluoromethane	YES	YES	
75003	Chloroethane (ethyl chloride)	YES	YES	
67663	Chloroform	YES	YES	
95578	2-Chlorophenol	YES	YES	
75296	2-Chloropropane	YES	YES	
218019	Chrysene	YES	YES	
156592	cis-1,2-Dichloroethylene	YES	YES	
123739	Crotonaldehyde (2-butenal)	YES	YES	
98828	Cumene	YES	YES	
72548	DDD	YES	NO	NA
72559	DDE	YES	YES	
50293	DDT	YES	NO	NA
53703	Dibenz(a,h)anthracene	YES	NO	NA
132649	Dibenzofuran	YES	YES	
96128	1,2-Dibromo-3-chloropropane	YES	YES	
106934	1,2-Dibromoethane (ethylene dibromide)	YES	YES	
541731	1,3-Dichlorobenzene	YES	YES	
95501	1,2-Dichlorobenzene	YES	YES	
106467	1,4-Dichlorobenzene	YES	YES	
91941	3,3-Dichlorobenzidine	YES	NO	NA
75718	Dichlorodifluoromethane	YES	YES	

Table 1: Question 1 Summary Sheet.

CAS No.	Chemical	Is Chemical Sufficiently Toxic? [1]	Is Chemical Sufficiently Volatile? [2]	Check Here if Known or Reasonably Suspected To Be Present [3]
75343	1,1-Dichloroethane	YES	YES	
107062	1,2-Dichloroethane	YES	YES	
75354	1,1-Dichloroethylene	YES	YES	
120832	2,4-Dichlorophenol	YES	NO	NA
78875	1,2-Dichloropropane	YES	YES	
542756	1,3-Dichloropropene	YES	YES	
60571	Dieldrin	YES	YES	
84662	Diethylphthalate	YES	NO	NA
105679	2,4-Dimethylphenol	YES	NO	NA
131113	Dimethylphthalate	NA	NO	NA
84742	Di-n-butyl phthalate	NO	NO	NA
534521	4,6-Dinitro-2-methylphenol (4,6-dinitro-o-cresol)	YES	NO	NA
51285	2,4-Dinitrophenol	YES	NO	NA
121142	2,4-Dinitrotoluene	YES	NO	NA
606202	2,6-Dinitrotoluene	YES	NO	NA
117840	Di-n-octyl phthalate	NO	YES	NA
115297	Endosulfan	YES	YES	
72208	Endrin	YES	NO	NA
106898	Epichlorohydrin	YES	YES	
60297	Ethyl ether	YES	YES	
141786	Ethylacetate	YES	YES	
100414	Ethylbenzene	YES	YES	
75218	Ethylene oxide	YES	YES	
97632	Ethylmethacrylate	YES	YES	
206440	Fluoranthene	NO	YES	NA
86737	Fluorene	YES	YES	
110009	Furan	YES	YES	
58899	gamma-HCH (Lindane)	YES	YES	
76448	Heptachlor	YES	YES	
1024573	Heptachlor epoxide	YES	NO	NA
87683	Hexachloro-1,3-butadiene	YES	YES	
118741	Hexachlorobenzene	YES	YES	
77474	Hexachlorocyclopentadiene	YES	YES	
67721	Hexachloroethane	YES	YES	
110543	Hexane	YES	YES	
74908	Hydrogen cyanide	YES	YES	
193395	Indeno(1,2,3-cd)pyrene	NO	NO	NA
78831	Isobutanol	YES	YES	
78591	Isophorone	YES	NO	NA
7439976	Mercury (elemental)	YES	YES	
126987	Methacrylonitrile	YES	YES	
72435	Methoxychlor	YES	YES	
79209	Methyl acetate	YES	YES	
96333	Methyl acrylate	YES	YES	
74839	Methyl bromide	YES	YES	
74873	Methyl chloride (chloromethane)	YES	YES	
108872	Methylcyclohexane	YES	YES	
74953	Methylene bromide	YES	YES	
75092	Methylene chloride	YES	YES	
78933	Methylethylketone (2-butanone)	YES	YES	
108101	Methylisobutylketone	YES	YES	
80626	Methylmethacrylate	YES	YES	
91576	2-Methylnaphthalene	YES	YES	
108394	3-Methylphenol (m-cresol)	YES	NO	NA
95487	2-Methylphenol (o-cresol)	YES	NO	NA
106455	4-Methylphenol (p-cresol)	YES	NO	NA
99081	m-Nitrotoluene	YES	NO	NA
1634044	MTBE	YES	YES	
108383	m-Xylene	YES	YES	
91203	Naphthalene	YES	YES	
104518	n-Butylbenzene	YES	YES	

Table 1: Question 1 Summary Sheet.

CAS No.	Chemical	Is Chemical Sufficiently Toxic? [1]	Is Chemical Sufficiently Volatile? [2]	Check Here if Known or Reasonably Suspected To Be Present [3]
98953	Nitrobenzene	YES	YES	
100027	4-Nitrophenol	YES	NO	NA
79469	2-Nitropropane	YES	YES	
924163	N-Nitroso-di-n-butylamine	YES	YES	
621647	N-Nitrosodi-n-propylamine	YES	NO	NA
86306	N-Nitrosodiphenylamine	YES	NO	NA
103651	n-Propylbenzene	YES	YES	
88722	o-Nitrotoluene	YES	YES	
95476	o-Xylene	YES	YES	
106478	p-Chloroaniline	YES	NO	NA
87865	Pentachlorophenol	YES	NO	NA
108952	Phenol	YES	NO	NA
99990	p-Nitrotoluene	YES	NO	NA
106423	p-Xylene	YES	YES	
129000	Pyrene	YES	YES	
110861	Pyridine	YES	NO	NA
135988	sec-Butylbenzene	YES	YES	
100425	Styrene	YES	YES	
98066	tert-Butylbenzene	YES	YES	
630206	1,1,1,2-Tetrachloroethane	YES	YES	
79345	1,1,2,2-Tetrachloroethane	YES	YES	
127184	Tetrachloroethylene	YES	YES	
108883	Toluene	YES	YES	
8001352	Toxaphene	YES	NO	NA
156605	trans-1,2-Dichloroethylene	YES	YES	
76131	1,1,2-Trichloro-1,2,2-trifluoroethane	YES	YES	
120821	1,2,4-Trichlorobenzene	YES	YES	
79005	1,1,2-Trichloroethane	YES	YES	
71556	1,1,1-Trichloroethane	YES	YES	
79016	Trichloroethylene	YES	YES	
75694	Trichlorofluoromethane	YES	YES	
95954	2,4,5-Trichlorophenol	YES	NO	NA
88062	2,4,6-Trichlorophenol	YES	NO	NA
96184	1,2,3-Trichloropropane	YES	YES	
95636	1,2,4-Trimethylbenzene	YES	YES	
108678	1,3,5-Trimethylbenzene	YES	YES	
108054	Vinyl acetate	YES	YES	
75014	Vinyl chloride (chloroethene)	YES	YES	

[1] A chemical is considered sufficiently toxic if the vapor concentration of the pure component (see Appendix D) poses an incremental lifetime cancer risk greater than 10^{-6} or a non-cancer hazard index greater than 1.

[2] A chemical is considered sufficiently volatile if its Henry's Law Constant is 1×10^{-5} atm-m^3/mol or greater (US EPA, 1991).

[3] Users should check off compounds that meet the criteria for toxicity <u>and</u> volatility and are known or reasonably suspected to be present.

Table 2a: Question 4 Generic Screening Levels and Summary Sheet [1]

Risk = 1 x 10^{-4}

CAS No.	Chemical	Compounds with Provisional Toxicity Data Extrapolated From Oral Sources	Basis of Target Concentration C=cancer risk NC=noncancer risk	Target Indoor Air Concentration to Satisfy Both the Prescribed Risk Level and the Target Hazard Index [R=10^{-4}, HI=1] C_{target}		Measured or Reasonably Estimated Indoor Air Concentration [if available]	Target Shallow Soil Gas Concentration Corresponding to Target Indoor Air Concentration Where the Soil Gas to Indoor Air Attenuation Factor=0.1 $C_{soil-gas}$		Measured or Reasonably Estimated Shallow Soil Gas Concentration [if available]	Target Deep Soil Gas Concentration Corresponding to Target Indoor Air Concentration Where the Soil Gas to Indoor Air Attenuation Factor=0.01 $C_{soil-gas}$		Measured or Reasonably Estimated Deep Soil Gas Concentration [if available]	Target Groundwater Concentration Corresponding to Target Indoor Air Concentration Where the Soil Gas to Indoor Air Attenuation Factor = 0.001 and Partitioning Across the Water Table Obeys Henry's Law C_{gw}	Measured or Reasonably Estimated Groundwater Concentration [if available]
				(ug/m^3)	(ppbv)	(specify units)	(ug/m^3)	(ppbv)	(specify units)	(ug/m^3)	(ppbv)	(specify units)	(ug/L)	(specify units)
83329	Acenaphthene	X	NC	2.1E+02	3.3E+01		2.1E+03	3.3E+02		2.1E+04	3.3E+03		**	
75070	Acetaldehyde		NC	9.0E+00	5.0E+00		9.0E+01	5.0E+01		9.0E+02	5.0E+02		2.8E+03	
67641	Acetone	X	NC	3.5E+02	1.5E+02		3.5E+03	1.5E+03		3.5E+04	1.5E+04		2.2E+05	
75058	Acetonitrile		NC	6.0E+01	3.6E+01		6.0E+02	3.6E+02		6.0E+03	3.6E+03		4.2E+04	
98862	Acetophenone	X	NC	3.5E+02	7.1E+01		3.5E+03	7.1E+02		3.5E+04	7.1E+03		8.0E+05	
107028	Acrolein		NC	2.0E-02	8.7E-03		2.0E-01	8.7E-02		2.0E+00	8.7E-01		4.0E+00	
107131	Acrylonitrile		NC	2.0E+00	9.2E-01		2.0E+01	9.2E+00		2.0E+02	9.2E+01		4.7E+02	
309002	Aldrin		C	5.0E-02	3.3E-03		5.0E-01	3.3E-02		5.0E+00	3.3E-01		7.1E+00	
319846	alpha-HCH (alpha-BHC)		C	1.4E-01	1.1E-02		1.4E+00	1.1E-01		1.4E+01	1.1E+00		3.1E+02	
100527	Benzaldehyde	X	NC	3.5E+02	8.1E+01		3.5E+03	8.1E+02		3.5E+04	8.1E+03		3.6E+05	
71432	Benzene		C	3.1E+01	9.8E+00		3.1E+02	9.8E+01		3.1E+03	9.8E+02		1.4E+02	
205992	Benzo(b)fluoranthene	X	C	1.2E+00	1.1E-01		**	**		**	**		**	
100447	Benzylchloride	X	C	5.0E+00	9.7E-01		5.0E+01	9.7E+00		5.0E+02	9.7E+01		3.0E+02	
91587	beta-Chloronaphthalene	X	NC	2.8E+02	4.2E+01		2.8E+03	4.2E+02		2.8E+04	4.2E+03		**	
92524	Biphenyl	X	NC	1.8E+02	2.8E+01		1.8E+03	2.8E+02		1.8E+04	2.8E+03		**	
111444	Bis(2-chloroethyl)ether		C	7.4E-01	1.3E-01		7.4E+00	1.3E+00		7.4E+01	1.3E+01		1.0E+03	
108601	Bis(2-chloroisopropyl)ether		C	2.4E+01	3.5E+00		2.4E+02	3.5E+01		2.4E+03	3.5E+02		5.1E+03	
542881	Bis(chloromethyl)ether		C	3.9E-03	8.4E-04		3.9E-02	8.4E-03		3.9E-01	8.4E-02		4.5E-01	
75274	Bromodichloromethane	X	C	1.4E+01	2.1E+00		1.4E+02	2.1E+01		1.4E+03	2.1E+02		2.1E+02	
75252	Bromoform		C	2.2E+02	2.1E+01		2.2E+03	2.1E+02		2.2E+04	2.1E+03		8.3E-01	
106990	1,3-Butadiene		C	8.7E-01	3.9E-01		8.7E+00	3.9E+00		8.7E+01	3.9E+01		2.9E-01	
75150	Carbon disulfide		NC	7.0E+02	2.2E+02		7.0E+03	2.2E+03		7.0E+04	2.2E+04		5.6E+02	
56235	Carbon tetrachloride		C	1.6E+01	2.6E+00		1.6E+02	2.6E+01		1.6E+03	2.6E+02		1.3E+01	
57749	Chlordane		NC	7.0E-01	4.2E-02		7.0E+00	4.2E-01		7.0E+01	4.2E+00		**	
126998	2-Chloro-1,3-butadiene (chloroprene)		NC	7.0E+00	1.9E+00		7.0E+01	1.9E+01		7.0E+02	1.9E+02		1.4E+01	
108907	Chlorobenzene		NC	6.0E+01	1.3E+01		6.0E+02	1.3E+02		6.0E+03	1.3E+03		3.9E+02	
109693	1-Chlorobutane	X	NC	1.4E+03	3.7E+02		1.4E+04	3.7E+03		1.4E+05	3.7E+04		2.0E+03	
124481	Chlorodibromomethane	X	C	1.0E+01	1.2E+00		1.0E+02	1.2E+01		1.0E+03	1.2E+02		3.2E+02	
75456	Chlorodifluoromethane		NC	5.0E+04	1.4E+04		5.0E+05	1.4E+05		**	**		**	
75003	Chloroethane (ethyl chloride)		NC	1.0E+04	3.8E+03		1.0E+05	3.8E+04		1.0E+06	3.8E+05		2.8E+04	
67663	Chloroform		C	1.1E+01	2.2E+00		1.1E+02	2.2E+01		1.1E+03	2.2E+02		8.0E+01 †	
95578	2-Chlorophenol	X	NC	1.8E+01	3.3E+00		1.8E+02	3.3E+01		1.8E+03	3.3E+02		1.1E+03	
75296	2-Chloropropane		NC	1.0E+02	3.2E+01		1.0E+03	3.2E+02		1.0E+04	3.2E+03		1.7E+02	
218019	Chrysene	X	*	*	*		*	*		*	*		*	
156592	cis-1,2-Dichloroethylene	X	NC	3.5E+01	8.8E+00		3.5E+02	8.8E+01		3.5E+03	8.8E+02		2.1E+02	
123739	Crotonaldehyde (2-butenal)	X	C	4.5E-01	1.6E-01		4.5E+00	1.6E+00		4.5E+01	1.6E+01		5.6E+02	
98828	Cumene		NC	4.0E+02	8.1E+01		4.0E+03	8.1E+02		4.0E+04	8.1E+03		8.4E+00	

Table 2a: Question 4 Generic Screening Levels and Summary Sheet [1]

Risk = 1 x 10^{-4}

CAS No.	Chemical	Compounds with Provisional Toxicity Data Extrapolated From Oral Sources	Basis of Target Concentration C=cancer risk NC=noncancer risk	Target Indoor Air Concentration to Satisfy Both the Prescribed Risk Level and the Target Hazard Index [R=10^{-4}, HI=1] C_{target}		Measured or Reasonably Estimated Indoor Air Concentration [if available]	Target Shallow Soil Gas Concentration Corresponding to Target Indoor Air Concentration Where the Soil Gas to Indoor Air Attenuation Factor=0.1 $C_{soil-gas}$		Measured or Reasonably Estimated Shallow Soil Gas Concentration [if available]	Target Deep Soil Gas Concentration Corresponding to Target Indoor Air Concentration Where the Soil Gas to Indoor Air Attenuation Factor=0.01 $C_{soil-gas}$		Measured or Reasonably Estimated Deep Soil Gas Concentration [if available]	Target Groundwater Concentration Corresponding to Target Indoor Air Concentration Where the Soil Gas to Indoor Air Attenuation Factor = 0.001 and Partitioning Across the Water Table Obeys Henry's Law C_{gw}	Measured or Reasonably Estimated Groundwater Concentration [if available]
				(ug/m^3)	(ppbv)	(specify units)	(ug/m^3)	(ppbv)	(specify units)	(ug/m^3)	(ppbv)	(specify units)	(ug/L)	(specify units)
72559	DDE	X	C	2.5E+00	1.9E-01		2.5E+01	1.9E+00		**	**		**	
132649	Dibenzofuran	X	NC	1.4E+01	2.0E+00		1.4E+02	2.0E+01		1.4E+03	2.0E+02		**	
96128	1,2-Dibromo-3-chloropropane		NC	2.0E-01	2.1E-02		2.0E+00	2.1E-01		2.0E+01	2.1E+00		3.3E+01	
106934	1,2-Dibromoethane (ethylene dibromide)		NC	2.0E-01	2.6E-02		2.0E+00	2.6E-01		2.0E+01	2.6E+00		6.6E+00	
541731	1,3-Dichlorobenzene	X	NC	1.1E+02	1.7E+01		1.1E+03	1.7E+02		1.1E+04	1.7E+03		8.3E+02	
95501	1,2-Dichlorobenzene		NC	2.0E+02	3.3E+01		2.0E+03	3.3E+02		2.0E+04	3.3E+03		2.6E+03	
106467	1,4-Dichlorobenzene		NC	8.0E+02	1.3E+02		8.0E+03	1.3E+03		8.0E+04	1.3E+04		8.2E+03	
75718	Dichlorodifluoromethane		NC	2.0E+02	4.0E+01		2.0E+03	4.0E+02		2.0E+04	4.0E+03		1.4E+01	
75343	1,1-Dichloroethane		NC	5.0E+02	1.2E+02		5.0E+03	1.2E+03		5.0E+04	1.2E+04		2.2E+03	
107062	1,2-Dichloroethane		C	9.4E+00	2.3E+00		9.4E+01	2.3E+01		9.4E+02	2.3E+02		2.3E+02	
75354	1,1-Dichloroethylene		NC	2.0E+02	5.0E+01		2.0E+03	5.0E+02		2.0E+04	5.0E+03		1.9E+02	
78875	1,2-Dichloropropane		NC	4.0E+00	8.7E-01		4.0E+01	8.7E+00		4.0E+02	8.7E+01		3.5E+01	
542756	1,3-Dichloropropene		NC	2.0E+01	4.4E+00		2.0E+02	4.4E+01		2.0E+03	4.4E+02		2.8E+01	
60571	Dieldrin		C	5.3E-02	3.4E-03		5.3E-01	3.4E-02		5.3E+00	3.4E-01		8.6E+01	
115297	Endosulfan	X	NC	2.1E+01	1.3E+00		2.1E+02	1.3E+01		**	**		**	
106898	Epichlorohydrin		NC	1.0E+00	2.6E-01		1.0E+01	2.6E+00		1.0E+02	2.6E+01		8.0E+02	
60297	Ethyl ether	X	NC	7.0E+02	2.3E+02		7.0E+03	2.3E+03		7.0E+04	2.3E+04		5.2E+02	
141786	Ethylacetate	X	NC	3.2E+03	8.7E+02		3.2E+04	8.7E+03		3.2E+05	8.7E+04		5.6E+05	
100414	Ethylbenzene		C	2.2E+02	5.1E+01		2.2E+03	5.1E+02		2.2E+04	5.1E+03		7.0E+02 †	
75218	Ethylene oxide		C	2.4E+00	1.4E+00		2.4E+01	1.4E+01		2.4E+02	1.4E+02		1.1E+02	
97632	Ethylmethacrylate	X	NC	3.2E+02	6.8E+01		3.2E+03	6.8E+02		3.2E+04	6.8E+03		9.1E+03	
86737	Fluorene	X	NC	1.4E+02	2.1E+01		1.4E+03	2.1E+02		**	**		**	
110009	Furan	X	NC	3.5E+00	1.3E+00		3.5E+01	1.3E+01		3.5E+02	1.3E+02		1.6E+01	
58899	gamma-HCH (Lindane)	X	C	6.6E-01	5.5E-02		6.6E+00	5.5E-01		6.6E+01	5.5E+00		1.1E+03	
76448	Heptachlor		C	1.9E-01	1.2E-02		1.9E+00	1.2E-01		1.9E+01	1.2E+00		4.0E-01 †	
87683	Hexachloro-1,3-butadiene		C	1.1E+01	1.0E+00		1.1E+02	1.0E+01		1.1E+03	1.0E+02		3.3E+01	
118741	Hexachlorobenzene		C	5.3E-01	4.5E-02		5.3E+00	4.5E-01		5.3E+01	4.5E+00		**	
77474	Hexachlorocyclopentadiene		NC	2.0E-01	1.8E-02		2.0E+00	1.8E-01		2.0E+01	1.8E+00		5.0E+01 †	
67721	Hexachloroethane		C	6.1E+01	6.3E+00		6.1E+02	6.3E+01		6.1E+03	6.3E+02		3.8E+02	
110543	Hexane		NC	2.0E+02	5.7E+01		2.0E+03	5.7E+02		2.0E+04	5.7E+03		2.9E+00	
74908	Hydrogen cyanide		NC	3.0E+00	2.7E+00		3.0E+01	2.7E+01		3.0E+02	2.7E+02		5.5E+02	
78831	Isobutanol	X	NC	1.1E+03	3.5E+02		1.1E+04	3.5E+03		1.1E+05	3.5E+04		2.2E+06	
7439976	Mercury (elemental)		NC	3.0E-01	3.7E-02		3.0E+00	3.7E-01		3.0E+01	3.7E+00		6.8E-01	
126987	Methacrylonitrile		NC	7.0E-01	2.6E-01		7.0E+00	2.6E+00		7.0E+01	2.6E+01		6.9E+01	
72435	Methoxychlor	X	NC	1.8E+01	1.2E+00		**	**		**	**		**	
79209	Methyl acetate	X	NC	3.5E+03	1.2E+03		3.5E+04	1.2E+04		3.5E+05	1.2E+05		7.2E+05	
96333	Methyl acrylate	X	NC	1.1E+02	3.0E+01		1.1E+03	3.0E+02		1.1E+04	3.0E+03		1.4E+04	

Table 2a: Question 4 Generic Screening Levels and Summary Sheet [1]

Risk = 1 x 10^{-4}

CAS No.	Chemical	Compounds with Provisional Toxicity Data Extrapolated From Oral Sources	Basis of Target Concentration C=cancer risk NC=noncancer risk	Target Indoor Air Concentration to Satisfy Both the Prescribed Risk Level and the Target Hazard Index [R=10^{-4}, HI=1] C_{target}		Measured or Reasonably Estimated Indoor Air Concentration [if available]	Target Shallow Soil Gas Concentration Corresponding to Target Indoor Air Concentration Where the Soil Gas to Indoor Air Attenuation Factor=0.1 $C_{soil-gas}$		Measured or Reasonably Estimated Shallow Soil Gas Concentration [if available]	Target Deep Soil Gas Concentration Corresponding to Target Indoor Air Concentration Where the Soil Gas to Indoor Air Attenuation Factor=0.01 $C_{soil-gas}$		Measured or Reasonably Estimated Deep Soil Gas Concentration [if available]	Target Groundwater Concentration Corresponding to Target Indoor Air Concentration Where the Soil Gas to Indoor Air Attenuation Factor = 0.001 and Partitioning Across the Water Table Obeys Henry's Law C_{gw}	Measured or Reasonably Estimated Groundwater Concentration [if available]
				(ug/m^3)	(ppbv)	(specify units)	(ug/m^3)	(ppbv)	(specify units)	(ug/m^3)	(ppbv)	(specify units)	(ug/L)	(specify units)
74839	Methyl bromide		NC	5.0E+00	1.3E+00		5.0E+01	1.3E+01		5.0E+02	1.3E+02		2.0E+01	
74873	Methyl chloride (chloromethane)		NC	9.0E+01	4.4E+01		9.0E+02	4.4E+02		9.0E+03	4.4E+03		2.5E+02	
108872	Methylcyclohexane		NC	3.0E+03	7.5E+02		3.0E+04	7.5E+03		3.0E+05	7.5E+04		7.1E+02	
74953	Methylene bromide	X	NC	3.5E+01	4.9E+00		3.5E+02	4.9E+01		3.5E+03	4.9E+02		9.9E+02	
75092	Methylene chloride		C	5.2E+02	1.5E+02		5.2E+03	1.5E+03		5.2E+04	1.5E+04		5.8E+03	
78933	Methylethylketone (2-butanone)		NC	1.0E+03	3.4E+02		1.0E+04	3.4E+03		1.0E+05	3.4E+04		4.4E+05	
108101	Methylisobutylketone		NC	8.0E+01	2.0E+01		8.0E+02	2.0E+02		8.0E+03	2.0E+03		1.4E+04	
80626	Methylmethacrylate		NC	7.0E+02	1.7E+02		7.0E+03	1.7E+03		7.0E+04	1.7E+04		5.1E+04	
91576	2-Methylnaphthalene	X	NC	7.0E+01	1.2E+01		7.0E+02	1.2E+02		7.0E+03	1.2E+03		3.3E+03	
1634044	MTBE		NC	3.0E+03	8.3E+02		3.0E+04	8.3E+03		3.0E+05	8.3E+04		1.2E+05	
108383	m-Xylene	X	NC	7.0E+03	1.6E+03		7.0E+04	1.6E+04		7.0E+05	1.6E+05		2.3E+04	
91203	Naphthalene		NC	3.0E+00	5.7E-01		3.0E+01	5.7E+00		3.0E+02	5.7E+01		1.5E+02	
104518	n-Butylbenzene	X	NC	1.4E+02	2.6E+01		1.4E+03	2.6E+02		1.4E+04	2.6E+03		2.6E+02	
98953	Nitrobenzene		NC	2.0E+00	4.0E-01		2.0E+01	4.0E+00		2.0E+02	4.0E+01		2.0E+03	
79469	2-Nitropropane		C	9.0E-02	2.5E-02		9.0E-01	2.5E-01		9.0E+00	2.5E+00		1.8E+01	
924163	N-Nitroso-di-n-butylamine		C	1.5E-01	2.4E-02		1.5E+00	2.4E-01		1.5E+01	2.4E+00		1.2E+01	
103651	n-Propylbenzene	X	NC	1.4E+02	2.8E+01		1.4E+03	2.8E+02		1.4E+04	2.8E+03		3.2E+02	
88722	o-Nitrotoluene	X	NC	3.5E+01	6.2E+00		3.5E+02	6.2E+01		3.5E+03	6.2E+02		6.8E+04	
95476	o-Xylene	X	NC	7.0E+03	1.6E+03		7.0E+04	1.6E+04		7.0E+05	1.6E+05		3.3E+04	
106423	p-Xylene	X	NC	7.0E+03	1.6E+03		7.0E+04	1.6E+04		7.0E+05	1.6E+05		2.2E+04	
129000	Pyrene	X	NC	1.1E+02	1.3E+01		**	**		**	**		**	
135988	sec-Butylbenzene	X	NC	1.4E+02	2.6E+01		1.4E+03	2.6E+02		1.4E+04	2.6E+03		2.5E+02	
100425	Styrene		NC	1.0E+03	2.3E+02		1.0E+04	2.3E+03		1.0E+05	2.3E+04		8.9E+03	
98066	tert-Butylbenzene	X	NC	1.4E+02	2.6E+01		1.4E+03	2.6E+02		1.4E+04	2.6E+03		2.9E+02	
630206	1,1,1,2-Tetrachloroethane		C	3.3E+01	4.8E+00		3.3E+02	4.8E+01		3.3E+03	4.8E+02		3.3E+02	
79345	1,1,2,2-Tetrachloroethane		C	4.2E+00	6.1E-01		4.2E+01	6.1E+00		4.2E+02	6.1E+01		3.0E+02	
127184	Tetrachloroethylene		C	8.1E+01	1.2E+01		8.1E+02	1.2E+02		8.1E+03	1.2E+03		1.1E+02	
108883	Toluene		NC	4.0E+02	1.1E+02		4.0E+03	1.1E+03		4.0E+04	1.1E+04		1.5E+03	
156605	trans-1,2-Dichloroethylene	X	NC	7.0E+01	1.8E+01		7.0E+02	1.8E+02		7.0E+03	1.8E+03		1.8E+02	
76131	1,1,2-Trichloro-1,2,2-trifluoroethane		NC	3.0E+04	3.9E+03		3.0E+05	3.9E+04		3.0E+06	3.9E+05		1.5E+03	
120821	1,2,4-Trichlorobenzene		NC	2.0E+02	2.7E+01		2.0E+03	2.7E+02		2.0E+04	2.7E+03		3.4E+03	
79005	1,1,2-Trichloroethane		C	1.5E+01	2.8E+00		1.5E+02	2.8E+01		1.5E+03	2.8E+02		4.1E+02	
71556	1,1,1-Trichloroethane		NC	2.2E+03	4.0E+02		2.2E+04	4.0E+03		2.2E+05	4.0E+04		3.1E+03	
79016	Trichloroethylene ††	X	C	2.2E+00	4.1E-01		2.2E+01	4.1E+00		2.2E+02	4.1E+01		5.3E+00	
75694	Trichlorofluoromethane		NC	7.0E+02	1.2E+02		7.0E+03	1.2E+03		7.0E+04	1.2E+04		1.8E+02	
96184	1,2,3-Trichloropropane		NC	4.9E+00	8.1E-01		4.9E+01	8.1E+00		4.9E+02	8.1E+01		2.9E+02	
95636	1,2,4-Trimethylbenzene		NC	6.0E+00	1.2E+00		6.0E+01	1.2E+01		6.0E+02	1.2E+02		2.4E+01	

Table 2a: Question 4 Generic Screening Levels and Summary Sheet [1]

Risk = 1 x 10^{-4}

CAS No.	Chemical	Compounds with Provisional Toxicity Data Extrapolated From Oral Sources	Basis of Target Concentration C=cancer risk NC=noncancer risk	Target Indoor Air Concentration to Satisfy Both the Prescribed Risk Level and the Target Hazard Index [R=10^{-4}, HI=1] C_{target}		Measured or Reasonably Estimated Indoor Air Concentration [if available]	Target Shallow Soil Gas Concentration Corresponding to Target Indoor Air Concentration Where the Soil Gas to Indoor Air Attenuation Factor=0.1 $C_{soil-gas}$		Measured or Reasonably Estimated Shallow Soil Gas Concentration [if available]	Target Deep Soil Gas Concentration Corresponding to Target Indoor Air Concentration Where the Soil Gas to Indoor Air Attenuation Factor=0.01 $C_{soil-gas}$		Measured or Reasonably Estimated Deep Soil Gas Concentration [if available]	Target Groundwater Concentration Corresponding to Target Indoor Air Concentration Where the Soil Gas to Indoor Air Attenuation Factor = 0.001 and Partitioning Across the Water Table Obeys Henry's Law C_{gw}	Measured or Reasonably Estimated Groundwater Concentration [if available]
				(ug/m^3)	(ppbv)	(specify units)	(ug/m^3)	(ppbv)	(specify units)	(ug/m^3)	(ppbv)	(specify units)	(ug/L)	(specify units)
108678	1,3,5-Trimethylbenzene		NC	6.0E+00	1.2E+00		6.0E+01	1.2E+01		6.0E+02	1.2E+02		2.5E+01	
108054	Vinyl acetate		NC	2.0E+02	5.7E+01		2.0E+03	5.7E+02		2.0E+04	5.7E+03		9.6E+03	
75014	Vinyl chloride (chloroethene)		C	2.8E+01	1.1E+01		2.8E+02	1.1E+02		2.8E+03	1.1E+03		2.5E+01	

[1] AF = 0.1 for Shallow Soil Gas Target Concentration
AF = 0.01 for Deep Soil Gas Target Concentration
AF = 0.001 for Groundwater Target Concentration

* Health-based target breathing concentration exceeds maximum possible chemical vapor concentration (pathway incomplete)

** Target soil gas concentration exceeds maximum possible vapor concentration (pathway incomplete)

† The target groundwater concentration is the MCL. (The MCL for chloroform is the MCL for total Trihalomethanes. The MCL listed for m-Xylene, o-Xylene, and p-Xylene is the MCL for total Xylenes.)

†† The target concentration for trichloroethylene is based on the upper bound cancer slope factor identified in EPA's draft risk assessment for trichloroethylene (US EPA, 2001). The slope factor is based on state-of-the-art methodology, however the TCE assessment is still undergoing review. As a result, the slope factor and the target concentration values for TCE may be revised further. (See Appendix D.)

Table 2b: Question 4 Generic Screening Levels and Summary Sheet [1]

Risk = 1 x 10^{-5}

CAS No.	Chemical	Compounds with Provisional Toxicity Data Extrapolated From Oral Sources	Basis of Target Concentration C=cancer risk NC=noncancer risk	Target Indoor Air Concentration to Satisfy Both the Prescribed Risk Level and the Target Hazard Index [R=10^{-5}, HI=1] C_{target}		Measured or Reasonably Estimated Indoor Air Concentration [if available]	Target Shallow Soil Gas Concentration Corresponding to Target Indoor Air Concentration Where the Soil Gas to Indoor Air Attenuation Factor=0.1 $C_{soil-gas}$		Measured or Reasonably Estimated Shallow Soil Gas Concentration [if available]	Target Deep Soil Gas Concentration Corresponding to Target Indoor Air Concentration Where the Soil Gas to Indoor Air Attenuation Factor=0.01 $C_{soil-gas}$		Measured or Reasonably Estimated Deep Soil Gas Concentration [if available]	Target Groundwater Concentration Corresponding to Target Indoor Air Concentration Where the Soil Gas to Indoor Air Attenuation Factor = 0.001 and Partitioning Across the Water Table Obeys Henry's Law C_{gw}	Measured or Reasonably Estimated Groundwater Concentration [if available]
				(ug/m3)	(ppbv)	(specify units)	(ug/m3)	(ppbv)	(specify units)	(ug/m3)	(ppbv)	(specify units)	(ug/L)	(specify units)
83329	Acenaphthene	X	NC	2.1E+02	3.3E+01		2.1E+03	3.3E+02		2.1E+04	3.3E+03		**	
75070	Acetaldehyde		NC	9.0E+00	5.0E+00		9.0E+01	5.0E+01		9.0E+02	5.0E+02		2.8E+03	
67641	Acetone	X	NC	3.5E+02	1.5E+02		3.5E+03	1.5E+03		3.5E+04	1.5E+04		2.2E+05	
75058	Acetonitrile		NC	6.0E+01	3.6E+01		6.0E+02	3.6E+02		6.0E+03	3.6E+03		4.2E+04	
98862	Acetophenone	X	NC	3.5E+02	7.1E+01		3.5E+03	7.1E+02		3.5E+04	7.1E+03		8.0E+05	
107028	Acrolein		NC	2.0E-02	8.7E-03		2.0E-01	8.7E-02		2.0E+00	8.7E-01		4.0E+00	
107131	Acrylonitrile		C	3.6E-01	1.7E-01		3.6E+00	1.7E+00		3.6E+01	1.7E+01		8.5E+01	
309002	Aldrin		C	5.0E-03	3.3E-04		5.0E-02	3.3E-03		5.0E-01	3.3E-02		7.1E-01	
319846	alpha-HCH (alpha-BHC)		C	1.4E-02	1.1E-03		1.4E-01	1.1E-02		1.4E+00	1.1E-01		3.1E+01	
100527	Benzaldehyde	X	NC	3.5E+02	8.1E+01		3.5E+03	8.1E+02		3.5E+04	8.1E+03		3.6E+05	
71432	Benzene		C	3.1E+00	9.8E-01		3.1E+01	9.8E+00		3.1E+02	9.8E+01		1.4E+01	
205992	Benzo(b)fluoranthene	X	C	1.2E-01	1.1E-02		1.2E+00	1.1E-01		**	**		**	
100447	Benzylchloride	X	C	5.0E-01	9.7E-02		5.0E+00	9.7E-01		5.0E+01	9.7E+00		3.0E+01	
91587	beta-Chloronaphthalene	X	NC	2.8E+02	4.2E+01		2.8E+03	4.2E+02		2.8E+04	4.2E+03		**	
92524	Biphenyl	X	NC	1.8E+02	2.8E+01		1.8E+03	2.8E+02		1.8E+04	2.8E+03		**	
111444	Bis(2-chloroethyl)ether		C	7.4E-02	1.3E-02		7.4E-01	1.3E-01		7.4E+00	1.3E+00		1.0E+02	
108601	Bis(2-chloroisopropyl)ether		C	2.4E+00	3.5E-01		2.4E+01	3.5E+00		2.4E+02	3.5E+01		5.1E+02	
542881	Bis(chloromethyl)ether		C	3.9E-04	8.4E-05		3.9E-03	8.4E-04		3.9E-02	8.4E-03		4.5E-02	
75274	Bromodichloromethane	X	C	1.4E+00	2.1E-01		1.4E+01	2.1E+00		1.4E+02	2.1E+01		2.1E+01	
75252	Bromoform		C	2.2E+01	2.1E+00		2.2E+02	2.1E+01		2.2E+03	2.1E+02		8.3E-02	
106990	1,3-Butadiene		C	8.7E-02	3.9E-02		8.7E-01	3.9E-01		8.7E+00	3.9E+00		2.9E-02	
75150	Carbon disulfide		NC	7.0E+02	2.2E+02		7.0E+03	2.2E+03		7.0E+04	2.2E+04		5.6E+02	
56235	Carbon tetrachloride		C	1.6E+00	2.6E-01		1.6E+01	2.6E+00		1.6E+02	2.6E+01		5.0E+00 †	
57749	Chlordane		C	2.4E-01	1.5E-02		2.4E+00	1.5E-01		2.4E+01	1.5E+00		**	
126998	2-Chloro-1,3-butadiene (chloroprene)		NC	7.0E+00	1.9E+00		7.0E+01	1.9E+01		7.0E+02	1.9E+02		1.4E+01	
108907	Chlorobenzene		NC	6.0E+01	1.3E+01		6.0E+02	1.3E+02		6.0E+03	1.3E+03		3.9E+02	
109693	1-Chlorobutane	X	NC	1.4E+03	3.7E+02		1.4E+04	3.7E+03		1.4E+05	3.7E+04		2.0E+03	
124481	Chlorodibromomethane	X	C	1.0E+00	1.2E-01		1.0E+01	1.2E+00		1.0E+02	1.2E+01		3.2E+01	
75456	Chlorodifluoromethane		NC	5.0E+04	1.4E+04		5.0E+05	1.4E+05		**	**		**	
75003	Chloroethane (ethyl chloride)		NC	1.0E+04	3.8E+03		1.0E+05	3.8E+04		1.0E+06	3.8E+05		2.8E+04	
67663	Chloroform		C	1.1E+00	2.2E-01		1.1E+01	2.2E+00		1.1E+02	2.2E+01		8.0E+01 †	
95578	2-Chlorophenol	X	NC	1.8E+01	3.3E+00		1.8E+02	3.3E+01		1.8E+03	3.3E+02		1.1E+03	
75296	2-Chloropropane		NC	1.0E+02	3.2E+01		1.0E+03	3.2E+02		1.0E+04	3.2E+03		1.7E+02	
218019	Chrysene	X	C	1.2E+01	1.2E+00		**	**		**	**		**	
156592	cis-1,2-Dichloroethylene	X	NC	3.5E+01	8.8E+00		3.5E+02	8.8E+01		3.5E+03	8.8E+02		2.1E+02	
123739	Crotonaldehyde (2-butenal)	X	C	4.5E-02	1.6E-02		4.5E-01	1.6E-01		4.5E+00	1.6E+00		5.6E+01	
98828	Cumene		NC	4.0E+02	8.1E+01		4.0E+03	8.1E+02		4.0E+04	8.1E+03		8.4E+00	

Table 2b: Question 4 Generic Screening Levels and Summary Sheet [1]

Risk = 1×10^{-5}

CAS No.	Chemical	Compounds with Provisional Toxicity Data Extrapolated From Oral Sources	Basis of Target Concentration C=cancer risk NC=noncancer risk	Target Indoor Air Concentration to Satisfy Both the Prescribed Risk Level and the Target Hazard Index [R=10^{-5}, HI=1] C_{target}		Measured or Reasonably Estimated Indoor Air Concentration [if available]	Target Shallow Soil Gas Concentration Corresponding to Target Indoor Air Concentration Where the Soil Gas to Indoor Air Attenuation Factor=0.1 $C_{soil\text{-}gas}$		Measured or Reasonably Estimated Shallow Soil Gas Concentration [if available]	Target Deep Soil Gas Concentration Corresponding to Target Indoor Air Concentration Where the Soil Gas to Indoor Air Attenuation Factor=0.01 $C_{soil\text{-}gas}$		Measured or Reasonably Estimated Deep Soil Gas Concentration [if available]	Target Groundwater Concentration Corresponding to Target Indoor Air Concentration Where the Soil Gas to Indoor Air Attenuation Factor = 0.001 and Partitioning Across the Water Table Obeys Henry's Law C_{gw}	Measured or Reasonably Estimated Groundwater Concentration [if available]
				(ug/m3)	(ppbv)	(specify units)	(ug/m3)	(ppbv)	(specify units)	(ug/m3)	(ppbv)	(specify units)	(ug/L)	(specify units)
72559	DDE	X	C	2.5E-01	1.9E-02		2.5E+00	1.9E-01		2.5E+01	1.9E+00		**	
132649	Dibenzofuran	X	NC	1.4E+01	2.0E+00		1.4E+02	2.0E+01		1.4E+03	2.0E+02		**	
96128	1,2-Dibromo-3-chloropropane		NC	2.0E-01	2.1E-02		2.0E+00	2.1E-01		2.0E+01	2.1E+00		3.3E+01	
106934	1,2-Dibromoethane (ethylene dibromide)		C	1.1E-01	1.4E-02		1.1E+00	1.4E-01		1.1E+01	1.4E+00		3.6E+00	
541731	1,3-Dichlorobenzene	X	NC	1.1E+02	1.7E+01		1.1E+03	1.7E+02		1.1E+04	1.7E+03		8.3E+02	
95501	1,2-Dichlorobenzene		NC	2.0E+02	3.3E+01		2.0E+03	3.3E+02		2.0E+04	3.3E+03		2.6E+03	
106467	1,4-Dichlorobenzene		NC	8.0E+02	1.3E+02		8.0E+03	1.3E+03		8.0E+04	1.3E+04		8.2E+03	
75718	Dichlorodifluoromethane		NC	2.0E+02	4.0E+01		2.0E+03	4.0E+02		2.0E+04	4.0E+03		1.4E+01	
75343	1,1-Dichloroethane		NC	5.0E+02	1.2E+02		5.0E+03	1.2E+03		5.0E+04	1.2E+04		2.2E+03	
107062	1,2-Dichloroethane		C	9.4E-01	2.3E-01		9.4E+00	2.3E+00		9.4E+01	2.3E+01		2.3E+01	
75354	1,1-Dichloroethylene		NC	2.0E+02	5.0E+01		2.0E+03	5.0E+02		2.0E+04	5.0E+03		1.9E+02	
78875	1,2-Dichloropropane		NC	4.0E+00	8.7E-01		4.0E+01	8.7E+00		4.0E+02	8.7E+01		3.5E+01	
542756	1,3-Dichloropropene		C	6.1E+00	1.3E+00		6.1E+01	1.3E+01		6.1E+02	1.3E+02		8.4E+00	
60571	Dieldrin		C	5.3E-03	3.4E-04		5.3E-02	3.4E-03		5.3E-01	3.4E-02		8.6E+00	
115297	Endosulfan	X	NC	2.1E+01	1.3E+00		2.1E+02	1.3E+01		**	**		**	
106898	Epichlorohydrin		NC	1.0E+00	2.6E-01		1.0E+01	2.6E+00		1.0E+02	2.6E+01		8.0E+02	
60297	Ethyl ether	X	NC	7.0E+02	2.3E+02		7.0E+03	2.3E+03		7.0E+04	2.3E+04		5.2E+02	
141786	Ethylacetate	X	NC	3.2E+03	8.7E+02		3.2E+04	8.7E+03		3.2E+05	8.7E+04		5.6E+05	
100414	Ethylbenzene		C	2.2E+01	5.1E+00		2.2E+02	5.1E+01		2.2E+03	5.1E+02		7.0E+02[†]	
75218	Ethylene oxide		C	2.4E-01	1.4E-01		2.4E+00	1.4E+00		2.4E+01	1.4E+01		1.1E+01	
97632	Ethylmethacrylate	X	NC	3.2E+02	6.8E+01		3.2E+03	6.8E+02		3.2E+04	6.8E+03		9.1E+03	
86737	Fluorene	X	NC	1.4E+02	2.1E+01		1.4E+03	2.1E+02		**	**		**	
110009	Furan	X	NC	3.5E+00	1.3E+00		3.5E+01	1.3E+01		3.5E+02	1.3E+02		1.6E+01	
58899	gamma-HCH (Lindane)	X	C	6.6E-02	5.5E-03		6.6E-01	5.5E-02		6.6E+00	5.5E-01		1.1E+02	
76448	Heptachlor		C	1.9E-02	1.2E-03		1.9E-01	1.2E-02		1.9E+00	1.2E-01		4.0E-01[†]	
87683	Hexachloro-1,3-butadiene		C	1.1E+00	1.0E-01		1.1E+01	1.0E+00		1.1E+02	1.0E+01		3.3E+00	
118741	Hexachlorobenzene		C	5.3E-02	4.5E-03		5.3E-01	4.5E-02		5.3E+00	4.5E-01		1.0E+00[†]	
77474	Hexachlorocyclopentadiene		NC	2.0E-01	1.8E-02		2.0E+00	1.8E-01		2.0E+01	1.8E+00		5.0E+01[†]	
67721	Hexachloroethane		C	6.1E+00	6.3E-01		6.1E+01	6.3E+00		6.1E+02	6.3E+01		3.8E+01	
110543	Hexane		NC	2.0E+02	5.7E+01		2.0E+03	5.7E+02		2.0E+04	5.7E+03		2.9E+00	
74908	Hydrogen cyanide		NC	3.0E+00	2.7E+00		3.0E+01	2.7E+01		3.0E+02	2.7E+02		5.5E+02	
78831	Isobutanol	X	NC	1.1E+03	3.5E+02		1.1E+04	3.5E+03		1.1E+05	3.5E+04		2.2E+06	
7439976	Mercury (elemental)		NC	3.0E-01	3.7E-02		3.0E+00	3.7E-01		3.0E+01	3.7E+00		6.8E-01	
126987	Methacrylonitrile		NC	7.0E-01	2.6E-01		7.0E+00	2.6E+00		7.0E+01	2.6E+01		6.9E+01	
72435	Methoxychlor	X	NC	1.8E+01	1.2E+00		**	**		**	**		**	
79209	Methyl acetate	X	NC	3.5E+03	1.2E+03		3.5E+04	1.2E+04		3.5E+05	1.2E+05		7.2E+05	
96333	Methyl acrylate	X	NC	1.1E+02	3.0E+01		1.1E+03	3.0E+02		1.1E+04	3.0E+03		1.4E+04	

Table 2b: Question 4 Generic Screening Levels and Summary Sheet [1]

Risk = 1 x 10^{-5}

CAS No.	Chemical	Compounds with Provisional Toxicity Data Extrapolated From Oral Sources	Basis of Target Concentration C=cancer risk NC=noncancer risk	Target Indoor Air Concentration to Satisfy Both the Prescribed Risk Level and the Target Hazard Index [R=10^{-5}, HI=1] C_{target}		Measured or Reasonably Estimated Indoor Air Concentration [if available]	Target Shallow Soil Gas Concentration Corresponding to Target Indoor Air Concentration Where the Soil Gas to Indoor Air Attenuation Factor=0.1 $C_{soil\text{-}gas}$		Measured or Reasonably Estimated Shallow Soil Gas Concentration [if available]	Target Deep Soil Gas Concentration Corresponding to Target Indoor Air Concentration Where the Soil Gas to Indoor Air Attenuation Factor=0.01 $C_{soil\text{-}gas}$		Measured or Reasonably Estimated Deep Soil Gas Concentration [if available]	Target Groundwater Concentration Corresponding to Target Indoor Air Concentration Where the Soil Gas to Indoor Air Attenuation Factor = 0.001 and Partitioning Across the Water Table Obeys Henry's Law C_{gw}	Measured or Reasonably Estimated Groundwater Concentration [if available]
				(ug/m3)	(ppbv)	(specify units)	(ug/m3)	(ppbv)	(specify units)	(ug/m3)	(ppbv)	(specify units)	(ug/L)	(specify units)
74839	Methyl bromide		NC	5.0E+00	1.3E+00		5.0E+01	1.3E+01		5.0E+02	1.3E+02		2.0E+01	
74873	Methyl chloride (chloromethane)		C	2.4E+01	1.2E+01		2.4E+02	1.2E+02		2.4E+03	1.2E+03		6.7E+01	
108872	Methylcyclohexane		NC	3.0E+03	7.5E+02		3.0E+04	7.5E+03		3.0E+05	7.5E+04		7.1E+02	
74953	Methylene bromide	X	NC	3.5E+01	4.9E+00		3.5E+02	4.9E+01		3.5E+03	4.9E+02		9.9E+02	
75092	Methylene chloride		C	5.2E+01	1.5E+01		5.2E+02	1.5E+02		5.2E+03	1.5E+03		5.8E+02	
78933	Methylethylketone (2-butanone)		NC	1.0E+03	3.4E+02		1.0E+04	3.4E+03		1.0E+05	3.4E+04		4.4E+05	
108101	Methylisobutylketone		NC	8.0E+01	2.0E+01		8.0E+02	2.0E+02		8.0E+03	2.0E+03		1.4E+04	
80626	Methylmethacrylate		NC	7.0E+02	1.7E+02		7.0E+03	1.7E+03		7.0E+04	1.7E+04		5.1E+04	
91576	2-Methylnaphthalene	X	NC	7.0E+01	1.2E+01		7.0E+02	1.2E+02		7.0E+03	1.2E+03		3.3E+03	
1634044	MTBE		NC	3.0E+03	8.3E+02		3.0E+04	8.3E+03		3.0E+05	8.3E+04		1.2E+05	
108383	m-Xylene	X	NC	7.0E+03	1.6E+03		7.0E+04	1.6E+04		7.0E+05	1.6E+05		2.3E+04	
91203	Naphthalene		NC	3.0E+00	5.7E-01		3.0E+01	5.7E+00		3.0E+02	5.7E+01		1.5E+02	
104518	n-Butylbenzene	X	NC	1.4E+02	2.6E+01		1.4E+03	2.6E+02		1.4E+04	2.6E+03		2.6E+02	
98953	Nitrobenzene		NC	2.0E+00	4.0E-01		2.0E+01	4.0E+00		2.0E+02	4.0E+01		2.0E+03	
79469	2-Nitropropane		C	9.0E-03	2.5E-03		9.0E-02	2.5E-02		9.0E-01	2.5E-01		1.8E+00	
924163	N-Nitroso-di-n-butylamine		C	1.5E-02	2.4E-03		1.5E-01	2.4E-02		1.5E+00	2.4E-01		1.2E+00	
103651	n-Propylbenzene	X	NC	1.4E+02	2.8E+01		1.4E+03	2.8E+02		1.4E+04	2.8E+03		3.2E+02	
88722	o-Nitrotoluene	X	NC	3.5E+01	6.2E+00		3.5E+02	6.2E+01		3.5E+03	6.2E+02		6.8E+04	
95476	o-Xylene	X	NC	7.0E+03	1.6E+03		7.0E+04	1.6E+04		7.0E+05	1.6E+05		3.3E+04	
106423	p-Xylene	X	NC	7.0E+03	1.6E+03		7.0E+04	1.6E+04		7.0E+05	1.6E+05		2.2E+04	
129000	Pyrene	X	NC	1.1E+02	1.3E+01		**	**		**	**		**	
135988	sec-Butylbenzene	X	NC	1.4E+02	2.6E+01		1.4E+03	2.6E+02		1.4E+04	2.6E+03		2.5E+02	
100425	Styrene		NC	1.0E+03	2.3E+02		1.0E+04	2.3E+03		1.0E+05	2.3E+04		8.9E+03	
98066	tert-Butylbenzene	X	NC	1.4E+02	2.6E+01		1.4E+03	2.6E+02		1.4E+04	2.6E+03		2.9E+02	
630206	1,1,1,2-Tetrachloroethane		C	3.3E+00	4.8E-01		3.3E+01	4.8E+00		3.3E+02	4.8E+01		3.3E+01	
79345	1,1,2,2-Tetrachloroethane		C	4.2E-01	6.1E-02		4.2E+00	6.1E-01		4.2E+01	6.1E+00		3.0E+01	
127184	Tetrachloroethylene		C	8.1E+00	1.2E+00		8.1E+01	1.2E+01		8.1E+02	1.2E+02		1.1E+01	
108883	Toluene		NC	4.0E+02	1.1E+02		4.0E+03	1.1E+03		4.0E+04	1.1E+04		1.5E+03	
156605	trans-1,2-Dichloroethylene	X	NC	7.0E+01	1.8E+01		7.0E+02	1.8E+02		7.0E+03	1.8E+03		1.8E+02	
76131	1,1,2-Trichloro-1,2,2-trifluoroethane		NC	3.0E+04	3.9E+03		3.0E+05	3.9E+04		3.0E+06	3.9E+05		1.5E+03	
120821	1,2,4-Trichlorobenzene		NC	2.0E+02	2.7E+01		2.0E+03	2.7E+02		2.0E+04	2.7E+03		3.4E+03	
79005	1,1,2-Trichloroethane		C	1.5E+00	2.8E-01		1.5E+01	2.8E+00		1.5E+02	2.8E+01		4.1E+01	
71556	1,1,1-Trichloroethane		NC	2.2E+03	4.0E+02		2.2E+04	4.0E+03		2.2E+05	4.0E+04		3.1E+03	
79016	Trichloroethylene [††]	X	C	2.2E-01	4.1E-02		2.2E+00	4.1E-01		2.2E+01	4.1E+00		5.0E+00 [†]	
75694	Trichlorofluoromethane		NC	7.0E+02	1.2E+02		7.0E+03	1.2E+03		7.0E+04	1.2E+04		1.8E+02	
96184	1,2,3-Trichloropropane		NC	4.9E+00	8.1E-01		4.9E+01	8.1E+00		4.9E+02	8.1E+01		2.9E+02	
95636	1,2,4-Trimethylbenzene		NC	6.0E+00	1.2E+00		6.0E+01	1.2E+01		6.0E+02	1.2E+02		2.4E+01	

Table 2b: Question 4 Generic Screening Levels and Summary Sheet [1]

Risk = 1 x 10^{-5}

CAS No.	Chemical	Compounds with Provisional Toxicity Data Extrapolated From Oral Sources	Basis of Target Concentration C=cancer risk NC=noncancer risk	Target Indoor Air Concentration to Satisfy Both the Prescribed Risk Level and the Target Hazard Index [R=10^{-5}, HI=1] C_{target}		Measured or Reasonably Estimated Indoor Air Concentration [if available]	Target Shallow Soil Gas Concentration Corresponding to Target Indoor Air Concentration Where the Soil Gas to Indoor Air Attenuation Factor=0.1 $C_{soil\text{-}gas}$		Measured or Reasonably Estimated Shallow Soil Gas Concentration [if available]	Target Deep Soil Gas Concentration Corresponding to Target Indoor Air Concentration Where the Soil Gas to Indoor Air Attenuation Factor=0.01 $C_{soil\text{-}gas}$		Measured or Reasonably Estimated Deep Soil Gas Concentration [if available]	Target Groundwater Concentration Corresponding to Target Indoor Air Concentration Where the Soil Gas to Indoor Air Attenuation Factor = 0.001 and Partitioning Across the Water Table Obeys Henry's Law C_{gw}	Measured or Reasonably Estimated Groundwater Concentration [if available]
				(ug/m3)	(ppbv)	(specify units)	(ug/m3)	(ppbv)	(specify units)	(ug/m3)	(ppbv)	(specify units)	(ug/L)	(specify units)
108678	1,3,5-Trimethylbenzene		NC	6.0E+00	1.2E+00		6.0E+01	1.2E+01		6.0E+02	1.2E+02		2.5E+01	
108054	Vinyl acetate		NC	2.0E+02	5.7E+01		2.0E+03	5.7E+02		2.0E+04	5.7E+03		9.6E+03	
75014	Vinyl chloride (chloroethene)		C	2.8E+00	1.1E+00		2.8E+01	1.1E+01		2.8E+02	1.1E+02		2.5E+00	

[1] AF = 0.1 for Shallow Soil Gas Target Concentration
AF = 0.01 for Deep Soil Gas Target Concentration
AF = 0.001 for Groundwater Target Concentration

* Health-based target breathing concentration exceeds maximum possible chemical vapor concentration (pathway incomplete)

** Target soil gas concentration exceeds maximum possible vapor concentration (pathway incomplete)

† The target groundwater concentration is the MCL. (The MCL for chloroform is the MCL for total Trihalomethanes. The MCL listed for m-Xylene, o-Xylene, and p-Xylene is the MCL for total Xylenes.)

†† The target concentration for trichloroethylene is based on the upper bound cancer slope factor identified in EPA's draft risk assessment for trichloroethylene (US EPA, 2001). The slope factor is based on state-of-the-art methodology, however the TCE assessment is still undergoing review. As a result, the slope factor and the target concentration values for TCE may be revised further. (See Appendix D.)

Table 2c: Question 4 Generic Screening Levels and Summary Sheet [1]

Risk = 1 x 10^{-6}

CAS No.	Chemical	Compounds with Provisional Toxicity Data Extrapolated From Oral Sources	Basis of Target Concentration C=cancer risk	Target Indoor Air Concentration to Satisfy Both the Prescribed Risk Level and the Target Hazard Index [R=10^{-6}, HI=1] C_{target}		Measured or Reasonably Estimated Indoor Air Concentration [if available]	Target Shallow Gas Concentration Corresponding to Target Indoor Air Concentration Where the Soil Gas to Indoor Air Attenuation Factor=0.1 $C_{soil\text{-}gas}$		Measured or Reasonably Estimated Shallow Soil Gas Concentration [if available]	Target Deep Soil Gas Concentration Corresponding to Target Indoor Air Concentration Where the Soil Gas to Indoor Air Attenuation Factor=0.01 $C_{soil\text{-}gas}$		Measured or Reasonably Estimated Deep Soil Gas Concentration [if available]	Target Groundwater Concentration Corresponding to Target Indoor Air Concentration Where the Soil Gas to Indoor Air Attenuation Factor = 0.001 and Partitioning Across the Water Table Obeys Henry's Law C_{gw}	Measured or Reasonably Estimated Groundwater Concentration [if available]
			NC=noncancer risk	(ug/m3)	(ppbv)	(specify units)	(ug/m3)	(ppbv)	(specify units)	(ug/m3)	(ppbv)	(specify units)	(ug/L)	(specify units)
83329	Acenaphthene	X	NC	2.1E+02	3.3E+01		2.1E+03	3.3E+02		2.1E+04	3.3E+03		**	
75070	Acetaldehyde		C	1.1E+00	6.1E-01		1.1E+01	6.1E+00		1.1E+02	6.1E+01		3.4E+02	
67641	Acetone	X	NC	3.5E+02	1.5E+02		3.5E+03	1.5E+03		3.5E+04	1.5E+04		2.2E+05	
75058	Acetonitrile		NC	6.0E+01	3.6E+01		6.0E+02	3.6E+02		6.0E+03	3.6E+03		4.2E+04	
98862	Acetophenone	X	NC	3.5E+02	7.1E+01		3.5E+03	7.1E+02		3.5E+04	7.1E+03		8.0E+05	
107028	Acrolein		NC	2.0E-02	8.7E-03		2.0E-01	8.7E-02		2.0E+00	8.7E-01		4.0E+00	
107131	Acrylonitrile		C	3.6E-02	1.7E-02		3.6E-01	1.7E-01		3.6E+00	1.7E+00		8.5E+00	
309002	Aldrin		C	5.0E-04	3.3E-05		5.0E-03	3.3E-04		5.0E-02	3.3E-03		7.1E-02	
319846	alpha-HCH (alpha-BHC)		C	1.4E-03	1.1E-04		1.4E-02	1.1E-03		1.4E-01	1.1E-02		3.1E+00	
100527	Benzaldehyde	X	NC	3.5E+02	8.1E+01		3.5E+03	8.1E+02		3.5E+04	8.1E+03		3.6E+05	
71432	Benzene		C	3.1E-01	9.8E-02		3.1E+00	9.8E-01		3.1E+01	9.8E+00		5.0E+00 †	
205992	Benzo(b)fluoranthene	X	C	1.2E-02	1.1E-03		1.2E-01	1.1E-02		1.2E+00	1.1E-01		**	
100447	Benzylchloride	X	C	5.0E-02	9.7E-03		5.0E-01	9.7E-02		5.0E+00	9.7E-01		3.0E+00	
91587	beta-Chloronaphthalene	X	NC	2.8E+02	4.2E+01		2.8E+03	4.2E+02		2.8E+04	4.2E+03		**	
92524	Biphenyl	X	NC	1.8E+02	2.8E+01		1.8E+03	2.8E+02		1.8E+04	2.8E+03		**	
111444	Bis(2-chloroethyl)ether		C	7.4E-03	1.3E-03		7.4E-02	1.3E-02		7.4E-01	1.3E-01		1.0E+01	
108601	Bis(2-chloroisopropyl)ether		C	2.4E-01	3.5E-02		2.4E+00	3.5E-01		2.4E+01	3.5E+00		5.1E+01	
542881	Bis(chloromethyl)ether		C	3.9E-05	8.4E-06		3.9E-04	8.4E-05		3.9E-03	8.4E-04		4.5E-03	
75274	Bromodichloromethane	X	C	1.4E-01	2.1E-02		1.4E+00	2.1E-01		1.4E+01	2.1E+00		2.1E+00	
75252	Bromoform		C	2.2E+00	2.1E-01		2.2E+01	2.1E+00		2.2E+02	2.1E+01		8.3E-03	
106990	1,3-Butadiene		C	8.7E-03	3.9E-03		8.7E-02	3.9E-02		8.7E-01	3.9E-01		2.9E-03	
75150	Carbon disulfide		NC	7.0E+02	2.2E+02		7.0E+03	2.2E+03		7.0E+04	2.2E+04		5.6E+02	
56235	Carbon tetrachloride		C	1.6E-01	2.6E-02		1.6E+00	2.6E-01		1.6E+01	2.6E+00		5.0E+00 †	
57749	Chlordane		C	2.4E-02	1.5E-03		2.4E-01	1.5E-02		2.4E+00	1.5E-01		1.2E+01	
126998	2-Chloro-1,3-butadiene (chloroprene)		NC	7.0E+00	1.9E+00		7.0E+01	1.9E+01		7.0E+02	1.9E+02		1.4E+01	
108907	Chlorobenzene		NC	6.0E+01	1.3E+01		6.0E+02	1.3E+02		6.0E+03	1.3E+03		3.9E+02	
109693	1-Chlorobutane	X	NC	1.4E+03	3.7E+02		1.4E+04	3.7E+03		1.4E+05	3.7E+04		2.0E+03	
124481	Chlorodibromomethane	X	C	1.0E-01	1.2E-02		1.0E+00	1.2E-01		1.0E+01	1.2E+00		3.2E+00	
75456	Chlorodifluoromethane		NC	5.0E+04	1.4E+04		5.0E+05	1.4E+05		**	**		**	
75003	Chloroethane (ethyl chloride)		NC	1.0E+04	3.8E+03		1.0E+05	3.8E+04		1.0E+06	3.8E+05		2.8E+04	
67663	Chloroform		C	1.1E-01	2.2E-02		1.1E+00	2.2E-01		1.1E+01	2.2E+00		8.0E+01 †	
95578	2-Chlorophenol	X	NC	1.8E+01	3.3E+00		1.8E+02	3.3E+01		1.8E+03	3.3E+02		1.1E+03	
75296	2-Chloropropane		NC	1.0E+02	3.2E+01		1.0E+03	3.2E+02		1.0E+04	3.2E+03		1.7E+02	
218019	Chrysene	X	C	1.2E+00	1.2E-01		1.2E+01	1.2E+00		**	**		**	
156592	cis-1,2-Dichloroethylene	X	NC	3.5E+01	8.8E+00		3.5E+02	8.8E+01		3.5E+03	8.8E+02		2.1E+02	
123739	Crotonaldehyde (2-butenal)	X	C	4.5E-03	1.6E-03		4.5E-02	1.6E-02		4.5E-01	1.6E-01		5.6E+00	
98828	Cumene		NC	4.0E+02	8.1E+01		4.0E+03	8.1E+02		4.0E+04	8.1E+03		8.4E+00	

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Table 2c: Question 4 Generic Screening Levels and Summary Sheet [1]

Risk = 1 x 10^{-6}

CAS No.	Chemical	Compounds with Provisional Toxicity Data Extrapolated From Oral Sources	Basis of Target Concentration C=cancer risk NC=noncancer risk	Target Indoor Air Concentration to Satisfy Both the Prescribed Risk Level and the Target Hazard Index [R=10^{-6}, HI=1] C_{target}		Measured or Reasonably Estimated Indoor Air Concentration [if available]	Target Shallow Gas Concentration Corresponding to Target Indoor Air Concentration Where the Soil Gas to Indoor Air Attenuation Factor=0.1 $C_{soil-gas}$		Measured or Reasonably Estimated Shallow Soil Gas Concentration [if available]	Target Deep Soil Gas Concentration Corresponding to Target Indoor Air Concentration Where the Soil Gas to Indoor Air Attenuation Factor=0.01 $C_{soil-gas}$		Measured or Reasonably Estimated Deep Soil Gas Concentration [if available]	Target Groundwater Concentration Corresponding to Target Indoor Air Concentration Where the Soil Gas to Indoor Air Attenuation Factor = 0.001 and Partitioning Across the Water Table Obeys Henry's Law C_{gw}	Measured or Reasonably Estimated Groundwater Concentration [if available]
				(ug/m3)	(ppbv)	(specify units)	(ug/m3)	(ppbv)	(specify units)	(ug/m3)	(ppbv)	(specify units)	(ug/L)	(specify units)
72559	DDE	X	C	2.5E-02	1.9E-03		2.5E-01	1.9E-02		2.5E+00	1.9E-01		2.9E+01	
132649	Dibenzofuran	X	NC	1.4E+01	2.0E+00		1.4E+02	2.0E+01		1.4E+03	2.0E+02		**	
96128	1,2-Dibromo-3-chloropropane		NC	2.0E-01	2.1E-02		2.0E+00	2.1E-01		2.0E+01	2.1E+00		3.3E+01	
106934	1,2-Dibromoethane (ethylene dibromide)		C	1.1E-02	1.4E-03		1.1E-01	1.4E-02		1.1E+00	1.4E-01		3.6E-01	
541731	1,3-Dichlorobenzene	X	NC	1.1E+02	1.7E+01		1.1E+03	1.7E+02		1.1E+04	1.7E+03		8.3E+02	
95501	1,2-Dichlorobenzene		NC	2.0E+02	3.3E+01		2.0E+03	3.3E+02		2.0E+04	3.3E+03		2.6E+03	
106467	1,4-Dichlorobenzene		NC	8.0E+02	1.3E+02		8.0E+03	1.3E+03		8.0E+04	1.3E+04		8.2E+03	
75718	Dichlorodifluoromethane		NC	2.0E+02	4.0E+01		2.0E+03	4.0E+02		2.0E+04	4.0E+03		1.4E+01	
75343	1,1-Dichloroethane		NC	5.0E+02	1.2E+02		5.0E+03	1.2E+03		5.0E+04	1.2E+04		2.2E+03	
107062	1,2-Dichloroethane		C	9.4E-02	2.3E-02		9.4E-01	2.3E-01		9.4E+00	2.3E+00		5.0E+00 †	
75354	1,1-Dichloroethylene		NC	2.0E+02	5.0E+01		2.0E+03	5.0E+02		2.0E+04	5.0E+03		1.9E+02	
78875	1,2-Dichloropropane		NC	4.0E+00	8.7E-01		4.0E+01	8.7E+00		4.0E+02	8.7E+01		3.5E+01	
542756	1,3-Dichloropropene		C	6.1E-01	1.3E-01		6.1E+00	1.3E+00		6.1E+01	1.3E+01		8.4E-01	
60571	Dieldrin		C	5.3E-04	3.4E-05		5.3E-03	3.4E-04		5.3E-02	3.4E-03		8.6E-01	
115297	Endosulfan	X	NC	2.1E+01	1.3E+00		2.1E+02	1.3E+01		**	**		**	
106898	Epichlorohydrin		NC	1.0E+00	2.6E-01		1.0E+01	2.6E+00		1.0E+02	2.6E+01		8.0E+02	
60297	Ethyl ether	X	NC	7.0E+02	2.3E+02		7.0E+03	2.3E+03		7.0E+04	2.3E+04		5.2E+02	
141786	Ethylacetate	X	NC	3.2E+03	8.7E+02		3.2E+04	8.7E+03		3.2E+05	8.7E+04		5.6E+05	
100414	Ethylbenzene		C	2.2E+00	5.1E-01		2.2E+01	5.1E+00		2.2E+02	5.1E+01		7.0E+02 †	
75218	Ethylene oxide		C	2.4E-02	1.4E-02		2.4E-01	1.4E-01		2.4E+00	1.4E+00		1.1E+00	
97632	Ethylmethacrylate	X	NC	3.2E+02	6.8E+01		3.2E+03	6.8E+02		3.2E+04	6.8E+03		9.1E+03	
86737	Fluorene	X	NC	1.4E+02	2.1E+01		1.4E+03	2.1E+02		**	**		**	
110009	Furan	X	NC	3.5E+00	1.3E+00		3.5E+01	1.3E+01		3.5E+02	1.3E+02		1.6E+01	
58899	gamma-HCH (Lindane)	X	C	6.6E-03	5.5E-04		6.6E-02	5.5E-03		6.6E-01	5.5E-02		1.1E+01	
76448	Heptachlor		C	1.9E-03	1.2E-04		1.9E-02	1.2E-03		1.9E-01	1.2E-02		4.0E-01 †	
87683	Hexachloro-1,3-butadiene		C	1.1E-01	1.0E-02		1.1E+00	1.0E-01		1.1E+01	1.0E+00		3.3E-01	
118741	Hexachlorobenzene		C	5.3E-03	4.5E-04		5.3E-02	4.5E-03		5.3E-01	4.5E-02		1.0E+00 †	
77474	Hexachlorocyclopentadiene		NC	2.0E-01	1.8E-02		2.0E+00	1.8E-01		2.0E+01	1.8E+00		5.0E+01 †	
67721	Hexachloroethane		C	6.1E-01	6.3E-02		6.1E+00	6.3E-01		6.1E+01	6.3E+00		3.8E+00	
110543	Hexane		NC	2.0E+02	5.7E+01		2.0E+03	5.7E+02		2.0E+04	5.7E+03		2.9E+00	
74908	Hydrogen cyanide		NC	3.0E+00	2.7E+00		3.0E+01	2.7E+01		3.0E+02	2.7E+02		5.5E+02	
78831	Isobutanol	X	NC	1.1E+03	3.5E+02		1.1E+04	3.5E+03		1.1E+05	3.5E+04		2.2E+06	
7439976	Mercury (elemental)		NC	3.0E-01	3.7E-02		3.0E+00	3.7E-01		3.0E+01	3.7E+00		6.8E-01	
126987	Methacrylonitrile		NC	7.0E-01	2.6E-01		7.0E+00	2.6E+00		7.0E+01	2.6E+01		6.9E+01	
72435	Methoxychlor	X	NC	1.8E+01	1.2E+00		**	**		**	**		**	
79209	Methyl acetate	X	NC	3.5E+03	1.2E+03		3.5E+04	1.2E+04		3.5E+05	1.2E+05		7.2E+05	
96333	Methyl acrylate	X	NC	1.1E+02	3.0E+01		1.1E+03	3.0E+02		1.1E+04	3.0E+03		1.4E+04	

Table 2c: Question 4 Generic Screening Levels and Summary Sheet [1]

Risk = 1 x 10^{-6}

		Compounds with Provisional Toxicity Data Extrapolated From Oral Sources	Basis of Target Concentration C=cancer risk	Target Indoor Air Concentration to Satisfy Both the Prescribed Risk Level and the Target Hazard Index [R=10^{-6}, HI=1] C_{target}		Measured or Reasonably Estimated Indoor Air Concentration [if available]	Target Shallow Gas Concentration Corresponding to Target Indoor Air Concentration Where the Soil Gas to Indoor Air Attenuation Factor=0.1 $C_{soil-gas}$		Measured or Reasonably Estimated Shallow Soil Gas Concentration [if available]	Target Deep Soil Gas Concentration Corresponding to Target Indoor Air Concentration Where the Soil Gas to Indoor Air Attenuation Factor=0.01 $C_{soil-gas}$		Measured or Reasonably Estimated Deep Soil Gas Concentration [if available]	Target Groundwater Concentration Corresponding to Target Indoor Air Concentration Where the Soil Gas to Indoor Air Attenuation Factor = 0.001 and Partitioning Across the Water Table Obeys Henry's Law C_{gw}	Measured or Reasonably Estimated Groundwater Concentration [if available]
CAS No.	Chemical		NC=noncancer risk	(ug/m3)	(ppbv)	(specify units)	(ug/m3)	(ppbv)	(specify units)	(ug/m3)	(ppbv)	(specify units)	(ug/L)	(specify units)
74839	Methyl bromide		NC	5.0E+00	1.3E+00		5.0E+01	1.3E+01		5.0E+02	1.3E+02		2.0E+01	
74873	Methyl chloride (chloromethane)		C	2.4E+00	1.2E+00		2.4E+01	1.2E+01		2.4E+02	1.2E+02		6.7E+00	
108872	Methylcyclohexane		NC	3.0E+03	7.5E+02		3.0E+04	7.5E+03		3.0E+05	7.5E+04		7.1E+02	
74953	Methylene bromide	X	NC	3.5E+01	4.9E+00		3.5E+02	4.9E+01		3.5E+03	4.9E+02		9.9E+02	
75092	Methylene chloride		C	5.2E+00	1.5E+00		5.2E+01	1.5E+01		5.2E+02	1.5E+02		5.8E+01	
78933	Methylethylketone (2-butanone)		NC	1.0E+03	3.4E+02		1.0E+04	3.4E+03		1.0E+05	3.4E+04		4.4E+05	
108101	Methylisobutylketone		NC	8.0E+01	2.0E+01		8.0E+02	2.0E+02		8.0E+03	2.0E+03		1.4E+04	
80626	Methylmethacrylate		NC	7.0E+02	1.7E+02		7.0E+03	1.7E+03		7.0E+04	1.7E+04		5.1E+04	
91576	2-Methylnaphthalene	X	NC	7.0E+01	1.2E+01		7.0E+02	1.2E+02		7.0E+03	1.2E+03		3.3E+03	
1634044	MTBE		NC	3.0E+03	8.3E+02		3.0E+04	8.3E+03		3.0E+05	8.3E+04		1.2E+05	
108383	m-Xylene	X	NC	7.0E+03	1.6E+03		7.0E+04	1.6E+04		7.0E+05	1.6E+05		2.3E+04	
91203	Naphthalene		NC	3.0E+00	5.7E-01		3.0E+01	5.7E+00		3.0E+02	5.7E+01		1.5E+02	
104518	n-Butylbenzene	X	NC	1.4E+02	2.6E+01		1.4E+03	2.6E+02		1.4E+04	2.6E+03		2.6E+02	
98953	Nitrobenzene		NC	2.0E+00	4.0E-01		2.0E+01	4.0E+00		2.0E+02	4.0E+01		2.0E+03	
79469	2-Nitropropane		C	9.0E-04	2.5E-04		9.0E-03	2.5E-03		9.0E-02	2.5E-02		1.8E-01	
924163	N-Nitroso-di-n-butylamine		C	1.5E-03	2.4E-04		1.5E-02	2.4E-03		1.5E-01	2.4E-02		1.2E-01	
103651	n-Propylbenzene	X	NC	1.4E+02	2.8E+01		1.4E+03	2.8E+02		1.4E+04	2.8E+03		3.2E+02	
88722	o-Nitrotoluene	X	NC	3.5E+01	6.2E+00		3.5E+02	6.2E+01		3.5E+03	6.2E+02		6.8E+04	
95476	o-Xylene	X	NC	7.0E+03	1.6E+03		7.0E+04	1.6E+04		7.0E+05	1.6E+05		3.3E+04	
106423	p-Xylene	X	NC	7.0E+03	1.6E+03		7.0E+04	1.6E+04		7.0E+05	1.6E+05		2.2E+04	
129000	Pyrene	X	NC	1.1E+02	1.3E+01		**	**		**	**		**	
135988	sec-Butylbenzene	X	NC	1.4E+02	2.6E+01		1.4E+03	2.6E+02		1.4E+04	2.6E+03		2.5E+02	
100425	Styrene		NC	1.0E+03	2.3E+02		1.0E+04	2.3E+03		1.0E+05	2.3E+04		8.9E+03	
98066	tert-Butylbenzene	X	NC	1.4E+02	2.6E+01		1.4E+03	2.6E+02		1.4E+04	2.6E+03		2.9E+02	
630206	1,1,1,2-Tetrachloroethane		C	3.3E-01	4.8E-02		3.3E+00	4.8E-01		3.3E+01	4.8E+00		3.3E+00	
79345	1,1,2,2-Tetrachloroethane		C	4.2E-02	6.1E-03		4.2E-01	6.1E-02		4.2E+00	6.1E-01		3.0E+00	
127184	Tetrachloroethylene		C	8.1E-01	1.2E-01		8.1E+00	1.2E+00		8.1E+01	1.2E+01		5.0E+00 †	
108883	Toluene		NC	4.0E+02	1.1E+02		4.0E+03	1.1E+03		4.0E+04	1.1E+04		1.5E+03	
156605	trans-1,2-Dichloroethylene	X	NC	7.0E+01	1.8E+01		7.0E+02	1.8E+02		7.0E+03	1.8E+03		1.8E+02	
76131	1,1,2-Trichloro-1,2,2-trifluoroethane		NC	3.0E+04	3.9E+03		3.0E+05	3.9E+04		3.0E+06	3.9E+05		1.5E+03	
120821	1,2,4-Trichlorobenzene		NC	2.0E+02	2.7E+01		2.0E+03	2.7E+02		2.0E+04	2.7E+03		3.4E+03	
79005	1,1,2-Trichloroethane		C	1.5E-01	2.8E-02		1.5E+00	2.8E-01		1.5E+01	2.8E+00		5.0E+00 †	
71556	1,1,1-Trichloroethane		NC	2.2E+03	4.0E+02		2.2E+04	4.0E+03		2.2E+05	4.0E+04		3.1E+03	
79016	Trichloroethylene ††	X	C	2.2E-02	4.1E-03		2.2E-01	4.1E-02		2.2E+00	4.1E-01		5.0E+00 †	
75694	Trichlorofluoromethane		NC	7.0E+02	1.2E+02		7.0E+03	1.2E+03		7.0E+04	1.2E+04		1.8E+02	
96184	1,2,3-Trichloropropane		NC	4.9E+00	8.1E-01		4.9E+01	8.1E+00		4.9E+02	8.1E+01		2.9E+02	
95636	1,2,4-Trimethylbenzene		NC	6.0E+00	1.2E+00		6.0E+01	1.2E+01		6.0E+02	1.2E+02		2.4E+01	

Table 2c: Question 4 Generic Screening Levels and Summary Sheet [1]

Risk = 1 x 10^{-6}

CAS No.	Chemical	Compounds with Provisional Toxicity Data Extrapolated From Oral Sources	Basis of Target Concentration C=cancer risk NC=noncancer risk	Target Indoor Air Concentration to Satisfy Both the Prescribed Risk Level and the Target Hazard Index [R=10^{-6}, HI=1] C_{target}		Measured or Reasonably Estimated Indoor Air Concentration [if available]	Target Shallow Gas Concentration Corresponding to Target Indoor Air Concentration Where the Soil Gas to Indoor Air Attenuation Factor=0.1 $C_{soil-gas}$		Measured or Reasonably Estimated Shallow Soil Gas Concentration [if available]	Target Deep Soil Gas Concentration Corresponding to Target Indoor Air Concentration Where the Soil Gas to Indoor Air Attenuation Factor=0.01 $C_{soil-gas}$		Measured or Reasonably Estimated Deep Soil Gas Concentration [if available]	Target Groundwater Concentration Corresponding to Target Indoor Air Concentration Where the Soil Gas to Indoor Air Attenuation Factor = 0.001 and Partitioning Across the Water Table Obeys Henry's Law C_{gw}	Measured or Reasonably Estimated Groundwater Concentration [if available]
				(ug/m3)	(ppbv)	(specify units)	(ug/m3)	(ppbv)	(specify units)	(ug/m3)	(ppbv)	(specify units)	(ug/L)	(specify units)
108678	1,3,5-Trimethylbenzene		NC	6.0E+00	1.2E+00		6.0E+01	1.2E+01		6.0E+02	1.2E+02		2.5E+01	
108054	Vinyl acetate		NC	2.0E+02	5.7E+01		2.0E+03	5.7E+02		2.0E+04	5.7E+03		9.6E+03	
75014	Vinyl chloride (chloroethene)		C	2.8E-01	1.1E-01		2.8E+00	1.1E+00		2.8E+01	1.1E+01		2.0E+00 †	

[1] AF = 0.1 for Shallow Soil Gas Target Concentration
AF = 0.01 for Deep Soil Gas Target Concentration
AF = 0.001 for Groundwater Target Concentration

* Health-based target breathing concentration exceeds maximum possible chemical vapor concentration (pathway incomplete)

** Target soil gas concentration exceeds maximum possible vapor concentration (pathway incomplete)

† The target groundwater concentration is the MCL. (The MCL for chloroform is the MCL for total Trihalomethanes. The MCL listed for m-Xylene, o-Xylene, and p-Xylene is the MCL for total Xylenes.)

†† The target concentration for trichloroethylene is based on the upper bound cancer slope factor identified in EPA's draft risk assessment for trichloroethylene (US EPA, 2001). The slope factor is based on state-of-the-art methodology, however the TCE assessment is still undergoing review. As a result, the slope factor and the target concentration values for TCE may be revised further. (See Appendix D.)

Table 3a-SG: Question 5 Soil Gas Screening Levels for Scenario-Specific Vapor Attenuation Factors (α) **DRAFT**

Risk = 1 x 10^{-4}

				Target Soil Gas Concentrations for Different Attenuation Factors									
		Compounds with Provisional Toxicity Data Extrapolated	Basis of Target Concentration C=cancer risk	$\alpha = 2\times10^{-3}$ $C_{soil\text{-}gas}$		$\alpha = 1\times10^{-3}$ $C_{soil\text{-}gas}$		$\alpha = 7\times10^{-4}$ $C_{soil\text{-}gas}$		$\alpha = 4\times10^{-4}$ $C_{soil\text{-}gas}$		$\alpha = 2\times10^{-4}$ $C_{soil\text{-}gas}$	
CAS No.	Chemical	From Oral Sources	NC=noncancer risk	(ug/m^3)	(ppbv)	(ug/m^3)	(ppbv)	(ug/m^3)	(ppbv)	(ug/m^3)	(ppbv)	(ug/m^3)	(ppbv)
83329	Acenaphthene	X	NC	**	**	**	**	**	**	**	**	**	**
75070	Acetaldehyde		NC	4.5E+03	2.5E+03	9.0E+03	5.0E+03	1.3E+04	7.1E+03	2.2E+04	1.2E+04	4.5E+04	2.5E+04
67641	Acetone	X	NC	1.8E+05	7.4E+04	3.5E+05	1.5E+05	5.0E+05	2.1E+05	8.8E+05	3.7E+05	1.8E+06	7.4E+05
75058	Acetonitrile		NC	3.0E+04	1.8E+04	6.0E+04	3.6E+04	8.6E+04	5.1E+04	1.5E+05	8.9E+04	3.0E+05	1.8E+05
98862	Acetophenone	X	NC	1.8E+05	3.6E+04	3.5E+05	7.1E+04	5.0E+05	1.0E+05	8.8E+05	1.8E+05	1.8E+06	3.6E+05
107028	Acrolein		NC	1.0E+01	4.4E+00	2.0E+01	8.7E+00	2.9E+01	1.2E+01	5.0E+01	2.2E+01	1.0E+02	4.4E+01
107131	Acrylonitrile		NC	1.0E+03	4.6E+02	2.0E+03	9.2E+02	2.9E+03	1.3E+03	5.0E+03	2.3E+03	1.0E+04	4.6E+03
309002	Aldrin		C	2.5E+01	1.7E+00	5.0E+01	3.3E+00	7.1E+01	4.8E+00	**	**	**	**
319846	alpha-HCH (alpha-BHC)		C	6.8E+01	5.7E+00	1.4E+02	1.1E+01	1.9E+02	1.6E+01	3.4E+02	2.8E+01	6.8E+02	5.7E+01
100527	Benzaldehyde	X	NC	1.8E+05	4.0E+04	3.5E+05	8.1E+04	5.0E+05	1.2E+05	8.8E+05	2.0E+05	1.8E+06	4.0E+05
71432	Benzene		C	1.6E+04	4.9E+03	3.1E+04	9.8E+03	4.5E+04	1.4E+04	7.8E+04	2.4E+04	1.6E+05	4.9E+04
205992	Benzo(b)fluoranthene	X	C	**	**	**	**	**	**	**	**	**	**
100447	Benzylchloride	X	C	2.5E+03	4.8E+02	5.0E+03	9.7E+02	7.2E+03	1.4E+03	1.3E+04	2.4E+03	2.5E+04	4.8E+03
91587	beta-Chloronaphthalene	X	NC	1.4E+05	2.1E+04	**	**	**	**	**	**	**	**
92524	Biphenyl	X	NC	8.8E+04	1.4E+04	**	**	**	**	**	**	**	**
111444	Bis(2-chloroethyl)ether		C	3.7E+02	6.3E+01	7.4E+02	1.3E+02	1.1E+03	1.8E+02	1.8E+03	3.2E+02	3.7E+03	6.3E+02
108601	Bis(2-chloroisopropyl)ether		C	1.2E+04	1.7E+03	2.4E+04	3.5E+03	3.5E+04	5.0E+03	6.1E+04	8.7E+03	1.2E+05	1.7E+04
542881	Bis(chloromethyl)ether		C	2.0E+00	4.2E-01	3.9E+00	8.4E-01	5.6E+00	1.2E+00	9.8E+00	2.1E+00	2.0E+01	4.2E+00
75274	Bromodichloromethane	X	C	6.9E+03	1.0E+03	1.4E+04	2.1E+03	2.0E+04	2.9E+03	3.4E+04	5.1E+03	6.9E+04	1.0E+04
75252	Bromoform		C	1.1E+05	1.1E+04	2.2E+05	2.1E+04	3.2E+05	3.1E+04	5.5E+05	5.4E+04	1.1E+06	1.1E+05
106990	1,3-Butadiene		C	4.3E+02	2.0E+02	8.7E+02	3.9E+02	1.2E+03	5.6E+02	2.2E+03	9.8E+02	4.3E+03	2.0E+03
75150	Carbon disulfide		NC	3.5E+05	1.1E+05	7.0E+05	2.2E+05	1.0E+06	3.2E+05	1.8E+06	5.6E+05	3.5E+06	1.1E+06
56235	Carbon tetrachloride		C	8.1E+03	1.3E+03	1.6E+04	2.6E+03	2.3E+04	3.7E+03	4.1E+04	6.5E+03	8.1E+04	1.3E+04
57749	Chlordane		NC	**	**	**	**	**	**	**	**	**	**
126998	2-Chloro-1,3-butadiene (chloroprene)		NC	3.5E+03	9.7E+02	7.0E+03	1.9E+03	1.0E+04	2.8E+03	1.8E+04	4.8E+03	3.5E+04	9.7E+03
108907	Chlorobenzene		NC	3.0E+04	6.5E+03	6.0E+04	1.3E+04	8.5E+04	1.8E+04	1.5E+05	3.2E+04	3.0E+05	6.5E+04
109693	1-Chlorobutane	X	NC	7.0E+05	1.8E+05	1.4E+06	3.7E+05	2.0E+06	5.3E+05	3.5E+06	9.2E+05	7.0E+06	1.8E+06
124481	Chlorodibromomethane	X	C	5.1E+03	6.0E+02	1.0E+04	1.2E+03	1.4E+04	1.7E+03	2.5E+04	3.0E+03	5.1E+04	6.0E+03
75456	Chlorodifluoromethane		NC	**	**	**	**	**	**	**	**	**	**
75003	Chloroethane (ethyl chloride)		NC	5.0E+06	1.9E+06	1.0E+07	3.8E+06	1.4E+07	5.4E+06	2.5E+07	9.5E+06	5.0E+07	1.9E+07
67663	Chloroform		C	5.3E+03	1.1E+03	1.1E+04	2.2E+03	1.5E+04	3.1E+03	2.6E+04	5.4E+03	5.3E+04	1.1E+04
95578	2-Chlorophenol	X	NC	8.8E+03	1.7E+03	1.8E+04	3.3E+03	2.5E+04	4.8E+03	4.4E+04	8.3E+03	8.8E+04	1.7E+04
75296	2-Chloropropane		NC	5.1E+04	1.6E+04	1.0E+05	3.2E+04	1.5E+05	4.5E+04	2.5E+05	7.9E+04	5.1E+05	1.6E+05
218019	Chrysene	X	*	*	*	*	*	*	*	*	*	*	*
156592	cis-1,2-Dichloroethylene	X	NC	1.8E+04	4.4E+03	3.5E+04	8.8E+03	5.0E+04	1.3E+04	8.8E+04	2.2E+04	1.8E+05	4.4E+04
123739	Crotonaldehyde (2-butenal)	X	C	2.2E+02	7.8E+01	4.5E+02	1.6E+02	6.4E+02	2.2E+02	1.1E+03	3.9E+02	2.2E+03	7.8E+02
98828	Cumene		NC	2.0E+05	4.1E+04	4.0E+05	8.1E+04	5.7E+05	1.2E+05	1.0E+06	2.0E+05	2.0E+06	4.1E+05
72559	DDE	X	C	**	**	**	**	**	**	**	**	**	**
132649	Dibenzofuran	X	NC	**	**	**	**	**	**	**	**	**	**
96128	1,2-Dibromo-3-chloropropane		NC	1.0E+02	1.0E+01	2.0E+02	2.1E+01	2.9E+02	3.0E+01	5.0E+02	5.2E+01	1.0E+03	1.0E+02
106934	1,2-Dibromoethane (ethylene dibromide)		NC	1.0E+02	1.3E+01	2.0E+02	2.6E+01	2.9E+02	3.7E+01	5.0E+02	6.5E+01	1.0E+03	1.3E+02
541731	1,3-Dichlorobenzene	X	NC	5.3E+04	8.7E+03	1.1E+05	1.7E+04	1.5E+05	2.5E+04	2.6E+05	4.4E+04	5.3E+05	8.7E+04

Table 3a-SG: Question 5 Soil Gas Screening Levels for Scenario-Specific Vapor Attenuation Factors (α)

Risk = 1 x 10^{-4}

				Target Soil Gas Concentrations for Different Attenuation Factors									
		Compounds with Provisional Toxicity Data Extrapolated From Oral Sources	Basis of Target Concentration C=cancer risk NC=noncancer risk	α = $2x10^{-3}$ $C_{soil\text{-}gas}$		α = $1x10^{-3}$ $C_{soil\text{-}gas}$		α = $7x10^{-4}$ $C_{soil\text{-}gas}$		α = $4x10^{-4}$ $C_{soil\text{-}gas}$		α = $2x10^{-4}$ $C_{soil\text{-}gas}$	
CAS No.	Chemical			(ug/m^3)	(ppbv)	(ug/m^3)	(ppbv)	(ug/m^3)	(ppbv)	(ug/m^3)	(ppbv)	(ug/m^3)	(ppbv)
95501	1,2-Dichlorobenzene		NC	1.0E+05	1.7E+04	2.0E+05	3.3E+04	2.9E+05	4.8E+04	5.0E+05	8.3E+04	1.0E+06	1.7E+05
106467	1,4-Dichlorobenzene		NC	4.0E+05	6.7E+04	8.0E+05	1.3E+05	1.1E+06	1.9E+05	2.0E+06	3.3E+05	4.0E+06	6.7E+05
75718	Dichlorodifluoromethane		NC	1.0E+05	2.0E+04	2.0E+05	4.0E+04	2.9E+05	5.8E+04	5.0E+05	1.0E+05	1.0E+06	2.0E+05
75343	1,1-Dichloroethane		NC	2.5E+05	6.2E+04	5.0E+05	1.2E+05	7.1E+05	1.8E+05	1.3E+06	3.1E+05	2.5E+06	6.2E+05
107062	1,2-Dichloroethane		C	4.7E+03	1.2E+03	9.4E+03	2.3E+03	1.3E+04	3.3E+03	2.3E+04	5.8E+03	4.7E+04	1.2E+04
75354	1,1-Dichloroethylene		NC	1.0E+05	2.5E+04	2.0E+05	5.0E+04	2.9E+05	7.2E+04	5.0E+05	1.3E+05	1.0E+06	2.5E+05
78875	1,2-Dichloropropane		NC	2.0E+03	4.3E+02	4.0E+03	8.7E+02	5.7E+03	1.2E+03	1.0E+04	2.2E+03	2.0E+04	4.3E+03
542756	1,3-Dichloropropene		NC	1.0E+04	2.2E+03	2.0E+04	4.4E+03	2.9E+04	6.3E+03	5.0E+04	1.1E+04	1.0E+05	2.2E+04
60571	Dieldrin		C	2.6E+01	1.7E+00	5.3E+01	3.4E+00	7.6E+01	4.9E+00	**	**	**	**
115297	Endosulfan	X	NC	**	**	**	**	**	**	**	**	**	**
106898	Epichlorohydrin		NC	5.0E+02	1.3E+02	1.0E+03	2.6E+02	1.4E+03	3.8E+02	2.5E+03	6.6E+02	5.0E+03	1.3E+03
60297	Ethyl ether	X	NC	3.5E+05	1.2E+05	7.0E+05	2.3E+05	1.0E+06	3.3E+05	1.8E+06	5.8E+05	3.5E+06	1.2E+06
141786	Ethylacetate	X	NC	1.6E+06	4.4E+05	3.2E+06	8.7E+05	4.5E+06	1.2E+06	7.9E+06	2.2E+06	1.6E+07	4.4E+06
100414	Ethylbenzene		C	1.1E+05	2.5E+04	2.2E+05	5.1E+04	3.2E+05	7.3E+04	5.5E+05	1.3E+05	1.1E+06	2.5E+05
75218	Ethylene oxide		C	1.2E+03	6.8E+02	2.4E+03	1.4E+03	3.5E+03	1.9E+03	6.1E+03	3.4E+03	1.2E+04	6.8E+03
97632	Ethylmethacrylate	X	NC	1.6E+05	3.4E+04	3.2E+05	6.8E+04	4.5E+05	9.6E+04	7.9E+05	1.7E+05	1.6E+06	3.4E+05
86737	Fluorene	X	NC	**	**	**	**	**	**	**	**	**	**
110009	Furan	X	NC	1.8E+03	6.3E+02	3.5E+03	1.3E+03	5.0E+03	1.8E+03	8.8E+03	3.1E+03	1.8E+04	6.3E+03
58899	gamma-HCH (Lindane)	X	C	3.3E+02	2.8E+01	6.6E+02	5.5E+01	9.4E+02	7.9E+01	1.6E+03	1.4E+02	3.3E+03	2.8E+02
76448	Heptachlor		C	9.4E+01	6.1E+00	1.9E+02	1.2E+01	2.7E+02	1.8E+01	4.7E+02	3.1E+01	9.4E+02	6.1E+01
87683	Hexachloro-1,3-butadiene		C	5.5E+03	5.2E+02	1.1E+04	1.0E+03	1.6E+04	1.5E+03	2.8E+04	2.6E+03	5.5E+04	5.2E+03
118741	Hexachlorobenzene		C	2.6E+02	2.3E+01	**	**	**	**	**	**	**	**
77474	Hexachlorocyclopentadiene		NC	1.0E+02	9.0E+00	2.0E+02	1.8E+01	2.9E+02	2.6E+01	5.0E+02	4.5E+01	1.0E+03	9.0E+01
67721	Hexachloroethane		C	3.0E+04	3.1E+03	6.1E+04	6.3E+03	8.7E+04	9.0E+03	1.5E+05	1.6E+04	3.0E+05	3.1E+04
110543	Hexane		NC	1.0E+05	2.8E+04	2.0E+05	5.7E+04	2.9E+05	8.1E+04	5.0E+05	1.4E+05	1.0E+06	2.8E+05
74908	Hydrogen cyanide		NC	1.5E+03	1.4E+03	3.0E+03	2.7E+03	4.3E+03	3.9E+03	7.5E+03	6.8E+03	1.5E+04	1.4E+04
78831	Isobutanol	X	NC	5.3E+05	1.7E+05	1.1E+06	3.5E+05	1.5E+06	5.0E+05	2.6E+06	8.7E+05	5.3E+06	1.7E+06
7439976	Mercury (elemental)		NC	1.5E+02	1.8E+01	3.0E+02	3.7E+01	4.3E+02	5.2E+01	7.5E+02	9.1E+01	1.5E+03	1.8E+02
126987	Methacrylonitrile		NC	3.5E+02	1.3E+02	7.0E+02	2.6E+02	1.0E+03	3.6E+02	1.8E+03	6.4E+02	3.5E+03	1.3E+03
72435	Methoxychlor	X	NC	**	**	**	**	**	**	**	**	**	**
79209	Methyl acetate	X	NC	1.8E+06	5.8E+05	3.5E+06	1.2E+06	5.0E+06	1.7E+06	8.8E+06	2.9E+06	**	**
96333	Methyl acrylate	X	NC	5.3E+04	1.5E+04	1.1E+05	3.0E+04	1.5E+05	4.3E+04	2.6E+05	7.5E+04	5.3E+05	1.5E+05
74839	Methyl bromide		NC	2.5E+03	6.4E+02	5.0E+03	1.3E+03	7.1E+03	1.8E+03	1.3E+04	3.2E+03	2.5E+04	6.4E+03
74873	Methyl chloride (chloromethane)		NC	4.5E+04	2.2E+04	9.0E+04	4.4E+04	1.3E+05	6.2E+04	2.3E+05	1.1E+05	4.5E+05	2.2E+05
108872	Methylcyclohexane		NC	1.5E+06	3.7E+05	3.0E+06	7.5E+05	4.3E+06	1.1E+06	7.5E+06	1.9E+06	1.5E+07	3.7E+06
74953	Methylene bromide	X	NC	1.8E+04	2.5E+03	3.5E+04	4.9E+03	5.0E+04	7.0E+03	8.8E+04	1.2E+04	1.8E+05	2.5E+04
75092	Methylene chloride		C	2.6E+05	7.5E+04	5.2E+05	1.5E+05	7.4E+05	2.1E+05	1.3E+06	3.7E+05	2.6E+06	7.5E+05
78933	Methylethylketone (2-butanone)		NC	5.0E+05	1.7E+05	1.0E+06	3.4E+05	1.4E+06	4.8E+05	2.5E+06	8.5E+05	5.0E+06	1.7E+06
108101	Methylisobutylketone		NC	4.0E+04	9.8E+03	8.0E+04	2.0E+04	1.1E+05	2.8E+04	2.0E+05	4.9E+04	4.0E+05	9.8E+04
80626	Methylmethacrylate		NC	3.5E+05	8.6E+04	7.0E+05	1.7E+05	1.0E+06	2.4E+05	1.8E+06	4.3E+05	3.5E+06	8.6E+05
91576	2-Methylnaphthalene	X	NC	3.5E+04	6.0E+03	7.0E+04	1.2E+04	1.0E+05	1.7E+04	1.8E+05	3.0E+04	3.5E+05	6.0E+04
1634044	MTBE		NC	1.5E+06	4.2E+05	3.0E+06	8.3E+05	4.3E+06	1.2E+06	7.5E+06	2.1E+06	1.5E+07	4.2E+06

Table 3a-SG: Question 5 Soil Gas Screening Levels for Scenario-Specific Vapor Attenuation Factors (α)

Risk = 1 x 10^{-4}

CAS No.	Chemical	Compounds with Provisional Toxicity Data Extrapolated From Oral Sources	Basis of Target Concentration C=cancer risk NC=noncancer risk	Target Soil Gas Concentrations for Different Attenuation Factors									
				α = 2x10^{-3} $C_{soil\text{-}gas}$		α = 1x10^{-3} $C_{soil\text{-}gas}$		α = 7x10^{-4} $C_{soil\text{-}gas}$		α = 4x10^{-4} $C_{soil\text{-}gas}$		α = 2x10^{-4} $C_{soil\text{-}gas}$	
				(ug/m^3)	(ppbv)	(ug/m^3)	(ppbv)	(ug/m^3)	(ppbv)	(ug/m^3)	(ppbv)	(ug/m^3)	(ppbv)
108383	m-Xylene	X	NC	3.5E+06	8.1E+05	7.0E+06	1.6E+06	1.0E+07	2.3E+06	1.8E+07	4.0E+06	3.5E+07	8.1E+06
91203	Naphthalene		NC	1.5E+03	2.9E+02	3.0E+03	5.7E+02	4.3E+03	8.2E+02	7.5E+03	1.4E+03	1.5E+04	2.9E+03
104518	n-Butylbenzene	X	NC	7.0E+04	1.3E+04	1.4E+05	2.6E+04	2.0E+05	3.6E+04	3.5E+05	6.4E+04	7.0E+05	1.3E+05
98953	Nitrobenzene		NC	1.0E+03	2.0E+02	2.0E+03	4.0E+02	2.9E+03	5.7E+02	5.0E+03	9.9E+02	1.0E+04	2.0E+03
79469	2-Nitropropane		C	4.5E+01	1.2E+01	9.0E+01	2.5E+01	1.3E+02	3.5E+01	2.3E+02	6.2E+01	4.5E+02	1.2E+02
924163	N-Nitroso-di-n-butylamine		C	7.6E+01	1.2E+01	1.5E+02	2.4E+01	2.2E+02	3.4E+01	3.8E+02	5.9E+01	7.6E+02	1.2E+02
103651	n-Propylbenzene	X	NC	7.0E+04	1.4E+04	1.4E+05	2.8E+04	2.0E+05	4.1E+04	3.5E+05	7.1E+04	7.0E+05	1.4E+05
88722	o-Nitrotoluene	X	NC	1.8E+04	3.1E+03	3.5E+04	6.2E+03	5.0E+04	8.9E+03	8.8E+04	1.6E+04	1.8E+05	3.1E+04
95476	o-Xylene	X	NC	3.5E+06	8.1E+05	7.0E+06	1.6E+06	1.0E+07	2.3E+06	1.8E+07	4.0E+06	3.5E+07	8.1E+06
106423	p-Xylene	X	NC	3.5E+06	8.1E+05	7.0E+06	1.6E+06	1.0E+07	2.3E+06	1.8E+07	4.0E+06	3.5E+07	8.1E+06
129000	Pyrene	X	NC	**	**	**	**	**	**	**	**	**	**
135988	sec-Butylbenzene	X	NC	7.0E+04	1.3E+04	1.4E+05	2.6E+04	2.0E+05	3.6E+04	3.5E+05	6.4E+04	7.0E+05	1.3E+05
100425	Styrene		NC	5.0E+05	1.2E+05	1.0E+06	2.3E+05	1.4E+06	3.4E+05	2.5E+06	5.9E+05	5.0E+06	1.2E+06
98066	tert-Butylbenzene	X	NC	7.0E+04	1.3E+04	1.4E+05	2.6E+04	2.0E+05	3.6E+04	3.5E+05	6.4E+04	7.0E+05	1.3E+05
630206	1,1,1,2-Tetrachloroethane		C	1.6E+04	2.4E+03	3.3E+04	4.8E+03	4.7E+04	6.8E+03	8.2E+04	1.2E+04	1.6E+05	2.4E+04
79345	1,1,2,2-Tetrachloroethane		C	2.1E+03	3.1E+02	4.2E+03	6.1E+02	6.0E+03	8.7E+02	1.0E+04	1.5E+03	2.1E+04	3.1E+03
127184	Tetrachloroethylene		C	4.1E+04	6.0E+03	8.1E+04	1.2E+04	1.2E+05	1.7E+04	2.0E+05	3.0E+04	4.1E+05	6.0E+04
108883	Toluene		NC	2.0E+05	5.3E+04	4.0E+05	1.1E+05	5.7E+05	1.5E+05	1.0E+06	2.7E+05	2.0E+06	5.3E+05
156605	trans-1,2-Dichloroethylene	X	NC	3.5E+04	8.8E+03	7.0E+04	1.8E+04	1.0E+05	2.5E+04	1.8E+05	4.4E+04	3.5E+05	8.8E+04
76131	1,1,2-Trichloro-1,2,2-trifluoroethane		NC	1.5E+07	2.0E+06	3.0E+07	3.9E+06	4.3E+07	5.6E+06	7.5E+07	9.8E+06	1.5E+08	2.0E+07
120821	1,2,4-Trichlorobenzene		NC	1.0E+05	1.3E+04	2.0E+05	2.7E+04	2.9E+05	3.8E+04	5.0E+05	6.7E+04	1.0E+06	1.3E+05
79005	1,1,2-Trichloroethane		C	7.6E+03	1.4E+03	1.5E+04	2.8E+03	2.2E+04	4.0E+03	3.8E+04	7.0E+03	7.6E+04	1.4E+04
71556	1,1,1-Trichloroethane		NC	1.1E+06	2.0E+05	2.2E+06	4.0E+05	3.1E+06	5.8E+05	5.5E+06	1.0E+06	1.1E+07	2.0E+06
79016	Trichloroethylene ††	X	C	1.1E+03	2.1E+02	2.2E+03	4.1E+02	3.2E+03	5.9E+02	5.5E+03	1.0E+03	1.1E+04	2.1E+03
75694	Trichlorofluoromethane		NC	3.5E+05	6.2E+04	7.0E+05	1.2E+05	1.0E+06	1.8E+05	1.8E+06	3.1E+05	3.5E+06	6.2E+05
96184	1,2,3-Trichloropropane		NC	2.5E+03	4.1E+02	4.9E+03	8.1E+02	7.0E+03	1.2E+03	1.2E+04	2.0E+03	2.5E+04	4.1E+03
95636	1,2,4-Trimethylbenzene		NC	3.0E+03	6.1E+02	6.0E+03	1.2E+03	8.5E+03	1.7E+03	1.5E+04	3.0E+03	3.0E+04	6.1E+03
108678	1,3,5-Trimethylbenzene		NC	3.0E+03	6.1E+02	6.0E+03	1.2E+03	8.5E+03	1.7E+03	1.5E+04	3.0E+03	3.0E+04	6.1E+03
108054	Vinyl acetate		NC	1.0E+05	2.8E+04	2.0E+05	5.7E+04	2.9E+05	8.1E+04	5.0E+05	1.4E+05	1.0E+06	2.8E+05
75014	Vinyl chloride (chloroethene)		C	1.4E+04	5.4E+03	2.8E+04	1.1E+04	4.0E+04	1.5E+04	6.9E+04	2.7E+04	1.4E+05	5.4E+04

* Health-based target breathing concentration exceeds maximum possible chemical vapor concentration (pathway incomplete)

** Target soil gas concentration exceeds maximum possible vapor concentration at this soil gas to indoor air attenuation factor (pathway incomplete)

†† The target concentration for trichloroethylene is based on the upper bound cancer slope factor identified in EPA's draft risk assessment for trichloroethylene (US EPA, 2001). The slope factor is based on state-of-the-art methodology, however the TCE assessment is still undergoing review. As a result, the slope factor and the target concentration values for TCE may be revised further. (See Appendix D.)

Table 3b-SG: Question 5 Soil Gas Screening Levels for Scenario-Specific Vapor Attenuation Factors (α) DRAFT

Risk = 1 x 10^{-5}

				Target Soil Gas Concentrations for Different Attenuation Factors									
		Compounds with Provisional Toxicity Data Extrapolated	Basis of Target Concentration C=cancer risk	$\alpha = 2x10^{-3}$ $C_{soil-gas}$		$\alpha = 1x10^{-3}$ $C_{soil-gas}$		$\alpha = 7x10^{-4}$ $C_{soil-gas}$		$\alpha = 4x10^{-4}$ $C_{soil-gas}$		$\alpha = 2x10^{-4}$ $C_{soil-gas}$	
CAS No.	Chemical	From Oral Sources	NC=noncancer risk	(ug/m^3)	(ppbv)	(ug/m^3)	(ppbv)	(ug/m^3)	(ppbv)	(ug/m^3)	(ppbv)	(ug/m^3)	(ppbv)
83329	Acenaphthene	X	NC	**	**	**	**	**	**	**	**	**	**
75070	Acetaldehyde		NC	4.5E+03	2.5E+03	9.0E+03	5.0E+03	1.3E+04	7.1E+03	2.2E+04	1.2E+04	4.5E+04	2.5E+04
67641	Acetone	X	NC	1.8E+05	7.4E+04	3.5E+05	1.5E+05	5.0E+05	2.1E+05	8.8E+05	3.7E+05	1.8E+06	7.4E+05
75058	Acetonitrile		NC	3.0E+04	1.8E+04	6.0E+04	3.6E+04	8.6E+04	5.1E+04	1.5E+05	8.9E+04	3.0E+05	1.8E+05
98862	Acetophenone	X	NC	1.8E+05	3.6E+04	3.5E+05	7.1E+04	5.0E+05	1.0E+05	8.8E+05	1.8E+05	1.8E+06	3.6E+05
107028	Acrolein		NC	1.0E+01	4.4E+00	2.0E+01	8.7E+00	2.9E+01	1.2E+01	5.0E+01	2.2E+01	1.0E+02	4.4E+01
107131	Acrylonitrile		C	1.8E+02	8.3E+01	3.6E+02	1.7E+02	5.1E+02	2.4E+02	8.9E+02	4.1E+02	1.8E+03	8.3E+02
309002	Aldrin		C	2.5E+00	1.7E-01	5.0E+00	3.3E-01	7.1E+00	4.8E-01	1.2E+01	8.3E-01	2.5E+01	1.7E+00
319846	alpha-HCH (alpha-BHC)		C	6.8E+00	5.7E-01	1.4E+01	1.1E+00	1.9E+01	1.6E+00	3.4E+01	2.8E+00	6.8E+01	5.7E+00
100527	Benzaldehyde	X	NC	1.8E+05	4.0E+04	3.5E+05	8.1E+04	5.0E+05	1.2E+05	8.8E+05	2.0E+05	1.8E+06	4.0E+05
71432	Benzene		C	1.6E+03	4.9E+02	3.1E+03	9.8E+02	4.5E+03	1.4E+03	7.8E+03	2.4E+03	1.6E+04	4.9E+03
205992	Benzo(b)fluoranthene	X	C	**	**	**	**	**	**	**	**	**	**
100447	Benzylchloride	X	C	2.5E+02	4.8E+01	5.0E+02	9.7E+01	7.2E+02	1.4E+02	1.3E+03	2.4E+02	2.5E+03	4.8E+02
91587	beta-Chloronaphthalene	X	NC	1.4E+05	2.1E+04	**	**	**	**	**	**	**	**
92524	Biphenyl	X	NC	8.8E+04	1.4E+04	**	**	**	**	**	**	**	**
111444	Bis(2-chloroethyl)ether		C	3.7E+01	6.3E+00	7.4E+01	1.3E+01	1.1E+02	1.8E+01	1.8E+02	3.2E+01	3.7E+02	6.3E+01
108601	Bis(2-chloroisopropyl)ether		C	1.2E+03	1.7E+02	2.4E+03	3.5E+02	3.5E+03	5.0E+02	6.1E+03	8.7E+02	1.2E+04	1.7E+03
542881	Bis(chloromethyl)ether		C	2.0E-01	4.2E-02	3.9E-01	8.4E-02	5.6E-01	1.2E-01	9.8E-01	2.1E-01	2.0E+00	4.2E-01
75274	Bromodichloromethane	X	C	6.9E+02	1.0E+02	1.4E+03	2.1E+02	2.0E+03	2.9E+02	3.4E+03	5.1E+02	6.9E+03	1.0E+03
75252	Bromoform		C	1.1E+04	1.1E+03	2.2E+04	2.1E+03	3.2E+04	3.1E+03	5.5E+04	5.4E+03	1.1E+05	1.1E+04
106990	1,3-Butadiene		C	4.3E+01	2.0E+01	8.7E+01	3.9E+01	1.2E+02	5.6E+01	2.2E+02	9.8E+01	4.3E+02	2.0E+02
75150	Carbon disulfide		NC	3.5E+05	1.1E+05	7.0E+05	2.2E+05	1.0E+06	3.2E+05	1.8E+06	5.6E+05	3.5E+06	1.1E+06
56235	Carbon tetrachloride		C	8.1E+02	1.3E+02	1.6E+03	2.6E+02	2.3E+03	3.7E+02	4.1E+03	6.5E+02	8.1E+03	1.3E+03
57749	Chlordane		C	**	**	**	**	**	**	**	**	**	**
126998	2-Chloro-1,3-butadiene (chloroprene)		NC	3.5E+03	9.7E+02	7.0E+03	1.9E+03	1.0E+04	2.8E+03	1.8E+04	4.8E+03	3.5E+04	9.7E+03
108907	Chlorobenzene		NC	3.0E+04	6.5E+03	6.0E+04	1.3E+04	8.5E+04	1.8E+04	1.5E+05	3.2E+04	3.0E+05	6.5E+04
109693	1-Chlorobutane	X	NC	7.0E+05	1.8E+05	1.4E+06	3.7E+05	2.0E+06	5.3E+05	3.5E+06	9.2E+05	7.0E+06	1.8E+06
124481	Chlorodibromomethane	X	C	5.1E+02	6.0E+01	1.0E+03	1.2E+02	1.4E+03	1.7E+02	2.5E+03	3.0E+02	5.1E+03	6.0E+02
75456	Chlorodifluoromethane		NC	**	**	**	**	**	**	**	**	**	**
75003	Chloroethane (ethyl chloride)		NC	5.0E+06	1.9E+06	1.0E+07	3.8E+06	1.4E+07	5.4E+06	2.5E+07	9.5E+06	5.0E+07	1.9E+07
67663	Chloroform		C	5.3E+02	1.1E+02	1.1E+03	2.2E+02	1.5E+03	3.1E+02	2.6E+03	5.4E+02	5.3E+03	1.1E+03
95578	2-Chlorophenol	X	NC	8.8E+03	1.7E+03	1.8E+04	3.3E+03	2.5E+04	4.8E+03	4.4E+04	8.3E+03	8.8E+04	1.7E+04
75296	2-Chloropropane		NC	5.1E+04	1.6E+04	1.0E+05	3.2E+04	1.5E+05	4.5E+04	2.5E+05	7.9E+04	5.1E+05	1.6E+05
218019	Chrysene	X	C	**	**	**	**	**	**	**	**	**	**
156592	cis-1,2-Dichloroethylene	X	NC	1.8E+04	4.4E+03	3.5E+04	8.8E+03	5.0E+04	1.3E+04	8.8E+04	2.2E+04	1.8E+05	4.4E+04
123739	Crotonaldehyde (2-butenal)	X	C	2.2E+01	7.8E+00	4.5E+01	1.6E+01	6.4E+01	2.2E+01	1.1E+02	3.9E+01	2.2E+02	7.8E+01
98828	Cumene		NC	2.0E+05	4.1E+04	4.0E+05	8.1E+04	5.7E+05	1.2E+05	1.0E+06	2.0E+05	2.0E+06	4.1E+05
72559	DDE	X	C	**	**	**	**	**	**	**	**	**	**
132649	Dibenzofuran	X	NC	**	**	**	**	**	**	**	**	**	**
96128	1,2-Dibromo-3-chloropropane		NC	1.0E+02	1.0E+01	2.0E+02	2.1E+01	2.9E+02	3.0E+01	5.0E+02	5.2E+01	1.0E+03	1.0E+02
106934	1,2-Dibromoethane (ethylene dibromide)		C	5.5E+01	7.2E+00	1.1E+02	1.4E+01	1.6E+02	2.1E+01	2.8E+02	3.6E+01	5.5E+02	7.2E+01
541731	1,3-Dichlorobenzene	X	NC	5.3E+04	8.7E+03	1.1E+05	1.7E+04	1.5E+05	2.5E+04	2.6E+05	4.4E+04	5.3E+05	8.7E+04

Table 3b-SG: Question 5 Soil Gas Screening Levels for Scenario-Specific Vapor Attenuation Factors (α) **DRAFT**

Risk = 1 x 10^{-5}

CAS No.	Chemical	Compounds with Provisional Toxicity Data Extrapolated From Oral Sources	Basis of Target Concentration C=cancer risk NC=noncancer risk	Target Soil Gas Concentrations for Different Attenuation Factors									
				α = 2x10^{-3} $C_{soil-gas}$		α = 1x10^{-3} $C_{soil-gas}$		α = 7x10^{-4} $C_{soil-gas}$		α = 4x10^{-4} $C_{soil-gas}$		α = 2x10^{-4} $C_{soil-gas}$	
				(ug/m^3)	(ppbv)	(ug/m^3)	(ppbv)	(ug/m^3)	(ppbv)	(ug/m^3)	(ppbv)	(ug/m^3)	(ppbv)
95501	1,2-Dichlorobenzene		NC	1.0E+05	1.7E+04	2.0E+05	3.3E+04	2.9E+05	4.8E+04	5.0E+05	8.3E+04	1.0E+06	1.7E+05
106467	1,4-Dichlorobenzene		NC	4.0E+05	6.7E+04	8.0E+05	1.3E+05	1.1E+06	1.9E+05	2.0E+06	3.3E+05	4.0E+06	6.7E+05
75718	Dichlorodifluoromethane		NC	1.0E+05	2.0E+04	2.0E+05	4.0E+04	2.9E+05	5.8E+04	5.0E+05	1.0E+05	1.0E+06	2.0E+05
75343	1,1-Dichloroethane		NC	2.5E+05	6.2E+04	5.0E+05	1.2E+05	7.1E+05	1.8E+05	1.3E+06	3.1E+05	2.5E+06	6.2E+05
107062	1,2-Dichloroethane		C	4.7E+02	1.2E+02	9.4E+02	2.3E+02	1.3E+03	3.3E+02	2.3E+03	5.8E+02	4.7E+03	1.2E+03
75354	1,1-Dichloroethylene		NC	1.0E+05	2.5E+04	2.0E+05	5.0E+04	2.9E+05	7.2E+04	5.0E+05	1.3E+05	1.0E+06	2.5E+05
78875	1,2-Dichloropropane		NC	2.0E+03	4.3E+02	4.0E+03	8.7E+02	5.7E+03	1.2E+03	1.0E+04	2.2E+03	2.0E+04	4.3E+03
542756	1,3-Dichloropropene		C	3.0E+03	6.7E+02	6.1E+03	1.3E+03	8.7E+03	1.9E+03	1.5E+04	3.4E+03	3.0E+04	6.7E+03
60571	Dieldrin		C	2.6E+00	1.7E-01	5.3E+00	3.4E-01	7.6E+00	4.9E-01	1.3E+01	8.5E-01	2.6E+01	1.7E+00
115297	Endosulfan	X	NC	**	**	**	**	**	**	**	**	**	**
106898	Epichlorohydrin		NC	5.0E+02	1.3E+02	1.0E+03	2.6E+02	1.4E+03	3.8E+02	2.5E+03	6.6E+02	5.0E+03	1.3E+03
60297	Ethyl ether	X	NC	3.5E+05	1.2E+05	7.0E+05	2.3E+05	1.0E+06	3.3E+05	1.8E+06	5.8E+05	3.5E+06	1.2E+06
141786	Ethylacetate	X	NC	1.6E+06	4.4E+05	3.2E+06	8.7E+05	4.5E+06	1.2E+06	7.9E+06	2.2E+06	1.6E+07	4.4E+06
100414	Ethylbenzene		C	1.1E+04	2.5E+03	2.2E+04	5.1E+03	3.2E+04	7.3E+03	5.5E+04	1.3E+04	1.1E+05	2.5E+04
75218	Ethylene oxide		C	1.2E+02	6.8E+01	2.4E+02	1.4E+02	3.5E+02	1.9E+02	6.1E+02	3.4E+02	1.2E+03	6.8E+02
97632	Ethylmethacrylate	X	NC	1.6E+05	3.4E+04	3.2E+05	6.8E+04	4.5E+05	9.6E+04	7.9E+05	1.7E+05	1.6E+06	3.4E+05
86737	Fluorene	X	NC	**	**	**	**	**	**	**	**	**	**
110009	Furan	X	NC	1.8E+03	6.3E+02	3.5E+03	1.3E+03	5.0E+03	1.8E+03	8.8E+03	3.1E+03	1.8E+04	6.3E+03
58899	gamma-HCH (Lindane)	X	C	3.3E+01	2.8E+00	6.6E+01	5.5E+00	9.4E+01	7.9E+00	1.6E+02	1.4E+01	3.3E+02	2.8E+01
76448	Heptachlor		C	9.4E+00	6.1E-01	1.9E+01	1.2E+00	2.7E+01	1.8E+00	4.7E+01	3.1E+00	9.4E+01	6.1E+00
87683	Hexachloro-1,3-butadiene		C	5.5E+02	5.2E+01	1.1E+03	1.0E+02	1.6E+03	1.5E+02	2.8E+03	2.6E+02	5.5E+03	5.2E+02
118741	Hexachlorobenzene		C	2.6E+01	2.3E+00	5.3E+01	4.5E+00	7.6E+01	6.5E+00	1.3E+02	1.1E+01	2.6E+02	2.3E+01
77474	Hexachlorocyclopentadiene		NC	1.0E+02	9.0E+00	2.0E+02	1.8E+01	2.9E+02	2.6E+01	5.0E+02	4.5E+01	1.0E+03	9.0E+01
67721	Hexachloroethane		C	3.0E+03	3.1E+02	6.1E+03	6.3E+02	8.7E+03	9.0E+02	1.5E+04	1.6E+03	3.0E+04	3.1E+03
110543	Hexane		NC	1.0E+05	2.8E+04	2.0E+05	5.7E+04	2.9E+05	8.1E+04	5.0E+05	1.4E+05	1.0E+06	2.8E+05
74908	Hydrogen cyanide		NC	1.5E+03	1.4E+03	3.0E+03	2.7E+03	4.3E+03	3.9E+03	7.5E+03	6.8E+03	1.5E+04	1.4E+04
78831	Isobutanol	X	NC	5.3E+05	1.7E+05	1.1E+06	3.5E+05	1.5E+06	5.0E+05	2.6E+06	8.7E+05	5.3E+06	1.7E+06
7439976	Mercury (elemental)		NC	1.5E+02	1.8E+01	3.0E+02	3.7E+01	4.3E+02	5.2E+01	7.5E+02	9.1E+01	1.5E+03	1.8E+02
126987	Methacrylonitrile		NC	3.5E+02	1.3E+02	7.0E+02	2.6E+02	1.0E+03	3.6E+02	1.8E+03	6.4E+02	3.5E+03	1.3E+03
72435	Methoxychlor	X	NC	**	**	**	**	**	**	**	**	**	**
79209	Methyl acetate	X	NC	1.8E+06	5.8E+05	3.5E+06	1.2E+06	5.0E+06	1.7E+06	8.8E+06	2.9E+06	**	**
96333	Methyl acrylate	X	NC	5.3E+04	1.5E+04	1.1E+05	3.0E+04	1.5E+05	4.3E+04	2.6E+05	7.5E+04	5.3E+05	1.5E+05
74839	Methyl bromide		NC	2.5E+03	6.4E+02	5.0E+03	1.3E+03	7.1E+03	1.8E+03	1.3E+04	3.2E+03	2.5E+04	6.4E+03
74873	Methyl chloride (chloromethane)		C	1.2E+04	5.9E+03	2.4E+04	1.2E+04	3.5E+04	1.7E+04	6.1E+04	2.9E+04	1.2E+05	5.9E+04
108872	Methylcyclohexane		NC	1.5E+06	3.7E+05	3.0E+06	7.5E+05	4.3E+06	1.1E+06	7.5E+06	1.9E+06	1.5E+07	3.7E+06
74953	Methylene bromide	X	NC	1.8E+04	2.5E+03	3.5E+04	4.9E+03	5.0E+04	7.0E+03	8.8E+04	1.2E+04	1.8E+05	2.5E+04
75092	Methylene chloride		C	2.6E+04	7.5E+03	5.2E+04	1.5E+04	7.4E+04	2.1E+04	1.3E+05	3.7E+04	2.6E+05	7.5E+04
78933	Methylethylketone (2-butanone)		NC	5.0E+05	1.7E+05	1.0E+06	3.4E+05	1.4E+06	4.8E+05	2.5E+06	8.5E+05	5.0E+06	1.7E+06
108101	Methylisobutylketone		NC	4.0E+04	9.8E+03	8.0E+04	2.0E+04	1.1E+05	2.8E+04	2.0E+05	4.9E+04	4.0E+05	9.8E+04
80626	Methylmethacrylate		NC	3.5E+05	8.6E+04	7.0E+05	1.7E+05	1.0E+06	2.4E+05	1.8E+06	4.3E+05	3.5E+06	8.6E+05
91576	2-Methylnaphthalene	X	NC	3.5E+04	6.0E+03	7.0E+04	1.2E+04	1.0E+05	1.7E+04	1.8E+05	3.0E+04	3.5E+05	6.0E+04
1634044	MTBE		NC	1.5E+06	4.2E+05	3.0E+06	8.3E+05	4.3E+06	1.2E+06	7.5E+06	2.1E+06	1.5E+07	4.2E+06

Table 3b-SG: Question 5 Soil Gas Screening Levels for Scenario-Specific Vapor Attenuation Factors (α) **DRAFT**

Risk = 1 x 10^{-5}

CAS No.	Chemical	Compounds with Provisional Toxicity Data Extrapolated From Oral Sources	Basis of Target Concentration C=cancer risk NC=noncancer risk	Target Soil Gas Concentrations for Different Attenuation Factors									
				$\alpha = 2\text{x}10^{-3}$ $C_{soil\text{-}gas}$		$\alpha = 1\text{x}10^{-3}$ $C_{soil\text{-}gas}$		$\alpha = 7\text{x}10^{-4}$ $C_{soil\text{-}gas}$		$\alpha = 4\text{x}10^{-4}$ $C_{soil\text{-}gas}$		$\alpha = 2\text{x}10^{-4}$ $C_{soil\text{-}gas}$	
				(ug/m^3)	(ppbv)	(ug/m^3)	(ppbv)	(ug/m^3)	(ppbv)	(ug/m^3)	(ppbv)	(ug/m^3)	(ppbv)
108383	m-Xylene	X	NC	3.5E+06	8.1E+05	7.0E+06	1.6E+06	1.0E+07	2.3E+06	1.8E+07	4.0E+06	3.5E+07	8.1E+06
91203	Naphthalene		NC	1.5E+03	2.9E+02	3.0E+03	5.7E+02	4.3E+03	8.2E+02	7.5E+03	1.4E+03	1.5E+04	2.9E+03
104518	n-Butylbenzene	X	NC	7.0E+04	1.3E+04	1.4E+05	2.6E+04	2.0E+05	3.6E+04	3.5E+05	6.4E+04	7.0E+05	1.3E+05
98953	Nitrobenzene		NC	1.0E+03	2.0E+02	2.0E+03	4.0E+02	2.9E+03	5.7E+02	5.0E+03	9.9E+02	1.0E+04	2.0E+03
79469	2-Nitropropane		C	4.5E+00	1.2E+00	9.0E+00	2.5E+00	1.3E+01	3.5E+00	2.3E+01	6.2E+00	4.5E+01	1.2E+01
924163	N-Nitroso-di-n-butylamine		C	7.6E+00	1.2E+00	1.5E+01	2.4E+00	2.2E+01	3.4E+00	3.8E+01	5.9E+00	7.6E+01	1.2E+01
103651	n-Propylbenzene	X	NC	7.0E+04	1.4E+04	1.4E+05	2.8E+04	2.0E+05	4.1E+04	3.5E+05	7.1E+04	7.0E+05	1.4E+05
88722	o-Nitrotoluene	X	NC	1.8E+04	3.1E+03	3.5E+04	6.2E+03	5.0E+04	8.9E+03	8.8E+04	1.6E+04	1.8E+05	3.1E+04
95476	o-Xylene	X	NC	3.5E+06	8.1E+05	7.0E+06	1.6E+06	1.0E+07	2.3E+06	1.8E+07	4.0E+06	3.5E+07	8.1E+06
106423	p-Xylene	X	NC	3.5E+06	8.1E+05	7.0E+06	1.6E+06	1.0E+07	2.3E+06	1.8E+07	4.0E+06	3.5E+07	8.1E+06
129000	Pyrene	X	NC	**	**	**	**	**	**	**	**	**	**
135988	sec-Butylbenzene	X	NC	7.0E+04	1.3E+04	1.4E+05	2.6E+04	2.0E+05	3.6E+04	3.5E+05	6.4E+04	7.0E+05	1.3E+05
100425	Styrene		NC	5.0E+05	1.2E+05	1.0E+06	2.3E+05	1.4E+06	3.4E+05	2.5E+06	5.9E+05	5.0E+06	1.2E+06
98066	tert-Butylbenzene	X	NC	7.0E+04	1.3E+04	1.4E+05	2.6E+04	2.0E+05	3.6E+04	3.5E+05	6.4E+04	7.0E+05	1.3E+05
630206	1,1,1,2-Tetrachloroethane		C	1.6E+03	2.4E+02	3.3E+03	4.8E+02	4.7E+03	6.8E+02	8.2E+03	1.2E+03	1.6E+04	2.4E+03
79345	1,1,2,2-Tetrachloroethane		C	2.1E+02	3.1E+01	4.2E+02	6.1E+01	6.0E+02	8.7E+01	1.0E+03	1.5E+02	2.1E+03	3.1E+02
127184	Tetrachloroethylene		C	4.1E+03	6.0E+02	8.1E+03	1.2E+03	1.2E+04	1.7E+03	2.0E+04	3.0E+03	4.1E+04	6.0E+03
108883	Toluene		NC	2.0E+05	5.3E+04	4.0E+05	1.1E+05	5.7E+05	1.5E+05	1.0E+06	2.7E+05	2.0E+06	5.3E+05
156605	trans-1,2-Dichloroethylene	X	NC	3.5E+04	8.8E+03	7.0E+04	1.8E+04	1.0E+05	2.5E+04	1.8E+05	4.4E+04	3.5E+05	8.8E+04
76131	1,1,2-Trichloro-1,2,2-trifluoroethane		NC	1.5E+07	2.0E+06	3.0E+07	3.9E+06	4.3E+07	5.6E+06	7.5E+07	9.8E+06	1.5E+08	2.0E+07
120821	1,2,4-Trichlorobenzene		NC	1.0E+05	1.3E+04	2.0E+05	2.7E+04	2.9E+05	3.8E+04	5.0E+05	6.7E+04	1.0E+06	1.3E+05
79005	1,1,2-Trichloroethane		C	7.6E+02	1.4E+02	1.5E+03	2.8E+02	2.2E+03	4.0E+02	3.8E+03	7.0E+02	7.6E+03	1.4E+03
71556	1,1,1-Trichloroethane		NC	1.1E+06	2.0E+05	2.2E+06	4.0E+05	3.1E+06	5.8E+05	5.5E+06	1.0E+06	1.1E+07	2.0E+06
79016	Trichloroethylene ††	X	C	1.1E+02	2.1E+01	2.2E+02	4.1E+01	3.2E+02	5.9E+01	5.5E+02	1.0E+02	1.1E+03	2.1E+02
75694	Trichlorofluoromethane		NC	3.5E+05	6.2E+04	7.0E+05	1.2E+05	1.0E+06	1.8E+05	1.8E+06	3.1E+05	3.5E+06	6.2E+05
96184	1,2,3-Trichloropropane		NC	2.5E+03	4.1E+02	4.9E+03	8.1E+02	7.0E+03	1.2E+03	1.2E+04	2.0E+03	2.5E+04	4.1E+03
95636	1,2,4-Trimethylbenzene		NC	3.0E+03	6.1E+02	6.0E+03	1.2E+03	8.5E+03	1.7E+03	1.5E+04	3.0E+03	3.0E+04	6.1E+03
108678	1,3,5-Trimethylbenzene		NC	3.0E+03	6.1E+02	6.0E+03	1.2E+03	8.5E+03	1.7E+03	1.5E+04	3.0E+03	3.0E+04	6.1E+03
108054	Vinyl acetate		NC	1.0E+05	2.8E+04	2.0E+05	5.7E+04	2.9E+05	8.1E+04	5.0E+05	1.4E+05	1.0E+06	2.8E+05
75014	Vinyl chloride (chloroethene)		C	1.4E+03	5.4E+02	2.8E+03	1.1E+03	4.0E+03	1.5E+03	6.9E+03	2.7E+03	1.4E+04	5.4E+03

* Health-based target breathing concentration exceeds maximum possible chemical vapor concentration (pathway incomplete)

** Target soil gas concentration exceeds maximum possible vapor concentration at this soil gas to indoor air attenuation factor (pathway incomplete)

†† The target concentration for trichloroethylene is based on the upper bound cancer slope factor identified in EPA's draft risk assessment for trichloroethylene (US EPA, 2001). The slope factor is based on state-of-the-art methodology, however the TCE assessment is still undergoing review. As a result, the slope factor and the target concentration values for TCE may be revised further. (See Appendix D.)

Table 3c-SG: Question 5 Soil Gas Screening Levels for Scenario-Specific Vapor Attenuation Factors (α) **DRAFT**

Risk = 1 x 10^{-6}

				Target Soil Gas Concentrations for Different Attenuation Factors									
		Compounds with Provisional Toxicity Data Extrapolated From Oral Sources	Basis of Target Concentration C=cancer risk NC=noncancer risk	$\alpha = 2\times10^{-3}$ $C_{soil\text{-}gas}$		$\alpha = 1\times10^{-3}$ $C_{soil\text{-}gas}$		$\alpha = 7\times10^{-4}$ $C_{soil\text{-}gas}$		$\alpha = 4\times10^{-4}$ $C_{soil\text{-}gas}$		$\alpha = 2\times10^{-4}$ $C_{soil\text{-}gas}$	
CAS No.	Chemical			(ug/m^3)	(ppbv)	(ug/m^3)	(ppbv)	(ug/m^3)	(ppbv)	(ug/m^3)	(ppbv)	(ug/m^3)	(ppbv)
83329	Acenaphthene	X	NC	**	**	**	**	**	**	**	**	**	**
75070	Acetaldehyde		C	5.5E+02	3.1E+02	1.1E+03	6.1E+02	1.6E+03	8.8E+02	2.8E+03	1.5E+03	5.5E+03	3.1E+03
67641	Acetone	X	NC	1.8E+05	7.4E+04	3.5E+05	1.5E+05	5.0E+05	2.1E+05	8.8E+05	3.7E+05	1.8E+06	7.4E+05
75058	Acetonitrile		NC	3.0E+04	1.8E+04	6.0E+04	3.6E+04	8.6E+04	5.1E+04	1.5E+05	8.9E+04	3.0E+05	1.8E+05
98862	Acetophenone	X	NC	1.8E+05	3.6E+04	3.5E+05	7.1E+04	5.0E+05	1.0E+05	8.8E+05	1.8E+05	1.8E+06	3.6E+05
107028	Acrolein		NC	1.0E+01	4.4E+00	2.0E+01	8.7E+00	2.9E+01	1.2E+01	5.0E+01	2.2E+01	1.0E+02	4.4E+01
107131	Acrylonitrile		C	1.8E+01	8.3E+00	3.6E+01	1.7E+01	5.1E+01	2.4E+01	8.9E+01	4.1E+01	1.8E+02	8.3E+01
309002	Aldrin		C	2.5E-01	1.7E-02	5.0E-01	3.3E-02	7.1E-01	4.8E-02	1.2E+00	8.3E-02	2.5E+00	1.7E-01
319846	alpha-HCH (alpha-BHC)		C	6.8E-01	5.7E-02	1.4E+00	1.1E-01	1.9E+00	1.6E-01	3.4E+00	2.8E-01	6.8E+00	5.7E-01
100527	Benzaldehyde	X	NC	1.8E+05	4.0E+04	3.5E+05	8.1E+04	5.0E+05	1.2E+05	8.8E+05	2.0E+05	1.8E+06	4.0E+05
71432	Benzene		C	1.6E+02	4.9E+01	3.1E+02	9.8E+01	4.5E+02	1.4E+02	7.8E+02	2.4E+02	1.6E+03	4.9E+02
205992	Benzo(b)fluoranthene	X	C	5.8E+00	5.6E-01	**	**	**	**	**	**	**	**
100447	Benzylchloride	X	C	2.5E+01	4.8E+00	5.0E+01	9.7E+00	7.2E+01	1.4E+01	1.3E+02	2.4E+01	2.5E+02	4.8E+01
91587	beta-Chloronaphthalene	X	NC	1.4E+05	2.1E+04	**	**	**	**	**	**	**	**
92524	Biphenyl	X	NC	8.8E+04	1.4E+04	**	**	**	**	**	**	**	**
111444	Bis(2-chloroethyl)ether		C	3.7E+00	6.3E-01	7.4E+00	1.3E+00	1.1E+01	1.8E+00	1.8E+01	3.2E+00	3.7E+01	6.3E+00
108601	Bis(2-chloroisopropyl)ether		C	1.2E+02	1.7E+01	2.4E+02	3.5E+01	3.5E+02	5.0E+01	6.1E+02	8.7E+01	1.2E+03	1.7E+02
542881	Bis(chloromethyl)ether		C	2.0E-02	4.2E-03	3.9E-02	8.4E-03	5.6E-02	1.2E-02	9.8E-02	2.1E-02	2.0E-01	4.2E-02
75274	Bromodichloromethane	X	C	6.9E+01	1.0E+01	1.4E+02	2.1E+01	2.0E+02	2.9E+01	3.4E+02	5.1E+01	6.9E+02	1.0E+02
75252	Bromoform		C	1.1E+03	1.1E+02	2.2E+03	2.1E+02	3.2E+03	3.1E+02	5.5E+03	5.4E+02	1.1E+04	1.1E+03
106990	1,3-Butadiene		C	4.3E+00	2.0E+00	8.7E+00	3.9E+00	1.2E+01	5.6E+00	2.2E+01	9.8E+00	4.3E+01	2.0E+01
75150	Carbon disulfide		NC	3.5E+05	1.1E+05	7.0E+05	2.2E+05	1.0E+06	3.2E+05	1.8E+06	5.6E+05	3.5E+06	1.1E+06
56235	Carbon tetrachloride		C	8.1E+01	1.3E+01	1.6E+02	2.6E+01	2.3E+02	3.7E+01	4.1E+02	6.5E+01	8.1E+02	1.3E+02
57749	Chlordane		C	1.2E+01	7.3E-01	2.4E+01	1.5E+00	3.5E+01	2.1E+00	6.1E+01	3.6E+00	**	**
126998	2-Chloro-1,3-butadiene (chloroprene)		NC	3.5E+03	9.7E+02	7.0E+03	1.9E+03	1.0E+04	2.8E+03	1.8E+04	4.8E+03	3.5E+04	9.7E+03
108907	Chlorobenzene		NC	3.0E+04	6.5E+03	6.0E+04	1.3E+04	8.5E+04	1.8E+04	1.5E+05	3.2E+04	3.0E+05	6.5E+04
109693	1-Chlorobutane	X	NC	7.0E+05	1.8E+05	1.4E+06	3.7E+05	2.0E+06	5.3E+05	3.5E+06	9.2E+05	7.0E+06	1.8E+06
124481	Chlorodibromomethane	X	C	5.1E+01	6.0E+00	1.0E+02	1.2E+01	1.4E+02	1.7E+01	2.5E+02	3.0E+01	5.1E+02	6.0E+01
75456	Chlorodifluoromethane		NC	**	**	**	**	**	**	**	**	**	**
75003	Chloroethane (ethyl chloride)		NC	5.0E+06	1.9E+06	1.0E+07	3.8E+06	1.4E+07	5.4E+06	2.5E+07	9.5E+06	5.0E+07	1.9E+07
67663	Chloroform		C	5.3E+01	1.1E+01	1.1E+02	2.2E+01	1.5E+02	3.1E+01	2.6E+02	5.4E+01	5.3E+02	1.1E+02
95578	2-Chlorophenol	X	NC	8.8E+03	1.7E+03	1.8E+04	3.3E+03	2.5E+04	4.8E+03	4.4E+04	8.3E+03	8.8E+04	1.7E+04
75296	2-Chloropropane		NC	5.1E+04	1.6E+04	1.0E+05	3.2E+04	1.5E+05	4.5E+04	2.5E+05	7.9E+04	5.1E+05	1.6E+05
218019	Chrysene	X	C	**	**	**	**	**	**	**	**	**	**
156592	cis-1,2-Dichloroethylene	X	NC	1.8E+04	4.4E+03	3.5E+04	8.8E+03	5.0E+04	1.3E+04	8.8E+04	2.2E+04	1.8E+05	4.4E+04
123739	Crotonaldehyde (2-butenal)	X	C	2.2E+00	7.8E-01	4.5E+00	1.6E+00	6.4E+00	2.2E+00	1.1E+01	3.9E+00	2.2E+01	7.8E+00
98828	Cumene		NC	2.0E+05	4.1E+04	4.0E+05	8.1E+04	5.7E+05	1.2E+05	1.0E+06	2.0E+05	2.0E+06	4.1E+05
72559	DDE	X	C	1.3E+01	9.6E-01	2.5E+01	1.9E+00	3.6E+01	2.8E+00	6.3E+01	4.8E+00	**	**
132649	Dibenzofuran	X	NC	**	**	**	**	**	**	**	**	**	**
96128	1,2-Dibromo-3-chloropropane		NC	1.0E+02	1.0E+01	2.0E+02	2.1E+01	2.9E+02	3.0E+01	5.0E+02	5.2E+01	1.0E+03	1.0E+02
106934	1,2-Dibromoethane (ethylene dibromide)		C	5.5E+00	7.2E-01	1.1E+01	1.4E+00	1.6E+01	2.1E+00	2.8E+01	3.6E+00	5.5E+01	7.2E+00
541731	1,3-Dichlorobenzene	X	NC	5.3E+04	8.7E+03	1.1E+05	1.7E+04	1.5E+05	2.5E+04	2.6E+05	4.4E+04	5.3E+05	8.7E+04

Table 3c-SG: Question 5 Soil Gas Screening Levels for Scenario-Specific Vapor Attenuation Factors (α) **DRAFT**

Risk = 1 x 10^{-6}

				Target Soil Gas Concentrations for Different Attenuation Factors									
		Compounds with Provisional Toxicity Data Extrapolated	Basis of Target Concentration C=cancer risk	α = $2x10^{-3}$ $C_{soil-gas}$		α = $1x10^{-3}$ $C_{soil-gas}$		α = $7x10^{-4}$ $C_{soil-gas}$		α = $4x10^{-4}$ $C_{soil-gas}$		α = $2x10^{-4}$ $C_{soil-gas}$	
CAS No.	Chemical	From Oral Sources	NC=noncancer risk	(ug/m^3)	(ppbv)	(ug/m^3)	(ppbv)	(ug/m^3)	(ppbv)	(ug/m^3)	(ppbv)	(ug/m^3)	(ppbv)
95501	1,2-Dichlorobenzene		NC	1.0E+05	1.7E+04	2.0E+05	3.3E+04	2.9E+05	4.8E+04	5.0E+05	8.3E+04	1.0E+06	1.7E+05
106467	1,4-Dichlorobenzene		NC	4.0E+05	6.7E+04	8.0E+05	1.3E+05	1.1E+06	1.9E+05	2.0E+06	3.3E+05	4.0E+06	6.7E+05
75718	Dichlorodifluoromethane		NC	1.0E+05	2.0E+04	2.0E+05	4.0E+04	2.9E+05	5.8E+04	5.0E+05	1.0E+05	1.0E+06	2.0E+05
75343	1,1-Dichloroethane		NC	2.5E+05	6.2E+04	5.0E+05	1.2E+05	7.1E+05	1.8E+05	1.3E+06	3.1E+05	2.5E+06	6.2E+05
107062	1,2-Dichloroethane		C	4.7E+01	1.2E+01	9.4E+01	2.3E+01	1.3E+02	3.3E+01	2.3E+02	5.8E+01	4.7E+02	1.2E+02
75354	1,1-Dichloroethylene		NC	1.0E+05	2.5E+04	2.0E+05	5.0E+04	2.9E+05	7.2E+04	5.0E+05	1.3E+05	1.0E+06	2.5E+05
78875	1,2-Dichloropropane		NC	2.0E+03	4.3E+02	4.0E+03	8.7E+02	5.7E+03	1.2E+03	1.0E+04	2.2E+03	2.0E+04	4.3E+03
542756	1,3-Dichloropropene		C	3.0E+02	6.7E+01	6.1E+02	1.3E+02	8.7E+02	1.9E+02	1.5E+03	3.4E+02	3.0E+03	6.7E+02
60571	Dieldrin		C	2.6E-01	1.7E-02	5.3E-01	3.4E-02	7.6E-01	4.9E-02	1.3E+00	8.5E-02	2.6E+00	1.7E-01
115297	Endosulfan	X	NC	**	**	**	**	**	**	**	**	**	**
106898	Epichlorohydrin		NC	5.0E+02	1.3E+02	1.0E+03	2.6E+02	1.4E+03	3.8E+02	2.5E+03	6.6E+02	5.0E+03	1.3E+03
60297	Ethyl ether	X	NC	3.5E+05	1.2E+05	7.0E+05	2.3E+05	1.0E+06	3.3E+05	1.8E+06	5.8E+05	3.5E+06	1.2E+06
141786	Ethylacetate	X	NC	1.6E+06	4.4E+05	3.2E+06	8.7E+05	4.5E+06	1.2E+06	7.9E+06	2.2E+06	1.6E+07	4.4E+06
100414	Ethylbenzene		C	1.1E+03	2.5E+02	2.2E+03	5.1E+02	3.2E+03	7.3E+02	5.5E+03	1.3E+03	1.1E+04	2.5E+03
75218	Ethylene oxide		C	1.2E+01	6.8E+00	2.4E+01	1.4E+01	3.5E+01	1.9E+01	6.1E+01	3.4E+01	1.2E+02	6.8E+01
97632	Ethylmethacrylate	X	NC	1.6E+05	3.4E+04	3.2E+05	6.8E+04	4.5E+05	9.6E+04	7.9E+05	1.7E+05	1.6E+06	3.4E+05
86737	Fluorene	X	NC	**	**	**	**	**	**	**	**	**	**
110009	Furan	X	NC	1.8E+03	6.3E+02	3.5E+03	1.3E+03	5.0E+03	1.8E+03	8.8E+03	3.1E+03	1.8E+04	6.3E+03
58899	gamma-HCH (Lindane)	X	C	3.3E+00	2.8E-01	6.6E+00	5.5E-01	9.4E+00	7.9E-01	1.6E+01	1.4E+00	3.3E+01	2.8E+00
76448	Heptachlor		C	9.4E-01	6.1E-02	1.9E+00	1.2E-01	2.7E+00	1.8E-01	4.7E+00	3.1E-01	9.4E+00	6.1E-01
87683	Hexachloro-1,3-butadiene		C	5.5E+01	5.2E+00	1.1E+02	1.0E+01	1.6E+02	1.5E+01	2.8E+02	2.6E+01	5.5E+02	5.2E+01
118741	Hexachlorobenzene		C	2.6E+00	2.3E-01	5.3E+00	4.5E-01	7.6E+00	6.5E-01	1.3E+01	1.1E+00	2.6E+01	2.3E+00
77474	Hexachlorocyclopentadiene		NC	1.0E+02	9.0E+00	2.0E+02	1.8E+01	2.9E+02	2.6E+01	5.0E+02	4.5E+01	1.0E+03	9.0E+01
67721	Hexachloroethane		C	3.0E+02	3.1E+01	6.1E+02	6.3E+01	8.7E+02	9.0E+01	1.5E+03	1.6E+02	3.0E+03	3.1E+02
110543	Hexane		NC	1.0E+05	2.8E+04	2.0E+05	5.7E+04	2.9E+05	8.1E+04	5.0E+05	1.4E+05	1.0E+06	2.8E+05
74908	Hydrogen cyanide		NC	1.5E+03	1.4E+03	3.0E+03	2.7E+03	4.3E+03	3.9E+03	7.5E+03	6.8E+03	1.5E+04	1.4E+04
78831	Isobutanol	X	NC	5.3E+05	1.7E+05	1.1E+06	3.5E+05	1.5E+06	5.0E+05	2.6E+06	8.7E+05	5.3E+06	1.7E+06
7439976	Mercury (elemental)		NC	1.5E+02	1.8E+01	3.0E+02	3.7E+01	4.3E+02	5.2E+01	7.5E+02	9.1E+01	1.5E+03	1.8E+02
126987	Methacrylonitrile		NC	3.5E+02	1.3E+02	7.0E+02	2.6E+02	1.0E+03	3.6E+02	1.8E+03	6.4E+02	3.5E+03	1.3E+03
72435	Methoxychlor	X	NC	**	**	**	**	**	**	**	**	**	**
79209	Methyl acetate	X	NC	1.8E+06	5.8E+05	3.5E+06	1.2E+06	5.0E+06	1.7E+06	8.8E+06	2.9E+06	**	**
96333	Methyl acrylate	X	NC	5.3E+04	1.5E+04	1.1E+05	3.0E+04	1.5E+05	4.3E+04	2.6E+05	7.5E+04	5.3E+05	1.5E+05
74839	Methyl bromide		NC	2.5E+03	6.4E+02	5.0E+03	1.3E+03	7.1E+03	1.8E+03	1.3E+04	3.2E+03	2.5E+04	6.4E+03
74873	Methyl chloride (chloromethane)		C	1.2E+03	5.9E+02	2.4E+03	1.2E+03	3.5E+03	1.7E+03	6.1E+03	2.9E+03	1.2E+04	5.9E+03
108872	Methylcyclohexane		NC	1.5E+06	3.7E+05	3.0E+06	7.5E+05	4.3E+06	1.1E+06	7.5E+06	1.9E+06	1.5E+07	3.7E+06
74953	Methylene bromide	X	NC	1.8E+04	2.5E+03	3.5E+04	4.9E+03	5.0E+04	7.0E+03	8.8E+04	1.2E+04	1.8E+05	2.5E+04
75092	Methylene chloride		C	2.6E+03	7.5E+02	5.2E+03	1.5E+03	7.4E+03	2.1E+03	1.3E+04	3.7E+03	2.6E+04	7.5E+03
78933	Methylethylketone (2-butanone)		NC	5.0E+05	1.7E+05	1.0E+06	3.4E+05	1.4E+06	4.8E+05	2.5E+06	8.5E+05	5.0E+06	1.7E+06
108101	Methylisobutylketone		NC	4.0E+04	9.8E+03	8.0E+04	2.0E+04	1.1E+05	2.8E+04	2.0E+05	4.9E+04	4.0E+05	9.8E+04
80626	Methylmethacrylate		NC	3.5E+05	8.6E+04	7.0E+05	1.7E+05	1.0E+06	2.4E+05	1.8E+06	4.3E+05	3.5E+06	8.6E+05
91576	2-Methylnaphthalene	X	NC	3.5E+04	6.0E+03	7.0E+04	1.2E+04	1.0E+05	1.7E+04	1.8E+05	3.0E+04	3.5E+05	6.0E+04
1634044	MTBE		NC	1.5E+06	4.2E+05	3.0E+06	8.3E+05	4.3E+06	1.2E+06	7.5E+06	2.1E+06	1.5E+07	4.2E+06

Table 3c-SG: Question 5 Soil Gas Screening Levels for Scenario-Specific Vapor Attenuation Factors (α)

Risk = 1 x 10^{-6}

				Target Soil Gas Concentrations for Different Attenuation Factors									
		Compounds with Provisional Toxicity Data Extrapolated	Basis of Target Concentration C=cancer risk	$\alpha = 2x10^{-3}$ $C_{soil\text{-}gas}$		$\alpha = 1x10^{-3}$ $C_{soil\text{-}gas}$		$\alpha = 7x10^{-4}$ $C_{soil\text{-}gas}$		$\alpha = 4x10^{-4}$ $C_{soil\text{-}gas}$		$\alpha = 2x10^{-4}$ $C_{soil\text{-}gas}$	
CAS No.	Chemical	From Oral Sources	NC=noncancer risk	(ug/m^3)	(ppbv)	(ug/m^3)	(ppbv)	(ug/m^3)	(ppbv)	(ug/m^3)	(ppbv)	(ug/m^3)	(ppbv)
108383	m-Xylene	X	NC	3.5E+06	8.1E+05	7.0E+06	1.6E+06	1.0E+07	2.3E+06	1.8E+07	4.0E+06	3.5E+07	8.1E+06
91203	Naphthalene		NC	1.5E+03	2.9E+02	3.0E+03	5.7E+02	4.3E+03	8.2E+02	7.5E+03	1.4E+03	1.5E+04	2.9E+03
104518	n-Butylbenzene	X	NC	7.0E+04	1.3E+04	1.4E+05	2.6E+04	2.0E+05	3.6E+04	3.5E+05	6.4E+04	7.0E+05	1.3E+05
98953	Nitrobenzene		NC	1.0E+03	2.0E+02	2.0E+03	4.0E+02	2.9E+03	5.7E+02	5.0E+03	9.9E+02	1.0E+04	2.0E+03
79469	2-Nitropropane		C	4.5E-01	1.2E-01	9.0E-01	2.5E-01	1.3E+00	3.5E-01	2.3E+00	6.2E-01	4.5E+00	1.2E+00
924163	N-Nitroso-di-n-butylamine		C	7.6E-01	1.2E-01	1.5E+00	2.4E-01	2.2E+00	3.4E-01	3.8E+00	5.9E-01	7.6E+00	1.2E+00
103651	n-Propylbenzene	X	NC	7.0E+04	1.4E+04	1.4E+05	2.8E+04	2.0E+05	4.1E+04	3.5E+05	7.1E+04	7.0E+05	1.4E+05
88722	o-Nitrotoluene	X	NC	1.8E+04	3.1E+03	3.5E+04	6.2E+03	5.0E+04	8.9E+03	8.8E+04	1.6E+04	1.8E+05	3.1E+04
95476	o-Xylene	X	NC	3.5E+06	8.1E+05	7.0E+06	1.6E+06	1.0E+07	2.3E+06	1.8E+07	4.0E+06	3.5E+07	8.1E+06
106423	p-Xylene	X	NC	3.5E+06	8.1E+05	7.0E+06	1.6E+06	1.0E+07	2.3E+06	1.8E+07	4.0E+06	3.5E+07	8.1E+06
129000	Pyrene	X	NC	**	**	**	**	**	**	**	**	**	**
135988	sec-Butylbenzene	X	NC	7.0E+04	1.3E+04	1.4E+05	2.6E+04	2.0E+05	3.6E+04	3.5E+05	6.4E+04	7.0E+05	1.3E+05
100425	Styrene		NC	5.0E+05	1.2E+05	1.0E+06	2.3E+05	1.4E+06	3.4E+05	2.5E+06	5.9E+05	5.0E+06	1.2E+06
98066	tert-Butylbenzene	X	NC	7.0E+04	1.3E+04	1.4E+05	2.6E+04	2.0E+05	3.6E+04	3.5E+05	6.4E+04	7.0E+05	1.3E+05
630206	1,1,1,2-Tetrachloroethane		C	1.6E+02	2.4E+01	3.3E+02	4.8E+01	4.7E+02	6.8E+01	8.2E+02	1.2E+02	1.6E+03	2.4E+02
79345	1,1,2,2-Tetrachloroethane		C	2.1E+01	3.1E+00	4.2E+01	6.1E+00	6.0E+01	8.7E+00	1.0E+02	1.5E+01	2.1E+02	3.1E+01
127184	Tetrachloroethylene		C	4.1E+02	6.0E+01	8.1E+02	1.2E+02	1.2E+03	1.7E+02	2.0E+03	3.0E+02	4.1E+03	6.0E+02
108883	Toluene		NC	2.0E+05	5.3E+04	4.0E+05	1.1E+05	5.7E+05	1.5E+05	1.0E+06	2.7E+05	2.0E+06	5.3E+05
156605	trans-1,2-Dichloroethylene	X	NC	3.5E+04	8.8E+03	7.0E+04	1.8E+04	1.0E+05	2.5E+04	1.8E+05	4.4E+04	3.5E+05	8.8E+04
76131	1,1,2-Trichloro-1,2,2-trifluoroethane		NC	1.5E+07	2.0E+06	3.0E+07	3.9E+06	4.3E+07	5.6E+06	7.5E+07	9.8E+06	1.5E+08	2.0E+07
120821	1,2,4-Trichlorobenzene		NC	1.0E+05	1.3E+04	2.0E+05	2.7E+04	2.9E+05	3.8E+04	5.0E+05	6.7E+04	1.0E+06	1.3E+05
79005	1,1,2-Trichloroethane		C	7.6E+01	1.4E+01	1.5E+02	2.8E+01	2.2E+02	4.0E+01	3.8E+02	7.0E+01	7.6E+02	1.4E+02
71556	1,1,1-Trichloroethane		NC	1.1E+06	2.0E+05	2.2E+06	4.0E+05	3.1E+06	5.8E+05	5.5E+06	1.0E+06	1.1E+07	2.0E+06
79016	Trichloroethylene ††	X	C	1.1E+01	2.1E+00	2.2E+01	4.1E+00	3.2E+01	5.9E+00	5.5E+01	1.0E+01	1.1E+02	2.1E+01
75694	Trichlorofluoromethane		NC	3.5E+05	6.2E+04	7.0E+05	1.2E+05	1.0E+06	1.8E+05	1.8E+06	3.1E+05	3.5E+06	6.2E+05
96184	1,2,3-Trichloropropane		NC	2.5E+03	4.1E+02	4.9E+03	8.1E+02	7.0E+03	1.2E+03	1.2E+04	2.0E+03	2.5E+04	4.1E+03
95636	1,2,4-Trimethylbenzene		NC	3.0E+03	6.1E+02	6.0E+03	1.2E+03	8.5E+03	1.7E+03	1.5E+04	3.0E+03	3.0E+04	6.1E+03
108678	1,3,5-Trimethylbenzene		NC	3.0E+03	6.1E+02	6.0E+03	1.2E+03	8.5E+03	1.7E+03	1.5E+04	3.0E+03	3.0E+04	6.1E+03
108054	Vinyl acetate		NC	1.0E+05	2.8E+04	2.0E+05	5.7E+04	2.9E+05	8.1E+04	5.0E+05	1.4E+05	1.0E+06	2.8E+05
75014	Vinyl chloride (chloroethene)		C	1.4E+02	5.4E+01	2.8E+02	1.1E+02	4.0E+02	1.5E+02	6.9E+02	2.7E+02	1.4E+03	5.4E+02

* Health-based target breathing concentration exceeds maximum possible chemical vapor concentration (pathway incomplete)

** Target soil gas concentration exceeds maximum possible vapor concentration at this soil gas to indoor air attenuation factor (pathway incomplete)

†† The target concentration for trichloroethylene is based on the upper bound cancer slope factor identified in EPA's draft risk assessment for trichloroethylene (US EPA, 2001). The slope factor is based on state-of-the-art methodology, however the TCE assessment is still undergoing review. As a result, the slope factor and the target concentration values for TCE may be revised further. (See Appendix D.)

Table 3a - GW: Question 5 Groundwater Screening Levels for Scenario-Specific Vapor Attenuation Factors (α)

Risk = 1 x 10^{-4}

				Target Groundwater Concentrations at Different Attenuation Factors				
CAS No.	Chemical	Compounds with Provisional Toxicity Data Extrapolated From Oral Sources	Basis of Target Concentration C=cancer risk NC=noncancer risk	$\alpha = 7\text{x}10^{-4}$ C_{gw} (ug/L)	$\alpha = 5\text{x}10^{-4}$ C_{gw} (ug/L)	$\alpha = 3\text{x}10^{-4}$ C_{gw} (ug/L)	$\alpha = 2\text{x}10^{-4}$ C_{gw} (ug/L)	$\alpha = 1\text{x}10^{-4}$ C_{gw} (ug/L)
83329	Acenaphthene	X	NC	**	**	**	**	**
75070	Acetaldehyde		NC	4.0E+03	5.6E+03	9.3E+03	1.4E+04	2.8E+04
67641	Acetone	X	NC	3.2E+05	4.4E+05	7.4E+05	1.1E+06	2.2E+06
75058	Acetonitrile		NC	6.1E+04	8.5E+04	1.4E+05	2.1E+05	4.2E+05
98862	Acetophenone	X	NC	1.1E+06	1.6E+06	2.7E+06	4.0E+06	**
107028	Acrolein		NC	5.7E+00	8.0E+00	1.3E+01	2.0E+01	4.0E+01
107131	Acrylonitrile		NC	6.8E+02	9.5E+02	1.6E+03	2.4E+03	4.7E+03
309002	Aldrin		C	1.0E+01	1.4E+01	**	**	**
319846	alpha-HCH (alpha-BHC)		C	4.5E+02	6.2E+02	1.0E+03	1.6E+03	**
100527	Benzaldehyde	X	NC	5.1E+05	7.2E+05	1.2E+06	1.8E+06	**
71432	Benzene		C	2.0E+02	2.7E+02	4.6E+02	6.9E+02	1.4E+03
205992	Benzo(b)fluoranthene	X	C	**	**	**	**	**
100447	Benzylchloride	X	C	4.2E+02	5.9E+02	9.8E+02	1.5E+03	3.0E+03
91587	beta-Chloronaphthalene	X	NC	**	**	**	**	**
92524	Biphenyl	X	NC	**	**	**	**	**
111444	Bis(2-chloroethyl)ether		C	1.4E+03	2.0E+03	3.3E+03	5.0E+03	1.0E+04
108601	Bis(2-chloroisopropyl)ether		C	7.3E+03	1.0E+04	1.7E+04	2.5E+04	5.1E+04
542881	Bis(chloromethyl)ether		C	6.4E-01	9.0E-01	1.5E+00	2.3E+00	4.5E+00
75274	Bromodichloromethane	X	C	3.0E+02	4.2E+02	7.0E+02	1.1E+03	2.1E+03
75252	Bromoform		C	1.2E+00	1.7E+00	2.8E+00	4.2E+00	8.3E+00
106990	1,3-Butadiene		C	4.1E-01	5.8E-01	9.6E-01	1.4E+00	2.9E+00
75150	Carbon disulfide		NC	8.1E+02	1.1E+03	1.9E+03	2.8E+03	5.6E+03
56235	Carbon tetrachloride		C	1.9E+01	2.6E+01	4.3E+01	6.5E+01	1.3E+02
57749	Chlordane		NC	**	**	**	**	**
126998	2-Chloro-1,3-butadiene (chloroprene)		NC	2.0E+01	2.9E+01	4.8E+01	7.1E+01	1.4E+02
108907	Chlorobenzene		NC	5.6E+02	7.9E+02	1.3E+03	2.0E+03	3.9E+03
109693	1-Chlorobutane	X	NC	2.9E+03	4.0E+03	6.7E+03	1.0E+04	2.0E+04
124481	Chlorodibromomethane	X	C	4.5E+02	6.3E+02	1.1E+03	1.6E+03	3.2E+03
75456	Chlorodifluoromethane		NC	**	**	**	**	**
75003	Chloroethane (ethyl chloride)		NC	4.0E+04	5.5E+04	9.2E+04	1.4E+05	2.8E+05
67663	Chloroform		C	1.0E+02	1.4E+02	2.3E+02	3.5E+02	7.0E+02
95578	2-Chlorophenol	X	NC	1.6E+03	2.2E+03	3.6E+03	5.5E+03	1.1E+04
75296	2-Chloropropane		NC	2.4E+02	3.4E+02	5.7E+02	8.6E+02	1.7E+03

Table 3a - GW: Question 5 Groundwater Screening Levels for Scenario-Specific Vapor Attenuation Factors (α)

Risk = 1 x 10^{-4}

				Target Groundwater Concentrations at Different Attenuation Factors				
CAS No.	Chemical	Compounds with Provisional Toxicity Data Extrapolated From Oral Sources	Basis of Target Concentration C=cancer risk NC=noncancer risk	α = 7x10^{-4} C_{gw} (ug/L)	α = 5x10^{-4} C_{gw} (ug/L)	α = 3x10^{-4} C_{gw} (ug/L)	α = 2x10^{-4} C_{gw} (ug/L)	α = 1x10^{-4} C_{gw} (ug/L)
218019	Chrysene	X	*	*	*	*	*	*
156592	cis-1,2-Dichloroethylene	X	NC	3.0E+02	4.2E+02	7.0E+02	1.0E+03	2.1E+03
123739	Crotonaldehyde (2-butenal)	X	C	8.0E+02	1.1E+03	1.9E+03	2.8E+03	5.6E+03
98828	Cumene		NC	1.2E+01	1.7E+01	2.8E+01	4.2E+01	8.4E+01
72559	DDE	X	C	**	**	**	**	**
132649	Dibenzofuran	X	NC	**	**	**	**	**
96128	1,2-Dibromo-3-chloropropane		NC	4.8E+01	6.7E+01	1.1E+02	1.7E+02	3.3E+02
106934	1,2-Dibromoethane (ethylene dibromide)		NC	9.4E+00	1.3E+01	2.2E+01	3.3E+01	6.6E+01
541731	1,3-Dichlorobenzene	X	NC	1.2E+03	1.7E+03	2.8E+03	4.1E+03	8.3E+03
95501	1,2-Dichlorobenzene		NC	3.7E+03	5.1E+03	8.6E+03	1.3E+04	2.6E+04
106467	1,4-Dichlorobenzene		NC	1.2E+04	1.6E+04	2.7E+04	4.1E+04	**
75718	Dichlorodifluoromethane		NC	2.0E+01	2.9E+01	4.8E+01	7.1E+01	1.4E+02
75343	1,1-Dichloroethane		NC	3.1E+03	4.4E+03	7.3E+03	1.1E+04	2.2E+04
107062	1,2-Dichloroethane		C	3.3E+02	4.7E+02	7.8E+02	1.2E+03	2.3E+03
75354	1,1-Dichloroethylene		NC	2.7E+02	3.7E+02	6.2E+02	9.4E+02	1.9E+03
78875	1,2-Dichloropropane		NC	5.0E+01	7.0E+01	1.2E+02	1.7E+02	3.5E+02
542756	1,3-Dichloropropene		NC	3.9E+01	5.5E+01	9.2E+01	1.4E+02	2.8E+02
60571	Dieldrin		C	1.2E+02	1.7E+02	**	**	**
115297	Endosulfan	X	NC	**	**	**	**	**
106898	Epichlorohydrin		NC	1.1E+03	1.6E+03	2.7E+03	4.0E+03	8.0E+03
60297	Ethyl ether	X	NC	7.4E+02	1.0E+03	1.7E+03	2.6E+03	5.2E+03
141786	Ethylacetate	X	NC	8.0E+05	1.1E+06	1.9E+06	2.8E+06	5.6E+06
100414	Ethylbenzene		C	9.8E+02	1.4E+03	2.3E+03	3.4E+03	6.9E+03
75218	Ethylene oxide		C	1.5E+02	2.1E+02	3.6E+02	5.4E+02	1.1E+03
97632	Ethylmethacrylate	X	NC	1.3E+04	1.8E+04	3.0E+04	4.6E+04	9.1E+04
86737	Fluorene	X	NC	**	**	**	**	**
110009	Furan	X	NC	2.3E+01	3.2E+01	5.3E+01	7.9E+01	1.6E+02
58899	gamma-HCH (Lindane)	X	C	1.6E+03	2.3E+03	3.8E+03	5.7E+03	**
76448	Heptachlor		C	4.0E-01[†]	4.0E-01[†]	4.0E-01[†]	4.0E-01[†]	4.0E-01[†]
87683	Hexachloro-1,3-butadiene		C	4.7E+01	6.6E+01	1.1E+02	1.7E+02	3.3E+02
118741	Hexachlorobenzene		C	**	**	**	**	**
77474	Hexachlorocyclopentadiene		NC	5.0E+01[†]	5.0E+01[†]	5.0E+01[†]	5.0E+01[†]	5.0E+01[†]
67721	Hexachloroethane		C	5.5E+02	7.6E+02	1.3E+03	1.9E+03	3.8E+03

Table 3a - GW: Question 5 Groundwater Screening Levels for Scenario-Specific Vapor Attenuation Factors (α)

Risk = 1 x 10^{-4}

				Target Groundwater Concentrations at Different Attenuation Factors				
CAS No.	Chemical	Compounds with Provisional Toxicity Data Extrapolated From Oral Sources	Basis of Target Concentration C=cancer risk NC=noncancer risk	α = 7x10^{-4} C_{gw} (ug/L)	α = 5x10^{-4} C_{gw} (ug/L)	α = 3x10^{-4} C_{gw} (ug/L)	α = 2x10^{-4} C_{gw} (ug/L)	α = 1x10^{-4} C_{gw} (ug/L)
110543	Hexane		NC	4.2E+00	5.9E+00	9.8E+00	1.5E+01	2.9E+01
74908	Hydrogen cyanide		NC	7.9E+02	1.1E+03	1.8E+03	2.8E+03	5.5E+03
78831	Isobutanol	X	NC	3.1E+06	4.4E+06	7.3E+06	1.1E+07	2.2E+07
7439976	Mercury (elemental)		NC	9.7E-01	1.4E+00	2.3E+00	3.4E+00	6.8E+00
126987	Methacrylonitrile		NC	9.9E+01	1.4E+02	2.3E+02	3.5E+02	6.9E+02
72435	Methoxychlor	X	NC	**	**	**	**	**
79209	Methyl acetate	X	NC	1.0E+06	1.4E+06	**	**	**
96333	Methyl acrylate	X	NC	2.0E+04	2.7E+04	4.6E+04	6.8E+04	1.4E+05
74839	Methyl bromide		NC	2.8E+01	3.9E+01	6.5E+01	9.8E+01	2.0E+02
74873	Methyl chloride (chloromethane)		NC	3.6E+02	5.0E+02	8.3E+02	1.2E+03	2.5E+03
108872	Methylcyclohexane		NC	1.0E+03	1.4E+03	2.4E+03	3.6E+03	7.1E+03
74953	Methylene bromide	X	NC	1.4E+03	2.0E+03	3.3E+03	5.0E+03	9.9E+03
75092	Methylene chloride		C	8.3E+03	1.2E+04	1.9E+04	2.9E+04	5.8E+04
78933	Methylethylketone (2-butanone)		NC	6.2E+05	8.7E+05	1.5E+06	2.2E+06	4.4E+06
108101	Methylisobutylketone		NC	2.0E+04	2.8E+04	4.7E+04	7.1E+04	1.4E+05
80626	Methylmethacrylate		NC	7.3E+04	1.0E+05	1.7E+05	2.5E+05	5.1E+05
91576	2-Methylnaphthalene	X	NC	4.7E+03	6.6E+03	1.1E+04	1.7E+04	**
1634044	MTBE		NC	1.7E+05	2.3E+05	3.9E+05	5.9E+05	1.2E+06
108383	m-Xylene	X	NC	3.3E+04	4.7E+04	7.8E+04	1.2E+05	**
91203	Naphthalene		NC	2.2E+02	3.0E+02	5.1E+02	7.6E+02	1.5E+03
104518	n-Butylbenzene	X	NC	3.7E+02	5.2E+02	8.7E+02	1.3E+03	**
98953	Nitrobenzene		NC	2.9E+03	4.1E+03	6.8E+03	1.0E+04	2.0E+04
79469	2-Nitropropane		C	2.6E+01	3.6E+01	6.0E+01	9.0E+01	1.8E+02
924163	N-Nitroso-di-n-butylamine		C	1.7E+01	2.4E+01	3.9E+01	5.9E+01	1.2E+02
103651	n-Propylbenzene	X	NC	4.6E+02	6.4E+02	1.1E+03	1.6E+03	3.2E+03
88722	o-Nitrotoluene	X	NC	9.8E+04	1.4E+05	2.3E+05	3.4E+05	**
95476	o-Xylene	X	NC	4.7E+04	6.6E+04	1.1E+05	1.6E+05	**
106423	p-Xylene	X	NC	3.2E+04	4.5E+04	7.4E+04	1.1E+05	**
129000	Pyrene	X	NC	**	**	**	**	**
135988	sec-Butylbenzene	X	NC	3.5E+02	4.9E+02	8.2E+02	1.2E+03	2.5E+03
100425	Styrene		NC	1.3E+04	1.8E+04	3.0E+04	4.4E+04	8.9E+04
98066	tert-Butylbenzene	X	NC	4.1E+02	5.8E+02	9.6E+02	1.4E+03	2.9E+03
630206	1,1,1,2-Tetrachloroethane		C	4.7E+02	6.6E+02	1.1E+03	1.7E+03	3.3E+03

Table 3a - GW: Question 5 Groundwater Screening Levels for Scenario-Specific Vapor Attenuation Factors (α)

Risk = 1 x 10^{-4}

				Target Groundwater Concentrations at Different Attenuation Factors				
CAS No.	Chemical	Compounds with Provisional Toxicity Data Extrapolated From Oral Sources	Basis of Target Concentration C=cancer risk NC=noncancer risk	$\alpha = 7\times10^{-4}$ C_{gw} (ug/L)	$\alpha = 5\times10^{-4}$ C_{gw} (ug/L)	$\alpha = 3\times10^{-4}$ C_{gw} (ug/L)	$\alpha = 2\times10^{-4}$ C_{gw} (ug/L)	$\alpha = 1\times10^{-4}$ C_{gw} (ug/L)
79345	1,1,2,2-Tetrachloroethane		C	4.2E+02	5.9E+02	9.9E+02	1.5E+03	3.0E+03
127184	Tetrachloroethylene		C	1.5E+02	2.2E+02	3.6E+02	5.4E+02	1.1E+03
108883	Toluene		NC	2.1E+03	2.9E+03	4.9E+03	7.4E+03	1.5E+04
156605	trans-1,2-Dichloroethylene	X	NC	2.6E+02	3.6E+02	6.1E+02	9.1E+02	1.8E+03
76131	1,1,2-Trichloro-1,2,2-trifluoroethane		NC	2.2E+03	3.1E+03	5.1E+03	7.7E+03	1.5E+04
120821	1,2,4-Trichlorobenzene		NC	4.9E+03	6.9E+03	1.1E+04	1.7E+04	3.4E+04
79005	1,1,2-Trichloroethane		C	5.8E+02	8.1E+02	1.4E+03	2.0E+03	4.1E+03
71556	1,1,1-Trichloroethane		NC	4.5E+03	6.3E+03	1.0E+04	1.6E+04	3.1E+04
79016	Trichloroethylene ††	X	C	7.5E+00	1.1E+01	1.8E+01	2.6E+01	5.3E+01
75694	Trichlorofluoromethane		NC	2.5E+02	3.5E+02	5.9E+02	8.8E+02	1.8E+03
96184	1,2,3-Trichloropropane		NC	4.2E+02	5.9E+02	9.8E+02	1.5E+03	2.9E+03
95636	1,2,4-Trimethylbenzene		NC	3.4E+01	4.7E+01	7.9E+01	1.2E+02	2.4E+02
108678	1,3,5-Trimethylbenzene		NC	3.5E+01	4.9E+01	8.2E+01	1.2E+02	2.5E+02
108054	Vinyl acetate		NC	1.4E+04	1.9E+04	3.2E+04	4.8E+04	9.6E+04
75014	Vinyl chloride (chloroethene)		C	3.6E+01	5.0E+01	8.3E+01	1.3E+02	2.5E+02

* Health-based target breathing concentration exceeds maximum possible chemical vapor concentration (pathway incomplete)

** Target soil gas concentration exceeds maximum possible vapor concentration at this soil gas to indoor air attenuation factor (pathway incomplete)

† The target groundwater concentrations is the MCL. (The MCL for chloroform is the MCL for total Trihalomethanes. The MCL listed for m-Xylene, o-Xylene, and p-Xylene is the MCL for total Xylenes.

†† The target concentration for trichloroethylene is based on the upper bound cancer slope factor identified in EPA's draft risk assessment for trichloroethylene (US EPA, 2001). The slope factor is based on state-of-the-art methodology, however the TCE assessment is still undergoing review. As a result, the slope factor and the target concentration values for TCE may be revised further. (See Appendix D.)

Table 3b - GW: Question 5 Groundwater Screening Levels for Scenario-Specific Vapor Attenuation Factors (α)

Risk = 1 x 10^{-5}

				Target Groundwater Concentrations at Different Attenuation Factors				
CAS No.	Chemical	Compounds with Provisional Toxicity Data Extrapolated From Oral Sources	Basis of Target Concentration C=cancer risk NC=noncancer risk	$\alpha = 7\times10^{-4}$ C_{gw} (ug/L)	$\alpha = 5\times10^{-4}$ C_{gw} (ug/L)	$\alpha = 3\times10^{-4}$ C_{gw} (ug/L)	$\alpha = 2\times10^{-4}$ C_{gw} (ug/L)	$\alpha = 1\times10^{-4}$ C_{gw} (ug/L)
83329	Acenaphthene	X	NC	**	**	**	**	**
75070	Acetaldehyde		NC	4.0E+03	5.6E+03	9.3E+03	1.4E+04	2.8E+04
67641	Acetone	X	NC	3.2E+05	4.4E+05	7.4E+05	1.1E+06	2.2E+06
75058	Acetonitrile		NC	6.1E+04	8.5E+04	1.4E+05	2.1E+05	4.2E+05
98862	Acetophenone	X	NC	1.1E+06	1.6E+06	2.7E+06	4.0E+06	**
107028	Acrolein		NC	5.7E+00	8.0E+00	1.3E+01	2.0E+01	4.0E+01
107131	Acrylonitrile		C	1.2E+02	1.7E+02	2.8E+02	4.2E+02	8.5E+02
309002	Aldrin		C	1.0E+00	1.4E+00	2.4E+00	3.6E+00	7.1E+00
319846	alpha-HCH (alpha-BHC)		C	4.5E+01	6.2E+01	1.0E+02	1.6E+02	3.1E+02
100527	Benzaldehyde	X	NC	5.1E+05	7.2E+05	1.2E+06	1.8E+06	**
71432	Benzene		C	2.0E+01	2.7E+01	4.6E+01	6.9E+01	1.4E+02
205992	Benzo(b)fluoranthene	X	C	**	**	**	**	**
100447	Benzylchloride	X	C	4.2E+01	5.9E+01	9.8E+01	1.5E+02	3.0E+02
91587	beta-Chloronaphthalene	X	NC	**	**	**	**	**
92524	Biphenyl	X	NC	**	**	**	**	**
111444	Bis(2-chloroethyl)ether		C	1.4E+02	2.0E+02	3.3E+02	5.0E+02	1.0E+03
108601	Bis(2-chloroisopropyl)ether		C	7.3E+02	1.0E+03	1.7E+03	2.5E+03	5.1E+03
542881	Bis(chloromethyl)ether		C	6.4E-02	9.0E-02	1.5E-01	2.3E-01	4.5E-01
75274	Bromodichloromethane	X	C	3.0E+01	4.2E+01	7.0E+01	1.1E+02	2.1E+02
75252	Bromoform		C	1.2E-01	1.7E-01	2.8E-01	4.2E-01	8.3E-01
106990	1,3-Butadiene		C	4.1E-02	5.8E-02	9.6E-02	1.4E-01	2.9E-01
75150	Carbon disulfide		NC	8.1E+02	1.1E+03	1.9E+03	2.8E+03	5.6E+03
56235	Carbon tetrachloride		C	5.0E+00 †	5.0E+00 †	5.0E+00 †	6.5E+00	1.3E+01
57749	Chlordane		C	**	**	**	**	**
126998	2-Chloro-1,3-butadiene (chloroprene)		NC	2.0E+01	2.9E+01	4.8E+01	7.1E+01	1.4E+02
108907	Chlorobenzene		NC	5.6E+02	7.9E+02	1.3E+03	2.0E+03	3.9E+03
109693	1-Chlorobutane	X	NC	2.9E+03	4.0E+03	6.7E+03	1.0E+04	2.0E+04
124481	Chlorodibromomethane	X	C	4.5E+01	6.3E+01	1.1E+02	1.6E+02	3.2E+02
75456	Chlorodifluoromethane		NC	**	**	**	**	**
75003	Chloroethane (ethyl chloride)		NC	4.0E+04	5.5E+04	9.2E+04	1.4E+05	2.8E+05
67663	Chloroform		C	8.0E+01 †	8.0E+01 †	8.0E+01 †	8.0E+01 †	8.0E+01 †
95578	2-Chlorophenol	X	NC	1.6E+03	2.2E+03	3.6E+03	5.5E+03	1.1E+04
75296	2-Chloropropane		NC	2.4E+02	3.4E+02	5.7E+02	8.6E+02	1.7E+03

Table 3b - GW: Question 5 Groundwater Screening Levels for Scenario-Specific Vapor Attenuation Factors (α)

Risk = 1 x 10^{-5}

				Target Groundwater Concentrations at Different Attenuation Factors				
CAS No.	Chemical	Compounds with Provisional Toxicity Data Extrapolated From Oral Sources	Basis of Target Concentration C=cancer risk NC=noncancer risk	α = 7x10^{-4} C_{gw} (ug/L)	α = 5x10^{-4} C_{gw} (ug/L)	α = 3x10^{-4} C_{gw} (ug/L)	α = 2x10^{-4} C_{gw} (ug/L)	α = 1x10^{-4} C_{gw} (ug/L)
218019	Chrysene	X	C	**	**	**	**	**
156592	cis-1,2-Dichloroethylene	X	NC	3.0E+02	4.2E+02	7.0E+02	1.0E+03	2.1E+03
123739	Crotonaldehyde (2-butenal)	X	C	8.0E+01	1.1E+02	1.9E+02	2.8E+02	5.6E+02
98828	Cumene		NC	1.2E+01	1.7E+01	2.8E+01	4.2E+01	8.4E+01
72559	DDE	X	C	**	**	**	**	**
132649	Dibenzofuran	X	NC	**	**	**	**	**
96128	1,2-Dibromo-3-chloropropane		NC	4.8E+01	6.7E+01	1.1E+02	1.7E+02	3.3E+02
106934	1,2-Dibromoethane (ethylene dibromide)		C	5.2E+00	7.3E+00	1.2E+01	1.8E+01	3.6E+01
541731	1,3-Dichlorobenzene	X	NC	1.2E+03	1.7E+03	2.8E+03	4.1E+03	8.3E+03
95501	1,2-Dichlorobenzene		NC	3.7E+03	5.1E+03	8.6E+03	1.3E+04	2.6E+04
106467	1,4-Dichlorobenzene		NC	1.2E+04	1.6E+04	2.7E+04	4.1E+04	**
75718	Dichlorodifluoromethane		NC	2.0E+01	2.9E+01	4.8E+01	7.1E+01	1.4E+02
75343	1,1-Dichloroethane		NC	3.1E+03	4.4E+03	7.3E+03	1.1E+04	2.2E+04
107062	1,2-Dichloroethane		C	3.3E+01	4.7E+01	7.8E+01	1.2E+02	2.3E+02
75354	1,1-Dichloroethylene		NC	2.7E+02	3.7E+02	6.2E+02	9.4E+02	1.9E+03
78875	1,2-Dichloropropane		NC	5.0E+01	7.0E+01	1.2E+02	1.7E+02	3.5E+02
542756	1,3-Dichloropropene		C	1.2E+01	1.7E+01	2.8E+01	4.2E+01	8.4E+01
60571	Dieldrin		C	1.2E+01	1.7E+01	2.9E+01	4.3E+01	8.6E+01
115297	Endosulfan	X	NC	**	**	**	**	**
106898	Epichlorohydrin		NC	1.1E+03	1.6E+03	2.7E+03	4.0E+03	8.0E+03
60297	Ethyl ether	X	NC	7.4E+02	1.0E+03	1.7E+03	2.6E+03	5.2E+03
141786	Ethylacetate	X	NC	8.0E+05	1.1E+06	1.9E+06	2.8E+06	5.6E+06
100414	Ethylbenzene		C	7.0E+02 †	7.0E+02 †	7.0E+02 †	7.0E+02 †	7.0E+02 †
75218	Ethylene oxide		C	1.5E+01	2.1E+01	3.6E+01	5.4E+01	1.1E+02
97632	Ethylmethacrylate	X	NC	1.3E+04	1.8E+04	3.0E+04	4.6E+04	9.1E+04
86737	Fluorene	X	NC	**	**	**	**	**
110009	Furan	X	NC	2.3E+01	3.2E+01	5.3E+01	7.9E+01	1.6E+02
58899	gamma-HCH (Lindane)	X	C	1.6E+02	2.3E+02	3.8E+02	5.7E+02	1.1E+03
76448	Heptachlor		C	4.0E-01 †	4.0E-01 †	4.0E-01 †	4.0E-01 †	4.0E-01 †
87683	Hexachloro-1,3-butadiene		C	4.7E+00	6.6E+00	1.1E+01	1.7E+01	3.3E+01
118741	Hexachlorobenzene		C	1.4E+00	2.0E+00	3.3E+00	4.9E+00	**
77474	Hexachlorocyclopentadiene		NC	5.0E+01 †	5.0E+01 †	5.0E+01 †	5.0E+01 †	5.0E+01 †
67721	Hexachloroethane		C	5.5E+01	7.6E+01	1.3E+02	1.9E+02	3.8E+02

Table 3b - GW: Question 5 Groundwater Screening Levels for Scenario-Specific Vapor Attenuation Factors (α)
Risk = 1 x 10^{-5}

				Target Groundwater Concentrations at Different Attenuation Factors				
CAS No.	Chemical	Compounds with Provisional Toxicity Data Extrapolated From Oral Sources	Basis of Target Concentration C=cancer risk NC=noncancer risk	α = 7x10^{-4} C_{gw} (ug/L)	α = 5x10^{-4} C_{gw} (ug/L)	α = 3x10^{-4} C_{gw} (ug/L)	α = 2x10^{-4} C_{gw} (ug/L)	α = 1x10^{-4} C_{gw} (ug/L)
110543	Hexane		NC	4.2E+00	5.9E+00	9.8E+00	1.5E+01	2.9E+01
74908	Hydrogen cyanide		NC	7.9E+02	1.1E+03	1.8E+03	2.8E+03	5.5E+03
78831	Isobutanol	X	NC	3.1E+06	4.4E+06	7.3E+06	1.1E+07	2.2E+07
7439976	Mercury (elemental)		NC	9.7E-01	1.4E+00	2.3E+00	3.4E+00	6.8E+00
126987	Methacrylonitrile		NC	9.9E+01	1.4E+02	2.3E+02	3.5E+02	6.9E+02
72435	Methoxychlor	X	NC	**	**	**	**	**
79209	Methyl acetate	X	NC	1.0E+06	1.4E+06	**	**	**
96333	Methyl acrylate	X	NC	2.0E+04	2.7E+04	4.6E+04	6.8E+04	1.4E+05
74839	Methyl bromide		NC	2.8E+01	3.9E+01	6.5E+01	9.8E+01	2.0E+02
74873	Methyl chloride (chloromethane)		C	9.6E+01	1.3E+02	2.2E+02	3.4E+02	6.7E+02
108872	Methylcyclohexane		NC	1.0E+03	1.4E+03	2.4E+03	3.6E+03	7.1E+03
74953	Methylene bromide	X	NC	1.4E+03	2.0E+03	3.3E+03	5.0E+03	9.9E+03
75092	Methylene chloride		C	8.3E+02	1.2E+03	1.9E+03	2.9E+03	5.8E+03
78933	Methylethylketone (2-butanone)		NC	6.2E+05	8.7E+05	1.5E+06	2.2E+06	4.4E+06
108101	Methylisobutylketone		NC	2.0E+04	2.8E+04	4.7E+04	7.1E+04	1.4E+05
80626	Methylmethacrylate		NC	7.3E+04	1.0E+05	1.7E+05	2.5E+05	5.1E+05
91576	2-Methylnaphthalene	X	NC	4.7E+03	6.6E+03	1.1E+04	1.7E+04	**
1634044	MTBE		NC	1.7E+05	2.3E+05	3.9E+05	5.9E+05	1.2E+06
108383	m-Xylene	X	NC	3.3E+04	4.7E+04	7.8E+04	1.2E+05	**
91203	Naphthalene		NC	2.2E+02	3.0E+02	5.1E+02	7.6E+02	1.5E+03
104518	n-Butylbenzene	X	NC	3.7E+02	5.2E+02	8.7E+02	1.3E+03	**
98953	Nitrobenzene		NC	2.9E+03	4.1E+03	6.8E+03	1.0E+04	2.0E+04
79469	2-Nitropropane		C	2.6E+00	3.6E+00	6.0E+00	9.0E+00	1.8E+01
924163	N-Nitroso-di-n-butylamine		C	1.7E+00	2.4E+00	3.9E+00	5.9E+00	1.2E+01
103651	n-Propylbenzene	X	NC	4.6E+02	6.4E+02	1.1E+03	1.6E+03	3.2E+03
88722	o-Nitrotoluene	X	NC	9.8E+04	1.4E+05	2.3E+05	3.4E+05	**
95476	o-Xylene	X	NC	4.7E+04	6.6E+04	1.1E+05	1.6E+05	**
106423	p-Xylene	X	NC	3.2E+04	4.5E+04	7.4E+04	1.1E+05	**
129000	Pyrene	X	NC	**	**	**	**	**
135988	sec-Butylbenzene	X	NC	3.5E+02	4.9E+02	8.2E+02	1.2E+03	2.5E+03
100425	Styrene		NC	1.3E+04	1.8E+04	3.0E+04	4.4E+04	8.9E+04
98066	tert-Butylbenzene	X	NC	4.1E+02	5.8E+02	9.6E+02	1.4E+03	2.9E+03
630206	1,1,1,2-Tetrachloroethane		C	4.7E+01	6.6E+01	1.1E+02	1.7E+02	3.3E+02

Table 3b - GW: Question 5 Groundwater Screening Levels for Scenario-Specific Vapor Attenuation Factors (α)

Risk = 1 x 10^{-5}

				Target Groundwater Concentrations at Different Attenuation Factors				
CAS No.	Chemical	Compounds with Provisional Toxicity Data Extrapolated From Oral Sources	Basis of Target Concentration C=cancer risk NC=noncancer risk	α = 7x10^{-4} C_{gw} (ug/L)	α = 5x10^{-4} C_{gw} (ug/L)	α = 3x10^{-4} C_{gw} (ug/L)	α = 2x10^{-4} C_{gw} (ug/L)	α = 1x10^{-4} C_{gw} (ug/L)
79345	1,1,2,2-Tetrachloroethane		C	4.2E+01	5.9E+01	9.9E+01	1.5E+02	3.0E+02
127184	Tetrachloroethylene		C	1.5E+01	2.2E+01	3.6E+01	5.4E+01	1.1E+02
108883	Toluene		NC	2.1E+03	2.9E+03	4.9E+03	7.4E+03	1.5E+04
156605	trans-1,2-Dichloroethylene	X	NC	2.6E+02	3.6E+02	6.1E+02	9.1E+02	1.8E+03
76131	1,1,2-Trichloro-1,2,2-trifluoroethane		NC	2.2E+03	3.1E+03	5.1E+03	7.7E+03	1.5E+04
120821	1,2,4-Trichlorobenzene		NC	4.9E+03	6.9E+03	1.1E+04	1.7E+04	3.4E+04
79005	1,1,2-Trichloroethane		C	5.8E+01	8.1E+01	1.4E+02	2.0E+02	4.1E+02
71556	1,1,1-Trichloroethane		NC	4.5E+03	6.3E+03	1.0E+04	1.6E+04	3.1E+04
79016	Trichloroethylene[††]	X	C	5.0E+00[†]	5.0E+00[†]	5.0E+00[†]	5.0E+00[†]	5.3E+00
75694	Trichlorofluoromethane		NC	2.5E+02	3.5E+02	5.9E+02	8.8E+02	1.8E+03
96184	1,2,3-Trichloropropane		NC	4.2E+02	5.9E+02	9.8E+02	1.5E+03	2.9E+03
95636	1,2,4-Trimethylbenzene		NC	3.4E+01	4.7E+01	7.9E+01	1.2E+02	2.4E+02
108678	1,3,5-Trimethylbenzene		NC	3.5E+01	4.9E+01	8.2E+01	1.2E+02	2.5E+02
108054	Vinyl acetate		NC	1.4E+04	1.9E+04	3.2E+04	4.8E+04	9.6E+04
75014	Vinyl chloride (chloroethene)		C	3.6E+00	5.0E+00	8.3E+00	1.3E+01	2.5E+01

* Health-based target breathing concentration exceeds maximum possible chemical vapor concentration (pathway incomplete)

** Target soil gas concentration exceeds maximum possible vapor concentration at this soil gas to indoor air attenuation factor (pathway incomplete)

† The target groundwater concentrations is the MCL. (The MCL for chloroform is the MCL for total Trihalomethanes. The MCL listed for m-Xylene, o-Xylene, and p-Xylene is the MCL for total Xylenes.

†† The target concentration for trichloroethylene is based on the upper bound cancer slope factor identified in EPA's draft risk assessment for trichloroethylene (US EPA, 2001). The slope factor is based on state-of-the-art methodology, however the TCE assessment is still undergoing review. As a result, the slope factor and the target concentration values for TCE may be revised further. (See Appendix D.)

Table 3c - GW: Question 5 Groundwater Screening Levels for Scenario-Specific Vapor Attenuation Factors (α)

Risk = 1 x 10^{-6}

				Target Groundwater Concentrations at Different Attenuation Factors				
CAS No.	Chemical	Compounds with Provisional Toxicity Data Extrapolated From Oral Sources	Basis of Target Concentration C=cancer risk NC=noncancer risk	α = 7x10^{-4} C_{gw} (ug/L)	α = 5x10^{-4} C_{gw} (ug/L)	α = 3x10^{-4} C_{gw} (ug/L)	α = 2x10^{-4} C_{gw} (ug/L)	α = 1x10^{-4} C_{gw} (ug/L)
83329	Acenaphthene	X	NC	**	**	**	**	**
75070	Acetaldehyde		C	4.9E+02	6.9E+02	1.1E+03	1.7E+03	3.4E+03
67641	Acetone	X	NC	3.2E+05	4.4E+05	7.4E+05	1.1E+06	2.2E+06
75058	Acetonitrile		NC	6.1E+04	8.5E+04	1.4E+05	2.1E+05	4.2E+05
98862	Acetophenone	X	NC	1.1E+06	1.6E+06	2.7E+06	4.0E+06	**
107028	Acrolein		NC	5.7E+00	8.0E+00	1.3E+01	2.0E+01	4.0E+01
107131	Acrylonitrile		C	1.2E+01	1.7E+01	2.8E+01	4.2E+01	8.5E+01
309002	Aldrin		C	1.0E-01	1.4E-01	2.4E-01	3.6E-01	7.1E-01
319846	alpha-HCH (alpha-BHC)		C	4.5E+00	6.2E+00	1.0E+01	1.6E+01	3.1E+01
100527	Benzaldehyde	X	NC	5.1E+05	7.2E+05	1.2E+06	1.8E+06	**
71432	Benzene		C	5.0E+00 †	5.0E+00 †	5.0E+00 †	6.9E+00	1.4E+01
205992	Benzo(b)fluoranthene	X	C	**	**	**	**	**
100447	Benzylchloride	X	C	4.2E+00	5.9E+00	9.8E+00	1.5E+01	3.0E+01
91587	beta-Chloronaphthalene	X	NC	**	**	**	**	**
92524	Biphenyl	X	NC	**	**	**	**	**
111444	Bis(2-chloroethyl)ether		C	1.4E+01	2.0E+01	3.3E+01	5.0E+01	1.0E+02
108601	Bis(2-chloroisopropyl)ether		C	7.3E+01	1.0E+02	1.7E+02	2.5E+02	5.1E+02
542881	Bis(chloromethyl)ether		C	6.4E-03	9.0E-03	1.5E-02	2.3E-02	4.5E-02
75274	Bromodichloromethane	X	C	3.0E+00	4.2E+00	7.0E+00	1.1E+01	2.1E+01
75252	Bromoform		C	1.2E-02	1.7E-02	2.8E-02	4.2E-02	8.3E-02
106990	1,3-Butadiene		C	4.1E-03	5.8E-03	9.6E-03	1.4E-02	2.9E-02
75150	Carbon disulfide		NC	8.1E+02	1.1E+03	1.9E+03	2.8E+03	5.6E+03
56235	Carbon tetrachloride		C	5.0E+00 †	5.0E+00 †	5.0E+00 †	5.0E+00 †	5.0E+00 †
57749	Chlordane		C	1.7E+01	2.4E+01	4.1E+01	**	**
126998	2-Chloro-1,3-butadiene (chloroprene)		NC	2.0E+01	2.9E+01	4.8E+01	7.1E+01	1.4E+02
108907	Chlorobenzene		NC	5.6E+02	7.9E+02	1.3E+03	2.0E+03	3.9E+03
109693	1-Chlorobutane	X	NC	2.9E+03	4.0E+03	6.7E+03	1.0E+04	2.0E+04
124481	Chlorodibromomethane	X	C	4.5E+00	6.3E+00	1.1E+01	1.6E+01	3.2E+01
75456	Chlorodifluoromethane		NC	**	**	**	**	**
75003	Chloroethane (ethyl chloride)		NC	4.0E+04	5.5E+04	9.2E+04	1.4E+05	2.8E+05
67663	Chloroform		C	8.0E+01 †	8.0E+01 †	8.0E+01 †	8.0E+01 †	8.0E+01 †
95578	2-Chlorophenol	X	NC	1.6E+03	2.2E+03	3.6E+03	5.5E+03	1.1E+04
75296	2-Chloropropane		NC	2.4E+02	3.4E+02	5.7E+02	8.6E+02	1.7E+03

Table 3c - GW: Question 5 Groundwater Screening Levels for Scenario-Specific Vapor Attenuation Factors (α)

Risk = 1 x 10^{-6}

				Target Groundwater Concentrations at Different Attenuation Factors				
CAS No.	Chemical	Compounds with Provisional Toxicity Data Extrapolated From Oral Sources	Basis of Target Concentration C=cancer risk NC=noncancer risk	α = 7x10^{-4} C_{gw} (ug/L)	α = 5x10^{-4} C_{gw} (ug/L)	α = 3x10^{-4} C_{gw} (ug/L)	α = 2x10^{-4} C_{gw} (ug/L)	α = 1x10^{-4} C_{gw} (ug/L)
218019	Chrysene	X	C	**	**	**	**	**
156592	cis-1,2-Dichloroethylene	X	NC	3.0E+02	4.2E+02	7.0E+02	1.0E+03	2.1E+03
123739	Crotonaldehyde (2-butenal)	X	C	8.0E+00	1.1E+01	1.9E+01	2.8E+01	5.6E+01
98828	Cumene		NC	1.2E+01	1.7E+01	2.8E+01	4.2E+01	8.4E+01
72559	DDE	X	C	4.2E+01	5.8E+01	9.7E+01	**	**
132649	Dibenzofuran	X	NC	**	**	**	**	**
96128	1,2-Dibromo-3-chloropropane		NC	4.8E+01	6.7E+01	1.1E+02	1.7E+02	3.3E+02
106934	1,2-Dibromoethane (ethylene dibromide)		C	5.2E-01	7.3E-01	1.2E+00	1.8E+00	3.6E+00
541731	1,3-Dichlorobenzene	X	NC	1.2E+03	1.7E+03	2.8E+03	4.1E+03	8.3E+03
95501	1,2-Dichlorobenzene		NC	3.7E+03	5.1E+03	8.6E+03	1.3E+04	2.6E+04
106467	1,4-Dichlorobenzene		NC	1.2E+04	1.6E+04	2.7E+04	4.1E+04	**
75718	Dichlorodifluoromethane		NC	2.0E+01	2.9E+01	4.8E+01	7.1E+01	1.4E+02
75343	1,1-Dichloroethane		NC	3.1E+03	4.4E+03	7.3E+03	1.1E+04	2.2E+04
107062	1,2-Dichloroethane		C	5.0E+00[†]	5.0E+00[†]	7.8E+00	1.2E+01	2.3E+01
75354	1,1-Dichloroethylene		NC	2.7E+02	3.7E+02	6.2E+02	9.4E+02	1.9E+03
78875	1,2-Dichloropropane		NC	5.0E+01	7.0E+01	1.2E+02	1.7E+02	3.5E+02
542756	1,3-Dichloropropene		C	1.2E+00	1.7E+00	2.8E+00	4.2E+00	8.4E+00
60571	Dieldrin		C	1.2E+00	1.7E+00	2.9E+00	4.3E+00	8.6E+00
115297	Endosulfan	X	NC	**	**	**	**	**
106898	Epichlorohydrin		NC	1.1E+03	1.6E+03	2.7E+03	4.0E+03	8.0E+03
60297	Ethyl ether	X	NC	7.4E+02	1.0E+03	1.7E+03	2.6E+03	5.2E+03
141786	Ethylacetate	X	NC	8.0E+05	1.1E+06	1.9E+06	2.8E+06	5.6E+06
100414	Ethylbenzene		C	7.0E+02[†]	7.0E+02[†]	7.0E+02[†]	7.0E+02[†]	7.0E+02[†]
75218	Ethylene oxide		C	1.5E+00	2.1E+00	3.6E+00	5.4E+00	1.1E+01
97632	Ethylmethacrylate	X	NC	1.3E+04	1.8E+04	3.0E+04	4.6E+04	9.1E+04
86737	Fluorene	X	NC	**	**	**	**	**
110009	Furan	X	NC	2.3E+01	3.2E+01	5.3E+01	7.9E+01	1.6E+02
58899	gamma-HCH (Lindane)	X	C	1.6E+01	2.3E+01	3.8E+01	5.7E+01	1.1E+02
76448	Heptachlor		C	4.0E-01[†]	4.0E-01[†]	4.0E-01[†]	4.0E-01[†]	4.0E-01[†]
87683	Hexachloro-1,3-butadiene		C	4.7E-01	6.6E-01	1.1E+00	1.7E+00	3.3E+00
118741	Hexachlorobenzene		C	1.0E+00[†]	1.0E+00[†]	1.0E+00[†]	1.0E+00[†]	1.0E+00[†]
77474	Hexachlorocyclopentadiene		NC	5.0E+01[†]	5.0E+01[†]	5.0E+01[†]	5.0E+01[†]	5.0E+01[†]
67721	Hexachloroethane		C	5.5E+00	7.6E+00	1.3E+01	1.9E+01	3.8E+01

Table 3c - GW: Question 5 Groundwater Screening Levels for Scenario-Specific Vapor Attenuation Factors (α)

Risk = 1 x 10^{-6}

				Target Groundwater Concentrations at Different Attenuation Factors				
CAS No.	Chemical	Compounds with Provisional Toxicity Data Extrapolated From Oral Sources	Basis of Target Concentration C=cancer risk NC=noncancer risk	α = 7x10^{-4} C_{gw} (ug/L)	α = 5x10^{-4} C_{gw} (ug/L)	α = 3x10^{-4} C_{gw} (ug/L)	α = 2x10^{-4} C_{gw} (ug/L)	α = 1x10^{-4} C_{gw} (ug/L)
110543	Hexane		NC	4.2E+00	5.9E+00	9.8E+00	1.5E+01	2.9E+01
74908	Hydrogen cyanide		NC	7.9E+02	1.1E+03	1.8E+03	2.8E+03	5.5E+03
78831	Isobutanol	X	NC	3.1E+06	4.4E+06	7.3E+06	1.1E+07	2.2E+07
7439976	Mercury (elemental)		NC	9.7E-01	1.4E+00	2.3E+00	3.4E+00	6.8E+00
126987	Methacrylonitrile		NC	9.9E+01	1.4E+02	2.3E+02	3.5E+02	6.9E+02
72435	Methoxychlor	X	NC	**	**	**	**	**
79209	Methyl acetate	X	NC	1.0E+06	1.4E+06	**	**	**
96333	Methyl acrylate	X	NC	2.0E+04	2.7E+04	4.6E+04	6.8E+04	1.4E+05
74839	Methyl bromide		NC	2.8E+01	3.9E+01	6.5E+01	9.8E+01	2.0E+02
74873	Methyl chloride (chloromethane)		C	9.6E+00	1.3E+01	2.2E+01	3.4E+01	6.7E+01
108872	Methylcyclohexane		NC	1.0E+03	1.4E+03	2.4E+03	3.6E+03	7.1E+03
74953	Methylene bromide	X	NC	1.4E+03	2.0E+03	3.3E+03	5.0E+03	9.9E+03
75092	Methylene chloride		C	8.3E+01	1.2E+02	1.9E+02	2.9E+02	5.8E+02
78933	Methylethylketone (2-butanone)		NC	6.2E+05	8.7E+05	1.5E+06	2.2E+06	4.4E+06
108101	Methylisobutylketone		NC	2.0E+04	2.8E+04	4.7E+04	7.1E+04	1.4E+05
80626	Methylmethacrylate		NC	7.3E+04	1.0E+05	1.7E+05	2.5E+05	5.1E+05
91576	2-Methylnaphthalene	X	NC	4.7E+03	6.6E+03	1.1E+04	1.7E+04	**
1634044	MTBE		NC	1.7E+05	2.3E+05	3.9E+05	5.9E+05	1.2E+06
108383	m-Xylene	X	NC	3.3E+04	4.7E+04	7.8E+04	1.2E+05	**
91203	Naphthalene		NC	2.2E+02	3.0E+02	5.1E+02	7.6E+02	1.5E+03
104518	n-Butylbenzene	X	NC	3.7E+02	5.2E+02	8.7E+02	1.3E+03	**
98953	Nitrobenzene		NC	2.9E+03	4.1E+03	6.8E+03	1.0E+04	2.0E+04
79469	2-Nitropropane		C	2.6E-01	3.6E-01	6.0E-01	9.0E-01	1.8E+00
924163	N-Nitroso-di-n-butylamine		C	1.7E-01	2.4E-01	3.9E-01	5.9E-01	1.2E+00
103651	n-Propylbenzene	X	NC	4.6E+02	6.4E+02	1.1E+03	1.6E+03	3.2E+03
88722	o-Nitrotoluene	X	NC	9.8E+04	1.4E+05	2.3E+05	3.4E+05	**
95476	o-Xylene	X	NC	4.7E+04	6.6E+04	1.1E+05	1.6E+05	**
106423	p-Xylene	X	NC	3.2E+04	4.5E+04	7.4E+04	1.1E+05	**
129000	Pyrene	X	NC	**	**	**	**	**
135988	sec-Butylbenzene	X	NC	3.5E+02	4.9E+02	8.2E+02	1.2E+03	2.5E+03
100425	Styrene		NC	1.3E+04	1.8E+04	3.0E+04	4.4E+04	8.9E+04
98066	tert-Butylbenzene	X	NC	4.1E+02	5.8E+02	9.6E+02	1.4E+03	2.9E+03
630206	1,1,1,2-Tetrachloroethane		C	4.7E+00	6.6E+00	1.1E+01	1.7E+01	3.3E+01

Table 3c - GW: Question 5 Groundwater Screening Levels for Scenario-Specific Vapor Attenuation Factors (α)

Risk = 1 x 10^{-6}

				Target Groundwater Concentrations at Different Attenuation Factors				
CAS No.	Chemical	Compounds with Provisional Toxicity Data Extrapolated From Oral Sources	Basis of Target Concentration C=cancer risk NC=noncancer risk	α = 7x10^{-4} C_{gw} (ug/L)	α = 5x10^{-4} C_{gw} (ug/L)	α = 3x10^{-4} C_{gw} (ug/L)	α = 2x10^{-4} C_{gw} (ug/L)	α = 1x10^{-4} C_{gw} (ug/L)
79345	1,1,2,2-Tetrachloroethane		C	4.2E+00	5.9E+00	9.9E+00	1.5E+01	3.0E+01
127184	Tetrachloroethylene		C	5.0E+00 †	5.0E+00 †	5.0E+00 †	5.4E+00	1.1E+01
108883	Toluene		NC	2.1E+03	2.9E+03	4.9E+03	7.4E+03	1.5E+04
156605	trans-1,2-Dichloroethylene	X	NC	2.6E+02	3.6E+02	6.1E+02	9.1E+02	1.8E+03
76131	1,1,2-Trichloro-1,2,2-trifluoroethane		NC	2.2E+03	3.1E+03	5.1E+03	7.7E+03	1.5E+04
120821	1,2,4-Trichlorobenzene		NC	4.9E+03	6.9E+03	1.1E+04	1.7E+04	3.4E+04
79005	1,1,2-Trichloroethane		C	5.8E+00	8.1E+00	1.4E+01	2.0E+01	4.1E+01
71556	1,1,1-Trichloroethane		NC	4.5E+03	6.3E+03	1.0E+04	1.6E+04	3.1E+04
79016	Trichloroethylene ††	X	C	5.0E+00 †	5.0E+00 †	5.0E+00 †	5.0E+00 †	5.0E+00 †
75694	Trichlorofluoromethane		NC	2.5E+02	3.5E+02	5.9E+02	8.8E+02	1.8E+03
96184	1,2,3-Trichloropropane		NC	4.2E+02	5.9E+02	9.8E+02	1.5E+03	2.9E+03
95636	1,2,4-Trimethylbenzene		NC	3.4E+01	4.7E+01	7.9E+01	1.2E+02	2.4E+02
108678	1,3,5-Trimethylbenzene		NC	3.5E+01	4.9E+01	8.2E+01	1.2E+02	2.5E+02
108054	Vinyl acetate		NC	1.4E+04	1.9E+04	3.2E+04	4.8E+04	9.6E+04
75014	Vinyl chloride (chloroethene)		C	2.0E+00 †	2.0E+00 †	2.0E+00 †	2.0E+00 †	2.5E+00

* Health-based target breathing concentration exceeds maximum possible chemical vapor concentration (pathway incomplete)

** Target soil gas concentration exceeds maximum possible vapor concentration at this soil gas to indoor air attenuation factor (pathway incomplete)

† The target groundwater concentrations is the MCL. (The MCL for chloroform is the MCL for total Trihalomethanes. The MCL listed for m-Xylene, o-Xylene, and p-Xylene is the MCL for total Xylenes.

†† The target concentration for trichloroethylene is based on the upper bound cancer slope factor identified in EPA's draft risk assessment for trichloroethylene (US EPA, 2001). The slope factor is based on state-of-the-art methodology, however the TCE assessment is still undergoing review. As a result, the slope factor and the target concentration values for TCE may be revised further. (See Appendix D.)

APPENDIX A

DATA QUALITY ASSURANCE CONSIDERATIONS

The assessment of information to determine if there is a problem associated with the migration of volatile compounds from the groundwater will require the collection and assessment of environmental data and possibly the use of modeling as part of the assessment. As the guidance indicates, decisions to screen out sites after the first tier of screening from further analysis should be based either upon definitive measurement data or upon multiple lines of converging information. The ability to measure contamination levels in different media and to characterize the variability associated with sampling are key considerations.

OSWER expects that site-specific projects assess the impact of groundwater contaminants on indoor VOCs will be addressed by an approved Quality Assurance Project Plan (QAPP). This appendix is intended to provide a few recommendations on developing a QAPP, which need to follow EPA Requirements for Quality Assurance Project Plans (QA/R-5).

> *Recommendation 1: Using the Conceptual Site Model, develop the project plan and quality assurance project plan through a process that involves all key players and share these materials with interested parties in draft form so that potential study weaknesses can be addressed early.*

The collection and assessment of data, or the use of a model for the assessment of the data, warrants the development of a Quality Assurance Project Plan as part of a systematic planning process (EPA, 2000a,b, 2001). The EPA Region 1 guidance on the Quality Assurance Project Plan may be a useful reference that can aid site managers (EPA, 1999).

Data Quality Objectives (DQOs) play a central role in the systematic planning process as they help to ensure that the data collected will be of sufficient quality to support their intended use. Data Quality Objectives will generally be addressed within the Quality Assurance Project Plan and are typically a critical element in the planning for much of the work that EPA undertakes. The Agency guidance for DQOs, *Guidance for the Data Quality Objectives Process (G-4)*, provides useful information to implement DQOs (EPA, 2000c).

Table A-1 summarizes the steps in the DQO process, the purpose of each step, and provides some examples of how plans could be structured.

Table A-2 summarizes the sensitivity/detection limits of a variety of currently available methods for the analysis of VOCs along with estimated cost information. Table A-2 has been prepared to summarize some information that can serve as a general guide but should be updated as individual projects are undertaken.

The determination of the analytic and sampling methods to use, the number of samples, location of samples, and timing is a challenging task that will be related to a number of factors, including the values for screening and risk that will use the monitored results. These sampling issues can be addressed, at least in part, by employing software that has been designed to optimize sampling so that confidence in results will be maximized. Visual Sample Plan (VSP)[http://dqo.pnl.gov/vsp/] has been developed to provide statistical solutions to sampling design, mathematical and statistical algorithms, and a user-friendly visual interface, while answering the following two important questions in sample planning:

- How many samples are needed?

  The algorithms involved in determining the number of samples needed can be quite involved and intimidating to the non-expert. VSP aids in the calculation of the number of samples often needed for various scenarios at different costs.

- Where should the samples be taken?

  Sample placement based on professional judgment is prone to bias. VSP provides the alternative of random or gridded sampling locations overlaid on the site map.

References

EPA, 1999. ***EPA New England Compendium of Quality Assurance Project Plan Requirements and Guidance***. EPA, Region 1, Boston, MA. (http://www.epa.gov/NE/measure/qappcompendium.pdf).

EPA, 2000a. ***EPA Order 5360.1.A2, Policy and Program Requirements for the Mandatory Agency-wide Quality System***. EPA, Washington, D.C. (http://www.epa.gov/quality/qs-docs/5360-1.pdf).

EPA, 2000b. ***EPA Quality Manual for Environmental Programs.*** EPA, Washington, D.C. (http://www.epa.gov/quality/qs-docs/5360.pdf).

EPA, 2000c. ***Guidance for the Data Quality Objectives Process (G-4).*** EPA, Washington, D.C. (http://www.epa.gov/quality/qs-docs/g4-final.pdf)

EPA, 2001. ***EPA Requirements for QA Project Plans (QA/R-5)***. EPA, Washington, D.C. (http://www.epa.gov/quality/qs-docs/r5-final.pdf) and (http://www.epa.gov/QUALITY/qapps.html)

Visual Sample Plan (VSP)[http://dqo.pnl.gov/vsp/]

Table A-1. Example of Steps in the DQO Process using Q5©) of guidance

DQO Step	Purpose of the DQO Step	Example Application
1. State the Problem	Summarize the problem that will require new environmental data (the monitoring hypothesis) and modeling (if modeling is to be used).	Do measured or reasonably estimated groundwater concentrations exceed the target media-specific concentrations given in Table 2 (from the main body of the guidance)?
2. Identify the Decision	Identify the decision that requires new data/analysis to address the problem.	The decisions will be whether available information is sufficient to screen the site from further study.
3. Identify the Inputs to the Decision	Identify the information needed to support the decision and specify that inputs will require new information.	Ground water monitoring data will be compared with the screening values provided in guidance along with information to determine what comparisons would be most appropriate (e.g., soil type, screening wells at water table).
4. Define the Boundaries of the Study	Specify the spatial and temporal aspects of the environmental media or endpoints that the data must represent to support the decision.	The boundaries of the study will be defined by the extent to which indoor air contamination can be associated with site-related contamination. Groundwater contamination closest to the residential units would be of greatest relevance but other contamination may pose a risk to residential units in the future.

DQO Step	Purpose of the DQO Step	Example Application
5. Develop a Decision Rule	Develop a logical "if..then" statement that defines the conditions that will inform the decision maker to choose among alternative decisions.	For example, "If any measured VOC concentration in groundwater is above the action level for groundwater screening in Question 5c, then further assessment (including soil gas concentrations, and possibly indoor air concentrations, depending on the magnitude of the concentrations) should be performed as appropriate.
6. Specify Tolerable Limits on Decision Errors	Specify acceptable limits on decision errors, which are used to establish performance goals for limiting uncertainly in the analysis.	Decision errors could result from failing to appreciate uncertainty in sampling, analysis or performing analyses. Decision performance goals may be useful in managing uncertainty. The use of a computer program, such as *Visual Sample Plan* (VSP) can aid in understanding and managing uncertainties associated with sampling and analysis.[1]
7. Optimize the Design for Obtaining Data	Identify the most resource-effective sampling and analysis design for generating the information needed to satisfy the DQOs.	Again, using a tool like VSP may prove very useful in understanding and managing uncertainty in this study. See discussion of VSP.

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[1] VSP is a computer program that is useful for optimizing sampling efforts so that the greatest value in confidence of information can be collected for an expenditure of resources.

Table A-2. VOC Analytical Methods, their Detection Limits and Estimated Costs

(compiled July 2002)

Media	Analytical Method / Reference	Description	Average Practical Detection Limits	Analyte List	Estimated Analytical Costs
Water	**OSW - SW 846 Method 8260C** http://www.epa.gov/epaoswer/hazwaste/test/main.htm	Purge and trap GC/MS	5 ug/L	1	$ 100
Water	**OW Drinking Water Method 524.2** http://www.epa.gov/safewater/methods/methods.html	Purge and trap GC/MS	0.5 ug/L	2	$ 90
Water	**OERR/AOC SOW OLM04.2** http://www.epa.gov/superfund/programs/clp/olm42.htm	Purge and trap GC/MS	10 ug/L	3	$ 130
Water	**OERR/AOC SOW OLC03.2** http://www.epa.gov/superfund/programs/clp/olc32.htm	Purge and trap GC/MS	0.5 ug/L	4	$ 100
Soil	**OSW - SW 846 Method 8260C** http://www.epa.gov/epaoswer/hazwaste/test/main.htm	Purge and trap GC/MS	5 ug/kg	1	$ 100
Soil	**OERR/AOC SOW OLM04.2** http://www.epa.gov/superfund/programs/clp/olm42.htm	Purge and trap GC/MS	10 ug/kg	3	$130
Air	**OSW SW846 Method 5041** http://www.epa.gov/epaoswer/hazwaste/test/pdfs/5041a.pdf	Sorbent tubes/Thermal Desporption	0.1 ug/m3	5	$100
Air	**NIOSH Method 1003** Chlorinated VOCs http://www.cdc.gov/niosh/nmam/pdfs/1003.pdf	Charcoal Tubes / GC	0.01mg/L	6	$ 50
Air	**NIOSH Method 1501** http://www.cdc.gov/niosh/nmam/pdfs/1501.pdf	Charcoal Tubes/ GC	0.001 mg/L	7	$ 50

Air	**OAR TO-15** http://www.epa.gov/ttnamti1/airtox.html	Canisters/GC/MS	0.2-0.5 ug/m3 Scan Method 0.02 SIM Method	8	$ 250
Air	**OAR TO-17** http://www.epa.gov/ttnamti1/airtox.html	Sorbent Tubes/GC/MS	0.2-0.5 ug/m3	8	?
Air	**ASTM Method D-1945**	(GC/TCD/FID) .	Reporting Limit = 10 ppmv, O_2 and N_2 = 1000 (0.1%) ppmv, CH_4 = 1 ppmv.	Atmospheric gases plus C_1-C_6 hydrocarbon speciation	
Air	**ASTM Method D-1946** (GC/TCD/FID)	Atmospheric gases		O_2, N_2, CO, CO_2, CH_4, ethane, ethylene	?
Air	**Method TO-5 HPLC** http://www.epa.gov/ttnamti1/airtox.html	Selected aldehydes and ketones collected via dinitrophenylhydrazine (DNPH) midget impinger.	0.05 ug	-	?
Air	**Method TO-11 HPLC** http://www.epa.gov/ttnamti1/airtox.html	Selected aldehydes and ketones collected on a dinitrophenylhydrazine (DNPH) coated Sep-Pak cartridge	0.05 ug.	-	?

VOC Methods Analyte Lists

List 1 Office of Solid Waste SW 846 Method 8260 C

Acetone
Acetonitrile
Acrolein (Propenal)
Acrylonitrile
Allyl alcohol
Allyl chloride
Benzene
Benzyl chloride
Bis(2-chloroethyl)sulfide
Bromoacetone
Bromochloromethane
Bromodichloromethane
Bromoform
Bromomethane
n-Butanol
2-Butanone (MEK)
t-Butyl alcohol
Carbon disulfide
Carbon tetrachloride
Chloral hydrate
Chlorobenzene
Chlorodibromomethane
Chloroethane
2-Chloroethanol
2-Chloroethyl vinyl ether
Chloroform
Chloromethane
Chloroprene
3-Chloropropionitrile
Crotonaldehyde
1,2-Dibromo-3-chloropropane
1,2-Dibromoethane
Dibromomethane
1,2-Dichlorobenzene
1,3-Dichlorobenzene
1,4-Dichlorobenzene
cis-1,4-Dichloro-2-butene
trans-1,4-Dichloro-2-butene
Dichlorodifluoromethane
1,1-Dichloroethane
1,2-Dichloroethane
1,1-Dichloroethene
trans-1,2-Dichloroethene
1,2-Dichloropropane
1,3-Dichloro-2-propanol
cis-1,3-Dichloropropene
trans-1,3-Dichloropropene
1,2,3,4-Diepoxybutane
Diethyl ether
1,4-Dioxane
Epichlorohydrin
Ethanol
Ethyl acetate
Ethylbenzene
Ethylene oxide
Ethyl methacrylate
Hexachlorobutadiene
Hexachloroethane
2-Hexanone
2-Hydroxypropionitrile
Iodomethane
Isobutyl alcohol
Isopropylbenzene
Malononitrile
Methacrylonitrile
Methanol
Methylene chloride
Methyl methacrylate
4-Methyl-2-pentanone (MIBK)
Naphthalene
Bromobenzene
1,3-Dichloropropane
n-Butylbenzene
2,2-Dichloropropane
sec-Butylbenzene
1,1-Dichloropropene
tert-Butylbenzene
p-Isopropyltoluene
Chloroacetonitrile
Methyl acrylate
1-Chlorobutane
Methyl-t-butyl ether
1-Chlorohexane
Pentafluorobenzene
2-Chlorotoluene
n-Propylbenzene
4-Chlorotoluene
1,2,3-Trichlorobenzene
Dibromofluoromethane
1,2,4-Trimethylbenzene
cis-1,2-Dichloroethene
1,3,5-trimethylbenzene

VOC Methods Analyte Lists (cont.)

List 2 EPA Office of Water Method 524.2	List 3 OERR (Superfund) CLP Statement of Work OLM04.2
Chloroform	1,1-Dichloroethane
Bromodichloromethane	1,1-Dichloroethene
Bromoform	1,1,1-Trichloroethane
Chlorodibromomethane	1,1,2-Trichloro-
Bromobenzene	1,1,2-Trichloroethane
Bromochloromethane	1,1,2,2-Tetrachloroethane
Bromomethane	1,2-Dibromo-3-chloropropane
n-Butylbenzene	1,2-Dibromoethane
tert-Butylbenzene	1,2-Dichlorobenzene
Chloroethane	1,2-Dichloroethane
Chloromethane	1,2-Dichloropropane
o-Chlorotoluene	1,2,2-trifluoroethane
p-Chlorotoluene	1,2,4-Trichlorobenzene
Dibromomethane	1,3-Dichlorobenzene
m-Dichlorobenzene	1,4-Dichlorobenzene
Dichlorodifluoromethane	2-Butanone [78-93-3]
1,1-Dichloroethane	2-Hexanone
1,3-Dichloropropane	4-Methyl-2-pentanone
2,2-Dichloropropane	Acetone
1,1-Dichloropropene	Benzene
1,3-Dichloropropene	Bromodichloromethane
Fluorotrichloromethane	Bromoform
Hexachlorobutadiene	Bromomethane
Isopropylbenzene	Carbon Disulfide
p-Isopropyltoluene	Carbon Tetrachloride [56-23-5]
Naphthalene	Chlorobenzene
n-Propylbenzene	Chloroethane
1,1,2,2-Tetrachloroethane	Chloroform [67-66-3]
1,1,1,2-Tetrachloroethane	Chloromethane
1,2,3-Trichlorobenzene	cis-1,2-Dichloroethene
1,2,3-Trichloropropane	cis-1,3-Dichloropropene
1,2,4-Trimethylbenzene	Cyclohexane [110-82-7]
1,3,5 -Trimethylbenzene	Dibromochloromethane
	Dichlorodifluoromethane
	Ethylbenzene
	Isopropylbenzene
	Methyl tert-Butyl Ether
	Methyl Acetate
	Methylcyclohexane
	Methylene Chloride
	Styrene
	Tetrachloroethene
	Toluene
	trans-1,2-Dichloroethene
	trans-1,3-Dichloropropene
	Trichloroethene
	Trichlorofluoromethane
	Vinyl Chloride
	Xylenes (total)

VOC Methods Analyte Lists (cont.)

List 4 OERR (Superfund) CLP Statement of Work OLC03.2	List 5 Office of Solid Waste SW 846 Method 5041
1,1-Dichloroethane 1,1-Dichloroethene 1,1,1-Trichloroethane 1,1,2-Trichloro-1,2,2-trifluoroethane 1,1,2-Trichloroethane 1,1,2,2-Tetrachloroethane 1,2-Dibromo-3-chloropropane 1,2-Dibromoethane 1,2-Dichlorobenzene 1,2-Dichloroethane 1,2-Dichloropropane 1,2,3-Trichlorobenzene 1,2,4-Trichlorobenzene 1,3-Dichlorobenzene 1,4-Dichlorobenzene 2-Butanone 2-Hexanone 4-Methyl-2-pentanone Acetone Benzene Bromochloromethane Bromodichloromethane Bromoform Bromomethane Carbon Disulfide Carbon Tetrachloride Chlorobenzene Chloroethane Chloroform Chloromethane cis-1,2-Dichloroethene cis-1,3-Dichloropropene Cyclohexane Dibromochloromethane Dichlorodifluoromethane Ethylbenzene Isopropylbenzene Methyl Acetate Methyl tert-Butyl Ether Methylcyclohexane Methylene Chloride Styrene Tetrachloroethene Toluene trans-1,2-Dichloroethene trans-1,3-Dichloropropene Trichloroethene Trichlorofluoromethane Vinyl Chloride Xylenes (total)	Acetone Acrylonitrile Benzene Bromodichloromethane Bromoform Bromomethane Carbon disulfide Carbon tetrachloride Chlorobenzene Chlorodibromomethane Chloroethane Chloroform Chloromethane Dibromomethane 1,1-Dichloroethane 1,2-Dichloroethane 1,1-Dichloroethene trans-1,2-Dichloroethene 1,2-Dichloropropane cis-1,3-Dichloropropene trans-1,3-Dichloropropene Ethylbenzene Iodomethane Methylene chloride Styrene 1,1,2,2-Tetrachloroethane Tetrachloroethene Toluene 1,1,1-Trichloroethane 1,1,2-Trichloroethane Trichloroethene Trichlorofluoromethane 1,2,3-Trichloropropane Vinyl chloride Xylenes

VOC Methods Analyte Lists (cont.)

List 6 NIOSH Method 1003	List 7 NIOSH Method 1501
Benzyl chloride Bromoform Carbon tetrachlorideab Chlorobenzene Chlorobromomethane Chloroform o-Dichlorobenzene p-Dichlorobenzene 1,1-Dichloroethane 1,2-Dichloroethylene Ethylene dichloride Hexachloroethane 1,1,1-trichloroethane Tetrachloroethylene 1,1,2-Trichloroethane 1,2,3-Trichloropropane	1-tert-butyl-4-methylbenzene a-methylstyrene benzene cumene dimethylbenzene (p-xylene) (meta) ethylbenzene isopropenylbenzene isopropylbenzene methylbenzene methylstyrene methylvinylbenzene (ortho) naphthalene p-tert-butyltoluene styrene toluene vinylbenzene xylene

VOC Methods Analyte Lists (cont.)

List 8 EPA Office of Air and Radiation TO-15 & TO-17

1,1-Dimethylhydrazine;
1,1,2-Trichloroethane;
1,1,2,2-Tetrachloroethane;
1,2-Dibromo-3-chloropropane;
1,2-Epoxybutane (1,2-butylene oxide);
1,2-Propyleneimine (2-methylazindine);
1,2,4-Trichlorobenzene;
1,3-Butadiene;
1,3-Dichloropropene;
1,3-Propane sultone;
1,4-Dichlorobenzene (p-);
1,4-Dioxane (1,4 Diethylene oxide);
2-Nitropropane;
2,2,4-Trimethyl pentane;
Acetaldehyde (ethanal);
Acetonitrile (cyanomethane);
Acetophenone;
Acrolein (2-propenal);
Acrylamide;
Acrylic acid;
Acrylonitrile (2-propenenitrile);
Allyl chloride (3-chloropropene);
Aniline (aminobenzene);
Benzene;
Benzyl chloride (a-chlorotoluene);
Beta-Propiolactone;
Bis(2-Chloroethyl)ether;
Bis(chloromethyl) ether;
Bromoform (tribromomethane);
Carbon tetrachloride;
Carbon disulfide;
Carbonyl sulfide;
Catechol (o-hydroxyphenol);
Chloroacetic acid;
Chlorobenzene;
Chloroform;
Chloromethyl methyl ether;
Chloroprene (2-chloro-1,3-butadiene);
Cresylic acid (cresol isomer mixture);
Cumene (isopropylbenzene);
Diazomethane;
Diethyl sulfate;
Dimethyl sulfate;
Dimethylcarbamyl chloride;
Epichlorohydrin (l-chloro-2,3-epoxy propane);
Ethyl acrylate;
Ethyl carbamate (urethane);
Ethyl chloride (chloroethane);
Ethylbenzene;
Ethylene dibromide (1,2-dibromoethane);
Ethylene dichloride (1,2-dichloroethane);
Ethylene oxide;
Ethyleneimine (aziridine);
Ethylidene dichloride (1,1-dichloroethane);
Formaldehyde;
Hexachlorobutadiene;
Hexachloroethane;
Hexane;
Isophorone;
m-Xylene;
Methanol;
Methyl methacrylate;
Methyl isobutyl ketone (hexone);
Methyl chloride (chloromethane);
Methyl bromide (bromomethane);
Methyl ethyl ketone (2-butanone);
Methyl isocyanate;
Methyl iodide (iodomethane);
Methyl chloroform (1,1,1 trichloroethane);
Methyl tert-butyl ether;
Methylene chloride;
Methylhydrazine;
N-Nitrosodimethylamine;
N-Nitrosomorpholine;
N-Nitrso-N-methylurea;
Nitrobenzene;
N,N-Dimethylaniline;
N,N-Dimethylformamide;
o-Cresol;
o-Xylene;
p-Xylene;
Phenol;
Phosgene;
Propionaldehyde;
Propylene dichloride (1,2-dichloropropane);
Propylene oxide;
Styrene oxide;
Styrene;
Tetrachloroethylene;
Toluene;
Trichloethylene;
Triethylamine;
Vinyl acetate;
Vinyl bromide (bromoethene);
Vinyl chloride (chloroethene);
Vinylidene chloride (1,1-dichloroethylene);
Xylenes (isomer & mixtures);

APPENDIX B

DEVELOPMENT OF A CONCEPTUAL SITE MODEL (CSM) FOR ASSESSMENT OF THE VAPOR INTRUSION PATHWAY

1. Introduction

A conceptual site model (CSM) is a simplified version (picture and/or description) of a complex real-world system. A CSM is not an analytical or mathematical computer model (although a detailed CSM may serve as a foundation for such models). The goal for developing a CSM in the assessment of the vapor intrusion pathway is to assemble a comprehensive (as possible) three-dimensional "picture" based on available reliable data describing the sources of the contamination, the release/transport mechanisms, the possible subsurface pathways, and the potential receptors, as well as historical uses of the site, cleanup concerns expressed by the community, and future land use plans. All the important features relevant to characterization of a site should be included in a CSM and any irrelevant ones excluded. The CSM should present both a narrative and a visual representation of the actual or predicted relationships between receptors (humans and/or ecological entities) and the contaminants at the site, as well as reflect any relevant background levels.

Development of a CSM is an important first step in planning and scoping any site assessment designed to determine the potential impacts of contamination on public health and the environment. In documenting current site conditions, a CSM should be supported by maps, cross sections and site diagrams, and the narrative description should clearly distinguish what aspects are known or determined and what assumptions have been made in its development. The CSM should provide all interested parties a conceptual understanding of the potential for exposure to any hazardous contaminants at a site. As such, it serves as an essential tool to aid management decisions associated with the site and also serves as a valuable communication tool both internally with the "site team" and externally with the community.

A well-defined, detailed CSM will facilitate the identification of additional data needs and development of appropriate Data Quality Objectives (DQOs) in planning any sample collection/analyses to support the site risk assessment. It can also provide useful information for prompt development of a strategy for early response actions if the vapor intrusion pathway is considered to be complete and may pose an imminent potential risk to public health.

Because the CSM is likely to evolve over the course of the site assessment process, it should be considered dynamic in nature. Integration of newly developed information is an iterative process that can occur throughout the early stages of the site assessment process. This should include stakeholder input from persons who are knowledgeable about the community and activities which may have generated the contaminants or affected their movement. As additional data become available during implementation of the site assessment DQO process, the CSM should be updated. Such updates could also suggest iterative refinement of the DQO process (optimization step), since changes in the CSM may lead to identification of additional data or information not previously recognized as needed. As a fundamental site assessment tool, the CSM warrants prompt updating and distribution to interested parties during the site assessment process.

2. Collecting Existing Site Data

The following general types of information are important for preparing a CSM:

- site maps, sample location maps, aerial photos
- historical site activity, chronology of land use, populations information
- State soil surveys
- published data on local and regional climate, soils, and hydrogeology
- any previous site studies and actions (e.g. Preliminary Assessment/Site Investigation)
- an overview of the nature and extent of the contamination

The CSM developed should identify, in as comprehensive a manner as possible, all potential or suspected sources of contamination (soil, groundwater, soil gas, etc.); the types and concentrations of contamination detected at the site; all potential subsurface pathways, including preferential pathways; and the media and buildings associated with each pathway cleanup. Additional considerations that may be important to include in developing an optimal CSM for use in management decisions are presented below.

3. Additional Considerations for CSM Development for the Vapor Intrusion Pathway

- sensitive populations, including but not limited to:
  - the elderly
  - pregnant or nursing women
  - infants
  - children
  - people suffering from chronic illnesses

- people exposed to particularly high levels of contaminants

- circumstances where a disadvantaged population is exposed (Environmental Justice situation)

- significant contamination sources
  - NAPLs
  - very shallow contaminated groundwater or soil

- vapor transport pathways (see Figure B-1)
  - diffusion upwards
  - lateral vapor transport
  - preferential vapor pathways such as fractured sediments or utility features

- potential non-site related sources of contaminants
  - ambient (outdoor) air sources
  - indoor air emission sources

- building construction quality
  - foundation type (basement, slab on grade, crawlspace)
  - foundation integrity

- building use
  - open windows (etc.)

4. Organizing Existing Site Data for Inclusion in a CSM

The ***Conceptual Site Model Summary*** presented in Attachment A of the ***Soil Screening Guidance: User's Guide*** contains four detailed forms for compiling site data useful in developing a CSM for soil screening purposes. These CSM Summary forms systematically organize the site data according to general site information, soil contaminant source characteristics, exposure pathways and receptors. ***Planning Table 1*** presented in the ***Risk Assessment Guidance for Superfund: Volume I - Human Health Evaluation Manual, Part D - Standardized Planning, Reporting, and Review of Superfund Risk Assessments*** may be used in a similar manner to prepare/supplement the CSM. ***Planning Table 1*** is intended to accompany the CSM and present the possible receptors, exposure routes, and exposure pathways, as well as the rationale for selection or exclusion of each potential exposure pathway. The exposure pathways that were examined and excluded from analysis and the exposure pathways that will be evaluated qualitatively or quantitatively in the site risk assessment are clearly reflected when ***Planning Table 1*** is used. Either of these systematic site information organizing formats that are useful for CSM development can also be used to communicate risk information about the site to interested parties outside EPA. The systematic and comprehensive approach encouraged by compilation of data and information in these standard formats, like other steps in the site risk assessment process, may suggest further refinement of the CSM.

• Constructing Conceptual Site Model Diagrams

An example of a complete CSM including diagrams prepared for soil screening purposes can be found in ***Attachment A*** of the ***Soil Screening Guidance: User's Guide***. A software application that can generate CSM diagrams and reflect relevant site data has been developed (DOE). The ***Site Conceptual Exposure Model Builder*** can be found on the internet.
(URL = http://tis-nt.eh.doe.gov/oepa/programs/scem.cfm)

• Additional Resources for CSM Development Guidance

(1) The following provide more specific guidance for developing a CSM for cleanup programs:

Soil Screening Guidance: User's Guide. **Part 2.1 and Attachment A**; EPA-540-R-96-018. Office of Emergency and Remedial Response/EPA. July 1996.

Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites Office of Emergency and Remedial Response/EPA

Risk Assessment Guidance for Superfund (RAGS): Volume I - Human Health Evaluation Manual, Part D - (Standardized Planning, Reporting, and Review of Superfund Risk Assessments), Final December 2001. Pub. # - 9285.7-47; *Chapter 2 - Risk Considerations in Project Scoping*; EPA - Office of Emergency and Remedial Response.

Site Conceptual Exposure Model Builder - User Manual - for PC (Windows version) application to assist in preparing a site model; U.S. Dept of Energy, RCRA/CERCLA Division; July 1997.

Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA. EPA 540-G-89-004. Office of Emergency and Remedial Response/EPA . 1989.

Expedited Site Assessment Tools for Underground Storage Tank Sites: A Guide for Regulators. Chapter 2. EPA 510-B-97-001; Office of Underground Storage Tanks/EPA; March 1997.

(2) Selected risk assessment guidance and related documents that contain discussions concerning necessary problem formulation, and planning and scoping prior to conducting a risk assessment can provide some additional perspective to consider in preparation of a Conceptual Site Model.

Quality Assurance Guidance for Conducting Brownfields Site Assessments, EPA 540-R-98-038; OSWER 9230.0-83P; PB98-963307; September 1998.

Guidelines for Ecological Risk Assessment, EPA 630-R-95-002F, Federal Register Vol 63, pp.26846-26924; May 14, 1998.

Framework for Cumulative Risk Assessment - External Review Draft, EPA 630-P-02-001A; Risk Assessment Forum; April 23, 2002.

Risk Characterization Handbook, EPA 100-B-00-002, December 2000.

Guidance For The Data Quality Objectives Process - EPA QA/G-4; EPA-600-R-96-055; September 1994.

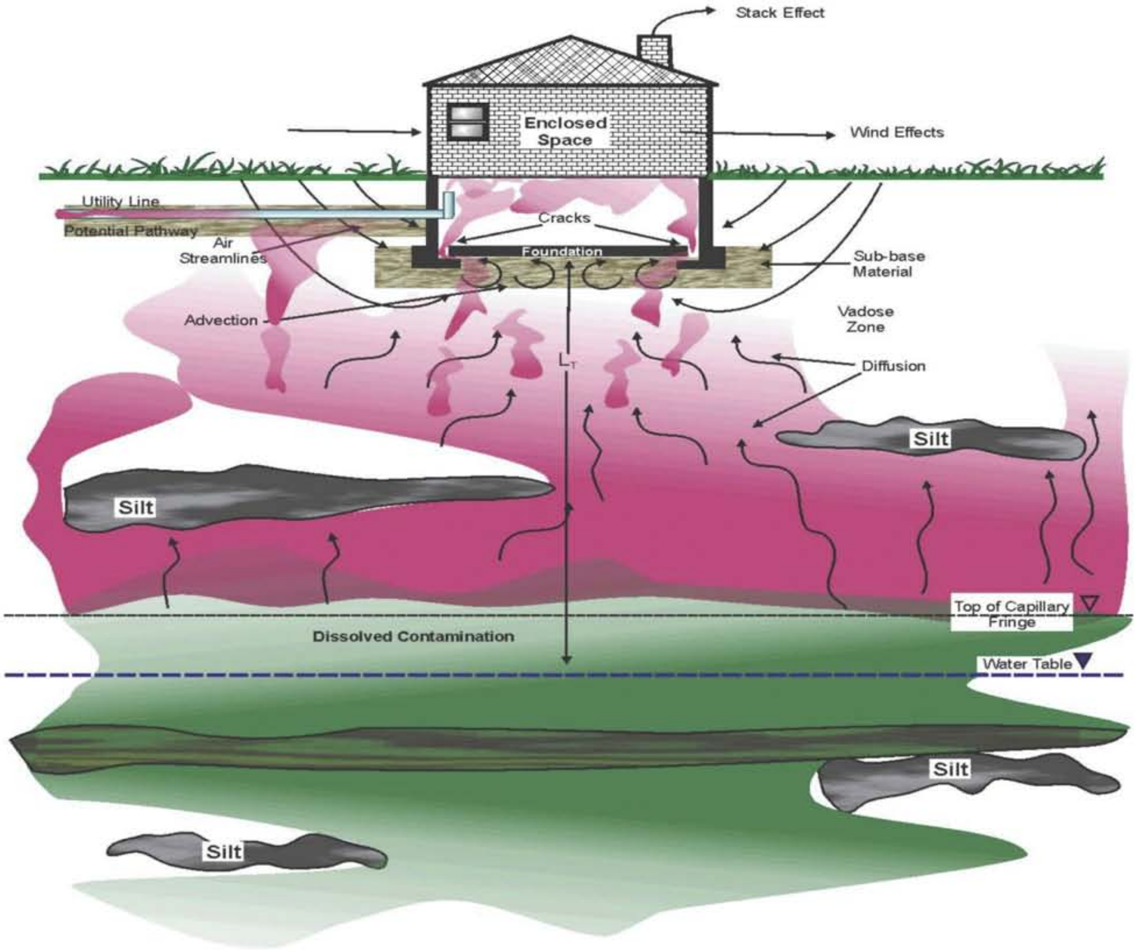
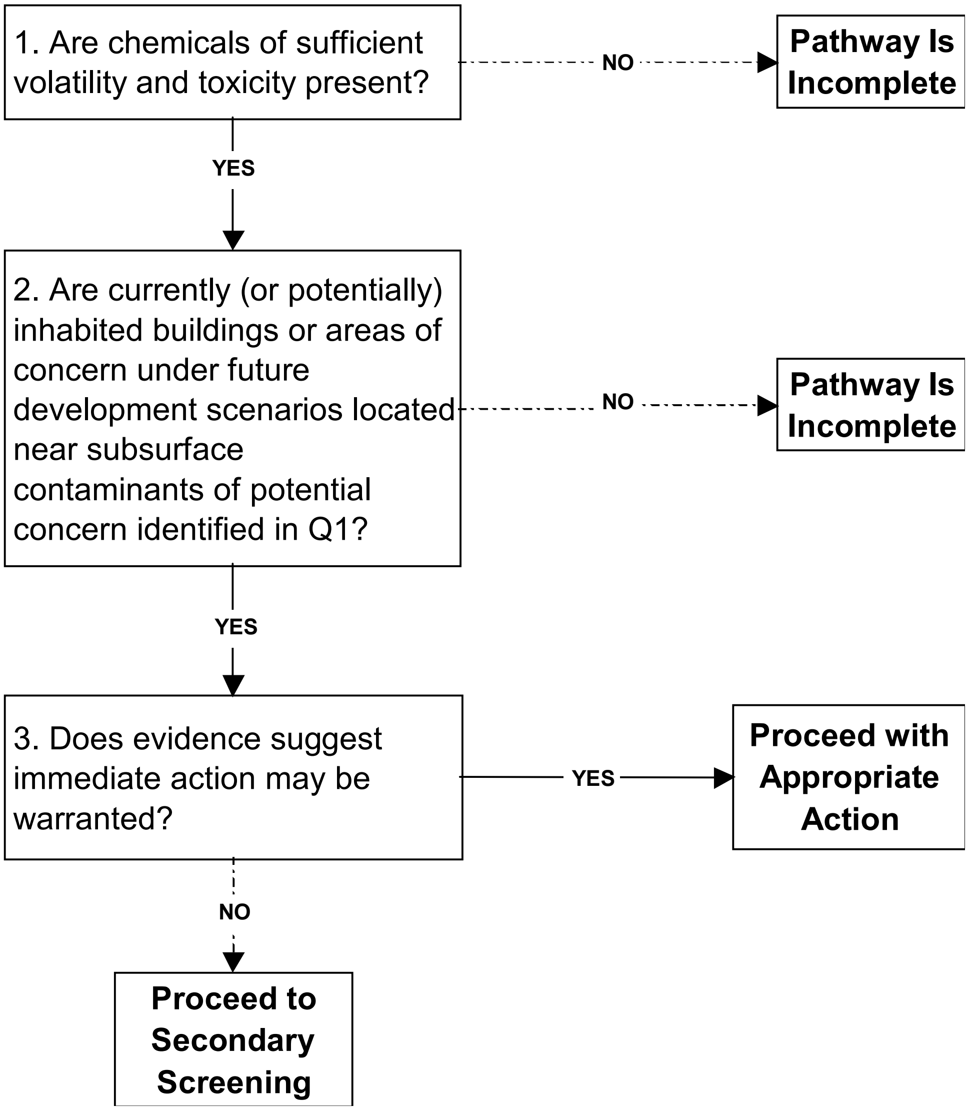


Figure B-1. Example of Conceptual Site Model cross section diagram illustrating potential subsurface vapor intrusion pathways

APPENDIX C

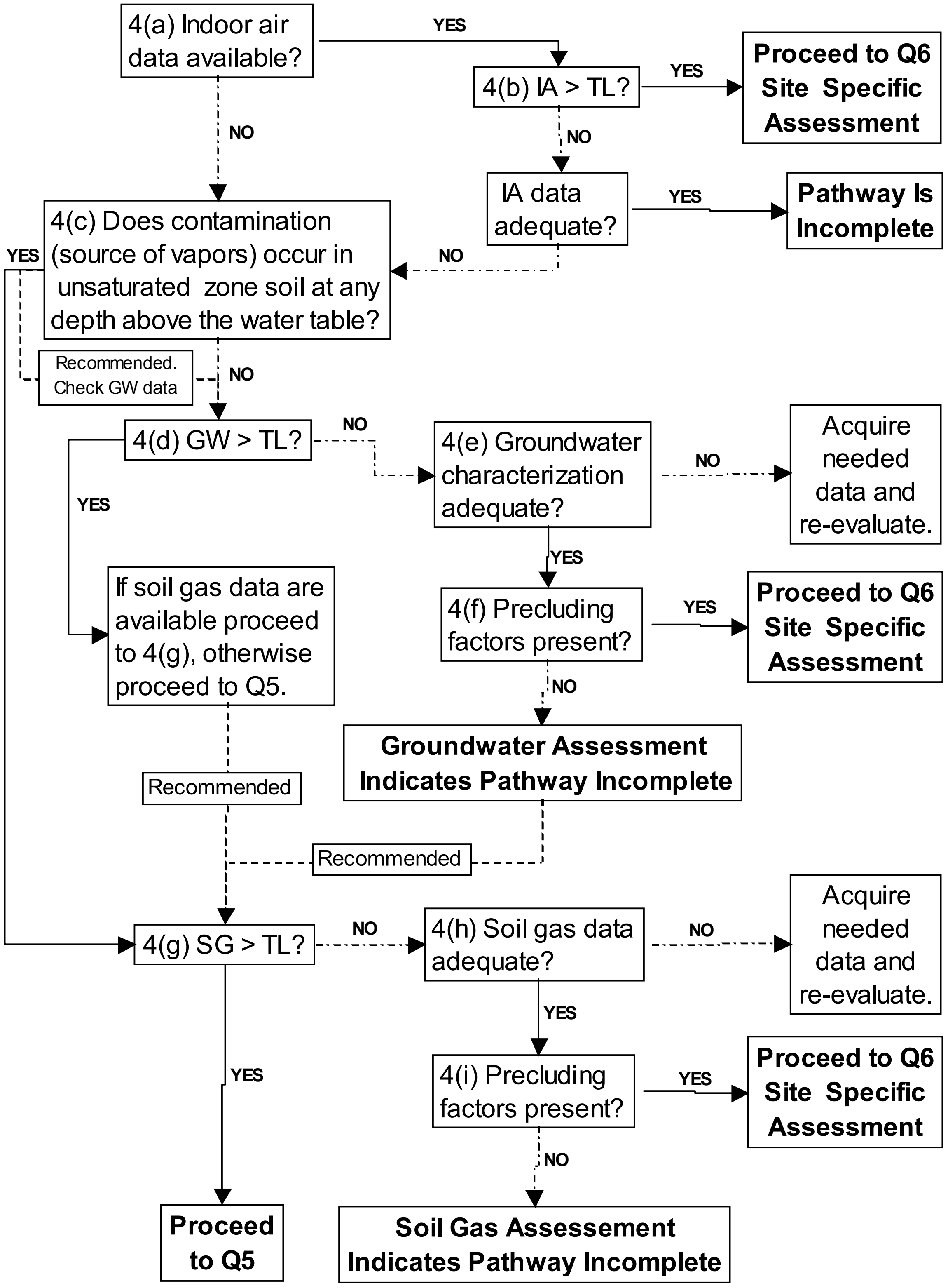
DETAILED FLOW DIAGRAMS OF THE EVALUATION APPROACH USED IN THE GUIDANCE

PRIMARY SCREENING



SECONDARY SCREENING
Question 4 – Generic Screening

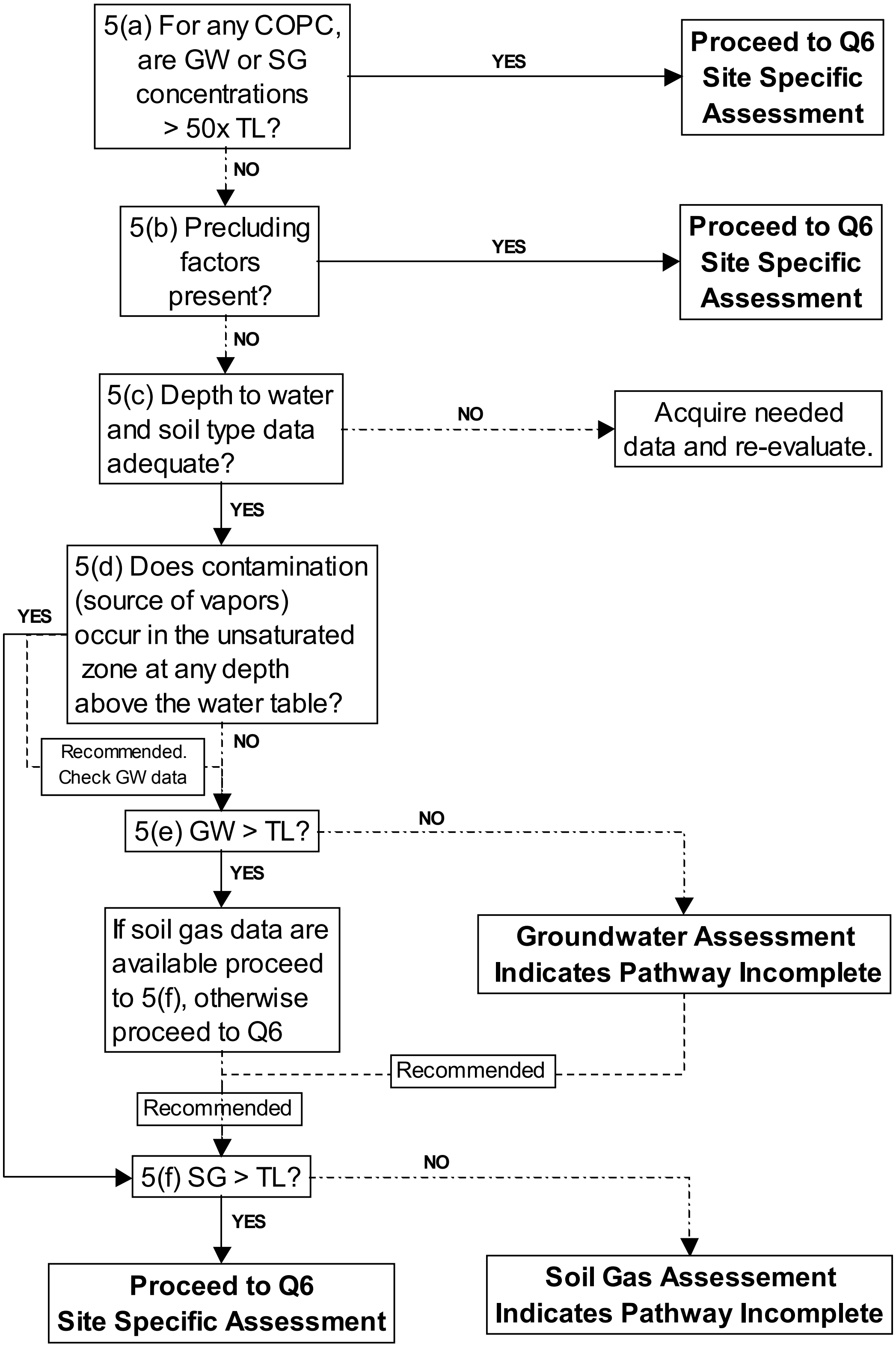
(TL = appropriate media specific target level)



SECONDARY SCREENING

Question 5 – Semi-Site Specific Screening

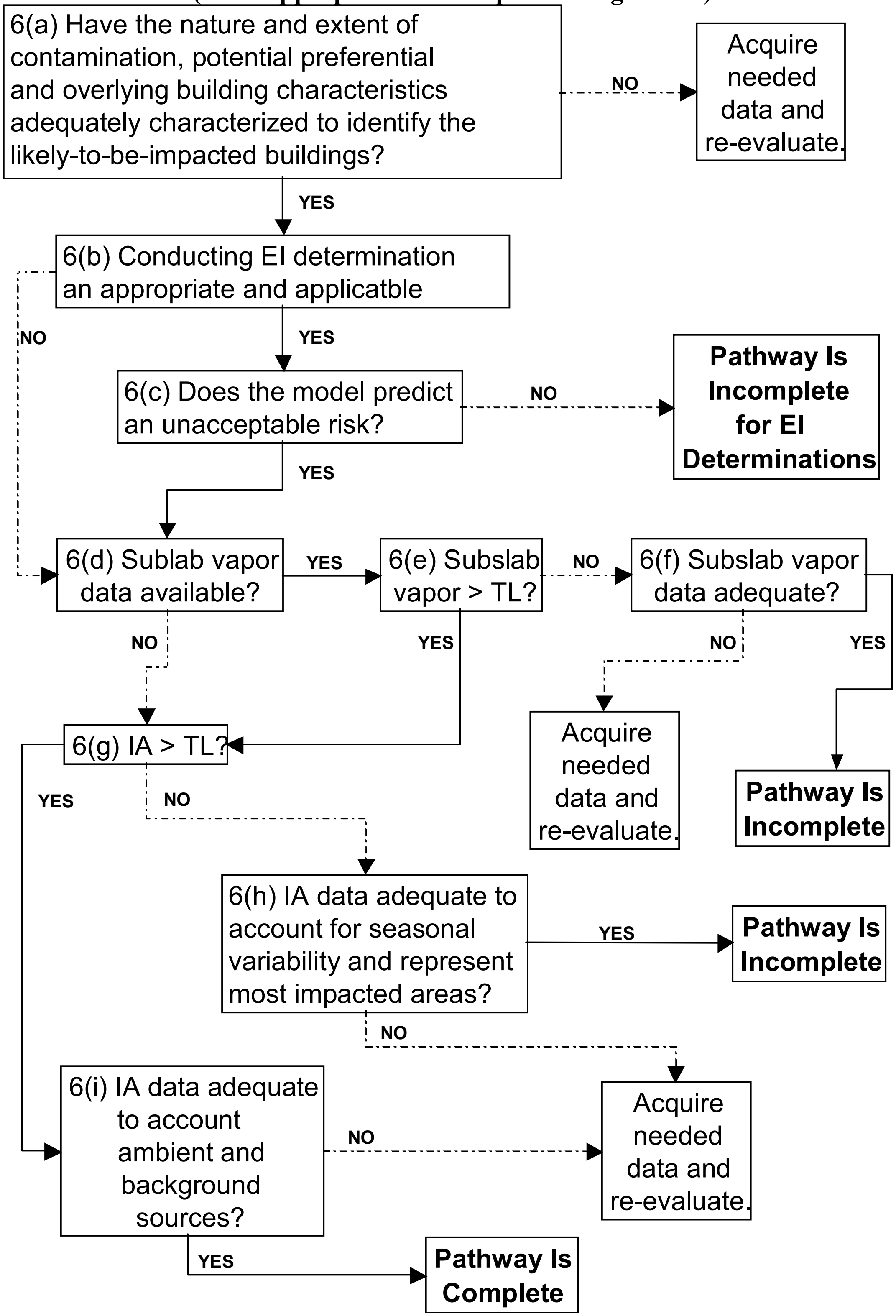
(TL = appropriate media specific target level)



SITE SPECIFIC SCREENING

Question 6

(TL = appropriate media specific target level)



APPENDIX D

DEVELOPMENT OF TABLES 1, 2, AND 3

1. Introduction

This appendix describes the data and calculations used to develop Tables 1, 2, and 3 in the guidance. Table 1 lists chemicals that may be present at hazardous waste sites and indicates whether, in our judgment, they are of sufficient toxicity and volatility to result in a potentially unacceptable indoor inhalation risk. Tables 2 and 3 provide generally recommended target concentrations for contaminants in indoor air, groundwater, and soil gas. For non-carcinogens, these values are based on the appropriate reference concentration, and for carcinogens, they are calculated using a method consistent with the approach in EPA's *Supplemental Guidance for Developing Soil Screening Levels* (EPA, to be published). Only chemicals that are, in our judgment, sufficiently volatile and toxic to pose an inhalation risk are included in Tables 2 and 3. The approach described here also can be used, as appropriate, to evaluate chemicals not listed in the tables.

2. Description of Tables 1, 2 and 3

Table 1 lists the chemicals that may be found at hazardous waste sites and indicates whether, in our judgment, they are sufficiently toxic and volatile to result in a potentially unacceptable indoor inhalation risk. It also provides a column for checking off the chemicals found or reasonably suspected to be present in the subsurface at a site. Under this approach, a chemical is considered sufficiently toxic if the vapor concentration of the pure component (see Section 4 below) poses an incremental lifetime cancer risk greater than 10^{-6} or results in a non-cancer hazard index greater than one (see Section 5 below). A chemical is considered sufficiently volatile if its Henry's Law Constant is 1×10^{-5} atm-m^3/mol or greater (US EPA, 1991). In our judgement, if a chemical does not meet both of these criteria, it need not be further considered as part of the evaluation.

Table 2 provides generic soil gas and groundwater screening concentrations corresponding to risk-based concentrations for indoor air in residential settings calculated using the methodology described in Section 5 below. Blank columns are included to allow the user to enter measured or reasonably estimated concentrations specific to a site. The target soil gas and groundwater concentrations are calculated using generic vapor intrusion attenuation factors (see Appendix F) as described in Sections 6 and 7 below.

Table 3 provides soil gas and groundwater screening concentrations for a select set of attenuation factors. Guidance for selecting the appropriate attenuation factor to use is given in Question 5. As with Table 2, the target soil gas and groundwater concentrations are calculated using the approach described in Sections 6 and 7 below and correspond to risk-based concentrations for indoor air in residential settings calculated using the methodology described in Section 5 below.

The target concentrations in Tables 2 and 3 are screening levels. They are not intended to be used as clean-up levels nor are they intended to supercede existing criteria of the lead regulatory authority. The lead regulatory authority for a site may determine that criteria other than those provided herein are appropriate for the specific site or area. Thus, we recommend that the user's initial first step should involve consultation with their lead regulatory authority to identify the most appropriate criteria to use.

3. Data Sources

Chemical Property Data - The source of chemical data used to calculate the values in Tables 1, 2, and 3 is primarily EPA's Superfund Chemical Data Matrix (SCDM) database. EPA's WATER9 database was used for chemicals not included in the SCDM database.

Toxicity Values - EPA's Integrated Risk Information System (IRIS) is the generally preferred source of carcinogenic unit risks and non-carcinogenic reference concentrations (RfCs) for inhalation exposure.[1] The following two sources were consulted, in order of preference, when IRIS values were not available: provisional toxicity values recommended by EPA's National Center for Environmental Assessment (NCEA) and EPA's Health Effects Assessment Summary Tables (HEAST). If no inhalation toxicity data could be obtained from IRIS, NCEA, or HEAST, we derived extrapolated unit risks and/or RfCs using toxicity data for oral exposure (cancer slope factors and/or reference doses, respectively) from these same sources utilizing the same preference order.[2] Target concentrations that were calculated using these extrapolated toxicity values are clearly indicated in Tables 2 and 3. Note that for most compounds, extrapolation from oral data introduces considerable uncertainty into the resulting inhalation value. Values obtained from inhalation studies or from pharmacokinetic modeling applied to oral doses will be less uncertain than those calculated using the equations below.

EPA's Integrated Risk Information System (IRIS) currently does not include carcinogenicity data for TCE, a volatile contaminant frequently encountered at hazardous waste sites. The original carcinogenicity assessment for TCE, which was based on a health risk assessment conducted in the late 1980's, was withdrawn from IRIS in 1994. The Superfund Technical Support Center has continued to recommend use of the cancer slope factor from the withdrawn assessment, until a reassessment of the carcinogenicity of TCE is completed. In 2001, the Agency published a draft of the TCE toxicity assessment for public comment.[3] In this guidance, we have calculated TCE target concentrations using a cancer slope factor identified in that document, which is available on the National Center for Environmental Assessment (NCEA) web site. We selected this slope factor because it is based on state-of-the-art methodology. However, because this document is still undergoing review, the slope factor and the target concentrations calculated for TCE are subject to change and should be considered "provisional" values.

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[1] U.S. EPA. 2002. Integrated Risk Information System (IRIS). http://www.epa.gov/iriswebp/iris/index.html. November.

[2] The oral-to-inhalation extrapolations assume an adult inhalation rate (IR) of 20 m^3/day and an adult body weight (BW) of 70 kg. Unit risks (URs) were extrapolated from cancer slope factors (CSFs) using the following equation:

$$\text{UR } (\mu\text{g/m}^3)^{-1} = \text{CSF } (\text{mg/kg/d})^{-1} * \text{IR } (\text{m}^3/\text{d}) * (1/\text{BW}) \ (\text{kg}^{-1}) * (10^{-3}\ \text{mg}/\mu\text{g})$$

Reference concentrations (RfCs) were extrapolated from reference doses (RfDs) using the following equation:

$$\text{RfC } (\text{mg/m}^3) = \text{RfD } (\text{mg/kg/d}) * (1/\text{IR}) \ (\text{m3/d})^{-1} * \text{BW (kg)}$$

[3] US EPA, Trichloroethylene Health Risk Assessment: Synthesis and Characterization - External Review Draft, Office of Research and Development, EPA/600/P-01/002A, August, 2001.

Table D-1 summarizes the toxicity values used in this guidance document, along with their sources. The table also indicates which unit risks and RfCs have been extrapolated from oral toxicity values and whether the indoor air target concentration is based on an oral extrapolated toxicity value. Please note that toxicity databases such as IRIS are routinely updated as new information becomes available; this table is current as of November 2002. Users of this guidance are strongly encouraged to research the latest toxicity values for contaminants of interest from the sources noted above. In the next year, IRIS reassessments are expected for several contaminants commonly found in subsurface contamination whose inhalation toxicity values today are based upon extrapolation.

4. Maximum Pure Component Vapor Concentration

The maximum possible vapor concentration is that corresponding to the pure chemical at the temperature of interest. In this case, all calculations were performed at the reference temperature of 25C using the equation:

$$C_{max,vp} = S * H * 10^3 \ :g/mg * 10^3 \ L/m^3$$

where

$C_{max,vp}$ = maximum pure component vapor concentration at 25C [:g/m^3],
S = pure component solubility at 25C [mg/L], and
H = dimensionless Henry's Law Constant at 25C [(mg/L – vapor)/(mg/L – H_2O)].

To determine if a chemical is sufficiently toxic to potentially pose an unacceptable inhalation risk, the calculated pure component vapor concentrations were compared to target indoor air concentrations corresponding to an incremental lifetime cancer risk greater than 10^{-6} or a non-cancer hazard index greater than one.

5. Target Indoor Air Concentration to Satisfy Both the Prescribed Cancer Risk Level and the Target Hazard Index.

The target breathing zone indoor air concentrations in Tables 1, 2, and 3 are risk-based screening levels for ambient air. The indoor air concentrations for non-carcinogens are set at the appropriate reference concentration, and the concentrations for carcinogens are calculated following an approach consistent with EPA's *Supplemental Guidance for Developing Soil Screening Levels* (EPA, to be published). The toxicity values on which the calculations are based are listed in Table D-1, which also shows the source of the toxicity data. Separate carcinogenic and non-carcinogenic target concentrations were calculated for each compound when both unit risks and reference concentrations were available. When inhalation toxicity values were not available, unit risks and/or reference concentrations were extrapolated from oral slope factors and/or reference doses, respectively. For carcinogens, target indoor air concentrations were based on an adult residential exposure scenario and assume exposure of an individual for 350 days per year over a period of 30 years. For non-carcinogens, target indoor air concentrations are set at the corresponding reference concentration. An inhalation rate of 20 m^3/day and a body weight of 70 kg are assumed and have been factored into the inhalation unit risk and reference concentration toxicity values.

For carcinogens,

$$C_{cancer}\ (\mu g/m^3) = [(TCR * AT_c)/(EF * ED * URF)]$$

For non-carcinogens,

$$C_{non\text{-}cancer}\ (\mu g/m^3) = (THQ * RfC * 1000\ \mu g/mg)$$

where

C_{cancer} = target indoor air concentration, carcinogen, ($\mu g/m^3$)
$C_{non\text{-}cancer}$ = target indoor air concentration, non-carcinogen, ($\mu g/m^3$)
TCR = target cancer risk (*e.g.*, 1.0×10^{-5})
THQ = target hazard quotient (*e.g.*, 1.0)
URF = unit risk factor ($\mu g/m^3$)$^{-1}$
RfC = reference concentration (mg/m^3)
AT_c = averaging time, carcinogens (25,550 days)
EF = exposure frequency (350 days/year)
ED = exposure duration (30 years)

For most compounds, the more stringent of the cancer- and non-cancer-based contaminant concentrations is chosen as the target indoor air concentration that satisfies both the prescribed cancer risk level and the target hazard quotient.

$$C_{target,ia} = MIN(C_{cancer}, C_{non\text{-}cancer})$$

However, we generally prefer to base the target concentration on non-extrapolated toxicity values wherever possible. Therefore, for compounds with one inhalation-based toxicity value and one oral-extrapolated value, the screening level based on the non-extrapolated toxicity value is chosen as the target indoor air concentration.[4]

For ease in application of the tables, the indoor air concentrations are given in units of $\mu g/m^3$ as well as ppbv. The conversion from ppbv to $\mu g/m^3$ is:

$$C\ [ppbv] = C\ [\mu g/m^3] * 10^9\ [ppb/atm] * 10^{-3}\ [m^3/L] * R * T/(MW * 10^6\ [\mu g/g])$$

where

---

[4] The target indoor air concentration for trichloroethylene is the lone exception. The target concentration is based on a carcinogenic unit risk extrapolated from an upper bound oral cancer slope factor of 4×10^{-1} per mg/kg/d cited in NCEA's draft risk assessment for trichloroethylene (US EPA, 2001). However, as noted in that document, available evidence from toxicological studies suggests similar carcinogenic effects from both the oral and inhalation routes of exposure. The existence of this evidence gives greater weight to the extrapolated unit risk, and given that the unit risk produces a lower target concentration than the non-extrapolated RfC, we used the unit risk-based value as the target indoor air concentration for trichloroethylene. (As noted earlier, the trichloroethylene risk assessment is still under review. As a result, the cancer slope factor and extrapolated unit risk values for trichloroethylene are subject to change.)

R = gas constant (0.0821 L-atm/mole-K),
T = absolute temperature (298 K), and
MW = molecular weight (g/mole).

The calculated target indoor air concentrations are listed in Tables 2 and 3 along with a column indicating whether cancer or non-cancer risks drive the target concentration. A separate column indicates whether risks are calculated using provisional, oral-extrapolated toxicity values (i.e., inhalation values extrapolated from oral CSFs or RfDs) (see Table D-1).

6. Target Soil Gas Concentration Corresponding to Target Indoor Air Concentration

The target soil gas concentration corresponding to a chemical's target indoor air concentration was calculated by dividing the indoor air concentration by an appropriate attenuation factor (see Questions 4 and 5 in the guidance and Appendix F). The attenuation factor represents the factor by which subsurface vapor concentrations migrating into indoor air spaces are reduced due to diffusive, advective, and/or other attenuating mechanisms. The attenuation factor can be empirically determined or calculated using an appropriate vapor intrusion model. Once the appropriate attenuation factor was determined, the target soil concentration was calculated as:

$$C_{soil\text{-}gas}\ [\mu g/m^3] = C_{target,ia}\ [\mu g/m^3] / \alpha$$

or

$$C_{soil\text{-}gas}\ [ppbv] = C_{target,ia}\ [ppbv] / \alpha$$

where

$C_{soil\text{-}gas}$ = target soil gas concentration [μg/m3] and
α = attenuation factor (ratio of indoor air concentration to source vapor concentration)

If $C_{target,ia}$ exceeds the maximum possible pure chemical vapor concentration, the designation "*" is entered in the table. If $C_{soil\text{-}gas}$ exceeds the maximum possible pure chemical vapor concentration at 25C, but $C_{target,ia}$ does not, then "**" is entered in the table.

7. Target Groundwater Concentration Corresponding to Target Indoor Air Concentration

The target groundwater concentration corresponding to a chemical's target indoor air concentration is calculated by dividing the target indoor air concentration by an appropriate attenuation factor (see Questions 4 and 5 in the guidance and Appendix F) and then converting the vapor concentration to an equivalent groundwater concentration assuming equilibrium between the aqueous and vapor phases at the water table. Diffusion resistances across the capillary fringe are assumed to be accounted for in the value of α. The equilibrium partitioning is assumed to obey Henry's Law so that:

$$C_{gw}\ [\mu g/L] = C_{target,ia}\ [\mu g/m^3] * 10^{-3}\ m^3/L * 1/H * 1/\alpha$$

where

C_{gw} = target groundwater concentration,
α = attenuation factor (ratio of indoor air concentration to source vapor concentration).
H = dimensionless Henry's Law Constant at 25C [(mg/L – vapor)/(mg/L – H_2O)].

If $C_{target,ia}$ exceeds the maximum possible pure chemical vapor concentration, the designation "*" is entered in the table. If C_{gw} exceeds the aqueous solubility of the pure chemical, but $C_{target,ia}$ does not, then "**" is entered in the table

If the calculated groundwater target concentration is less than the Maximum Contaminant Level (MCL) for the compound, the target concentration is set at the MCL. Target concentrations set at the MCL are indicated in Tables 2 and 3 by this symbol ("†").

8. References

US EPA, 1991, Risk Assessment Guidance for Superfund: Volume 1 – Human Health Evaluation Manual, Part B.

IRIS - Integrated Risk Information System - US EPA Office of Research and Development - National Center for Environmental Assessment. [http://www.epa.gov/iriswebp/iris/index.html] November 2002.

US EPA, Supplemental Guidance for Developing Soil Screening Levels, Office of Emergency and Remedial Response, OSWER 9355.4-24 (EPA, to be published).

US EPA, Trichloroethylene Health Risk Assessment: Synthesis and Characterization - External Review Draft, Office of Research and Development, EPA/600/P-01/002A, August 2001.

Table D-1

Toxicological Values Used to Calculate Target Concentrations in Indoor Air, Soil Gas, and Groundwater

CASN	Chemical	Unit Risk Factor (URF) (μg/m^3)$^{-1}$	URF Source	Is URF Extrapolated From Oral Value?	Reference Concentration (RfC) (mg/m^3)	RfC Source	Is RfC Extrapolated From Oral Value?	Is Indoor Air Target Concentration Based on Extrapolated Value?
83329	Acenaphthene	NA	NA		2.1E-01	I	yes	yes
75070	Acetaldehyde	2.2E-06	I	no	9.0E-03	I	no	no
67641	Acetone	NA	NA		3.5E-01	I	yes	yes
75058	Acetonitrile	NA	NA		6.0E-02	I	no	no
98862	Acetophenone	NA	NA		3.5E-01	I	yes	yes
107028	Acrolein	NA	NA		2.0E-05	I	no	no
107131	Acrylonitrile	6.8E-05	I	no	2.0E-03	I	no	no
309002	Aldrin	4.9E-03	I	no	1.1E-04	I	yes	no
319846	alpha-HCH (alpha-BHC)	1.8E-03	I	no	NA	NA		no
62533	Aniline	1.6E-06	I		1.0E-03	I	no	no
120127	Anthracene	NA	NA		1.1E+00	I	yes	yes
56553	Benz(a)anthracene	2.1E-04	E	yes	NA	NA		yes
100527	Benzaldehyde	NA	NA		3.5E-01	I	yes	yes
71432	Benzene	7.8E-06	I	no	NA	NA		no
50328	Benzo(a)pyrene	1.5E-01	I	yes	NA	NA		yes
205992	Benzo(b)fluoranthene	2.1E-04	E	yes	NA	NA		yes
207089	Benzo(k)fluoranthene	2.1E-05	E	yes	NA	NA		yes
65850	Benzoic Acid	NA	NA		1.4E+01	I	yes	yes
100516	Benzyl alcohol	NA	NA		1.1E+00	H	yes	yes
100447	Benzylchloride	4.9E-05	I	yes	NA	NA		yes

Table D-1

Toxicological Values Used to Calculate Target Concentrations in Indoor Air, Soil Gas, and Groundwater

CASN	Chemical	Unit Risk Factor (URF) (: g/m^{3})$^{-1}$	URF Source	Is URF Extrapolated From Oral Value?	Reference Concentration (RfC) (mg/m^{3})	RfC Source	Is RfC Extrapolated From Oral Value?	Is Indoor Air Target Concentration Based on Extrapolated Value?
91587	beta-Chloronaphthalene	NA	NA		2.8E-01	I	yes	yes
319857	beta-HCH (beta-BHC)	5.3E-04	I	no	NA	NA		no
92524	Biphenyl	NA	NA		1.8E-01	I	yes	yes
111444	Bis(2-chloroethyl)ether	3.3E-04	I	no	NA	NA		no
108601	Bis(2-chloroisopropyl)ether	1.0E-05	H	no	1.4E-01	I	yes	no
117817	Bis(2-ethylhexyl)phthalate	NA	NA		7.0E-02	I	yes	yes
542881	Bis(chloromethyl)ether	6.2E-02	I	no	NA	NA		no
75274	Bromodichloromethane	1.8E-05	I	yes	7.0E-02	I	yes	yes
75252	Bromoform	1.1E-06	I	no	7.0E-02	I	yes	no
106990	1,3-Butadiene	2.8E-04	I	no	NA	NA		no
71363	Butanol	NA	NA		3.5E-01	I	yes	yes
85687	Butyl benzyl phthalate	NA	NA		7.0E-01	I	yes	yes
86748	Carbazole	5.7E-06	H	yes	NA	NA		yes
75150	Carbon disulfide	NA	NA		7.0E-01	I	no	no
56235	Carbon tetrachloride	1.5E-05	I	no	NA	NA		no
57749	Chlordane	1.0E-04	I	no	7.0E-04	I	no	no
126998	2-Chloro-1,3-butadiene (chloroprene)	NA	NA		7.0E-03	H	no	no
108907	Chlorobenzene	NA	NA		6.0E-02	E	no	no
109693	1-Chlorobutane	NA	NA		1.4E+00	H	yes	yes

Table D-1

Toxicological Values Used to Calculate Target Concentrations in Indoor Air, Soil Gas, and Groundwater

CASN	Chemical	Unit Risk Factor (URF) (μg/m^3)$^{-1}$	URF Source	Is URF Extrapolated From Oral Value?	Reference Concentration (RfC) (mg/m^3)	RfC Source	Is RfC Extrapolated From Oral Value?	Is Indoor Air Target Concentration Based on Extrapolated Value?
124481	Chlorodibromomethane	2.4E-05	I	yes	7.0E-02	I	yes	yes
75456	Chlorodifluoromethane	NA	NA		5.0E+01	I	no	no
75003	Chloroethane (ethyl chloride)	8.3E-07	E	yes	1.0E+01	I	no	no
67663	Chloroform	2.3E-05	I	no	NA	NA		no
95578	2-Chlorophenol	NA	NA		1.8E-02	I	yes	yes
75296	2-Chloropropane	NA	NA		1.0E-01	H	no	no
218019	Chrysene	2.1E-06	E	yes	NA	NA		yes
156592	cis-1,2-Dichloroethylene	NA	NA		3.5E-02	H	yes	yes
123739	Crotonaldehyde (2-butenal)	5.4E-04	H	yes	NA	NA		yes
98828	Cumene	NA	NA		4.0E-01	I	no	no
72548	DDD	6.9E-05	I	yes	NA	NA		yes
72559	DDE	9.7E-05	I	yes	NA	NA		yes
50293	DDT	9.7E-05	I	no	1.8E-03	I	yes	no
53703	Dibenz(a,h)anthracene	2.1E-03	E	yes	NA	NA		yes
132649	Dibenzofuran	NA	NA		1.4E-02	E	yes	yes
96128	1,2-Dibromo-3-chloropropane	6.9E-07	H	no	2.0E-04	I	no	no
106934	1,2-Dibromoethane (ethylene dibromide)	2.2E-04	I	no	2.0E-04	H	no	no
541731	1,3-Dichlorobenzene	NA	NA		1.1E-01	E	yes	yes
95501	1,2-Dichlorobenzene	NA	NA		2.0E-01	H	no	no

Table D-1

Toxicological Values Used to Calculate Target Concentrations in Indoor Air, Soil Gas, and Groundwater

CASN	Chemical	Unit Risk Factor (URF) $(\mu g/m^3)^{-1}$	URF Source	Is URF Extrapolated From Oral Value?	Reference Concentration (RfC) (mg/m^3)	RfC Source	Is RfC Extrapolated From Oral Value?	Is Indoor Air Target Concentration Based on Extrapolated Value?
106467	1,4-Dichlorobenzene	NA	NA		8.0E-01	I	no	no
91941	3,3-Dichlorobenzidine	1.3E-04	I	yes	NA	NA		yes
75718	Dichlorodifluoromethane	NA	NA		2.0E-01	H	no	no
75343	1,1-Dichloroethane	NA	NA		5.0E-01	H	no	no
107062	1,2-Dichloroethane	2.6E-05	I	no	NA	NA		no
75354	1,1-Dichloroethylene	NA	NA		2.0E-01	E	no	no
120832	2,4-Dichlorophenol	NA	NA		1.1E-02	I	yes	yes
78875	1,2-Dichloropropane	1.9E-05	H	yes	4.0E-03	I	no	no
542756	1,3-Dichloropropene	4.0E-06	I	no	2.0E-02	I	no	no
60571	Dieldrin	4.6E-03	I	no	1.8E-04	I	yes	no
84662	Diethylphthalate	NA	NA		2.8E+00	I	yes	yes
105679	2,4-Dimethylphenol	NA	NA		7.0E-02	I	yes	yes
131113	Dimethylphthalate	NA	NA		NA	NA		
84742	Di-n-butyl phthalate	NA	NA		3.5E-01	I	yes	yes
534521	4,6-Dinitro-2-methylphenol (4,6-dinitro-o-cresol)	NA	NA		3.5E-03	E	yes	yes
51285	2,4-Dinitrophenol	NA	NA		7.0E-03	I	yes	yes
121142	2,4-Dinitrotoluene	1.9E-04	I	yes	7.0E-03	I	yes	yes
606202	2,6-Dinitrotoluene	1.9E-04	I	yes	3.5E-03	H	yes	yes

Table D-1

Toxicological Values Used to Calculate Target Concentrations in Indoor Air, Soil Gas, and Groundwater

CASN	Chemical	Unit Risk Factor (URF) (: g/m^3)$^{-1}$	URF Source	Is URF Extrapolated From Oral Value?	Reference Concentration (RfC) (mg/m^3)	RfC Source	Is RfC Extrapolated From Oral Value?	Is Indoor Air Target Concentration Based on Extrapolated Value?
117840	Di-n-octyl phthalate	NA	NA		7.0E-02	H	yes	yes
115297	Endosulfan	NA	NA		2.1E-02	I	yes	yes
72208	Endrin	NA	NA		1.1E-03	I	yes	yes
106898	Epichlorohydrin	1.2E-06	I	no	1.0E-03	I	no	no
60297	Ethyl ether	NA	NA		7.0E-01	I	yes	yes
141786	Ethylacetate	NA	NA		3.2E+00	I	yes	yes
100414	Ethylbenzene	1.1E-06	E	no	1.0E+00	I	no	no
75218	Ethylene oxide	1.0E-04	H	no	NA	NA		no
97632	Ethylmethacrylate	NA	NA		3.2E-01	H	yes	yes
206440	Fluoranthene	NA	NA		1.4E-01	I	yes	yes
86737	Fluorene	NA	NA		1.4E-01	I	yes	yes
110009	Furan	NA	NA		3.5E-03	I	yes	yes
58899	gamma-HCH (Lindane)	3.7E-04	H	yes	1.1E-03	I	yes	yes
76448	Heptachlor	1.3E-03	I	no	1.8E-03	I	yes	no
1024573	Heptachlor epoxide	2.6E-03	I	no	4.6E-05	I	yes	no
87683	Hexachloro-1,3-butadiene	2.2E-05	I	no	7.0E-04	H	yes	no
118741	Hexachlorobenzene	4.6E-04	I	no	2.8E-03	I	yes	no
77474	Hexachlorocyclopentadiene	NA	NA		2.0E-04	I	no	no
67721	Hexachloroethane	4.0E-06	I	no	3.5E-03	I	yes	no

Table D-1

Toxicological Values Used to Calculate Target Concentrations in Indoor Air, Soil Gas, and Groundwater

CASN	Chemical	Unit Risk Factor (URF) (: g/m^{3})$^{-1}$	URF Source	Is URF Extrapolated From Oral Value?	Reference Concentration (RfC) (mg/m^{3})	RfC Source	Is RfC Extrapolated From Oral Value?	Is Indoor Air Target Concentration Based on Extrapolated Value?
110543	Hexane	NA	NA		2.0E-01	I	no	no
74908	Hydrogen cyanide	NA	NA		3.0E-03	I	no	no
193395	Indeno(1,2,3-cd)pyrene	2.1E-04	E	yes	NA	NA		yes
78831	Isobutanol	NA	NA		1.1E+00	I	yes	yes
78591	Isophorone	2.7E-07	I	yes	7.0E-01	I	yes	yes
7439976	Mercury (elemental)	NA	NA		3.0E-04	I	no	no
126987	Methacrylonitrile	NA	NA		7.0E-04	A	no	no
72435	Methoxychlor	NA	NA		1.8E-02	I	yes	yes
79209	Methyl acetate	NA	NA		3.5E+00	H	yes	yes
96333	Methyl acrylate	NA	NA		1.1E-01	A	yes	yes
74839	Methyl bromide	NA	NA		5.0E-03	I	no	no
74873	Methyl chloride (chloromethane)	1.0E-06	E	no	9.0E-02	I	no	no
108872	Methylcyclohexane	NA	NA		3.0E+00	H	no	no
74953	Methylene bromide	NA	NA		3.5E-02	A	yes	yes
75092	Methylene chloride	4.7E-07	I	no	3.0E+00	H	no	no
78933	Methylethylketone (2-butanone)	NA	NA		1.0E+00	I	no	no
108101	Methylisobutylketone (4-methyl-2-pentanone)	NA	NA		8.0E-02	H	no	no
80626	Methylmethacrylate	NA	NA		7.0E-01	I	no	no

Table D-1

Toxicological Values Used to Calculate Target Concentrations in Indoor Air, Soil Gas, and Groundwater

CASN	Chemical	Unit Risk Factor (URF) (: g/m^3)$^{-1}$	URF Source	Is URF Extrapolated From Oral Value?	Reference Concentration (RfC) (mg/m^3)	RfC Source	Is RfC Extrapolated From Oral Value?	Is Indoor Air Target Concentration Based on Extrapolated Value?
91576	2-Methylnaphthalene	NA	NA		7.0E-02	E	yes	yes
108394	3-Methylphenol (m-cresol)	NA	NA		1.8E-01	I	yes	yes
95487	2-Methylphenol (o-cresol)	NA	NA		1.8E-01	I	yes	yes
106455	4-Methylphenol (p-cresol)	NA	NA		1.8E-02	H	yes	yes
99081	m-Nitrotoluene	NA	NA		7.0E-02	E	yes	yes
1634044	MTBE	NA	NA		3.0E+00	I	no	no
108383	m-Xylene	NA	NA		7.0E+00	H	yes	yes
91203	Naphthalene	NA	NA		3.0E-03	I	no	no
104518	n-Butylbenzene	NA	NA		1.4E-01	E	yes	yes
98953	Nitrobenzene	NA	NA		2.0E-03	H	no	no
100027	4-Nitrophenol	NA	NA		2.8E-02	E	yes	yes
79469	2-Nitropropane	2.7E-03	H	no	2.0E-02	I	no	no
924163	N-Nitroso-di-n-butylamine	1.6E-03	I	no	NA	NA		no
621647	N-Nitrosodi-n-propylamine	2.0E-03	I	yes	NA	NA		yes
86306	N-Nitrosodiphenylamine	1.4E-06	I	yes	NA	NA		yes
103651	n-Propylbenzene	NA	NA		1.4E-01	E	yes	yes
88722	o-Nitrotoluene	NA	NA		3.5E-02	H	yes	yes
95476	o-Xylene	NA	NA		7.0E+00	H	yes	yes
106478	p-Chloroaniline	NA	NA		1.4E-02	I	yes	yes

Table D-1

Toxicological Values Used to Calculate Target Concentrations in Indoor Air, Soil Gas, and Groundwater

CASN	Chemical	Unit Risk Factor (URF) (: g/m^3)$^{-1}$	URF Source	Is URF Extrapolated From Oral Value?	Reference Concentration (RfC) (mg/m^3)	RfC Source	Is RfC Extrapolated From Oral Value?	Is Indoor Air Target Concentration Based on Extrapolated Value?
87865	Pentachlorophenol	3.4E-05	I	yes	1.1E-01	I	yes	yes
108952	Phenol	NA	NA		2.1E+00	I	yes	yes
99990	p-Nitrotoluene	NA	NA		3.5E-02	H	yes	yes
106423	p-Xylene	NA	NA		7.0E+00	I	yes	yes
129000	Pyrene	NA	NA		1.1E-01	I	yes	yes
110861	Pyridine	NA	NA		3.5E-03	I	yes	yes
135988	sec-Butylbenzene	NA	NA		1.4E-01	E	yes	yes
100425	Styrene	NA	NA		1.0E+00	I	no	no
98066	tert-Butylbenzene	NA	NA		1.4E-01	E	yes	yes
630206	1,1,1,2-Tetrachloroethane	7.4E-06	I	no	1.1E-01	I	yes	no
79345	1,1,2,2-Tetrachloroethane	5.8E-05	I	no	2.1E-01	E	yes	no
127184	Tetrachloroethylene	3.0E-06	E	no	NA	NA		no
108883	Toluene	NA	NA		4.0E-01	I	no	no
8001352	Toxaphene	3.2E-04	I	no	NA	NA		no
156605	trans-1,2-Dichloroethylene	NA	NA		7.0E-02	I	yes	yes
76131	1,1,2-Trichloro-1,2,2-trifluoroethane	NA	NA		3.0E+01	H	no	no
120821	1,2,4-Trichlorobenzene	NA	NA		2.0E-01	H	no	no
79005	1,1,2-Trichloroethane	1.6E-05	I	no	1.4E-02	I	yes	no
71556	1,1,1-Trichloroethane	NA	NA		2.2E+00	E	no	no

Table D-1

Toxicological Values Used to Calculate Target Concentrations in Indoor Air, Soil Gas, and Groundwater

CASN	Chemical	Unit Risk Factor (URF) (: g/m^3)$^{-1}$	URF Source	Is URF Extrapolated From Oral Value?	Reference Concentration (RfC) (mg/m^3)	RfC Source	Is RfC Extrapolated From Oral Value?	Is Indoor Air Target Concentration Based on Extrapolated Value?
79016	Trichloroethylene *	1.1E-04	E	yes	4.0E-02	E	no	yes
75694	Trichlorofluoromethane	NA	NA		7.0E-01	A	no	no
95954	2,4,5-Trichlorophenol	NA	NA		3.5E-01	I	yes	yes
88062	2,4,6-Trichlorophenol	3.1E-06	I	no	NA	NA		no
96184	1,2,3-Trichloropropane	5.7E-04	E	yes	4.9E-03	E	no	no
95636	1,2,4-Trimethylbenzene	NA	NA		6.0E-03	E	no	no
108678	1,3,5-Trimethylbenzene	NA	NA		6.0E-03	E	no	no
108054	Vinyl acetate	NA	NA		2.00E-01	I	no	no
75014	Vinyl chloride (chloroethene)	8.80E-06	I	no	1.00E-01	I	no	no

Sources:
Hierarchy is as follows:
I = IRIS
E = EPA-NCEA provisional value
H = HEAST
A = HEAST Alternative

Notes:
If no inhalation data were available, toxicity data were extrapolated from oral studies.
Data are current as of November 2002.

* The target concentration for trichloroethylene is based on the upper bound cancer slope factor identified in EPA's draft risk assessment for trichloroethylene (US EPA, 2001). The slope factor is based on state-of-the-art methodology, however the TCE assessment is still undergoing review. As a result, the slope factor and the target concentration values for TCE may be revised further.

APPENDIX E – RELEVANT METHODS AND TECHNIQUES

I. Introduction

This appendix provides information on sampling and analysis methodologies that can be used to help evaluate vapor intrusion into indoor air. It should be noted that not all of these methods were developed specifically for this purpose. The Office of Research and Development (ORD) is evaluating the available methods to determine their applicability, and when methods have low reliability (e.g., sub-slab sampling), developing new protocols.

The technical references provided in this appendix originate from a variety of sources including non-EPA documents which may provide regional and state site managers, as well as the regulated community, useful technical information. However, such non-EPA documents do not replace current EPA or OSWER guidance or policies.

II. Site Characterization

Characterization of a site involves the collection of data and the development of a conceptual site model (See Appendix B) to assist in making decisions on the risks posed by contaminants to critical receptors. A variety of data may be employed in the process, and the data should be assessed for their quality and usefulness in making critical decisions on the risks posed by a site. Different media may be sampled with a variety of methods and may be analyzed in a variety of ways. We recommend that experts from appropriate disciplines be assembled at an early stage to develop objectives for the site investigation and to develop a sampling and analytical plan meeting data quality objectives (DQOs).

The Office of Research and Development's National Exposure Research Laboratory (NERL) has prepared a Compact Disk (CD) entitled "Site Characterization Library, Volume 1, Release 2.5," which contains more than 20,000 pages and 84 documents of guidance for the characterization of sites that can be searched, read, and printed (EPA/600/C-02/002). The documents are readable using Adobe Acrobat software. Twenty-five software programs are also included. The CD may be obtained from the National Center for Environmental Publications (NCEP). The CD identifies the following ASTM standards for site characterization:

D 5314	Guide for Soil Gas Monitoring in the Vadose Zone
D 4696	Guide for Pore-Liquid Sampling from the Vadose Zone
D 3404	Guide to Measuring Matric Potential in the Vadose Zone Using Tensiometers
D 4944	Test Method for Field Determination of Water (Moisture) Content of Soil by the Calcium Carbide Gas Pressure Tester Methods

D 3017	Test Method for Water Content of Soil and Rock In-Place by the Nuclear Method (Shallow Depth)
D 5220	Test Method for Water Content of Soil and Rock In-Place by Neutron Depth Probe Method
D 6031	Test Method for Logging In Situ Moisture Content and Density of Soil and Rock by the Nuclear Method in Horizontal, Slanted and Vertical Access Tubes

Other relevant ASTM methods include:

D 6235	Standard Practice for Expedited Site Characterization of Vadose Zone and Around Water Contamination at Hazardous Waste Contaminated Sites
D 5730	Guide for Site Characterization for Environmental Purposes with Emphasis on Soil, Rock, the Vadose Zone, and Groundwater

III. Groundwater Sampling and Analysis for VOCs

Prior to using groundwater data for evaluating the vapor intrusion pathway, we recommend that you establish that LNAPL is not floating on the groundwater, as the VOCs can partition directly from the pure product to the vapor phase rather than from the dissolved phase. This can be indicated by analytical results from water samples taken at the water table having values higher than the theoretical solubility for the specific LNAPL compounds present.

If possible, we recommend that groundwater samples be collected from wells screened at or across the top of the water table. This point of collection is necessary to be consistent with the derivation of the target groundwater criteria in Table 2, which assumes equilibrium partitioning between the aqueous and vapor phases and uses Henry's Law Constant to calculate source vapor concentrations corresponding to groundwater concentrations. It should be recognized that samples from groundwater monitoring wells maybe a blend of groundwater from different levels across the screened interval. This may result in either under- or over-estimation of the groundwater contaminant concentration at the top of the aquifer. For example, at site locations where concentrations are highest near the water table, the in-well blending will provide data with a negative bias (concentrations lower than representative). This may occur at locations where LNAPL is found near the water table, where recharge rates are low, or sites where there is an interface-zone plume (a fluctuating water table facilitates interactions between a vapor plume and the shallow groundwater). At other sites, shallow groundwater may have relatively low concentrations, and in-well blending will provide data with a positive bias (concentrations higher than representative). Examples include sites with a high rate of recharge from above, which can create a layer of shallow groundwater with little or no contamination that acts as a barrier to volatilization of vapors from deeper groundwater. [For more information, see Fitzpatrick, N. A., Fitzgerald, J. J. 1996. "An Evaluation of Vapor Intrusion Into Buildings Through a Study of Field Data," *Proceedings of the 11th Annual Conference on Contaminated Soils,* University of Massachusetts at Amherst.]

Confidence in the groundwater data can be increased through the use of a narrowly screened interval across the water table, the use of low flow sampling procedures to minimize mixing, or a variety of other depth-discrete sampling protocols. Methods of sampling such as direct push using a Geoprobe or cone penetrometers should concentrate on the upper few feet of the ground water.

There are numerous ASTM standards for groundwater sampling. Assuming wells already exist for sampling VOCs, the following standards are recommended:

D 5980	Standard Guide for Selection and Documentation of Existing Wells for Use in Environmental Site Characterization and Monitoring
D 6634	Standard Guide for the Selection of Purging and Sampling Devices for Ground-Water Monitoring Wells
D 5903	Guide for Planning and Preparing a Ground-Water Sampling Event
D 6452	Guide for Purging Methods for Wells Used for Ground-Water Quality Investigations
D 4448	Standard Guide for Sampling Ground-Water Monitoring Wells
D 6771	Standard Practice for Low-Flow Purging and Sampling for Wells and Devices Used for Ground-Water Quality Investigations
D 6564	Standard Guide for Field Filtration of Ground Water Samples
D 6517	Standard Guide for Field Preservation of Ground Water Samples
D 3694	Practices for Preparation of Sample Containers and for Preservation of Organic Constituents
D 6089	Guide for Documenting a Ground-Water Sampling Event

The following ASTM standards are useful if a monitoring system is not already in place:

D 5612	Standard Guide for Quality Planning and Field Implementation of a Water Quality Measurement Program
D 5730	Standard Guide for Site Characterization for Environmental Purposes with Emphasis on Soil, Rock, the Vadose Zone and Ground Water
D 6286	Standard Guide for Selection of Drilling Methods for Environmental Site Characterization

D 6001	Standard Guide for Direct-Push Water Sampling for Geoenvironmental Investigations
D 5092	Standard Practice for Design and Installation of Ground-Water Monitoring Wells in Aquifers
D 5521	Standard Guide for Development of Ground-Water Monitoring Wells in Granular Aquifers

Other Related ASTM Standards:

D 6312	Standard Guide for Developing Appropriate Statistical Approaches for Ground-Water Detection Monitoring Programs
D 5241	Standard Practice for Micro-Extraction of Water for Analysis of Volatile and Semi-Volatile Organic Compounds in Water
D 5314	Standard Guide for Soil Gas Monitoring in the Vadose Zone
D 4696	Standard Guide for Pore-Liquid Sampling from the Vadose Zone

IV. Indoor Air Sampling and Analysis

Indoor air sampling and analysis provide the most direct estimate of inhalation exposures. However, source attribution for the many compounds typically present in indoor air can be challenging. Constituents of indoor air can originate from indoor emission sources, from ambient (outdoor) air contributions, as well as from possible vapor intrusion of contaminated groundwater. Each of these sources can introduce concentrations of volatile chemicals to the indoor environment sufficient to pose an unacceptable health risk. In addition, concentrations of compounds found in indoor air are often subject to temporal and spatial variations, which may complicate estimates of exposure. If source attribution is pursued, then we recommend that the various potential sources contributing to the total concentration of a compound be identified. This is typically very challenging and may involve a series of measurements, or actions, whose purpose is to isolate the individual source contributions. Before conducting an indoor air sampling plan, we recommend consideration be made to other management options, such as proactive exposure controls, which may be cost competitive. Appendix A provides guidance in executing the DQO process for planning an indoor air-monitoring program.

Prior to indoor air sampling, we recommend conducting an inspection of the residence and an occupant survey to adequately identify the presence of any possible indoor air emission sources of (or occupant activities that could generate) target VOCs in the dwelling (see Appendices H & I). An indoor air quality survey has several components, and we recommend that it be consistent with data quality protocols appropriate for risk assessment (see Risks Assessment Guidance for Superfund Part B http://www.epa.gov/superfund/program/risk/ragsb/index.htm or EPA/540/R-

92/003). The Massachusetts Department of Environmental Protection (MA DEP) has prepared an *Indoor Air Sampling and Evaluation Guide (April 2002)* which is available at the following URL: http://www.state.ma.us/dep/ors/files/indair.pdf.

Many aspects of the protocols used for ambient air can also be applied to indoor air sampling (e.g., EPA TO-15 and TO-17 methods). Specially treated stainless steel evacuated canisters or adsorbent tubes are appropriate for sampling and we recommend that they be combined with an analytical method capable of obtaining the detection limits identified in the DQO process. To facilitate a reliable comparison of analytical results, a standard condition for sampling is recommended. Some guidance in establishing a standard monitoring condition is given in the following paragraphs.

We recommend that sampling units be placed within the normal breathing zone, 2 to 5 feet above the floor, in the lowest inhabited area. It is generally advisable to collect at least one 24-hour sample in both the probable place of highest concentration (e.g., basement) and in the main living area. Two or more sampling events at each location are desirable. Typically, we recommend that the house be closed (windows and doors shut) 12 to 24 hours before the measurements begin and the use of appliances that induce large pressure differences (e.g. exhaust fans, clothes dryers, operating fireplaces) be avoided during this time. Additionally, we recommend avoiding sampling locations adjacent to windows and air supplies.

We recommend gas sampling that will be used for direct assessment of vapor intrusion meet or exceed requirements for demonstrating method acceptability as specified in EPA Methods TO-15 (canister-based sample collection) and TO-17 (sorbent tube-based sample collection) or appropriately modified to achieve a lower method detection limit (MDL) corresponding to a given life-time risk level. Note: To achieve detection at or below the published 10^{-5} to 10^{-6} risk levels for many target compounds, the MDLs for TO-15 or TO-17, in our judgment, must be considerably below 0.5 ppbv.

To achieve TO-15 and TO-17 method acceptability, we recommend that a sampling and analysis protocol meet the recommended performance criteria for an enhanced method detection limit, replicate precision, and audit accuracy at compound concentrations corresponding to the 10^{-5} or 10^{-6} risk levels, and special attention be paid to quality control measures. Sufficiently low sample container blanks, analytical system blanks, analytical interferences, etc., are all implied in the ability to meet the technical acceptance criteria.

To ensure reliable measurements are obtained, we recommend that multiple simultaneous samples (more than one canister or sorbent tube) be taken for every sampling event and from the same inlet so that variability in nominally identical samples can be documented. Also, we recommend that knowledge of the performance of the analytical system be demonstrated, including blank response, the MDLs, calibration of the target compounds at or near the sample concentration range, and the likelihood of interferences. These are common sense considerations that are covered in TO-15 and TO-17, but call for special attention at the low concentration levels being considered.

Note: At this point in the development of the best approach to sorbent tube sampling (TO-17), reduction of co-collected water on the sorbent tubes is sometimes important to achieve a linear analytical response such as with ion trap mass spectrometers. Therefore, we recommend that preliminary experiments be performed to document the effect of different water vapor levels on analytical performance. Also, the interaction of target compounds with reactive compounds, e.g. ozone, depends on the extent to which the reactive compounds exist in the indoor air and the reaction rates. Until this specific problem with sampling is addressed, we recommend that the ozone concentration be determined at every sampling event. Also, an interaction of ozone with adsorbed compounds can destroy the compound. Certain target compounds have been tested for this (see McClenny, W.A., Oliver, K.D., Jacumin, H.H., Jr., and Daughtrey, E.H., Jr., 2002, Ambient volatile organic compound (VOC) monitoring using solid adsorbants - recent U.S. EPA developments, JEM 4(5) 695 – 705).

Recommended publications:

Compendium of Methods for the Determination of Toxic Organic Compounds in Ambient Air, Second Edition, EPA/625/R-96/010b

- Method TO-15, Determination of Volatile Organic Compounds (VOCs) in Air Collected in Specially-Prepared Canisters and Analyzed by Gas Chromatography/Mass Spectrometry (GC/MS). pp.15-1 through 15-62

- Method TO-17, Determination of Volatile Organic Compounds in Ambient Air using Active Sampling on Sorbent Tubes. pp. 17-1 through 17-49

- Compendium of Methods for the Determination of Air Pollutants in Indoor Air, EPA/600/4-90-010

V. Soil Gas Sampling

Soil gas sampling and analysis results tend to be more reliable at locations and depths where high contaminant concentrations are present and where the soils are relatively permeable. Reliability of the results tends to be lower in lower permeability settings and when sampling shallow soil gas. In both cases, leakage of atmospheric air into the samples is a valid concern. Consequently, it is recommended that samples collected at depths less than 5 feet below ground surface (bgs) not be used for this analysis, unless they are collected immediately below the building foundation several feet in from the edge (e.g., subslab samples). Reliability of soil gas sampling can be assessed by: a) measuring a vertical profile and inspecting to see if measured concentrations decrease with increasing distance from the vapor source, and b) checking to see if vapor concentrations correlate qualitatively and quantitatively with available groundwater concentration data. For example, with groundwater sources the highest soil gas concentrations should correlate with the highest groundwater concentrations, and vapor concentrations collected immediately above groundwater should not exceed the value calculated using Henry's Law. Parallel analysis of oxygen, carbon dioxide, and nitrogen in soil gas samples can often be used to help assess the reliability of a given sample result. Reliability is typically improved by using fixed probes and by ensuring that leakage of atmospheric air into the samples is avoided during purging or sampling. To avoid dilution of the sampling region, we recommend using the minimum purge volume deemed adequate to flush the sampling system. With respect to the spatial distribution of sampling points, close proximity to the building(s) of concern is generally preferred; however, it may be possible to reasonably estimate concentrations based on data from soil gas samples collected about a larger area. Additionally, as vapors are likely to migrate upward preferentially through the coarsest and driest material, we recommend soil gas samples be collected from the most permeable zones in the vadose zone underlying the inhabited buildings. Concentrations should be lower in the high permeability zones than the low permeability zones.

The velocity at which soil gas should be sampled is influenced by the soil permeability, and the volume of sample taken will determine the zone of soil that is sampled. The effects of low- versus high-velocity and micro- versus macro-volume soil gas sampling techniques are currently being evaluated.

Measurement of VOCs in the Subslab Soil Gas

Subslab sampling may entail drilling a series (e.g., 3 to 5) of small diameter (e.g., 9/16") holes in the foundation of a residential building. It may be advantageous to install flush mounted stainless steel or brass vapor probes in contaminant free cement. We recommend sampling be performed using EPA Method TO-15 or TO-17.

The preferred measurement location is in the central portion of the slab, well away from the edges where dilution is more likely to occur. We recommend the hole be plugged with a material such as tape or pliable caulk (VOC free) immediately after drilling the hole to minimize the disturbance of the sub slab concentrations. When drilling the hole, care should be taken not to puncture the surface of soil underneath. In cases where there is aggregate soil underneath the foundation, this care may not be important, but if the soil has a slightly compacted layer on top with a slight subsidence under the slab this compacted layer may actually provide some resistance to the entry of soil gas from underneath. In this case, a subslab sample can be collected by slowly pulling a volume of gas from the void of the subsidence. This initial measurement may be representative of the soil gas typically entering the house. After the subslab with undisturbed soil has been sampled, it may be instructive to penetrate the surface of the soil and resample. We recommend the subslab samples be collected at several locations to obtain representative values. It is important to not disturb the subslab region by applying excessive pressures that might induce dilution of vapors in this region. Significant pressures might result from excessive slamming of doors, or from appliances such as: exhaust fans, clothes dryers, downdraft grills, ceiling or roof mounted attic fans, or certain combinations of open windows on a windy day. If the subslab region is disturbed, it may require many hours to return to a steady state condition.

Additional points to consider before drilling into the foundation are whether or not the home has an existing vapor barrier, or is a tension slab. In either case, alternative sampling methods may be preferable.

Measurement of VOC’s in soil gas using slam bar methods

Slam bar methods have been widely used to measure contaminants in soil gas. The results of these measurements have been highly variable. Because this technique is frequently used for relatively shallow sampling, it is, in our judgment, prone to errors from dilution by surface air. This is especially true when the hole is punched or drilled with one instrument that is then replaced by a measurement probe (sometime of smaller diameter). We recommend great care be taken to ensure that leakage air does not enter the sample. Only the volume of air sufficient to flush the probe and sampling line should be extracted before collecting the sample. The larger the purge/sample volume, the larger the subsurface area of influence; if the contamination is contained within non-preferential flow paths or small discrete locations, a large purge/sample volume will dilute the concentration of contaminants.

Measurement of VOC’s in soil gas using push probe methods

This approach seems to be emerging as a powerful tool for conducting soil gas measurements. OSWER is working with ORD and will update this section on the EPA/OSWER website as further refinements of these methods are developed.

Recommend publications:

Soil Vapor Extraction Technology: Reference Handbook - Soil Vapor Extraction Technology: Reference Handbook March 1990. Environmental Protection Agency, Risk Reduction Engineering Lab. EPA/540/2-91/003

VI. Soil Sampling and Analysis

Soil sampling and analysis is not recommended for assessing whether or not the vapor intrusion pathway is complete. This is because the uncertainties associated with soil partitioning calculations, as well as the uncertainties associated with soil sampling and soil chemical analyses for volatile organic chemicals, are so great that, that in our judgment, use of soil concentrations for assessment of this pathway is not technically defensible. Thus, soil concentration criteria were not derived and the use of soil criteria is not encouraged in this guidance. Soil concentration data might, however, be used in a qualitative sense for delineation of sources provided the soil samples are preserved immediately upon collection with methanol. For example, high soil concentrations (e.g. >1000 mg/kg TPH) would definitely indicate impacted soils; unfortunately, the converse is not always true and we recommend that non-detect analytical results not be interpreted to conclude the absence of a vapor source.

VII. Other Issues

We recommend that detection limits be considered when choosing which media to sample and how to interpret the results. The properties of some chemicals and the biases in the analytical methods may be such that the sensitivity of detection is higher in one medium than another. For example, a high Henry's constant (H>1) chemical might be detectable in soil gas when the concentration in groundwater falls below the detection limit (e.g., vinyl chloride).

We recommend that transformation products also be considered when selecting the chemicals of concern. For example, 1,1,1-trichloroethane (111TCA) may be abiotically converted to 1,1-dichloroethene (11DCE) in groundwater, so that we recommend looking for both chemicals at 111TCA spill sites.

APPENDIX F

EMPIRICAL ATTENUATION FACTORS AND RELIABILITY ASSESSMENT

1. Introduction

The empirical attenuation factors used in this guidance were derived through review of data from sites with paired indoor air and soil gas and/or groundwater concentrations. These data have been compiled into a database with the structure and elements illustrated in Figure F-1.

The database contains information from 15 sites (CO - 5 Sites; CA - 1 Site; CT – 1 Site; MA – 7 Sites; and MI – 1 Site). Fifteen VOCs are represented: BTEX, Chloroform, 1,1-Dichloroethane, 1,2-Dichloroethane, 1,1-Dichloroethylene, cis-1,2-Dichloroethylene, trans-1,2-Dichloroethylene, Tetrachloroethylene, 1,1,1- Trichloroethane, 1,1,2-Trichloroethane, Trichloroethylene and Vinyl chloride. The result is a database with 274 total residence and chemical combinations, 35 of which represent BTEX compounds and the remaining 239 represent chlorinated hydrocarbons. Groundwater data are available for the entire set of residence and chemical combinations. Soil gas data are available only for 40 of the residence and chemical combinations.

The information in the database was used to calculate groundwater-to-indoor air and soil gas-to-indoor air attenuation factors for each of the chemicals measured at each of the residences monitored. The distributions of these calculated attenuation factors were used to define a conservative empirical attenuation factor for each medium, as described in Sections 2, 3, and 4 below.

An assessment was performed using the same database to determine the reliability of the selected attenuation factors for screening in residences with indoor air concentrations exceeding the target levels corresponding to a cancer risk of 10^{-6} and 10^{-5}. The reliability assessment was performed by determining the number of false negative and false positives corresponding to the selected attenuation factor using the guidelines described in Section 6 below.

2. Calculation of Attenuation Factors

The attenuation factor represents the ratio of the indoor air concentration measured in a residence to the vapor concentration measured in the subsurface materials underlying or adjacent to the residence. For soil gas, the attenuation factor (α) is calculated simply as:

$$\alpha = \frac{C_{indoor}}{C_{soil\ gas}}$$

where

C_{indoor} = measured indoor air concentration [ug/m^3]
$C_{soil\ gas}$ = measured soil gas concentration [ug/m^3]

For groundwater, the attenuation factor is calculated as:

$$\alpha = \frac{C_{indoor}}{C_{groundwater} H_c}$$

where

$C_{groundwater}$ = measured groundwater concentration [ug/L] x 1000 L/m^3
H_c = dimensionless Henry's Law Constant [--]

Henry's Law Constant is used to convert the measured groundwater concentration to a corresponding equilibrium soil gas concentration. Field data suggest that this conversion may result in over prediction of the soil gas concentration (by as much as a factor of ten) directly above the contaminated groundwater. However, this is not always the case and consequently Henry's Constant is used here without a correction factor.

In the database, attenuation factors are calculated using only those residences and chemicals for which both the indoor air and subsurface measurements were above the chemical's method detection limit (MDL). Because the subsurface concentrations are generally greater than the measured indoor air concentrations, the calculated attenuation factors are values less than one.

3. Groundwater-to-Indoor Air Attenuation Factor

The distribution of groundwater-to-indoor air attenuation factors is shown in Figures F-2 and F-3. Figure F-2 shows the distribution of attenuation factors for all residences in the database with associated measured indoor air and groundwater concentrations above the chemicals' MDLs. The calculated attenuation factors range from 10^{-1} to 10^{-7}. This range includes attenuation factors calculated for homes with high indoor air concentrations as well as for homes with indoor air concentrations at levels typical of background concentrations (Table F-1). Figure F-3 compares the distribution shown in Figure F-2 to the distribution of the subset of attenuation factors corresponding to residences with indoor air concentrations greater than the typical background levels (e.g., geometric mean of the mean background values shown in Table F-1). As can be seen in Figure F-3, fewer than 5% of the residences with indoor air concentrations above typical background levels have attenuation factors greater than 0.001 (1/1000). This means that for 95% of the residences in the database, the groundwater-to-indoor air attenuation factor is less than 0.001 (1/1000) and, consequently, this value (0.001) is considered to be a generally reasonable upper-bound value.

4. Soil Gas-to-Indoor Air Attenuation Factor

The shallow soil gas to indoor air attenuation factor represents the ratio of the indoor air concentration to the soil gas concentration at some shallow depth. For the purposes of this guidance, shallow soil gas samples are defined as those obtained either from directly below the foundation or from depths less than 5 feet below foundation level. Figure F-4 shows the distribution of subslab-to-indoor air attenuation factors for the subset of residences with indoor concentrations greater than the subslab concentration measured below the residence's foundation. As can be seen in the plot, approximately 15% of the residences have attenuation factors greater than 0.1 (1/10), or conversely, about 85% of the residences have attenuation factors smaller than 0.1 (1/10). Consequently, an attenuation factor of 0.1 was used to represent a generally reasonable upper-bound value for the case where the soil gas concentration immediately beneath a foundation is used (e.g., the indoor air concentration would not be expected to exceed 1/10 of the concentration immediately below the foundation). This value is also supported by an analysis of the dilution that occurs due to ventilation of a house. An attenuation factor of 0.1 suggests that 10% or less of the air exchanged in a house originates from the subsurface. This value is conservatively assumed to apply to shallow soil gas samples (< 5 feet below foundation level) as well as subslab samples.

Deep soil gas samples are defined for the purposes of this guidance as those obtained just above the water table or from depths greater than 5 feet below foundation level. A smaller attenuation factor than that used for shallow soil gas is warranted as the deep soil gas samples represent a more direct measurement of the source vapor concentration and are subject to less variability than is observed for shallow soil gas samples. On the other hand, a more conservative value than that used for groundwater is warranted, as there is not the added safety factor incorporated in the groundwater attenuation factor, which assumes equilibrium partitioning of chemicals between groundwater and soil vapor (Henry's Law). Consequently, a value of 0.01 was selected for deep soil gas.

5. BTEX versus Chlorinated Hydrocarbon Attenuation Factors

To be conservative, the recommended criteria developed for this guidance have been established assuming that the chemicals do not degrade as they migrate through the vadose zone. It should be recognized that many chemicals of interest do biodegrade. For example, petroleum hydrocarbon vapors will biodegrade in the presence of oxygen, and field studies have shown this biodegradation to be very significant in some settings. In contrast, analysis of data from sites impacted with chlorinated solvents suggest that degradation is insignificant for these compounds. The impact of biodegradation can be seen in the distribution of attenuation factors for BTEX compounds versus chlorinated hydrocarbons (Figure F-5). Figure F-5 suggests a three-fold to ten-fold decrease in attenuation factor for BTEX compounds.

Unfortunately, the significance of the biodegradation has also been highly variable, and the factors that determine its significance are not yet fully understood. In a very general sense, it is expected that aerobic biodegradation will have limited effect in settings where oxygen re-supply is limited, and also will have little effect on the attenuation factors used for soil gas samples collected near a building. At this time, we recommend that the significance of biodegradation be determined through collection of vertical soil gas profiles beneath the buildings of concern. The occurrence of aerobic biodegradation will be reflected qualitatively in the oxygen and contaminant soil vapor profiles, and the quantitative effects can be estimated by the methods described in Johnson et al. (1999), or other defensible analysis methods. It is unlikely that the extensive site-specific information required to determine the influence of biodegradation will be available in the initial stages of site characterization. Therefore, we believe that it is generally prudent to assume that biodegradation is not a factor when screening sites for vapor intrusion issues.

6. Reliability Assessment

The reliability of the evaluation approach used in Questions 4, 5, and 6 of this guidance was assessed using the database described above in Section 1 of this appendix. For the assessment at the generic screening level (Question 4), the target levels in Tables 2(a) and 2(b) were used. For the assessment of Question 5, the target levels in Tables 3(a) and 3(b) were used. For Question 6, the Johnson and Ettinger Model was applied as described in Appendix G using the updated default model parameters. The following sections briefly describe the analysis and results. This analysis shows that the evaluation approach used in this guidance yields reliable results at both the 10^{-5} and 10^{-6} cancer risk levels when assessing the vapor intrusion pathway at all sites reviewed.

6.1 Analysis Approach

Cancer risk levels at both the 10^{-5} and 10^{-6} levels were evaluated. Table 2 was used to select target levels for evaluation of Question 4. For Question 5, the appropriate attenuation factor to use when selecting screening levels from Table 3 was determined from the figures 3a and 3b in Question 5 of the guidance as a function of site-specific SCS soil types and depth to groundwater. For the Question 6 assessment, information on foundation type (either slab-on-grade or basement) and building mixing height was incorporated into the analysis (basement defaults were used for buildings with crawl spaces) and a site-specific attenuation factor was calculated.

The assessment was performed by determining the number of false negative and false positives obtained using the most recently available toxicity data. As shown in Table F-2, a false negative occurs when a chemical's measured indoor air concentration exceeds the target level, but the measured groundwater (or soil gas) concentration does not. False negatives may appear if indoor or ambient (outdoor) sources of VOCs are present and they exceed the indoor air target level at the selected risk level. A false positive occurs when a chemical's measured indoor air concentration is below the target level, but the measured groundwater (or soil gas) concentration is above the target level. Correct positives and correct negatives are defined in a similar fashion, as shown in Table F-2.

6.2 Results

In order to effectively understand the results, it is important to differentiate between samples, buildings, and sites. There are seven sites evaluated in this analysis (Alliant, Eau Claire, Hamilton-Sunstrand, LAFB, MADEP, Mountain View, and Uncasville). Each site has one or more buildings. For example, the Alliant site has only one building. LAFB has 13 buildings and Mountain View has seven buildings. Each building has its own unique address. Several samples were taken at each building. Each sample consists of paired indoor air and groundwater concentrations for a unique chemical at a certain building. The number of samples and the number of chemicals identified in these samples varies by building.

The results are grouped into two types of tables. Tables F-3 (risk level 10^{-5}) and F-5 (risk level 10^{-6}) organize the results by building at each site. It shows whether or not a building has a correct negative, correct positive, false negative, or false positive result. An important note regarding Tables F-3 and F-5 is the difference between buildings that are not applicable for vapor intrusion analysis ("NA" is added to the results of these buildings) and buildings with wet basements. Buildings that are not applicable are those where the depth from the bottom of the foundation (whether it be a basement or slab-on-grade) to groundwater contamination is less than 1.5 meters (5 feet). This is one of the precluding factors listed in the guidance. We still included results for these buildings, but marked their results with an "NA" to indicate that they would be excluded from this analysis according to protocols set forth in the guidance. The false negative, false positive, correct negative, and correct positive results for non-NA buildings are summed at the bottom of each table.

The second set of results presents outcomes by chemical at each site. Tables F-4 (risk level 10^{-5}) and F-6 (risk level 10^{-6}) show the number of false positive and false negative outcomes for each chemical at each site. They do not indicate whether the false results occur in just one or two buildings at the site, or evenly across all buildings. It is important to note that the numbers in these tables are counts of samples, not of buildings. Therefore, it is possible to have a false negative result for a chemical at a particular site, but each building at that site can have correct positive results based on the outcomes for other chemicals. It is also important to note that results for those samples that are considered not applicable (NA) according to the criteria discussed in the guidance are not included in this table.

Tables F-3 and F-5 show that the evaluation approach used in this guidance yields no false negatives with respect to sites or buildings at either the 10^{-5} or 10^{-6} cancer risk level. Tables F-4 and F-6 show that for most chemicals either no or few false negatives are obtained, with the exception of tetrachloroethene and 1,2-dichloroethane. These two chemicals show a number of false negatives, especially at the 10^{-6} cancer risk level. It is important to note, however, that both of these chemicals are typically found as background contaminants, which may account for some of the false negatives. Several of the chemical-specific false negative results shown in Tables F-4 and F-6 also appear to result from limiting the ground water target concentration to the MCL if the calculated target concentration would be less than the MCL.

Table F-1. Background indoor air concentrations for selected volatile organic compounds. All concentrations expressed in ug/m^3.

Compound	Shah and Singh (1988)	Samfield (1992)	Brown et al. (1994)	NOPES (1990)	Sheldon (1992)	MADEP (September 1998)	*EPA IAQ Reference Manual (July 1991)*	Foster et al., (2002)
1,1,1-Trichloroethane	271.4	-	-	-	-	30	70	0.7
1,1,2,2-Tetrachloroethane	0.098	-	-	-	-	0.01	-	-
1,1,2-Trichloroethane	-	-	-	-	-	-	-	RL (0.064)
1,1-Dichloroethylene	-	-	-	-	-	6.5	-	RL (0.08)
1,2-Dichloroethane	-	-	-	-	-	-	-	0.07
Acetaldehyde	-	9.6	-	-	-	-	-	-
Acetone	19.3	-	-	-	-	6	-	-
Benzene	16.8	8.2	8.0	-	2.2	21	14	4.08
Carbon Tetrachloride	2.6	12.0	-	-	0.5	1	5	-
Chlordane	-	2.8	-	0.18	-	-	-	-
Chlorobenzene	-	-	-	-	-	10	-	-
Chloroform	4.1	8.0	10.0	-	-	3	6	2.1
Cumene	0.2	5.1	-	-	-	-	-	-
DDE	-	-	-	0.001	-	-	-	-
Dichlorobenzenes	-	31.0	8.0	-	1.0	0.5	58	-
Ethylbenzene	12.7	13.8	5.0	-	-	10	14	-
Heptachlor	-	0.7	-	0.07	-	-	-	-
Hexachlorobenzene	-	0.0	-	0.0004	-	-	-	-
Hexane	-	33.0	12.0	-	-	-	-	-
Methoxychlor	-	-	-	0.0002	-	-	-	-
Methylene Chloride	-	342.0	17.0	-	15.0	10	-	0.98
Methylethylketone (2-butanone)	9.2	7.0	4.0	-	-	42	-	-
Methylisobutylketone (4-methyl-2-pentanone)	-	-	-	-	-	2	-	-
Naphthalene	-	11.0	-	-	-	-	-	-
Styrene	-	1.8	-	-	1.0	5	6	-
Tetrachloroethylene	21.1	9.5	7.0	-	0.3	11	28	1.62
Toluene	28.3	56.0	37.0	-	-	29	61	-
Trichlorobenzenes	0.5	-	-	-	-	-	-	-
Trichloroethylene	7.4	-	-	-	-	5	9	0.15
Vinyl chloride	-	-	-	-	-	-	-	0.01
Xylenes	-	25.0	24.0	-	6.0	3	14	-

Shah and Singh (1988): ES&T, Vl. 22, No.12, pp. 1381-1388, 1988

Samfield (1992): EPA-600-R-92-025, 1992.

Brown et al. (1994): Indoor Air, 4:123-134, 1994.

NOPES (1990): EPA/600/3-90/003, January 1990.

Sheldon (1992): California Air Resources Board, Final Report, January 1992.

MADEP (September 1998): From: Background Documentation for the Development of MCP Numerical Stds" April 1994, Table 4.2, except 1,1-dichloroethene (EPA TEAM study) and methylene chloride (Stolwijk, JAJ, 1990)

EPA IAQ Reference Manual (July 1991): Results from Wallace (1987), except toluene: Seifert & Abraham (1982).

Foster et al., (2002): Foster, S.J, J.P. Kurtz, and A.K. Woodland, Background indoor air risks at selected residences in Denver, Colorado, 2002.

Table F-2. Evaluation criteria for the reliability assessment.

Measurement	Relationship	Vapor Intrusion Screening Level	Condition
C(GW)	>	GWSL	CORRECT POSITIVE
C(IA)	>	IASL	
C(GW)	<	GWSL	CORRECT NEGATIVE
C(IA)	<	IASL	
C(GW)	<	GWSL	FALSE NEGATIVE
C(IA)	>	IASL	
C(GW)	>	GWSL	FALSE POSITIVE
C(IA)	<	IASL	

Table F-3
False Negative and False Positive Indoor Air Predictions Based on Comparison of Groundwater Concentrations to Target Levels, by Building at Each Site

$R=1x10^{-5}$

Site Name	Address	Vapor Intrusion Q4[1]	Vapor Intrusion Q5[2]	Compound(s) Responsible for False Result [3]
Alliant		NA(CP)	NA(CP)	
Eau Claire	Residence F	NA(CP)	WB	
	Residence K	NA(CP)	WB	
	Residence S	NA(CP)	WB	
Hamilton-Sunstrand	6800 Fern Dr.	CP	CP	
	6800 Osage St.	CP	CP	
	6800 Ruth Way	CP	CP	
	6801 Avrum Dr.	CP	CP	
	6801 Fern Dr.	CP	CP	
	6810 Jordan Dr.	CP	CP	
	6811 Ruth Way	CP	CP	
	6820 Fern Dr.	CP	CP	
	6821 Mariposa St.	CP	CP	
	6821 Pecos	CP	CP	
	6831 Navajo St.	CP	CP	
	6831 Zuni St.	CP	CP	
	6840 Mariposa	CP	CP	
LAFB	UA02	CP	CP	
	UA03	CP	CP	
	UA04	CP	CP	
	UA05	CP	CP	
	UA18	CP	CP	
	UA19	CP	CP	
	UA21	CP	CP	
	UA22	CP	CP	
	UA23	CP	CP	
	UA24	CP	CP	
	UA25	CP	CP	
	UA26	CP	CP	
	UA28	FP	FP	Trichloroethylene
MADEP	0907 A Hull	NA(CP)	WB	
	0907 B Hull	NA(CP)	WB	
	1019 Lynnf	NA(FP)	NA(FP)	Benzene, Ethylbenzene, Toluene
	11707 Quincy	NA(CP)	NA(CP)	
	12092 B Marble	CP	CP	Benzene
	1525 A Marble	NA(CP)	NA(CP)	
	1525 B Marble	NA(CP)	NA(CP)	
	2797 A Tewks	NA(FP)	NA(FP)	Benzene, Ethylbenzene, Toluene
	2797 B Tewks	NA(FP)	NA(FP)	Benzene, Ethylbenzene, Toluene
Mountain View	Residence 1	CP	CP	
	Residence 2	CP	CP	
	Residence 3	CP	CP	
	Residence 4	CP	CP	
	Residence 6	CP	CP	
	Residence 7	CP	CP	
	Residence 8	CP	CP	
Uncasville	Residence A	NA(CP)	NA(CP)	
	Residence B	NA(CP)	NA(CP)	
	Residence D	NA(CN)	NA(CN)	
	Residence E	NA(CP)	NA(CP)	

Key:
CP=Correct Positive; CN = Correct Negative
FP=False Positive; FN=False Negative
NA=Not applicable due to precluding factor--depth from foundation to groundwater contamination is less than 1.5 m.
WB=Wet Basement. This condition precludes the use of Figure 3 (for Q5).

Notes:

[1] Site data was compared to indoor air and groundwater screening values in Table 2.

[2] Site data was compared to indoor air and groundwater screening values in Table 3. The appropriate attenuation factor in this

[3] When false positive or false negative outcomes resulted with both Q4 and Q5, the same compounds were responsible for the false outcome in each scenario.

Table F-3 (continued)
Summary Table
False Negative and False Positive Indoor Air Predictions Based on Comparison of Groundwater Concentrations to Target Levels, by Building at Each Site
R=1x10^{-5}

	Q4 Number	Percent	Q5 Number	Percent
Total CP and CN	33	97.1%	33	97.1%
Total FP	1	2.9%	1	2.9%
Total FN	0	0.0%	0	0.0%
Total NA and WB	16	47.1%	11	32.4%
Total Number of Buildings	34		34	

Key:

CP=Correct Positive; CN = Correct Negative

FP=False Positive; FN=False Negative

NA=Not applicable due to precluding factor--depth from foundation to groundwater contamination is less than 1.5 m.

WB=Wet Basement. This condition precludes the use of Figure 3 (for Q5).

Notes:

[1] Site data was compared to indoor air and groundwater screening values in Table 2.

[2] Site data was compared to indoor air and groundwater screening values in Table 3. The appropriate attenuation factor in this analysis was obtained from Figure 3.

[3] When false positive or false negative outcomes resulted with both Q4 and Q5, the same compounds were responsible for the false outcome in each scenario.

Table F-4

Frequency of False Negative and False Positive Indoor Air Predictions Based on Comparison of Ground Water Concentrations to Target Levels, by Chemical[1]

Risk = 1x10^{-5}

	Location	Benzene			1,1- Dichloroethane			1,2-Dichloroethane			1,1-Dichloroethylene			cis-1,2-Dichloroethylene[2]			trans-1,2-Dichloroethylene[2]			Ethyl Benzene*		
		Samples	FP	FN	Samples	FP	FN	Samples	FP	FN	Samples	FP	FN	Samples	FP	FN	Samples	FP	FN	Samples	FP	FN
VI Q4 [3]	Alliant	--	--	--	--	--	--	0	0	0	0	0	0	0	0	0	--	--	--	--	--	--
	Eau Claire	--	--	--	--	--	--	--	--	--	--	--	--	0	0	0	--	--	--	--	--	--
	LAFB	--	--	--	13	0	0	13	0	1	13	0	0	13	0	0	13	0	0	--	--	--
	Uncasville	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	Hamilton-Sunstrand	--	--	--	--	--	--	--	--	--	13	0	0	--	--	--	--	--	--	--	--	--
	MADEP	1	0	0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1	0	0
	Mountain View	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	Total	**1**	**0**	**0**	**13**	**0**	**0**	**13**	**0**	**1**	**26**	**0**	**0**	**13**	**0**	**0**	**13**	**0**	**0**	**1**	**0**	**0**
VI Q5 [4]	Alliant	--	--	--	--	--	--	0	0	0	0	0	0	0	0	0	--	--	--	--	--	--
	Eau Claire	--	--	--	--	--	--	--	--	--	--	--	--	0	0	0	--	--	--	--	--	--
	LAFB	--	--	--	13	0	0	13	0	1	13	0	0	13	0	0	13	0	0	--	--	--
	Uncasville	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	Hamilton-Sunstrand	--	--	--	--	--	--	--	--	--	13	0	0	--	--	--	--	--	--	--	--	--
	MADEP	1	0	0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1	0	0
	Mountain View	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	Total	**1**	**0**	**0**	**13**	**0**	**0**	**13**	**0**	**1**	**26**	**0**	**0**	**13**	**0**	**0**	**13**	**0**	**0**	**1**	**0**	**0**

Table F-4 (continued)

Frequency of False Negative and False Positive Indoor Air Predictions Based on Comparison of Ground Water Concentrations to Target Levels, by Chemical[1]

Risk = $1x10^{-5}$

	Location	Tetrachloroethylene*			Toluene			1,1,1-Trichloroethane			1,1,2-Trichloroethane			Trichloroethylene*			Vinyl chloride*			Xylene[2]		
		Samples	FP	FN	Samples	FP	FN	Samples	FP	FN	Samples	FP	FN	Samples	FP	FN	Samples	FP	FN	Samples	FP	FN
VI Q4 [3]	Alliant	0	0	0	--	--	--	0	0	0	--	--	--	0	0	0	0	0	0	--	--	--
	Eau Claire	--	--	--	--	--	--	--	--	--	--	--	--	0	0	0	0	0	0	--	--	--
	LAFB	13	0	4	--	--	--	13	0	0	13	0	0	13	1	0	9	0	0	--	--	--
	Uncasville	0	0	0	--	--	--	0	0	0	--	--	--	0	0	0	--	--	--	--	--	--
	Hamilton-Sunstrand	--	--	--	--	--	--	--	--	--	--	--	--	13	0	0	--	--	--	--	--	--
	MADEP	--	--	--	1	0	0	--	--	--	--	--	--	0	0	0	--	--	--	1	0	0
	Mountain View	--	--	--	--	--	--	--	--	--	--	--	--	7	0	0	--	--	--	--	--	--
	Total	**13**	**0**	**4**	**1**	**0**	**0**	**13**	**0**	**0**	**13**	**0**	**0**	**33**	**1**	**0**	**9**	**0**	**0**	**1**	**0**	**0**
VI Q5 [4]	Alliant	0	0	0	--	--	--	0	0	0	--	--	--	0	0	0	0	0	0	--	--	--
	Eau Claire	--	--	--	--	--	--	--	--	--	--	--	--	0	0	0	0	0	0	--	--	--
	LAFB	13	0	4	--	--	--	13	0	0	13	0	0	13	1	0	9	0	0	--	--	--
	Uncasville	0	0	0	--	--	--	0	0	0	--	--	--	0	0	0	--	--	--	--	--	--
	Hamilton-Sunstrand	--	--	--	--	--	--	--	--	--	--	--	--	13	0	0	--	--	--	--	--	--
	MADEP	--	--	--	1	0	0	--	--	--	--	--	--	0	0	0	--	--	--	1	0	0
	Mountain View	--	--	--	--	--	--	--	--	--	--	--	--	7	0	0	--	--	--	--	--	--
	Total	**13**	**0**	**4**	**1**	**0**	**0**	**13**	**0**	**0**	**13**	**0**	**0**	**33**	**1**	**0**	**9**	**0**	**0**	**1**	**0**	**0**

Key:

FP=False Positive; FN=False Negative

Notes:

[1] For each chemical we indicate the total number of samples at each site for each chemical and the number of samples with False Positive or False Negative results at that site across all buildings. "--" means the chemical was not found at any building at that site.

[2] Toxicity values from oral studies were used to develop screening levels for this chemical.

[3] Site data was compared to indoor air and ground water screening values in Table 2.

[4] Site data was compared to indoor air and ground water screening values in Table 3.

* Ground water target concentration for this compound is based on the Maximum Contaminant Level (MCL) in drinking water.

Table F-5
False Negative and False Positive Indoor Air Predictions Based on Comparison of Groundwater Concentrations to Target Levels, by Building at Each Site
$R=1x10^{-6}$

Site Name	Address	Vapor Intrusion Q4[1]	Vapor Intrusion Q5[2]	J&E Site Specific [3]	Compound(s) Responsible for False Result [4]
Alliant		NA(CP)	NA(CP)	NA(CP)	
Eau Claire	Residence F	NA(CP)	WB	WB	
	Residence K	NA(CP)	WB	WB	
	Residence S	NA(CP)	WB	WB	
Hamilton-Sunstrand	6800 Fern Dr.	CP	CP	CP	
	6800 Osage St.	CP	CP	CP	
	6800 Ruth Way	CP	CP	CP	
	6801 Avrum Dr.	CP	CP	CP	
	6801 Fern Dr.	CP	CP	CP	
	6810 Jordan Dr.	CP	CP	CP	
	6811 Ruth Way	CP	CP	CP	
	6820 Fern Dr.	CP	CP	CP	
	6821 Mariposa St.	CP	CP	CP	
	6821 Pecos	CP	CP	CP	
	6831 Navajo St.	CP	CP	CP	
	6831 Zuni St.	CP	CP	CP	
	6840 Mariposa	CP	CP	CP	
LAFB	UA02	CP	CP	CP	
	UA03	CP	CP	CP	
	UA04	CP	CP	CP	
	UA05	CP	CP	CP	
	UA18	CP	CP	CP	
	UA19	CP	CP	CP	
	UA21	CP	CP	CP	
	UA22	CP	CP	CP	
	UA23	CP	CP	CP	
	UA24	CP	CP	CP	
	UA25	CP	CP	CP	
	UA26	CP	CP	CP	
	UA28	CP	CP	CP	
MADEP	0907 A Hull	NA(CP)	WB	WB	
	0907 B Hull	NA(CP)	WB	WB	
	1019 Lynnf	NA(CP)	NA(CP)	NA(CP)	
	11707 Quincy	NA(CP)	NA(CP)	NA(CP)	
	12092 B Marble	CP	CP	CP	
	1525 A Marble	NA(CP)	NA(CP)	NA(FN)	Trichloroethylene
	1525 B Marble	NA(CP)	NA(CP)	NA(FN)	Trichloroethylene
	2797 A Tewks	NA(CP)	NA(CP)	NA(CP)	
	2797 B Tewks	NA(CP)	NA(CP)	NA(CP)	
Mountain View	Residence 1	CP	CP	CP	
	Residence 2	CP	CP	CP	
	Residence 3	CP	CP	CP	
	Residence 4	CP	CP	CP	
	Residence 6	CP	CP	CP	
	Residence 7	CP	CP	CP	
	Residence 8	CP	CP	CP	
Uncasville	Residence A	NA(CP)	NA(CP)	NA(CP)	
	Residence B	NA(CP)	NA(CP)	NA(CP)	
	Residence D	NA(FN)	NA(FN)	NA(FN)	Tetrachloroethylene
	Residence E	NA(CP)	NA(CP)	NA(CP)	

Key:
CP=Correct Positive; CN = Correct Negative
FP=False Positive; FN=False Negative
NA=Not applicable due to precluding factor--depth from foundation to groundwater contamination is less than 1.5 m.
WB=Wet Basement. This condition precludes the use of Figure 3 (for Q5) and the use of the Johnson and Ettinger Model.

Notes:

[1] Site data was compared to indoor air and groundwater screening values in Table 2.

[2] Site data was compared to indoor air and groundwater screening values in Table 3. The appropriate attentuation factor in this analysis was obtained from Figure 3.

[3] Site specific soil type, depth to groundwater, and building foundation type were used in the Johnson and Ettinger (J&E) model.

[4] When false positive or false negative outcomes resulted with both Q4 and Q5, the same compounds were responsible for the false outcome in each scenario.

Table F-5 (continued)
Summary Table
False Negative and False Positive Indoor Air Predictions Based on Comparison of Groundwater Concentrations to Target Levels, by Building at Each Site
$R=1x10^{-6}$

	Q4		Q5		J&E Site Specific	
	Number	**Percent**	**Number**	**Percent**	**Number**	**Percent**
Total CP and CN	34	100.0%	34	100.0%	34	100.0%
Total FP	0	0.0%	0	0.0%	0	0.0%
Total FN	0	0.0%	0	0.0%	0	0.0%
Total NA and WB	16	--	16	--	16	--
Total Number of Buildings	34		34		34	

Key:
CP=Correct Positive; CN = Correct Negative
FP=False Positive; FN=False Negative
NA=Not applicable due to precluding factor--depth from foundation to groundwater contamination is less than 1.5 m.
WB=Wet Basement. This condition precludes the use of Figure 3 (for Q5) and the use of the Johnson and Ettinger Model.

Notes:

[1] Site data was compared to indoor air and groundwater screening values in Table 2.

[2] Site data was compared to indoor air and groundwater screening values in Table 3. The appropriate attentuation factor in this analysis was obtained from Figure 3.

[3] Site specific soil type, depth to groundwater, and building foundation type were used in the Johnson and Ettinger (J&E) model.

[4] When false positive or false negative outcomes resulted with both Q4 and Q5, the same compounds were responsible for the false outcome in each scenario.

Table F-6
Frequency of False Negative and False Positive Indoor Air Predictions Based on Comparison of Ground Water Concentrations to Target Levels, by Chemical[1]
Risk = $1x10^{-6}$

	Location	Benzene*			1,1- Dichloroethane			1,2-Dichloroethane*			1,1-Dichloroethylene			cis-1,2-Dichloroethylene [2]			trans-1,2-Dichloroethylene [2]		
		Samples	FP	FN	Samples	FP	FN	Samples	FP	FN	Samples	FP	FN	Samples	FP	FN	Samples	FP	FN
VI Q4 [3]	Alliant	--	--	--	--	--	--	0	0	0	0	0	0	0	0	0	--	--	--
	Eau Claire	--	--	--	--	--	--	--	--	--	--	--	--	0	0	0	--	--	--
	LAFB	--	--	--	13	0	0	13	0	13	13	0	0	13	0	0	13	0	0
	Uncasville	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	Hamilton-Sunstrand	--	--	--	--	--	--	--	--	--	13	0	0	--	--	--	--	--	--
	MADEP	1	0	0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	Mountain View	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	Total	**1**	**0**	**0**	**13**	**0**	**0**	**13**	**0**	**13**	**26**	**0**	**0**	**13**	**0**	**0**	**13**	**0**	**0**
VI Q5 [4]	Alliant	--	--	--	--	--	--	0	0	0	0	0	0	0	0	0	--	--	--
	Eau Claire	--	--	--	--	--	--	--	--	--	--	--	--	0	0	0	--	--	--
	LAFB	--	--	--	13	0	0	13	0	13	13	0	0	13	0	0	13	0	0
	Uncasville	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	Hamilton-Sunstrand	--	--	--	--	--	--	--	--	--	13	0	0	--	--	--	--	--	--
	MADEP	1	0	0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	Mountain View	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	Total	**1**	**0**	**0**	**13**	**0**	**0**	**13**	**0**	**13**	**26**	**0**	**0**	**13**	**0**	**0**	**13**	**0**	**0**
JE Site Specific [5]	Alliant	--	--	--	--	--	--	0	0	0	0	0	0	0	0	0	--	--	--
	Eau Claire	--	--	--	--	--	--	--	--	--	--	--	--	0	0	0	--	--	--
	LAFB	--	--	--	13	0	0	13	0	13	13	0	0	13	0	0	13	0	0
	Uncasville	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	Hamilton-Sunstrand	--	--	--	--	--	--	--	--	--	13	0	0	--	--	--	--	--	--
	MADEP	1	0	0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	Mountain View	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	Total	**1**	**0**	**0**	**13**	**0**	**0**	**13**	**0**	**13**	**26**	**0**	**0**	**13**	**0**	**0**	**13**	**0**	**0**

Table F-6 (continued)

Frequency of False Negative and False Positive Indoor Air Predictions Based on Comparison of Ground Water Concentrations to Target Levels, by Chemical [1]

Risk = $1x10^{-6}$

	Location	Ethylbenzene*			Tetrachloroethylene*			Toluene			1,1,1-Trichloroethane			1,1,2-Trichloroethane*			Trichloroethylene*			Vinyl chloride*			Xylene [2]		
		Samples	FP	FN	Samples	FP	FN	Samples	FP	FN	Samples	FP	FN	Samples	FP	FN	Samples	FP	FN	Samples	FP	FN	Samples	FP	FN
VI Q4 [3]	Alliant	--	--	--	0	0	0	--	--	--	0	0	0	--	--	--	0	0	0	0	0	0	--	--	--
	Eau Claire	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0	0	0	0	0	0	--	--	--
	LAFB	--	--	--	13	--	13	--	--	--	13	0	0	13	0	1	13	0	0	9	0	1	--	--	--
	Uncasville	--	--	--	0	0	0	--	--	--	0	0	0	--	--	--	0	0	0	--	--	--	--	--	--
	Hamilton-	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	13	0	0	--	--	--	--	--	--
	MADEP	1	0	1	--	--	--	1	0	0	--	--	--	--	--	--	0	0	0	--	--	--	1	0	0
	Mountain View	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	7	0	0	--	--	--	--	--	--
	Total	1	0	1	13	0	13	1	0	0	13	0	0	13	0	1	33	0	0	9	0	1	1	0	0
VI Q5 [4]	Alliant	--	--	--	0	0	0	--	--	--	0	0	0	--	--	--	0	0	0	0	0	0	--	--	--
	Eau Claire	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0	0	0	0	0	0	--	--	--
	LAFB	--	--	--	13	--	13	--	--	--	13	0	0	13	0	1	13	0	0	9	0	1	--	--	--
	Uncasville	--	--	--	0	0	0	--	--	--	0	0	0	--	--	--	0	0	0	--	--	--	--	--	--
	Hamilton-	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	13	0	0	--	--	--	--	--	--
	MADEP	1	0	1	--	--	--	1	0	0	--	--	--	--	--	--	0	0	0	--	--	--	1	0	1
	Mountain View	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	7	0	0	--	--	--	--	--	--
	Total	1	0	1	13	0	13	1	0	0	13	0	0	13	0	1	33	0	0	9	0	1	1	0	0
JE Site Specific [5]	Alliant	--	--	--	0	0	0	--	--	--	0	0	0	--	--	--	0	0	0	0	0	0	--	--	--
	Eau Claire	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0	0	0	0	0	0	--	--	--
	LAFB	--	--	--	13	--	13	--	--	--	13	0	0	13	0	1	13	0	0	9	0	1	--	--	--
	Uncasville	--	--	--	0	0	0	--	--	--	0	0	0	--	--	--	0	0	0	--	--	--	--	--	--
	Hamilton-	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	13	0	0	--	--	--	--	--	--
	MADEP	1	0	0	--	--	--	1	0	0	--	--	--	--	--	--	0	0	0	--	--	--	1	0	0
	Mountain View	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	7	0	0	--	--	--	--	--	--
	Total	1	0	0	13	0	13	1	0	0	13	0	0	13	0	1	33	0	0	9	0	1	1	0	0

Key:
FP=False Positive; FN=False Negative

Notes:

[1] For each chemical we indicate the total number of samples at each site for each chemical and the number of samples with False Positive or False Negative results at that site across all buildings. "--" means the chemical was not found at any building at that site.

[2] Toxicity values extrapolated from oral studies were used to develop screening levels for this chemical.

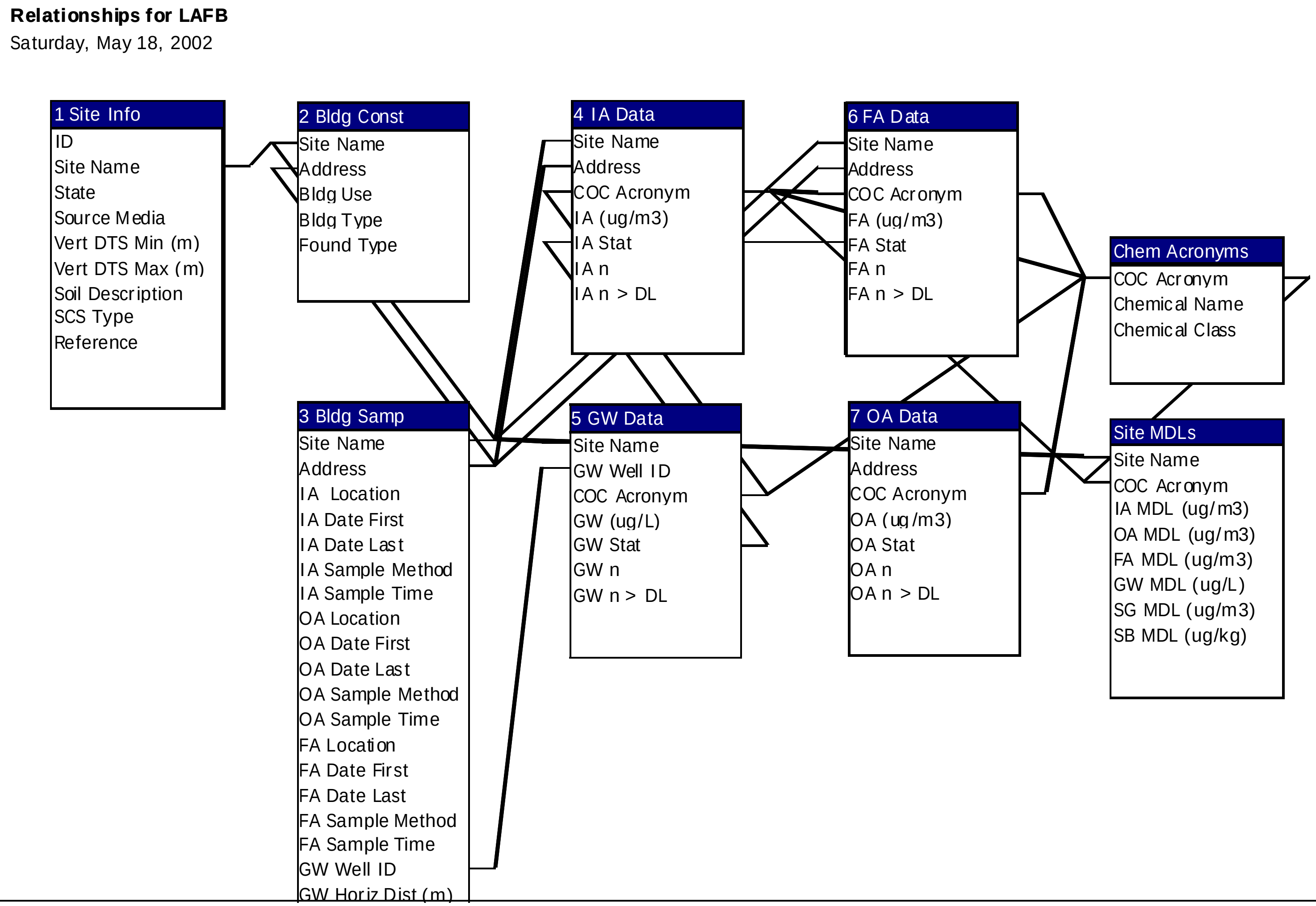
[3] Site data was compared to indoor air and ground water screening values in Table 2.

[4] Site data was compared to indoor air and ground water screening values in Table 3.

[5] Site specific soil type, depth to groundwater, and building foundation type were used in the J&E model.

* Ground water target concentration for this compound is based on the Maximum Contaminant Level (MCL) in drinking water.

Figure F-1. Schematic Diagram of Empirical Database Structure and Element



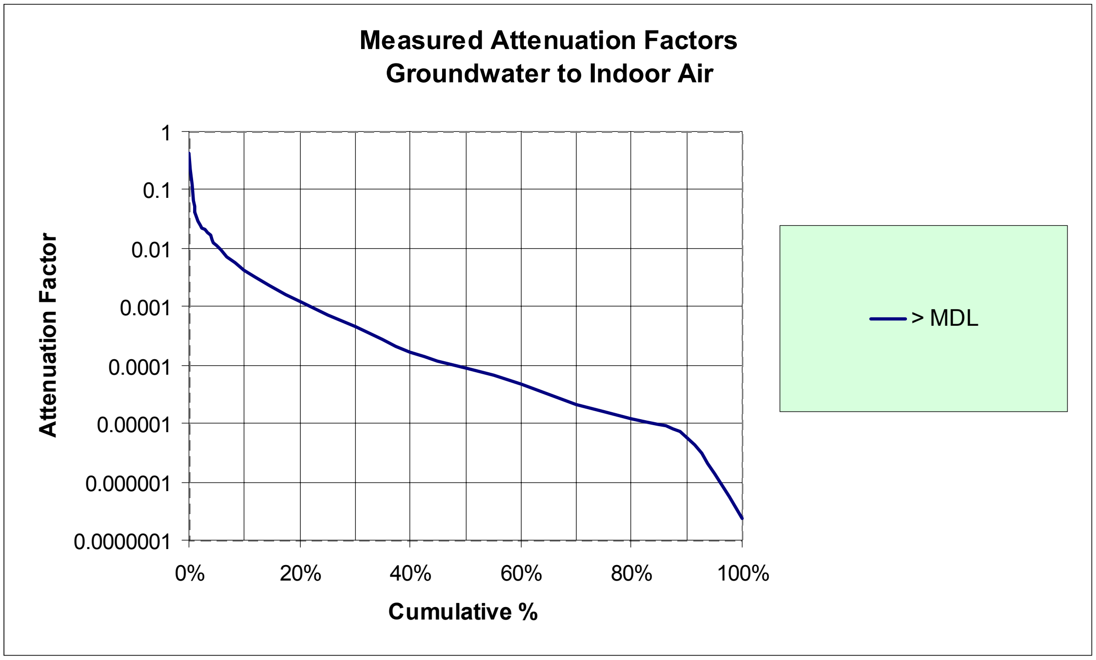


Figure F-2. Distribution of groundwater-to-indoor air attenuation factors for all residences in the empirical database with indoor air and groundwater measurements above their respective method detection limits (MDLs).

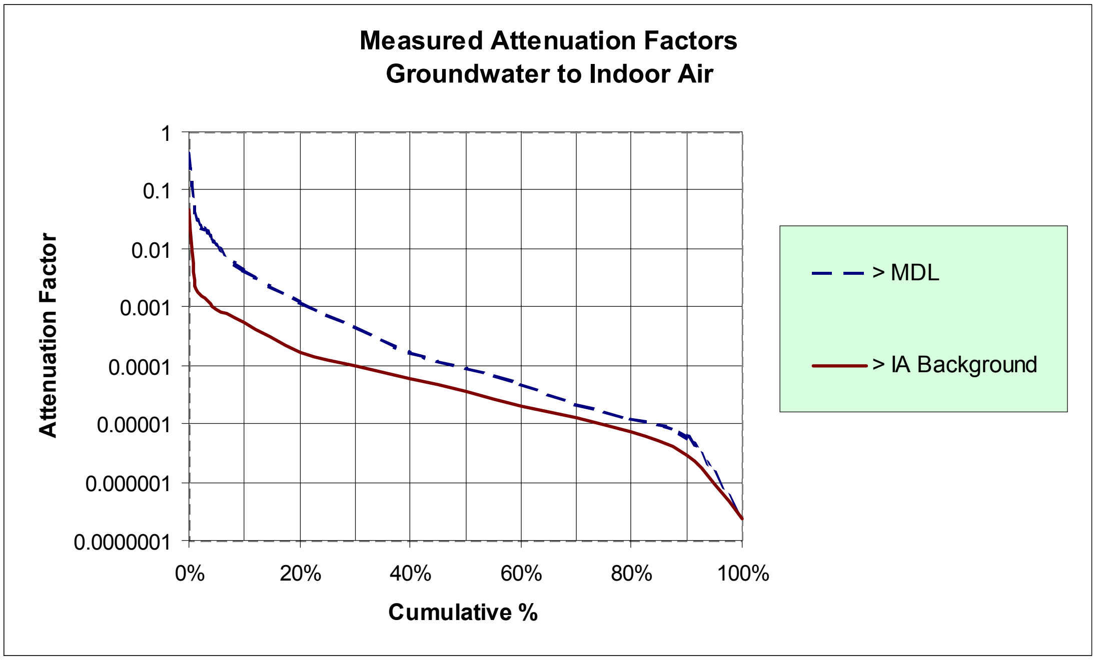


Figure F-3. Distribution of groundwater-to-indoor air attenuation factors for residences with concentrations above MDLs and above typical background levels.

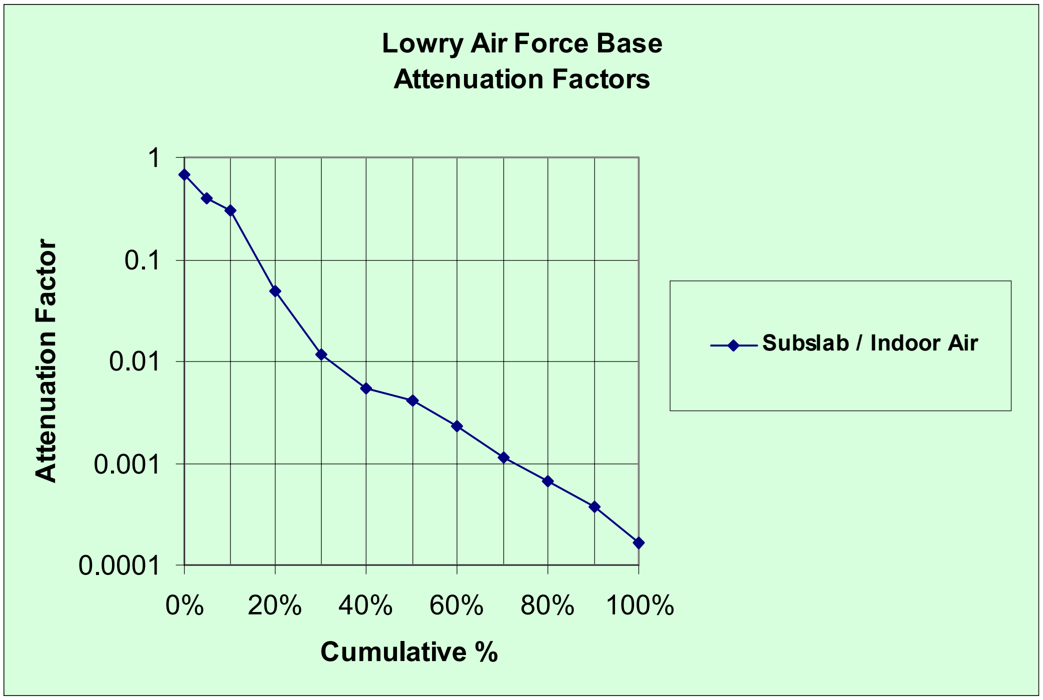


Figure F-4. Distribution of subslab-to-indoor air attenuation factors for residences for the subset of residences with indoor concentrations greater than the subslab concentrations measured below the residence's foundation. Subslab data were available for only one site—the Lowry Air Force Base in Colorado.

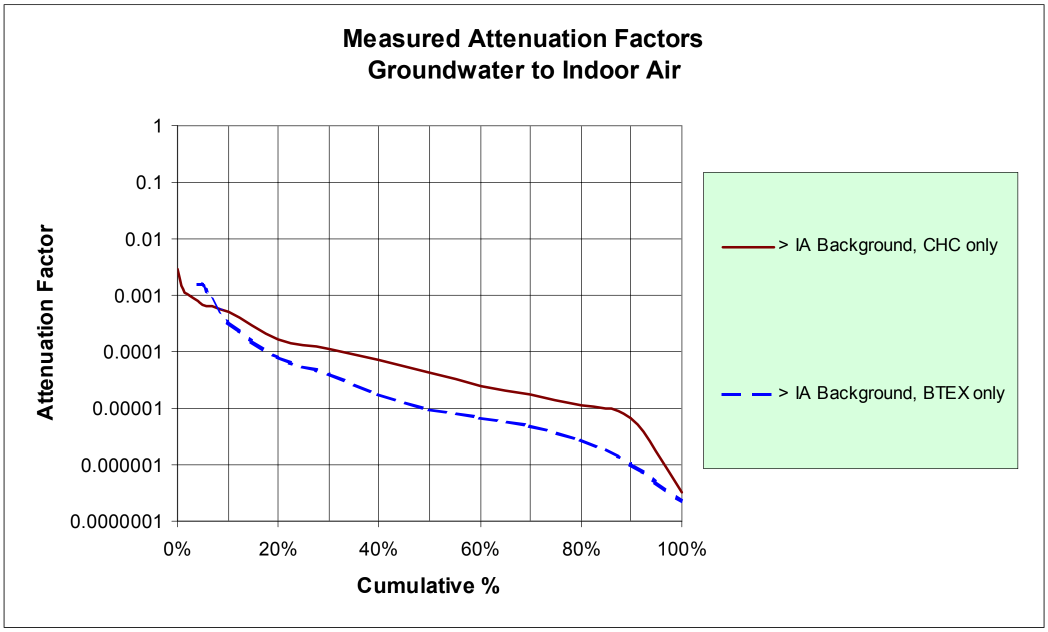


Figure F-5. Comparison of groundwater-to-indoor air attenuation factors for BTEX and chlorinated hydrocarbons (CHC).

APPENDIX G

CONSIDERATIONS FOR THE USE OF THE JOHNSON AND ETTINGER VAPOR INTRUSION MODEL

1. Introduction

At sites where soils or groundwater contain volatile or semi-volatile chemicals of concern, there is the potential for chemical vapors to migrate from the subsurface into indoor air spaces. Assessment of this potential indoor inhalation exposure pathway requires an understanding of the processes influencing vapor transport in the vadose zone and into buildings.

Johnson and Ettinger (1991) introduced a screening-level model for estimating the transport of contaminant vapors from a subsurface source into indoor air spaces. The model is a one-dimensional analytical solution to diffusive and convective transport of vapors formulated as an attenuation factor that relates the vapor concentration in the indoor space to the vapor concentration at the source. To facilitate use of the Johnson-Ettinger Model (JEM), EPA in 1997 developed spreadsheet versions of the model that calculate indoor air concentrations and associated health risks. A total of six spreadsheets were developed: a first tier and a more advanced version for each potential vapor source—groundwater, bulk soil, and soil gas. The spreadsheets were later updated in 2000 and 2002. The current spreadsheets may be downloaded from the web site:

http://www.epa.gov/superfund/programs/risk/airmodel/johnson_ettinger.htm

This appendix addresses the assumptions and limitations that we recommend be considered when the Johnson and Ettinger model as implemented by EPA is employed in the evaluation of the vapor intrusion pathway. This appendix also provides guidance for the model's use both as a first-tier screening level tool to identify sites needing further assessment and as a site-specific tool to estimate indoor air impacts resulting from vapor intrusion.

2. Assumptions and Limitations of the Johnson and Ettinger Model

The Johnson-Ettinger Model (JEM) was developed for use as a screening level model and, consequently, is based on a number of simplifying assumptions regarding contaminant distribution and occurrence, subsurface characteristics, transport mechanisms, and building construction. The assumptions of the JEM as implemented in EPA's spreadsheet version are listed in Table G-1 along with the implications of and limitations posed by the assumptions. Also provided in the table is an assessment of the likelihood that the assumptions can be verified through field evaluation. The JEM assumptions are typical of most simplified models of subsurface contaminant transport with the addition of a few assumptions regarding vapor flux into buildings.

The JEM as implemented by EPA assumes the subsurface is characterized by homogeneous soil layers with isotropic properties. The first tier spreadsheet versions accommodate only one layer; the advanced spreadsheet versions accommodate up to three layers. Sources of contaminants that can be modeled include dissolved, sorbed, or vapor sources where the concentrations are below the aqueous solubility limit, the soil saturation concentration, and/or the pure component vapor concentration. The contaminants are assumed to be homogeneously distributed at the source. All but one of the spreadsheets assumes an infinite source. The exception is the advanced model for a bulk soil source, which allows for a finite source. For the groundwater and bulk soil models, the vapor concentration at the source is calculated assuming equilibrium partitioning. Vapor from the source is assumed to diffuse directly upward (one-dimensional transport) through uncontaminated soil (including an uncontaminated capillary fringe if groundwater is the vapor source) to the base of a building foundation, where convection carries the vapor through cracks and openings in the foundation into the building. Both diffusive and convective transport processes are assumed to be at steady state. Neither sorption nor biodegradation is accounted for in the transport of vapor from source to the base of the building.

The assumptions described above and in Table G-1 suggest a number of conditions that under most scenarios would preclude the application of the JE model as implemented by EPA. These include:

- The presence or suspected presence of residual or free-product nonaqueous phase liquids (LNAPL, DNAPL, fuels, solvents, etc) in the subsurface.
- The presence of heterogeneous geologic materials (other than the three layers in the advanced spreadsheets) between the vapor source and building. The JE model does not apply to geologic materials that are fractured, contain macropores or other preferential pathways, or are composed of karst.
- Sites where significant lateral flow of vapors occurs. These can include geologic layers that deflect contaminants from a strictly upward motion and buried pipelines or conduits that form preferential paths. Permeability contrasts between layers greater than 1000 times also are likely to cause lateral flow of vapors. The model assumes the source of contaminants is directly below the potential receptors.
- Very shallow groundwater where the building foundation is wetted by the groundwater.
- Very small building air exchange rates (e.g., <0.25/hr)
- Buildings with crawlspace structures or other significant openings to the subsurface (e.g., earthen floors, stone buildings, etc.). The EPA spreadsheet only accommodates either slab on grade or basement construction.
- Contaminated groundwater sites with large fluctuations in the water table elevation. In these cases, the capillary fringe is likely to be contaminated, whereas in the groundwater source spreadsheets, the capillary fringe is assumed to be uncontaminated.
- Sites with transient (time-varying) flow rates and/or concentrations and for which a steady state assumption is not conservative.

In theory, the above limitations are readily conceptualized, but in practice the presence of these limiting conditions may be difficult to verify even when extensive site characterization data are available. Conditions that are particularly difficult to verify in the field include the presence of residual NAPLs in the unsaturated zone and the presence and influence of macropores, fractures and other preferential pathways in the subsurface. Additionally, in the initial stages of evaluation, especially at the screening level, information about building construction and water table fluctuations may not be available. Even the conceptually simple assumptions (e.g., one-dimensional flow, lack of preferential pathways) may be difficult to assess when there are limited site data available.

3. Guidance for Application of the JEM as a First-Tier Screening Level Tool

Use of the JEM as a first-tier screening tool to identify sites needing further assessment necessitates careful evaluation of the assumptions listed in the previous section to determine whether any conditions exist that would render the JEM inappropriate for the site. If the model is deemed applicable at the site, we recommend that care be taken to ensure reasonably conservative and self-consistent model parameters are used as input to the model. Considering the limited site data typically available in preliminary site assessments, the JEM can be expected to predict only whether or not a risk-based exposure level will be exceeded at the site. Precise prediction of concentration levels is not possible with this approach.

The suggested minimum site characterization information for a first-tier evaluation of the vapor intrusion pathway includes: site conceptual model, nature and extent of contamination distribution, soil lithologic descriptions, groundwater concentrations and/or possibly near source soil vapor concentrations. The number of samples and measurements needed to establish this information varies by site, and it is not possible to provide a hard and fast rule. We do not recommend use of bulk soil concentrations unless appropriately preserved during sampling.

Based on the conceptual site model, the user can select the appropriate spreadsheet corresponding to the vapor source at the site and determine whether to use the screening level spreadsheet (which accommodates only one soil type above the capillary fringe) or the more advanced version (which allows up to three layers above the capillary fringe). As most of the inputs to the JEM are not collected during a typical site characterization, conservative inputs are typically estimated or inferred from available data and other non-site-specific sources of information.

The uncertainty in determining key model parameters and sensitivity of the JEM to those key model parameters is qualitatively described in Table G-2. As shown in the table, building-related parameters with moderate to high uncertainty and model sensitivity include: Qsoil, building crack ratio, building air-exchange rate, and building mixing height. Building related parameters with low uncertainty and sensitivity include: foundation area, depth to base of foundation, and foundation slab thickness. Of the soil-dependent properties, the soil moisture parameters clearly are of critical importance for the attenuation value calculations.

A list of generally reasonable conservative model input parameters for building-related parameters is provided in Table G-3, which also provides the practical range, typical or mean value (if applicable), and most conservative value for these parameters. For building parameters with low uncertainty and sensitivity, only a single "fixed" value corresponding to the mean or typical value is provided in Table G-3. Soil-dependent properties are provided in Table G-4 for soils classified according to the US SCS system. If site soils are not classified according to the US SCS, Table G-5 can be used to assist in selecting an appropriate SCS soil type corresponding to the available site lithologic information. Note that the selection of the soil texture class should be biased towards the coarsest soil type of significance, as determined by the site characterization program.

The recommended values provided in Tables G-3 and G-4 were used in the advanced versions of the JEM spreadsheet to develop the graphs of attenuation factors provided in Question 5 of this draft guidance. These input parameters were developed considering soil-physics science, available studies of building characteristics, and expert opinion. Consequently, the input parameters listed in Tables G-3 and G-4 are considered default parameters for a first-tier assessment, which should in most cases provide a reasonably (but not overly) conservative estimate of the vapor intrusion attenuation factor for a site. Justification for the building-related and soil-dependent parameter values selected as default values for the JEM is described below.

3.1. Justification of Default Soil-Dependent Properties

The default soil-dependent parameters recommended for a first tier assessment (Table G-4) represent mean or typical values, rather than the most conservative value, in order to avoid overly conservative estimates of attenuation factors. Note, however, that the range of values for some soil properties can be very large, particularly in the case of moisture content and hydraulic conductivity. Consequently, selecting a soil type and corresponding typical soil property value may not accurately or conservatively represent a given site. Also, Table G-4 does not provide estimates of soil properties for very coarse soil types, such as gravel, gravelly sand, and sandy gravel, etc, which also may be present in the vadose zone. Consequently, in cases where the vadose zone is characterized by very coarse materials, the JEM may not provide a conservative estimate of attenuation factor.

As discussed above, the JEM is sensitive to the value of soil moisture content. Unfortunately, there is little information available on measured moisture contents below buildings; therefore, the typical approach is to use a water retention model (e.g., van Genuchten model) to approximate moisture contents. For the unsaturated zone, the selected default value for soil moisture is a value equal to half-way between the residual saturation value and field capacity, using the van Genuchten model-predicted values for U.S. SCS soil types. For the capillary transition zone, a moisture content corresponding to the air entry pressure head is calculated using the van Genuchten model. When compared to other available water retention models, the van Genuchten model yields somewhat lower water contents, which results in more conservative estimates of attenuation factor. However, the soil moisture contents listed in Table G-4 are based on agricultural samples, which are likely to have higher water contents than soils below building foundations and, consequently, result in less conservative estimates of attenuation factor.

3.2. Justification of Default Building-Related Properties

Building Air Exchange Rate (Default Value = 0.25 hr^{-1})

Results from 22 studies for which building air exchange data are available are summarized in Hers et al. (2001). There is a wide variation in ventilation rates ranging from about 0.1 air exchanges per hour (AEH) for energy efficient "air-tight" houses (built in cold climates) (Fellin and Otson, 1996) to over 2 AEH (AHRAE (1985); upper range). In general, ventilation rates will be higher in summer months when natural ventilation rates are highest. One of the most comprehensive studies of U.S. residential air exchange rates (sample size of 2844 houses) was conducted by Murray and Burmaster (1995). The data set was analyzed on a seasonal basis, and according to climatic region. When all the data was analyzed, the 10th, 50th and 90th percentile values were 0.21, 0.51 and 1.48 AEH. Air exchange rates varied depending on season and climatic region. For example, for the winter season and coldest climatic area (Region 1, Great Lakes area and extreme northeast US), the 10th, 50th and 90th percentile values were 0.11, 0.27 and 0.71 AEH. In contrast, for the winter season and warmest climatic area (Region 4, southern CA, TX, Florida, Georgia), the 10th, 50th and 90th percentile values were 0.24, 0.48 and 1.13 AEH. While building air exchange rates would be higher during the summer months, vapor intrusion during winter months (when house depressurization is expected to be most significant) would be of greatest concern. For this draft guidance, a default value of 0.25 for air exchange rate was selected to represent the lower end of these distributions.

Crack Width and Crack Ratio (Default Value = 0.0002 for basement house; = 0.0038 for slab-on-grade house)

The crack width and crack ratio are related. Assuming a square house and that the only crack is a continuous edge crack between the foundation slab and wall ("perimeter crack"), the crack ratio and crack width are related as follows:

$$\text{Crack Ratio} = \frac{4\,(\text{Crack Width})\sqrt{\text{Subsurface Foundation Area}}}{\text{Subsurface Foundation Area}}$$

Crack Ratio = Crack Width x 4 x (Subsurface Foundation Area)^0.5/Subsurface Foundation Area

There is little information available on crack width or crack ratio. One approach used by radon researchers is to back calculate crack ratios using a model for soil gas flow through cracks and the results of measured soil gas flow rates into a building. For example, the back-calculated values for a slab/wall edge crack based on soil gas-entry rates reported in Nazaroff (1992), Revzan *et al.* (1991) and Nazaroff *et al.* (1985) range from about 0.0001 to 0.001. Another possible approach is to measure crack openings although this, in practice, is difficult to do. Figley and Snodgrass (1992) present data from ten houses where edge crack measurements were made. At the eight houses where cracks were observed, the cracks widths ranged from hairline cracks up to 5 mm wide, while the total crack length per house ranged from 2.5 m to 17.3 m. Most crack widths were less than 1 mm. The suggested defaults for crack ratio in regulatory guidance, literature and models also vary. In ASTM E1739-95, a default crack ratio of 0.01 is used. The crack ratios suggested in the VOLASOIL model (developed by the Dutch Ministry of Environment) range from 0.0001 to 0.000001. The VOLASOIL model values correspond to values for a "good" and "bad" foundation, respectively. The crack ratio used by Johnson and Ettinger (1991) for illustrative purposes ranged from 0.001 to 0.01. The selected default values fall within the ranges observed.

Building Area and Subsurface Foundation Area (Default Value = 10 m by 10 m)

The default building area is based on the following information:

- default values used in the Superfund User's Guide **(9.61 m by 9.61 m or 92.4 m^2)**, and
- default values used by the State of Michigan, as documented in Part 201, Generic Groundwater and Soil Volatilization to Indoor Air Inhalation Criteria: Technical Support Document (**10.5 m by 10.5 m of 111.5 m^2**).

The Michigan guidance document indicates that the 111.5 m^2 area approximately corresponds to the 10th percentile floor space area for residential single family dwellings, based on statistics compiled by the U.S. DOC and U.S. HUD. The typical, upper and lower ranges presented in Table G-3 are subjectively chosen values. The subsurface foundation area is a function of the building area, and depth to the base of the foundation, which is fixed.

Building Mixing Height (Default Value = 2.44 m for slab-on-grade scenario; = 3.66 m for basement scenario)

The JEM assumes that subsurface volatiles migrating into the building are completely mixed within the building volume, which is determined by the building area and mixing height. The building mixing height will depend on a number of factors including the building height, the heating, ventilation and air conditioning (HVAC) system operation, environmental factors such as indoor-outdoor pressure differentials and wind loading, and seasonal factors. For a single-story house, the variation in mixing height can be approximated by the room height. For a multi-story house or apartment building, the mixing height will be greatest for houses with HVAC systems that result in significant air circulation (e.g., forced-air heating systems). Mixing heights would likely be less for houses with electrical baseboard heaters. It is likely that mixing height is, to some degree, correlated to the building air exchange rate.

There are little data available that provide for direct inference of mixing height. There are few sites, with a small number of houses where indoor air concentrations were above background, and where both measurements at ground level and the second floor were made (CDOT, Redfields, Eau Claire). Persons familiar with the data sets for these sites indicate that in most cases a fairly significant reduction in concentrations (factor of two or greater) was observed, although at one site (Eau Claire, “S” residence), the indoor TCE concentrations were similar in both the basement and second floor of the house. For the CDOT site apartments, there was an approximate five-fold reduction between the concentrations measured for the first floor and second floor units (Mr. Jeff Kurtz, EMSI, personal communication, June 2002). Less mixing would be expected for an apartment since there are less cross-floor connections than for a house. The value chosen for a basement house scenario (3.66 m) would be representative of a two-fold reduction or attenuation in vapor concentrations between floors.

Qsoil (Default Value = 5 L/min)

The method often used with the JEM for estimating the soil gas advection rate (Q_{soil}) through the building envelope is an analytical solution for two-dimensional soil gas flow to a small horizontal drain (Nazaroff 1992) (“Perimeter Crack Model”). Use of this model can be problematic in that Q_{soil} values are sensitive to soil-air permeability and consequently a wide range in flows can be predicted.

An alternate empirical approach is to select a Q_{soil} value on the basis of tracer tests (i.e., mass balance approach). When soil gas advection is the primary mechanism for tracer intrusion into a building, we recommend the Q_{soil} be estimated by measuring the concentrations of a chemical tracer in indoor air, outdoor air and in soil vapor below a building, and measuring the building ventilation rate (Hers et al. 2000a; Fischer et al. 1996; Garbesi et al. 1993; Rezvan et al. 1991; Garbesi and Sextro, 1989). The Q_{soil} values measured using this technique are compared to predicted rates using the Perimeter Crack model, for sites with coarse-grained soils. The Perimeter Crack model predictions are both higher and lower than the measured values, but overall are within one order of magnitude of the measured values. Although the Q_{soil} predicted by models and measured using field tracer tests are uncertain, the results suggest that a “typical” range for houses on coarse-grained soils is on the order of 1 to 10 L/min. A disadvantage with the tracer test approach is that there are only limited data, and there do not appear to be any tracer studies for field sites with fine-grained soils.

It is also important to recognize that the advective zone of influence for soil gas flow is limited to soil immediately adjacent to the building foundation. There is some data on pressure coupling that provides insight on the extent of the advective flow zone. For example, Garbesi *et al.* (1993) report a pressure coupling between soil and experimental basement (i.e., relative to that between the basement and atmosphere) equal to 96 % directly below the slab, between 29 % and 44 % at 1 m below the basement floor slab, and between 0.7 % and 27 % at a horizontal distance of 2 m from the basement wall. At the Chatterton site in Canada, the pressure coupling immediately below the building floor slab ranged from 90 % to 95 % and at a depth of 0.5 m was on the order of 50 %. These results indicate that the advective zone of influence will likely be limited to a zone within 1 m to 2 m of the building foundation.

Since the advective flow zone is relatively limited in extent, the soil type adjacent to the building foundation is of importance. In many cases, coarse-grained imported fill is placed below foundations, and either coarse-grained fill, or disturbed, loose fill is placed adjacent to the foundation walls. Therefore, a conservative approach for the purposes of this draft guidance is to assume that soil gas flow will be controlled by coarse-grained soil, and not to rely on the possible reduction in flow that would be caused by fine-grained soils near the house foundation. For these reasons, a soil gas flow rate of 5 L/min (midpoint between 1 and 10 L/min) was chosen as the input value.

4. Guidance for Application of JEM as a Site-Specific Tool

We generally recommend use of the JE model as a site-specific tool only where the site conceptual model matches the restrictive assumptions. When these assumptions cannot be met, we recommend that other models or direct measurement be substituted, because there is no *a priori* scientific reason to believe that the model is adequate to represent complex site conditions. If the JE model is deemed applicable to the site, critical model parameters from site data are needed. We recommend that site-specific information include soil moisture, soil permeability, building ventilation rate, and subslab as well as deep vapor concentrations.

In order to ensure the model can reproduce observed field observations, we recommend the model output be compared with measured concentrations, fluxes and/or other model outputs. Calibration has been developed as a process for minimizing the differences between model results and field observations. Through model calibration a parameter set is selected that causes the model to best fit the observed data. When done properly, this process establishes that the conceptualization and input parameters are appropriate for the site. Because of the number of parameters to be identified, calibration is known to produce non-unique results. This is particularly the case in heterogeneous environments where every parameter of the model can vary from point to point. Confidence in the model, however, is increased by using the calibrated model to predict the response to some additional concentration or flux data (i.e., that were not previously used in calibration). At each step in this process, additional site investigation data improve knowledge of the behavior of the system.

From a regulatory standpoint, the JE model when used as a site-specific tool typically should be calibrated to predict within an order of magnitude the indoor air concentrations resulting from intrusion of vapors from the subsurface. Consequently, prior to its use, we recommend an evaluation of the critical input parameters be performed. If the uncertainty in the critical parameters cannot be reduced to yield an order of magnitude estimate of indoor air concentrations, it may not be practical to perform the modeling.

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Table G-1. Assumptions and Limitations of the Johnson and Ettinger Vapor Intrusion Model

Assumption	**Implication**	**Field Evaluation**
Contaminant		
No contaminant free-liquid/precipitate phase present	JEM not representative of NAPL partitioning from source	NAPL presence–easier to evaluate for floating product or soil contamination sites. Most DNAPL sites with DNAPL below the water table defy easy characterization.
Contaminant is homogeneously distributed within the zone of contamination		
No contaminant sources or sinks in the building.	Indoor sources of contaminants and/or sorption of vapors on materials may confound interpretation of results.	Survey building for sources, assessment of sinks unlikely
Equilibrium partitioning at contaminant source.	Groundwater flow rates are low enough so that there are no mass transfer limitations at the source.	Not likely
Chemical or biological transformations are not significant (model will predict more intrusion)	Tendency to overpredict vapor intrusion for degradable compounds	From literature
Subsurface Characteristics		
Soil is homogeneous within any horizontal plane	Stratigraphy can be described by horizontal layers (not tilted layers)	Observe pattern of layers and unconformities. Note: In simplified JEM layering is not considered
All soil properties in any horizontal plane are homogeneous		
The top of the capillary fringe must be below the bottom of the building floor in contact with the soil.		
EPA version of JE Model assumes the capillary fringe is uncontaminated.		
Transport Mechanisms		
One-dimensional transport	Source is directly below building, stratigraphy does not influence flow direction, no effect of two- or three-dimensional flow patterns.	Observe location of source, observe stratigraphy, pipeline conduits, not likely to assess two- and three-dimensional pattern.
Two separate flow zones, one diffusive one convective.	No diffusion (disperson) in the convective flow zone. Plug flow in convective zone	Not likely
Vapor-phase diffusion is the dominant mechanism for transporting contaminant vapors from contaminant sources located away from the foundation to the soil region near the foundation	Neglects atmospheric pressure variation effects, others?	Not likely

Straight-line gradient in diffusive flow zone.	Inaccuracy in flux estimate at match point between diffusive and convective sections of the model.	Not likely
Diffusion through soil moisture will be insignificant (except for compounds with very low Henry's Law Constant	Transport through air phase only. Good for volatiles. Only low volatility compounds would fail this and they are probably not the compounds of concern for vapor intrusion	From literature value of Henry's Law Constant.
Convective transport is likely to be most significant in the region very close to a basement, or a foundation, and vapor velocities decrease rapidly with increasing distance from a structure		Not likely
Vapor flow described by Darcy's law	Porous media flow assumption.	Observations of fractured rock, fractured clay, karst, macropores, preferential flow channels.
Steady State convection	Flow not affected by barometric pressure, infiltration, etc.	Not likely
Uniform convective flow near the foundation	Flow rate does not vary by location	Not likely
Uniform convective velocity through crack or porous medium	No variation within cracks and openings and constant pressure field between interior spaces and the soil surface	Not likely
Significant convective transport only occurs in the vapor phase	Movement of soil water not included in vapor impact	Not likely
All contaminant vapors originating from directly below the basement will enter the basement, unless the floor and walls are perfect vapor barriers. (Makes model over est. vapors as none can flow around the building)	Model does not allow vapors to flow around the structure and not enter the building	Not likely
Contaminant vapors enter structures primarily through cracks and openings in the walls and foundation	Flow through the wall and foundation material itself neglected	Observe numbers of cracks and openings. Assessment of contribution from construction materials themselves not likely

Table G-2. Uncertainty and Sensitivity of Key Parameters for the Johnson & Ettinger Model.

Input Parameter	Parameter Uncertainty or Variability Variability	Parameter Sensitivity			
		Shallower Contamination Building Underpressurized	Deeper Contamination Building Underpressurized	Shallower Contamination Building Not Underpressurized	Deeper Contamination Building Not Underpressurized
Total Porosity	Low	Low	Low	Low	Low
Unsaturated Zone Water-filled Porosity	Moderate to High	Low to Moderate	Moderate to High	Moderate to High	Moderate to High
Capillary Transition Zone Water-filled Porosity	Moderate to High	Moderate to High	Moderate to High	Moderate to High	Moderate to High
Capillary Transition Zone Height	Moderate to High	Moderate to High	Moderate to High	Moderate to High	Moderate to High
Soil Bulk Density	Low	Low	Low	Low	Low
Qsoil	High	Moderate to High	Low to Moderate	N/A	N/A
Soil air permeability	High	Moderate to High	Low to Moderate	N/A	N/A
Building Depressurization	Moderate	Moderate	Low to Moderate	N/A	N/A
Henry's Law Constant (for single chemical)	Low to Moderate	Low to Moderate	Low to Moderate	Low to Moderate	Low to Moderate
Free-Air Diffusion Coefficient (single chemical)	Low	Low	Low	Low	Low
Building Air Exchange Rate	Moderate	Moderate	Moderate	Moderate	Moderate
Building Mixing Height	Moderate	Moderate	Moderate	Moderate	Moderate
Subsurface Foundation Area	Low to Moderate	Low to Moderate	Low to Moderate	Low to Moderate	Low to Moderate
Depth to Base of Foundation	Low	Low	Low	Low	Low
Building Crack Ratio	High	Low	Low	Moderate to High	Low to Moderate
Crack Moisture Content	High	Low	Low	Moderate to High	Low to Moderate
Building Foundation Slab Thickness	Low	Low	Low	Low	Low

Table G-3. Building-Related Parameters for the Johnson & Ettinger Model - First Tier Assessment.

Input Parameter	Units	Typical or Mean Value	Range	Conservative Value	Modeled
Total Porosity	cm^3/cm^3	*************** Specific to soil texture, see Table G-4 *************************			
Unsaturated Zone Water-filled Porosity	cm^3/cm^3	*************** Specific to soil texture, see Table G-4 *************************			
Capillary Transition Zone Water-filled Porosity	cm^3/cm^3	*************** Specific to soil texture, see Table G-4 *************************			
Capillary Transition Zone Height	cm^3/cm^3	*************** Specific to soil texture, see Table G-4 *************************			
Qsoil[1]	L/min	5	1-10	10	5
Soil air permeability	m^2	*************** Specific to soil texture, see Table G-4 *************************			
Building Depressurization	Pa	4	0-15	15	N/A
Henry's Law Constant (for single chemical)	-	********************** Specific to chemical *************************************			
Free-Air Diffusion Coefficient (single chemical)	-	********************** Specific to chemical *************************************			
Building Air Exchange Rate	hr^{-1}	0.5	0.1-1.5	0.1	0.25
Building Mixing Height - Basement scenario	m	3.66	2.44-4.88	2.44	3.66
Building Mixing Height - Slab-on-grade scenario	m	2.44	2.13-3.05	2.13	2.44
Building Footprint Area - Basement Scenario	m^2	120	80-200+	80	100
Building Footprint Area - Slab-on-Grade Scenario	m^2	120	80-200+	80	100
Subsurface Foundation Area - Basement Scenario	m^2	208	152-313+	152	180
Subsurface Foundation Area - Slab-on-Grade Scenario	m^2	127	85-208+	85	106
Depth to Base of Foundation - Basement Scenario	m	2	N/A	N/A	2
Depth to Base of Foundation - Slab-on-Grade Scenario	m	0.15	N/A	N/A	0.15
Perimeter Crack Width	mm	1	0.5-5	5	1
Building Crack Ratio - Slab-on-Grade Scenario	dimensionless	0.00038	0.00019-0.0019	0.0019	0.00038
Building Crack Ratio - Basement Scenario	dimensionless	0.0002	0.0001-0.001	0.001	0.00020
Crack Dust Water-Filled Porosity	cm^3/cm^3	Dry	N/A	N/A	Dry
Building Foundation Slab Thickness	m	0.1	N/A	N/A	0.1

[1] The values given for Qsoil are representative of sand, but are recommended for other soil types as well because coarse-grained soil or disturbed fine-grained soil often is found below and adjacent to foundations.

Table G-4. Soil-Dependent Properties for the Johnson & Ettinger Model - First Tier Assessment.

			Unsaturated Zone Water-Filled Porosity				Capillary Transition Zone		
U.S. Soil Conservation Service (SCS) Soil Texture	Saturated Water Content Total Porosity θ_s (cm^3/cm^3)	Residual Water Content θ_r (cm^3/cm^3)	Mean or Typical $(FC_{1/3bar}+\theta_r)/2$ $\theta_{w,unsat}$ (cm^3/cm^3)	Range $\theta_{w,unsat}$ (cm^3/cm^3)	Conservative $\theta_{w,unsat}$ (cm^3/cm^3)	Modeled $\theta_{w,unsat}$ (cm^3/cm^3)	Saturated Water Content Total Porosity θ_s (cm^3/cm^3)	$\theta_{w,cap}$ Cap @ air-entry	Height Cap Zone Fetter (94) (cm)
Clay	0.459	0.098	0.215	0.098-0.33	0.098	0.215	0.459	0.412	81.5
Clay Loam	0.442	0.079	0.168	0.079-0.26	0.079	0.168	0.442	0.375	46.9
Loam	0.399	0.061	0.148	0.061-0.24	0.061	0.148	0.399	0.332	37.5
Loamy Sand	0.39	0.049	0.076	0.049-0.1	0.049	0.076	0.39	0.303	18.8
Silt	0.489	0.05	0.167	0.05-0.28	0.050	0.167	0.489	0.382	163.0
Silt Loam	0.439	0.065	0.180	0.065-0.3	0.065	0.180	0.439	0.349	68.2
Silty Clay	0.481	0.111	0.216	0.11-0.32	0.111	0.216	0.481	0.424	192.0
Silty Clay Loam	0.482	0.09	0.198	0.09-0.31	0.090	0.198	0.482	0.399	133.9
Sand	0.375	0.053	0.054	0.053-0.055	0.053	0.054	0.375	0.253	17.0
Sandy Clay	0.385	0.117	0.197	0.117-0.28	0.117	0.197	0.385	0.355	30.0
Sandy Clay Loam	0.384	0.063	0.146	0.063-0.23	0.063	0.146	0.384	0.333	25.9
Sandy Loam	0.387	0.039	0.103	0.039-0.17	0.039	0.103	0.387	0.320	25.0
Loamy Sand	0.39	0.049	0.076	0.049-0.1	0.049	0.076	0.39	0.303	18.8

Table G-5. Guidance for Selection of US SCS Soil Type Based on Site Lithologic Information.

If your boring log indicates that the following materials are the predominant soil types …	*Then use the following texture classification when obtaining the attenuation factor.*
Sand or **Gravel** or **Sand and Gravel**, with less than about 12 % fines, where “fines” are smaller than 0.075 mm in size.	Sand
Sand or **Silty Sand**, with about 12 % to 25 % fines	Loamy Sand
Silty Sand, with about 25 % to 50 % fines	Sandy Loam
Silt and Sand or **Silty Sand** or **Clayey, Silty Sand** or **Sandy Silt** or **Clayey** with about 50 to 85 % fines	Loam

APPENDIX H

COMMUNITY INVOLVEMENT GUIDANCE

RECOMMENDATION FOR WHAT TO DO IF YOU HAVE A NEIGHBORHOOD NEEDING INDOOR AIR SAMPLING DUE TO SUBSURFACE VAPOR INTRUSION

As in any effort that strives for good community involvement, these five key principles are important considerations:

- ***Be proactive in engaging the community.***
- ***Listen carefully to what community members are saying.***
- ***Take the time needed to deal with community concerns.***
- ***Change plans where community suggestions have merit.***
- ***Explain to the community what is being done, by whom and why.***

The following provides an outline of recommended public participation activities that are consistent with EPA's ***1996 RCRA Public Participation Manual*** (EPA 530-R-96-007S) OSW September 1996
(URL = http://www.epa.gov/epaoswer/hazwaste/permit/pubpart/manual.htm) and the ***Superfund Community Involvement Handbook*** (EPA 540-K-01-003) OERR April 2002 (URL = http://www.epa.gov/superfund/tools/cag/ci_handbook.pdf) considered appropriate for addressing vapor intrusion concerns. These activities may occur concurrently or sequentially.

1. ***Get to know the neighborhood, key stakeholders and the concerns of the community***

- Demographics
- Elected officials (Congressional, local, and state)
- Homeowners association (HOA) board
- Local school district officials, principals, etc.
- Local church leaders
- Residents
- Languages - English-speaking or not; will translation capability be needed?
- Media (although typically the media will seek you out; at least some sense of their interest can be useful. Press statements are usually reserved for announcing major milestones or for particularly hot button issues.)
- Local health department(s)
- Local or neighboring businesses
- Conduct briefings with most key stakeholders (face-to-face meetings preferred, but not always possible)
- Conduct community interviews (determine some number to conduct)
- Consider other possibilities to listen to community members' concerns e.g. hotline, public availability sessions

.

2. ***Establish a mailing list of all interested parties***

In establishing a mailing list, it is important to clarify that anybody can sign up and that no cost is involved.

3. ***Inform stakeholders of the situation***

Part of informing and educating the community is the distribution of information. Easy to understand and technically accurate flyers describing the history of the spill or contamination, the chemicals of concern, the potential risks that may be posed, and who to contact for more information are usually well received by the community. Anticipate that people will want information and be ready to give it to them. Consider use of web pages and establishing a knowledgeable person as a contact to call for accurate information.

- Send a letter/newsletter explaining the situation and the need for indoor air sampling and invite them to an open house/informational meeting

- Hold an open house/informational meeting to explain:
  - environmental conditions at the site;
  - health impacts;
  - indoor air sampling;
  - what level of remediation is needed; and
  - the type(s)of remediation (have pictures of ventilation systems)

(*Note: we recommend having toxicologists, health professionals, or other knowledgeable individuals available for this meeting*)

- Devote one booth to explaining indoor air sampling, include a SUMMA cannister

- Devote one booth at the open house/informational meeting to obtaining permission to conduct the indoor air sampling

- Conduct an exit poll of people as they leave the open house to determine the effectiveness of the meeting and whether it met their needs

Note: include many visuals/maps in this meeting

4. ***Develop a community involvement/public participation plan*** - We recommend the plan highlight key community concerns, establish goals and objectives, and identify a commitment to ongoing communications activities. At RCRA sites, a community involvement plan that is a component of a RCRA 3008(h) order specifying implementation of a remedy is enforceable.

5. *Implement the Public Participation Plan*

- Establish an information repository; consider using web pages
- Establish knowledgeable persons who can provide accurate information as key points of contact
- Establish a hotline that includes a recorded message of key activities for the week or determined period of time and allows caller to leave message/ask questions, and be sure to call them back
- Establish a mailing list of all interested parties
- Prepare periodic status updates/newsletters
- Other items as needed

For areas targeted for indoor air sampling:

- Contact individuals via phone and mail and seek written permission to sample
- If no response, then send a certified letter
- If still no response, document that resident was contacted but did not give permission to sample
- If at all possible, try to visit homes not responding and talk directly with occupants

6. *Conduct indoor air sampling*

- Schedule appointments to 1) conduct an inspection of the residence, complete an occupant survey to adequately identify the presence of (or occupant activities that could generate) any possible indoor air emissions of target VOCs in the dwelling, 2) remove possible sources, and 3) conduct residential sampling
- Be prompt on the day scheduled for sampling
- Send someone extremely knowledgeable and articulate about the indoor air sampling to accompany technical folks who do the sampling; if necessary, include a translator

7. *Communicate indoor air sampling results*

- Send letters to residents with their individual indoor air sampling results
- Follow-up with a phone call to explain results
- Hold an open house/informational meeting to share sampling results and answer any questions

Note: include map of area sampled and indicate the levels found

8. *Continually evaluate what communication activities are needed to optimize public participation and community involvement*

Additional Tools - to increase effectiveness of involvement with community residents

The following are examples of pre-sampling interview forms that may be adapted by others for site specific use to facilitate interaction/involvement with building/dwelling occupants prior to indoor air sampling:

> ***Occupied Dwelling Questionnaire*** developed by the OERR Emergency Response Team (below).
>
> ***Massachusetts Department of Environmental Protection - Indoor Air Sampling Guide (April 2002)*** Appendix 2 of this document provides an *Indoor Air Quality Building Survey* form and a set of *Instructions for Residents of Homes to Be Sampled.* These can be found at:
> http://www.state.ma.us/dep/bwsc/finalpol.htm

OCCUPIED DWELLING QUESTIONNAIRE

Indoor Air Assessment Survey

Date: ________________

1. Name:____

   Address:____

   ____

   Home Phone:_________________________ Work Phone:______________________________

2. What is the best time to call to speak with you?________ At: Work ☐ or Home ☐?

3. Are you the Owner ☐, Renter ☐, Other ☐ (please specify)__________________________
   of this Home/Structure?

4. Total number of occupants/persons at this location?___________
   Number of children? _______ Ages?_________

5. How long have you lived at this location? ___________

General Home Description

6. Type of Home/Structure (check only one): Single Family Home ☐, Duplex ☐, Condominium☐, Townhouse ☐, Other ☐_______________________

7. Home/Structure Description: number of floors ________
   Basement? Yes ☐ No ☐
   Crawl Space? Yes ☐ No ☐
   If Yes, under how much of the house's area? ____%

8. Age of Home/Structure: ________ years, Not sure/Unknown ☐

9. General Above-Ground Home/Structure construction (check all that apply):
   Wood ☐, Brick ☐, Concrete ☐, Cement block ☐, Other ☐_____________

10. Foundation Construction (check all that apply):
    Concrete slab ☐
    Fieldstone ☐
    Concrete block ☐

Elevated above ground/grade ☐
Other______________________________

11. What is the source of your drinking water (check all that apply)?
Public water supply ☐
Private well ☐
Bottled water ☐
Other, please specify _________________________________

12. Do you have a private well for purposes other than drinking?
Yes ☐ No ☐
If yes, please describe what you use the well for:____________________________
____

13. Do you have a septic system? Yes ☐ No ☐ Not used ☐ Unknown ☐

14. Do you have standing water outside your home (pond, ditch, swale)? Yes ☐ No ☐

Basement Description, please check appropriate boxes.
<u>If you do not have a basement</u> go to question 23.

15. Is the basement finished ☐ or unfinished ☐?
16. If finished, how many rooms are in the basement?__________
How many are used for more than 2 hours/day?__________
17. Is the basement floor (check all that apply) concrete ☐, tile ☐, carpeted ☐, dirt ☐, other☐(describe)_________________________?
18. Are the basement walls poured concrete ☐, cement block ☐, stone ☐, wood ☐, brick ☐, other☐____?
19. Does the basement have a moisture problem (check one only)?
Yes, frequently (3 or more times/yr) ☐
Yes, occasionally (1-2 times/yr) ☐
Yes, rarely (less than 1 time/yr) ☐
No ☐

20. Does the basement ever flood (check one only)?
Yes, frequently (3 or more times/yr) ☐
Yes, occasionally (1-2 times/yr) ☐
Yes, rarely (less than 1 time/yr) ☐
No ☐

21. Does the basement have any of the following? (check all that apply) Floor cracks ☐, Wall cracks ☐, Sump ☐, Floor drain ☐, Other hole/opening in floor ☐ (describe)_______

22. Are any of the following used or stored in the basement (check all that apply)
Paint ☐ Paint stripper/remover ☐ Paint thinner ☐
Metal degreaser/cleaner ☐ Gasoline ☐ Diesel fuel ☐ Solvents ☐ Glue ☐
Laundry spot removers ☐ Drain cleaners ☐ Pesticides ☐

23. Have you recently (within the last six months) done any painting or remodeling in your home? Yes ☐ No ☐
If yes, please specify what was done, where in the home, and what month:
____
____

24. Have you installed new carpeting in your home within the last year? Yes ☐ No ☐
If yes, when and where?____

25. Do you regularly use or work in a dry cleaning service (check only one box)?
Yes, use dry-cleaning regularly (at least weekly)☐
Yes, use dry-cleaning infrequently (monthly or less)☐
Yes, work at a dry cleaning service ☐
No ☐

26. Does anyone in your home use solvents at work?
Yes ☐ If yes, how many persons__________
No ☐ If no, go to question 28

27. If yes for question 26 above, are the work clothes washed at home? Yes ☐ No ☐

28. Where is the washer/dryer located?
Basement ☐
Upstairs utility room ☐
Kitchen ☐
Garage ☐
Use a Laundromat ☐
Other, please specify ☐___________________________________

29. If you have a dryer, is it vented to the outdoors? Yes ☐ No ☐

30. What type(s) of home heating do you have (check all that apply)
Fuel type: Gas ☐, Oil ☐, Electric ☐, Wood ☐, Coal ☐, Other______________________
Heat conveyance system: Forced hot air ☐
Forced hot water ☐
Steam ☐
Radiant floor heat ☐
Wood stove ☐
Coal furnace ☐
Fireplace ☐
Other_________________________

31. Do you have air conditioning? Yes ☐ No ☐. If yes, please check the appropriate type(s)
Central air conditioning ☐
Window air conditioning unit(s)☐
Other ☐, please specify____

32. Do you use any of the following? Room fans ☐, Ceiling fans ☐, Attic fan ☐
Do you ventilate using the fan-only mode of your central air conditioning or forced air heating system? Yes ☐ No ☐

33. Has your home had termite or other pesticide treatment: Yes ☐ No ☐ Unknown ☐
If yes, please specify type of pest controlled, ______________________________________
and approximate date of service ____

34. Water Heater Type: Gas ☐, Electric ☐, By furnace ☐, Other ☐_______________________
Water heater location: Basement ☐, Upstairs utility room ☐, Garage ☐, Other ☐ (please describe) ____

35. What type of cooking appliance do you have? Electric ☐, Gas ☐, Other ☐_____________

36. Is there a stove exhaust hood present? Yes ☐ No ☐
Does it vent to the outdoors? Yes ☐ No ☐

37. Smoking in Home:
None ☐, Rare (only guests)☐, Moderate (residents light smokers)☐,
Heavy (at least one heavy smoker in household)☐

38. If yes to above, what do they smoke?
Cigarettes ☐ Cigars ☐
Pipe ☐ Other ☐

39. Do you regularly use air fresheners? Yes ☐ No ☐

40. Does anyone in the home have indoor home hobbies of crafts involving: None ☐
Heating ☐, soldering ☐, welding ☐, model glues ☐, paint ☐, spray paint, wood finishing ☐, Other ☐ Please specify what type of hobby: _________________________
____

41. General family/home use of consumer products (please circle appropriate): Assume that **Never** = never used, **Hardly ever** = less than once/month, **Occasionally** = about once/month, **Regularly** = about once/week, and **Often** = more than once/week.

Product	Frequency of Use				
Spray-on deodorant	Never	Hardly ever	Occasionally	Regularly	Often

Aerosol deodorizers	Never	Hardly ever	Occasionally	Regularly	Often
Insecticides	Never	Hardly ever	Occasionally	Regularly	Often
Disinfectants	Never	Hardly ever	Occasionally	Regularly	Often

(Question 41, continued)

Product	Frequency of Use				
Window cleaners	Never	Hardly ever	Occasionally	Regularly	Often
Spray-on oven cleaners	Never	Hardly ever	Occasionally	Regularly	Often
Nail polish remover	Never	Hardly ever	Occasionally	Regularly	Often
Hair sprays	Never	Hardly ever	Occasionally	Regularly	Often

42. Please check weekly household cleaning practices:
    Dusting ☐
    Dry sweeping ☐
    Vacuuming ☐
    Polishing (furniture, etc) ☐
    Washing/waxing floors ☐
    Other ☐ ________________________

43. Other comments: ____

APPENDIX I

CONSIDERATION OF BACKGROUND INDOOR AIR VOC LEVELS IN EVALUATING THE SUBSURFACE VAPOR INTRUSION PATHWAY

1. General

We recommend that the presence of background indoor air concentrations of VOCs at a site be carefully considered in evaluating the vapor intrusion to indoor air pathway at the site. The concentrations of VOCs detected in indoor air may originate from the subsurface contamination and/or they may represent typical concentrations of VOCs in that building from other sources. Consequently, indoor air sampling results may be difficult to interpret when background concentrations of the same VOCs emitted from other sources are present, if efforts are not made to identify and quantify the background concentrations.

Prior to indoor air sampling, it is generally important to conduct an inspection of the residence and an occupant survey to adequately identify the presence of (or occupant activities that could generate) any possible indoor air emission sources of target volatile organic chemicals (VOCs) in the dwelling (see Appendix H). For example, sources of indoor contaminants typically found in the home include consumer products (e.g., cleaners, paints, and glues), occupant activities (e.g., craft hobbies, smoking), and some construction materials. VOCs in ambient (outdoor) air may also contribute to indoor air background levels, though typically the main sources of background concentrations of VOCs in indoor air background arise from indoor activities or products used indoors. Any of these sources may result in relatively high background indoor air concentrations.

It is also important to recognize that typically there is high variability in background indoor air VOC concentrations both within and between buildings, so that small numbers of background samples typically available should be carefully interpreted. If there is more than one potential constituent of concern, we recommend that the ratios of potential constituents be used to distinguish subsurface-derived VOCs from those contributed by other non-subsurface-related sources (i.e, indoor air and/or ambient (outdoor) air emission sources). Collecting paired samples (spatially and temporally) of both indoor air and soil vapor data may also assist with establishing the constituents of concern.

Comparative review of VOCs air sampling results taken in various parts of a building may reveal contaminant concentration gradients or hot spots among the various floors or rooms in the building. Such gradients or hot spots shown in upper floors may indicate the indoor air VOC levels originated from other indoor emission sources rather than subsurface contamination, whereas, gradients or hot spots in basements or lower levels could suggest a scenario that is consistent with subsurface vapor intrusion or a preferential pathway. A contemporaneous ambient (outdoor) air sample may be useful to include for comparison to indoor concentrations and aid in characterizing possible background contribution from ambient (outdoor) air. More detail about indoor air sampling protocols is provided in Appendix E.

We recommend that all information on background indoor air concentrations be considered along with all of the information collected about the site and the nature of the contamination when conducting any site-specific risk assessments, determining appropriate risk management actions, and in advising citizens via risk communications. We recommend that the assessment of background contribution focus on the constituents and degradation products observed in the subsurface. However, while it is important to identify background indoor air concentrations, we recommend that they not be discounted when making a determination or communicating with the public about site-related impact and/or risk.

2. CERCLA Guidance on the Role of Background

EPA recently published the **"Role of Background in the CERCLA Cleanup Program"** (OSWER 9285.6-07P; APR 2002; URL = http://www.epa.gov/superfund/programs/risk/role.pdf) outlining a preferred approach for the consideration of background constituent concentrations of hazardous substances, pollutants, and contaminants in certain steps of the remedy selection process at Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA or "Superfund") sites. This policy recommends that when conducting site risk assessments contaminant concentrations attributable to background sources should *not* be eliminated from further consideration, since it could result in the loss of important risk information for those potentially exposed, even though cleanup may or may not eliminate a source of risks caused by background levels. This policy encourages a baseline risk assessment approach that retains constituents that exceed risk-based screening concentrations and encourages addressing site-specific background issues at the end of the risk assessment phase. Although VOCs and indoor air concerns are not explicit in the CERCLA "Role of Background..." it seems to suggest that VOCs with both subsurface site release-related and background-related sources should be included in any site risk assessment. Consistent with the CERCLA "Role of Background..."it is recommended that any significant background concentrations of VOCs be discussed in the risk characterization in a comprehensive manner along with any available data distinguishing the background contribution from site release-related VOC concentrations.

3. State Guidance Examples

Some states have developed specific approaches to considering indoor air background concentrations of VOCs when evaluating a cleanup site. Measurements of background VOC concentrations taken *before* any site-related contamination of the indoor air may have occurred are considered ideal. However, this type of data is rarely available. Given the variability in background concentrations in buildings, studies of representative indoor air background VOCs are preferred. In some cases, data may be available from background studies that have been conducted in representative "on-site" buildings out of the contamination zone or in nearby "off-site" buildings. The Colorado Department of Public Health and Environment (personal communication, August 2002) has stated that post-remediation studies of background indoor air VOCs provide reliable data.