This document contains Appendices G-I from the EPA "OSWER Draft Guidance for Evaluating the Vapor Intrusion to Indoor Air Pathway from Groundwater and Soils (Subsurface Vapor Intrusion Guidance)," published in November 2002. The reference number is EPA 530-D-02-004. You can find the entire document at http://www.epa.gov/epaoswer/hazwaste/ca/eis/vapor.htm.

OSWER Draft Guidance for Evaluating the Vapor Intrusion to Indoor Air Pathway from Groundwater and Soils (Subsurface Vapor Intrusion Guidance)

Appendix G: Considerations for the Use of the 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

November 2002

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:

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

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.

5. References

American Society for Testing and Materials (ASTM). 1995. Standard Guide for Risk-Based Corrective Action Applied at Petroleum Release Sites. E-1739-95.

American Society of Heating, Refrigerating, and Air-Conditioning Engineers, ASHRAE Handbook-1985 Fundamentals, chap. 22, Atlanta, GA.

Fellin, P. and R. Otson. 1996. The Effectiveness of Selected Materials in Moderation of Indoor VOC Levels, In *Volatile Organic Compounds in the Environment*, ASTM STP 1261, W.Wang, J. Schnoor, and J. Doi, Eds., American Society for Testing and Materials, 1996, pp. 135-146.

Figley, D.A., Snodgrass, L.J. June 21-26, 1992. "Comparative Foundation Air Leakage Performance of Ten Residential Concrete Basements", *Proceedings of the 85th Annual Meeting of Air and Waste Management Association*.

Fischer, M.L., Bentley, A.J., Dunkin, K.A., Hodgson, A.T., Nazaroff, W.W., Sextro, R.G., Daisey, J.M. 1996. Factors Affecting Indoor Air Concentrations of Volatile Organic Compounds at a Site of Subsurface Gasoline Contamination. *Environ. Sci. Technol.* **30 (10)**, 2948-2957.

Garbesi, K., Sextro, R.G., Fisk, W.J., Modera, M.P., Revzan, K.L. 1993. Soil-Gas Entry into an Experimental Basement: Model Measurement Comparisons and Seasonal Effects. *Environ. Sci. Technol.* **27**(**3)**, 466-473.

Garbesi, K. and Sextro, R.G. 1989. Modeling and Field Evidence of Pressure-Driven Entry of Soil Gas into a House through Permeable Below-Grade Walls. *Environ. Sci. Technol.* **23**(12**)**, 1481-1487.

Hers, I., Evans, D, Zapf-Gilje, R. and Li, L. 2002. Comparison, Validation and Use of Models for Predicting Indoor Air Quality from Soil and Groundwater Contamination. J. Soil and Sediment Contamination, 11 (4), 491-527.

Hers, I., R. Zapf-Gilje, L. Li, L. and J. Atwater. 2001. The use of indoor air measurements to evaluate exposure and risk from subsurface VOCs. J. Air & Waste Manage. Assoc. 51: 174-185.

Johnson, P.C. and R. Ettinger 1991. "Heuristic Model for Predicting the Intrusion Rate of Contaminant Vapours into Buildings" *Environmental Science and Technology*, 25 #8, 1445-1452.

Murray, D.M.; Burmaster, D.E. Residential air exchange rates in the United States: empirical and estimated parametric distributions by season and climatic region. *Risk Anal*. 1995, 15, 459-465.

Nazaroff, W.W. May 1992. "Radon Transport from Soil to Air", *Review of Geophysics*, 30 #2, 137-160.

Nazaroff, W.W., Feustel, H., Nero, A.V., Revzan, K.L., Grimsrud, D.T., Essling, M.A., Toohey, R.E. 1985. "Radon Transport into a Detached One-Story House with a Basement" *Atmospheric Environment*, 19(1) 31-46.

Revzan, K.L., Fisk, W.J., Gadgil, A.J. 1991. "Modelling Radon Entry into Houses with Basements: Model Description and Verification" *Indoor Air*, 2, 173-189.

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				Capillary Transition Zone		
			Water-Filled Porosity						
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. <u>Get to know the neighborhood, key stakeholders and the concerns of the community</u>

- 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.

The Massachusetts Department of Environmental Protection (MA DEP) suggests that comparing indoor air sample VOC concentrations to relevant values compiled in the recent scientific literature are suitable for use in characterizing background VOCs levels. However, MA DEP cautions against using background information as the sole basis for determining whether there is a site-related impact and believes that other compelling evidence of contamination from a site should not be ignored. MA DEP indicates that professional judgment should be used to systematically and logically come to a conclusion about site-related contamination impacts using all available information. ***(MA DEP Indoor Air Sampling and Evaluation Guide (April 2002)*** URL = http://www.state.ma.us/dep/bwsc/finalpol.htm)

References

Colorado Department of Public Health and Environment Personal Communication. Edgar Ethington. August 2002.

MA DEP Indoor Air Sampling and Evaluation Guide (April 2002) URL = http://www.state.ma.us/dep/bwsc/finalpol.htm

Role of Background in the CERCLA Cleanup Program" (OSWER 9285.6-07P; April 2002; URL = http://www.epa.gov/superfund/programs/risk/role.pdf)