15 Feb 02

Vapor Intrusion into Buildings from Groundwater and Soil under Pennsylvania (PA) Act 2 Statewide Health Standard (SHS)

Indoor air quality (IAQ) from the vapor intrusion of contaminants into buildings and below grade occupied space from groundwater and soil is not specifically regulated in Act 2, Chapter 250 *and Statewide Health Standards (SHS)*. However, responsible parties are increasingly unable to obtain a release from liability under SHS when this potential exposure pathway and risk is not addressed. The Risk Assessment Subcommittee (RASC) of the CSSAB was tasked in early 2001 to investigate and develop an approach to address IAQ under Act 2, when a responsible party is otherwise attaining the SHS for soil and groundwater.. An IAQ sub-team with members from the RASC, and other CSSAB members and Pennsylvania Department of Environmental Protection (PA DEP) personnel was formed (Appendix A). The group addressed the issue by customizing previously developed approaches to meet the needs of the SHS and the Act 2 program.

Figure 1 depicts a conceptual model of vapor intrusion into inhabited buildings and below grade occupied space from soil and groundwater. After extensive deliberation and review of approaches in other states (e.g., CT, MA, MI) as well as the American Society for Testing and Materials (ASTM) and the US Environmental Protection Agency (USEPA) approaches, the IAQ sub-team developed the approach for groundwater (Figure 2) and soil (Figure 3). These procedures build on the procedures proposed by the RASC in 1996, which were not adopted by PA DEP prior to the original publication of Chapter 250.

Each figure presents a decision matrix for consideration of IAQ under the statewide health or generic approach. In these matrices, several options are provided for determining if IAQ is a concern. These include:

- Comparison of media concentration to previously available soil and groundwater medium specific concentrations (MSCs). This option allows one to determine when a constituent is not of potential concern for indoor air if certain available MSCs are met. Specifically, with the exception of three compounds, none of the regulated substances for which an unused standard is listed in Chapter 250 would be a concern in groundwater if the MSCs for unused aquifers are met. The same is true for soil meeting a used aquifer standard, with only a few regulated substances being a concern in soil at levels between the used and unused aquifer standards published in Chapter 250.
- Comparison to conservative default screening values for soil and groundwater calculated using PA-specific parameters and the Johnson and Ettinger (J&E) Vapor Intrusion model (USEPA, 2001). These values are used to identify chemicals of potential indoor air concern (COPIACs) when this calculated screening level is lower than an MSC. However, the values can also be used to screen the concentration of COPIACs in a given medium to determine if additional evaluation or mitigation is warranted. For example, the screening value for chloroform in groundwater is 414 ppb. Based on this value, groundwater concentrations that meet the used aquifer MSC would not be of concern for the indoor air

pathway. However, concentrations above 414 ppb (including groundwater that meet the unused aquifer MSC) would require further evaluation.

- Comparison to soil gas values derived using the MSC_{IAQ} and a transfer factor to account for attenuation between the outside and inside of buildings. This allows one to measure vapor concentrations outside the buildings and extrapolate to safe levels inside the building.
- Comparison to MSC developed for IAQ (MSC_{IAQ}) using measured indoor air concentrations.

These different options are intended to provide flexibility in determining IAQ concerns. If IAQ is determined to be a concern based on the use of these matrices, one may address (mitigate) the contamination or perform a site-specific evaluation.

The Team recognized that evaluating the vapor intrusion into buildings and below grade occupied space on a generic basis is extremely difficult. For example, even though reasonable PA-specific assumptions were used, the J&E model as applied uses conservative processes (e.g., infinite source, no degradation). This tends to produce conservative screening values that may indicate a potential IAQ problem where there is not one. The group chose to err on the side of conservatism, since the option exists to further evaluate on a site-specific basis, if believed warranted. Another important concern is the prevalence of other sources of volatile organics (particularly indoors) that can complicate interpretation of sampling results. The Team suggests caution when making decisions based on both indoor and soil gas analyses.

The following sections describe the process outlined in the matrices, first for groundwater and then soil. Chemicals of potential indoor air concern (COPIACs) are defined for each medium for both residential and non-residential receptors. In addition, sections are provided which describe how odors and immediate threats and interim responses are considered in the process. An uncertainty section covers several issues that address the conservative approach that was taken. Finally, several appendices are provided to supplement the discussion provided in the text and which allow one to track the development of the process.

Process – General Screening Criteria

One hundred (100) feet from the source to receptor (inhabited building) was chosen as the criterion to define when sites need to be addressed for vapor intrusion. Although definitive studies on this topic have yet to be conducted, USEPA concluded that 100 feet is a reasonable criterion when considering vapor migration fundamentals, typical sampling density, and uncertainty in defining the actual contaminant spatial distribution (USEPA, 2001a). The rationale (as cited by USEPA) is based on the fact that vapor concentrations generally decrease with increasing distance away from a subsurface vapor source, and 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 building of concern.

Under SHS, if separate phase liquid (SPL – see definitions) is encountered beneath the site or within 100 feet of the receptor, soil gas or indoor air sampling are required. The model used does not account for SPL. In addition, the presence of preferential exposure pathways (see definitions) limits the further use of the matrix, i.e., the model used to develop default screening levels cannot account for preferential pathways. In this case, not only is it not possible to predict contaminant concentrations but it is not possible to determine where the material will end up. Hence, sampling is required to meet SHS, if preferential pathways are present.

Process – Groundwater

If the general criteria are met (i.e. the source is 100 feet or less from an inhabited building or below grade occupied space and there are no SPL or preferential pathways), the process as described in Figure 2 can be used. In Figure 2, the receptor location and type of soil are critical.

The IAQ sub-team completed extensive worst-case modeling (Johnson-Ettinger Vapor Intrusion Model; version 2.3, 2001-Appendix E) using PA specific inputs (Table 1). The results indicate that, in the absence of SPL, if the levels of regulated substances in groundwater are less than or equal to the MSC_{GW} for unused aquifers (see exception below), no further action is required.

Residential Receptors:
For residential receptors, the results (see Table 2) indicate that except for chloroform, dibromochloromethane, and xylenes for the 30+ contaminants typically associated with IAQ concerns none were considered potential IAQ risks to receptors when the MSC_{GW} for unused aquifers was not exceeded. For chloroform, dibromochloromethane, and xylenes, neither was considered potential IAQ risks when the MSC_{GW} for used aquifers was not exceeded.

Non-residential Receptors:
For non-residential (specifically commercial/industrial receptors), the results (see Table 3) similarly indicate that for the 30+ constituents, none except chloroform and dibromochloromethane are of potential IAQ concern. When using the EPA "toxicity" endpoints and commercial/industrial worker exposure assumptions, these materials are of potential concern when the MSC_{GW} for unused aquifer are exceeded. These materials are not considered of potential IAQ concern when the MSC_{GW} for used aquifer are not exceeded.

Further no constituents were found to be of concern when the OSHA endpoints (i.e., permissible exposure limits or PELs) were used with similar standard worker exposure assumptions. The primary difference arises because EPA endpoints protect the general population (including sensitive sub-populations), whereas OSHA is intended to protect healthy, informed workers. The PELs prescribe concentrations that cannot be exceeded during a workday. OSHA regulations also prescribe controls and monitoring of environment including exposures to vapors and gases as well as training medical surveillance, monitoring and information that must be available to employees that are exposed in the workplace. With OSHA regulations fully implemented (and documented), it is possible to use the OSHA-derived screen as an alternate to the default EPA-derived screen.

If the appropriate MSC_{GW} is exceeded, a potentially complete pathway exists if an inhabited building or below grade occupied space is:

- within100 feet of a source horizontally, and
- not separated vertically from the source by at least 30 feet (of sand) or 15 feet (of soil other than sand).

If either of these conditions is not met, then the pathway is not complete and no further IAQ activity for groundwater is required. Note that contamination elsewhere in the plume must meet the appropriate MSC. If both of these conditions are met, the evaluation should continue to examine potentially complete pathways.

For a potentially complete pathway, if the groundwater concentrations are less than the J-E PA default screening levels (Table 2 – residential, Table 3 – non-residential) and the GW is at greater than 5 feet from the receptor, then no further IAQ activity for groundwater is required.

If the groundwater concentration is greater than the J-E PA default screening levels, then the need to further evaluate or mitigate can be determined by comparison of:

- measured soil gas concentrations to soil gas MSC (MSC_{SG}), or
- measured indoor air concentrations to indoor air MSC (MSC_{IAQ}).

The MSC_{IAQ} are found in Table 4 and MSC_{SG} is a function of the MSC_{IAQ} and a transfer (or attenuation) factor from outside to inside the building.

If MSC_{SG} or MSC_{IAQ} are exceeded, then risk management (mitigation) activities are warranted, including another comparison to MSC_{IAQ} of either soil gas or measured indoor levels after mitigation. However, one may proceed to a site-specific risk analysis (including using the J&E model with site-specific input) in lieu of additional efforts under SHS. If MSC_{SG} or MSC_{IAQ} are not exceeded, then no further activity for groundwater is warranted.

Process – Soil

Soil is addressed similarly as groundwater (Figure 3). The presence of SPL (at or above the water table) within 100 feet of an inhabited building or below grade occupied space moves the process to sampling (i.e. soil gas screening or IAQ sampling). Also, if preferential pathways exist, then the decision matrix requires that soil gas or IAQ sampling be performed.

The J&E model was used to determine soil concentrations that would be of concern. The following chemicals were identified as COPIACs because their presence in soil even below the $MSC_{soil\ to\ gw}$ for unused aquifers may lead to indoor air concerns.

The COPIACs (those that should always be addressed) identified in soil based on specific receptors are as follows:

Residential	Non-Residential (Commercial/Industrial) Using USEPA Toxicity Endpoints	Non-residential (Commercial/Industrial) Using OSHA Endpoints
benzene bromoform carbon tetrachloride chloroform dibromochloromethane 1,4-dichlorobenzene 1,1 – dichloroethane 1,2-dichloroethane 1,1 – dichloroethene (EDC) cis – 1,2 – dichloroethene trans – 1,2 – dichloroethene 1,2-dichlorpropane toluene vinyl chloride xylenes (m-xylene)	Carbon tetrachloride Chloroform Dibromochloromethane 1,2-dichloroethane 1,1 – dichloroethene (EDC) cis – 1,2 – dichloroethene trans–1,2– dichloroethene Xylenes Vinyl Chloride	None

These COPIACs have been shown, using worst-case modeling (Johnson-Ettinger; USEPA version 2.3) and PA specific inputs, to potentially exceed acceptable levels in buildings even if they are below the $MSC_{soil\ to\ gw}$ for unused aquifers. For the other 30 + constituents, typically of concern for indoor air, the results indicate that if the soil concentrations of regulated substances do not exceed the $MSC_{soil\ to\ gw}$ for used aquifers, no further IAQ action is required. However, if exceedances are observed, the presence of one or more of these constituents in soil will also need to be addressed. The results for residential receptors are presented in Table 5 and for non-residential receptors in Table 6.

For non-residential receptors, the model runs were performed using EPA toxicity endpoints (RfCs and URFs) that are developed to be protective of the general population (including sensitive sub-populations) and OSHA PELs that are developed for healthy, informed workers. COPIACs based on EPA toxicity values are the default. The use of the OSHA-derived screen for commercial/industrial receptors as an alternate to the default EPA derived screen is possible only when OSHA regulations are fully implemented (and documented).

Consistent with the groundwater approach, receptor location, preferential exposure pathways, etc. are used to decide whether additional IAQ activity due to soil contamination is warranted.

A potentially complete pathway exists if an inhabited building is:

- within100 feet horizontally, and
- not separated vertically from the source by at least 10 feet of sand or soil-like (fill) material. * Soil-like materials is defined as a conglomeration of soils and residuals such as ashes from the residential burning of wood or coal, incinerator ash, coal ash, slag and dredged material and other similarly sized solid inert material.

If either of these conditions is not met, then the pathway is not complete and no further IAQ activity for groundwater is required. Note that the soils elsewhere at the site (including below 10 feet) must meet the applicable soil MSC and SHS for a non-use aquifer being met on the property. If these conditions are met, the evaluation should continue to examine potentially complete pathways.

For a potentially complete pathway, if the soil concentrations are less than the J-E PA default screening levels (Table 2 – residential, Table 3 – non-residential) and the contamination is at greater than 5 feet from the receptor, then no further IAQ activity for soil is required.

If the soil concentration is greater than the J-E PA default screening levels or the source is less than five feet below the receptor, then the need to further evaluate or mitigate can be determined by comparison of:

- measured soil gas concentrations to soil gas MSC (MSC_{SG}), or
- measured indoor air concentrations to indoor air MSC (MSC_{IAQ}).

If MSC_{SG} or MSC_{IAQ} are exceeded, then risk management (mitigation) activities are warranted, including another comparison to MSC_{IAQ} of either soil gas or measured indoor levels after mitigation. However, one may proceed to a site-specific risk analysis (including using the J&E model with site-specific input) in lieu of additional efforts under SHS. If MSC_{SG} or MSC_{IAQ} are not exceeded, then no further activity for soil is warranted.

Sampling

For either matrix, under SHS the presence of SPL requires sampling of either soil gas or indoor air at the location of the receptor for levels of regulated substances that may be present. In addition, the existence of preferential exposure pathways (see SHS Definitions) moves the process to sampling.

Approaches for soil gas screening and interpretation and IAQ sampling and interpretation are listed briefly in the Appendix F and will be listed in detail in the Technical Guidance Manual (TGM). Note that when sampling indoor air, many regulated substances have multiple sources and may be present in indoor air due to outdoor ambient levels or sources within the building rather than due to presence in groundwater or soil (e.g., benzene, chloroform). Sources are found in a variety of household products such as paints, fuels, varnishes and cleaning solutions, from personal habits (e.g., smoking) or hobbies (e.g., glues and adhesives). The Team suggests caution in taking indoor air samples and interpreting the results in this context.

Odors

Odor perception is highly subjective and not directly a human health concern; however, it has been potentially linked to perceived health issues and psychological disorders. For some compounds, one can detect the odors at levels that are lower than any human health concern (e.g., MSC_{IAQ}). The IAQ subteam addressed odor perception by comparing the odor threshold from literature sources to the corresponding MSC_{IAQ}. Except for styrene and toluene, odor thresholds were higher then the MSC_{IAQ}. Therefore, because there is not a substantial difference in values, odors were not considered further in the IAQ scheme under SHS (Table 4).

Immediate threats and interim response

Methods described in this guidance document address situations associated with historical releases of volatile substances where soils and groundwater concentrations are relatively low and exposure would be expected to occur over a relatively long period of time. Situations where liquids or vapors migrate into indoor spaces and cause strong odors or have the potential to flare or explode are obviously dangerous to human health and require immediate attention. Liquids and vapors can migrate into a building or below grade occupied space directly through foundations (via seepage or through holes) or along preferential pathways such as utility bedding corridors and pipes.

The following situations are considered to pose an immediate threat to human health or safety:

- Explosive levels, or concentrations of vapors that could cause acute health effects, are present or could accumulate in a residence or other building. Lower explosive limits are typically in the range of 1 to 5% by volume (10,000,000 ppbv to 50,000,000 ppbv).
- Explosive levels of vapors are present or could accumulate in subsurface utility system(s), but no building or residences are impacted.
- Ambient vapor/particulate concentrations exceed concentrations of concern from an acute exposure or safety viewpoint.

Occupants of buildings or residences are instructed to notify appropriate authorities if liquids or strong odors from an unknown origin are found or detected in a building. Moreover, the need to evacuate the building and immediate area should be evaluated. Interim measures such as increasing ventilation of the building or residence, preventing further free-product migration into the structure, and free-product recovery should begin as soon as it is safe to do so and by trained individuals. Responsible parties responding to a release from a storage tank shall do so in accordance with Chapter 245, the Storage Tank and Spill Prevention regulations.

Uncertainty

Although most inputs to the SHS process for indoor air are considered reasonable or realistic worst case, they are highly conservative and may tend to overestimate real, measured concentrations. In fact, for simplicity and conservatism, some processes are not included in this process (e.g., biodegradation of the substance was not included in the calculations and an infinite source is assumed). The IAQ subteam believes that it is better to be more inclusive (i.e., include false positives) than to miss potential problem situations (i.e., include false negatives) during this generic, SHS approach to the protection of indoor air quality.

Other issues that may influence the outcome of the evaluation include:

Treatment of chemicals without RfC or URF values:
IRIS is used as the primary source of toxicity values because the values quoted have been developed using standard techniques and the values have had the most rigorous review. There are several compounds where IRIS values have not been developed for reasons including because EPA does not consider that there are sufficient data to derive these values. As a result, EPA programs (such as Superfund SSLs) do not develop generic criteria for inhalation for these materials.

Here, the sub-team chose to use the CSSAB hierarchy of sources as alternate for the IRIS values. In addition, route to route extrapolation was used where appropriate (i.e., target organ and mechanism the same regardless of route), from IRIS oral RfDs and CSFs. A summary of how these values were arrived at is provided in Appendix C.

Use of Single vs Multi-media Evaluation:
In the development of generic SHS, each medium is addressed separately and only single medium values are provided. This is consistent will all currently available screening programs, e.g., Superfund SSLs. To address real world conditions where typically exposure may be to more than one medium, these screening analyses use conservative assumptions. In this evaluation, conservative assumptions included an infinite source, no degradation, and lifetime exposures.

As a further check that the evaluation was protective, model runs were performed using the residential scenario and the GSI/ASTM version of the J&E model (GSI, 1999). This software allows both soil and groundwater to be addressed simultaneously (whereas the USEPA version does not) but typically provides more conservative values that the USEPA model (because of inherent assumptions in the software that cannot is adjusted). The results indicate that the values derived separately using the PA defaults and USEPA J&E version is protective of both media together.

This conclusion is further supported by the empirical findings by GSI (presented at the NGWA/API Petroleum Hydrocarbons Conference in Houston, 11/01) and McHugh (2002). In their review of 31 sites that has soil, groundwater, soil gas and indoor air measurements, they found that:

1) Depth to Source: If the depth to the source (affected soil, groundwater, etc.) is greater then 10 feet below the foundation, no vapor impacts in excess of a 1×10^{-6} risk level (or HQ=1) occur for any chemical at any concentration (including NAPL) in any soil type for this database.

2) Fuel Constituent Depth and Concentration: For BTEX or MTBE, if the depth to the source is greater than 6 feet below the foundation and the dissolved concentration of any individual COC is less than 1 mg/L, no vapor impacts in excess of a 1×10^{-6} risk level (or HQ=1) occur for any soil type in this database.

OSHA vs. EPA Endpoints for Commercial/Industrial Receptors:

OSHA regulates exposures in the workplace. Evaluation of vapor intrusion from environmental contamination that could affect the work environment should be considered in the light of the work environment and the possible increase in risk to the employee. The work environment can be categorized as one that has potential exposure to the employee according to the process within the building.

OSHA regulations prescribe controls and monitoring of the environment including exposure to vapors and gases. The regulations prescribe values that may not be exceeded during a workday called Permissible Exposure Limits (PELs). OSHA also describes training, medical surveillance, monitoring and information that must be available to employees that are exposed in the workplace. Those enterprises that handle various volatile material must control exposure to employees, which is typically done using ventilation control and process enclosure plus appropriate monitoring and provision for informing employees of the hazards involved through material safety data sheets (MSDS).

Not all work places provide potential exposure to airborne contaminants by the nature of the business, for example, a typical office or many business environments. Any substantial exposure from environmental contamination within this workspace would increase risk to the employee. Conversely, most business and establishments employ ventilation systems that supply substantially more fresh air movement than found in the typical home which would provide a built in protective factor.

When OSHA regulations are fully implemented (and documented) at a site, it is possible to use these the OSHA-derived screen as an alternate to the default EPA-derived screen.

References

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United States Environmental Protection Agency (2001a). Supplemental guidance for evaluating the vapor intrusion to indoor air pathway. Partial response to question 3 of 02/05/99 RCRA Corrective Action Environmental Indicator RCRIS Code (CA725). Draft for comment. 10/23/01.

United States Environmental Protection Agency (2001b) User's Guide for the Johnson and Ettinger (1991) Model for Subsurface Vapor Intrusion into Buildings (Revised). Office of Emergency and Remedial Response. December.

Figures

Tables

Appendices

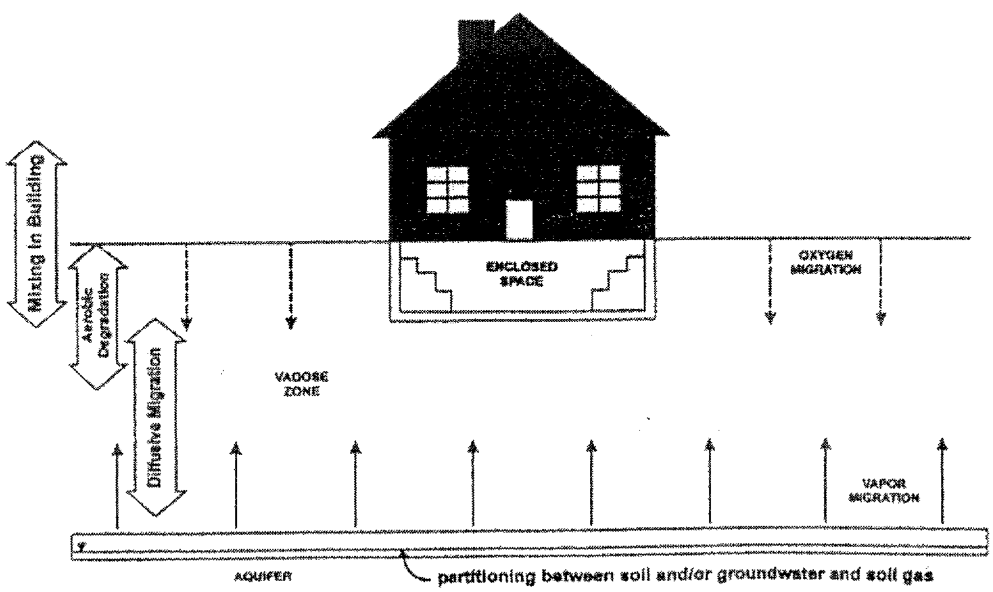
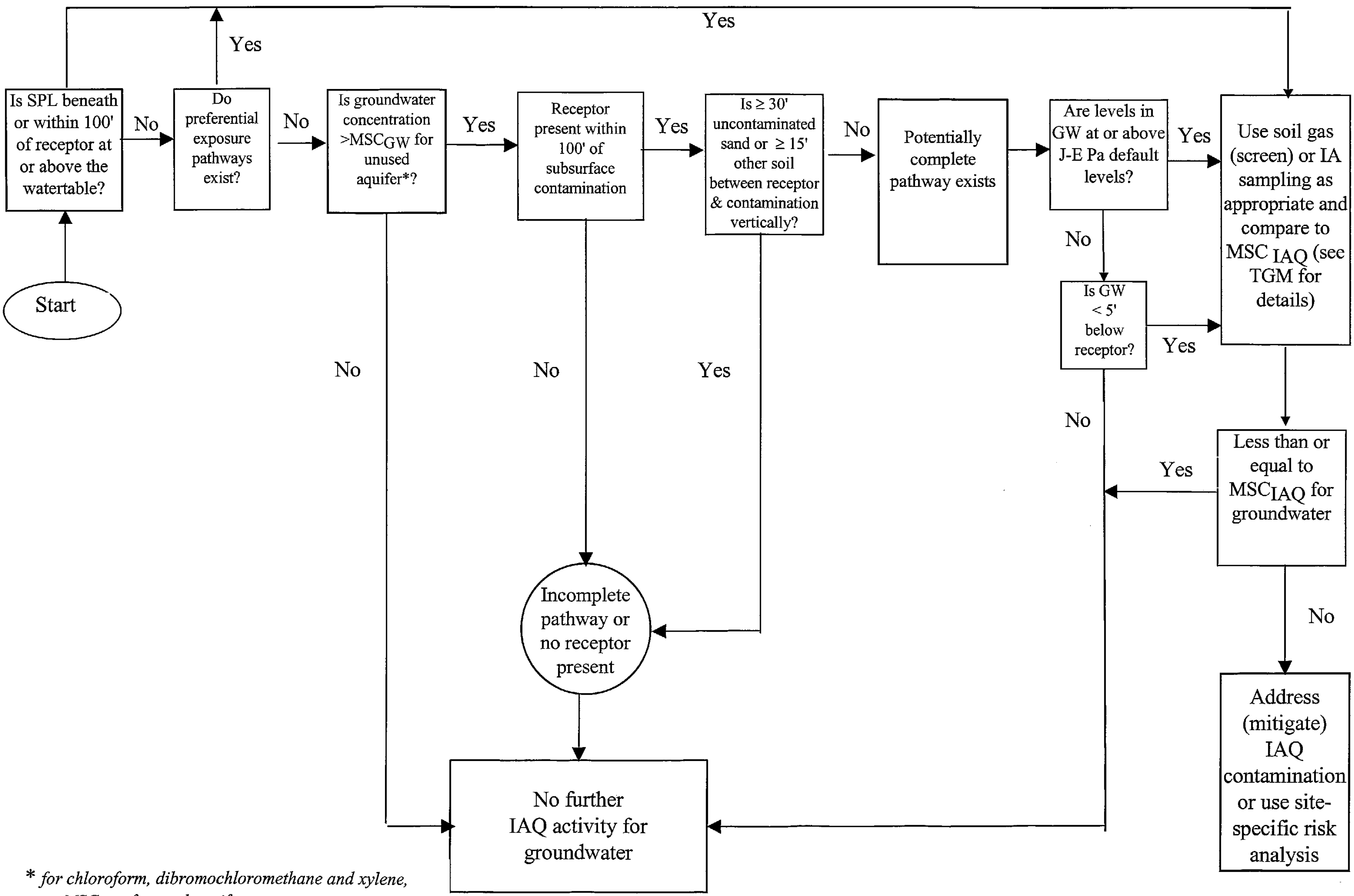
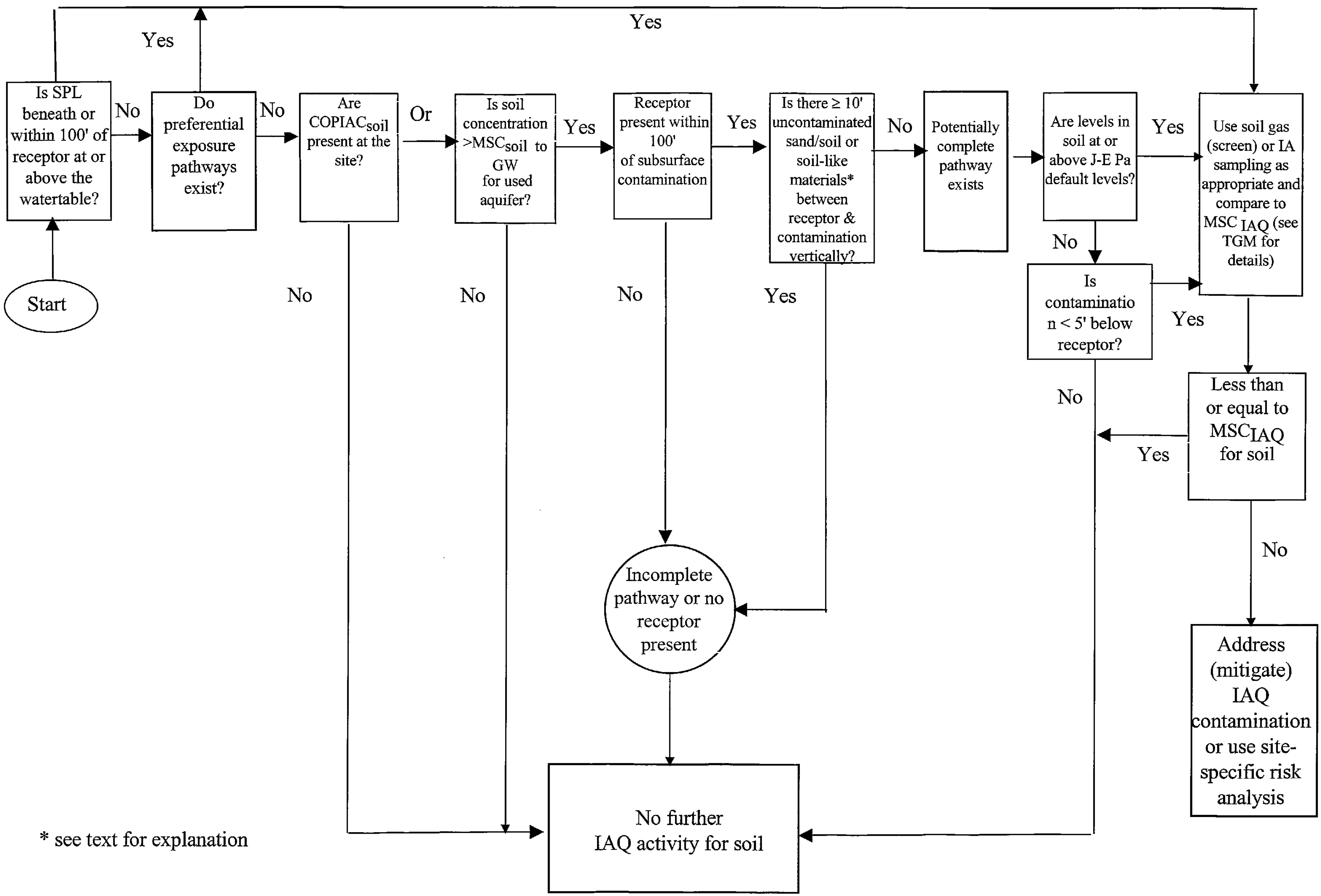


Figure 1. Schematic of vapor migration conceptual model (from Ettinger et al. 1999).



* *for chloroform, dibromochloromethane and xylene, use MSC_{GW} for used aquifer*

DRAFT Figure 2. Groundwater IAQ Decision Matrix for SHS 2/11/02



* see text for explanation

DRAFT Figure 3. Soil IAQ Decision Matrix for SHS

2/11/02

SHS Definitions for IAQ Decision Matrix
(see Figures 2 and 3)

Receptor — A receptor (humans in this case) is located in an occupied or potentially occupiable home or building built on a slab or below grade basement or area.

COPIAC — Contaminant (substance) of potential indoor air concern. Determined using contaminant lists from nearby states and PA-specific Johnson and Ettinger IAQ modeling.

COPIAC for soil — COPIACs (those that should always be addressed) identified in soil based on specific receptors are as follows:

Residential

benzene
bromoform
carbon tetrachloride
chloroform
dibromochloromethane
1,4 -dichlorobenzene
1,1 – dichloroethane
1,2-dichloroethane
1,1 – dichloroethene (EDC)
cis – 1,2 – dichloroethene
trans – 1,2 – dichloroethene
1,2-dichloropropane
toluene
vinyl chloride
xylenes

Non-Residential

Carbon tetrachloride
Chloroform
Dibromochloromethane
1,2-dichloroethane
1,1 – dichloroethene (EDC)
cis – 1,2 – dichloroethene
trans – 1,2 – dichloroethene
Vinyl chloride
Xylenes

COPIAC for groundwater	Chloroform Dibromochloromethane Xylenes
Potentially complete exposure pathway	An exposure pathway is the course a regulated substance(s) takes from the source area(s) to a species of concern including absorption or intake into the organism; a pathway must include a source or release from a source, a point of exposure, and an exposure route into the organism to be potentially complete. Completed exposure pathways need to be present for exposure of the receptor to occur. An exposure pathway must exist between substance and receptor.
Preferential exposure pathway	A preferential pathway is defined as a natural (e.g., shallow rock or vertically fractured soil) or manmade (e.g., buried utilities) feature that creates a sufficiently direct pathway from a source to a receptor to make the use of the default model for predicting indoor air concentrations unacceptable. Such pathways must be shown to significantly reduce the ability of the natural environment to attenuate the concentrations of VOCs at any point from the source to the receptor and to do so in a manner or to an extent that is not accounted for in the model assumptions and would substantially alter the default model's accuracy in predicting conservative indoor air concentrations. Shallow utilities buried at a depth that is insignificant with respect to the column of soil between the slab and the source does not automatically constitute a preferential pathway, nor should this definition include surface paving outside the building or the presence of crushed stone beneath the slab as normally placed for slab foundation material. If such a feature does not pass through the source, it must occur within 30 feet of the source in order to constitute a potential preferential pathway.
Soil gas	Because sampling VOCs in indoor air can be complicated by sources of VOCs within a home or building, soil gas measurements can be taken at a distance not to exceed 5 feet from the slab or basement edge and compared to MSCs for soil gas,

where MSCs for soil gas would be calculated as follows:

$$MSC_{SG} = \frac{MSC_{IAQ}}{TF}$$

Where:

MSC_{SG} = Medium-specific concentration for soil gas (mg/m^3);
MSC_{IA} = Medium-specific concentration for indoor air (mg/m^3); and
TG = TF Transfer factor from soil gas to indoor air,
= 0.01 (a conservative value relating concentrations in indoor air to concentrations in soil gas adjacent to a building based on data report in Management of Manufactured Gas Plant Sites, Volume III: Risk Assessment, Gas Research Institute, 1987, pages 6-30 and 6-31.

To use such a procedure, a method or methods for taking soil gas samples and performing soil gas analysis must be specified or suggested.

Johnson-Ettinger Vapor Intrusion Model (USEPA Version 2.3)

Johnson and Ettinger (1991) developed a model, which coupled steady-state diffusion from a planar source to vapor intrusion into basements of buildings via advection and diffusion processes. The model is based on permeation through cracks in the foundation/floor with the planar source at a finite depth, with a boundary around the building referred to as the "building zone of influence". The USEPA although initially attempting to develop generic soil screening levels (SSLs) for volatiles, has adopted the Johnson-Ettinger model to examine subsurface vapor intrusion into buildings via a site-specific approach. Degradation of the contaminant is not considered nor is convective water movement in the soil column (see Appendix E for details). The model is one-dimensional, providing an estimated attenuation coefficient that associates indoor vapor concentration to the vapor concentration at the source and is based on soil building pressure differentials (USEPA 2001b).

IAQ sampling

Indoor air samples are to be taken from the home or building beneath or adjacent to an occupied or potentially occupied home or building (where adjacent to is defined as within 15 feet of the home or building perimeter).

Passive badge samplers, direct measurement using a FID or PID, adsorption onto activated charcoal, or direct sample collection using evacuated SUMMA-passivated canisters (USEPA Method TO-15 or TO-14; Appendix D) with analytical testing at a laboratory certified by USEPA for such analyses. Direct air sampling using SUMMA canisters is often preferred by the USEPA and other agencies. Acrylonitrile and 1,3-Dichloropropane are not part of the TO-14/TO-15 analyte list, however they can be added if they are contaminants of concern. Factors such as cost, sensitivity, data reliability and the data quality objectives should be considered prior to selecting a method that best encompasses the contaminants of concern. Other considerations include but are not limited to the following: duration of sample collection, sample locations, analytes/contaminants of concern, number of samples, atmospheric conditions, ambient (background) air quality, and structural considerations. Rigorous indoor air quality monitoring programs can become quite expensive to implement.

These results are to be compared to the following criteria For residential exposures, the criteria are medium specific concentrations (MSCs) for indoor air calculated using the equations presented in Table 7. For non residential exposures, if, for any selected VOC at the site, OSHA regulates the chemical at the site and OSHA has jurisdiction over the site, then OSHA applies for that chemical and continued monitoring and reporting should occur to ensure continued compliance under OSHA. For all other chemicals, the criteria are medium-specific concentrations (MSCs) for indoor air calculated using the equations for nonresidential exposures presented in Table 7. Indoor air samples are to be taken from basements in those locations where the highest routine exposures are expected and the

	concentrations must be below the MSCs for indoor air. This procedure is only to be applied to homes and buildings with basements.
Separate phase liquid (SPL)	SPL is that component of contaminated environmental media comprised of interstitial non-aqueous phase liquid which is not adsorbed onto or diffused into the soil matrix or dissolved in groundwater. There are two principal modes of occurrence of SPL in soil: zones of accumulation and residual zones. Both can occur in the unsaturated and saturated zones, but accumulation zones are more commonly present at the water table and below the water table (for DNAPLs). A value of 10,000 mg/kg in soil can be used as a guideline to determine the presence of SPL.
Source	Soil or groundwater containing COPIACs at concentrations exceeding the acceptable levels specified in this document, or at any concentration if present at a depth of less than five feet below a receptor.

TABLE 1
Summary of Selected Input Paramenters
EPA's Johnson and Ettinger Model (Version 2.3, 2001)
February 14, 2002

Parameter	Soil Model (SL-SCREEN)	Groundwater Model (GW-SCREEN)
Depth below grade to bottom of enclosed space floor (15 or 200 cm)	15	15
Depth below grade to top of contamination (cm)	150	NA
Depth below grade to water table (cm)	NA	150
SCS soil type directly above water table	NA	SCL
Average soil temperature (C)	11.1	11.1
Vadose zone SCS soil type	SCL	SCL
Vadose zone soil dry bulk density (g/cm^3)SCS soil type	1.8	1.8
Vadose zone soil total porosity (cm^3/cm^3)	0.32	0.34
Vadose zone soil water-filled porosity (cm^3/cm^3)	0.2	0.2
Vadose zone air-filled porosity (cm^3/cm^3), input on "Intercalc" sheet	0.12	0.14
Vados Zone soil organic carbon fraction (unitless)	0.0025	NA
Target risk for carcinogens	1.00E-05	1.00E-05
Target hazard quotient for noncarcinogens	1	1
Averaging time for carcinogens (yrs)	70	70
Averaging time for noncarcinogens (yrs): residential, non-residential	30, 25	30, 25
Exposure duration (yrs): residential, non-residential	30, 25	30, 25
Exposure frequency (days/yr): residential, non-residential	350, 250	350, 250

Table 2 Groundwater Screening "Criteria" (ug/L) for Protection of Indoor Air - Residential

	Chemical	Pennsylvania GW MSC Used Aquifer	Pennsylvania GW MSC Unused Aquifer	PA Defaults Residential Volatilization to Indoor Air Criteria (a)
000067-64-1	Acetone	3,700	37,000	NOC
000107-13-1	Acrylonitrile	0.63	63	NA
000078-93-3	2-Butanone (MEK)	2,800	280,000	NA
000071-43-2	Benzene	5	500	3,500
000075-25-2	Bromoform	100	10,000	182,000
000056-23-5	Carbon Tetrachloride	5	50	1,400
000108-90-7	Chlorobenzene	55	5,500	27,400
000067-66-3	Chloroform	100	**1,000**	**414**
000124-48-1	Dibromochloromethane	100	**10,000**	**3,750**
000095-50-1	1,2-Dichlorobenzene	600	60,000	NOC
000541-73-1	1,3-Dichlorobenzene	600	60,000	NA
000106-46-7	1,4-Dichlorobenzene	75	7,500	8090
000075-34-3	1,1-Dichloroethane	27	270	15600
000107-06-2	1,2-Dichloroethane	5	50	2,770
000075-35-4	1,1-Dichloroethene	7	70	362
000156-59-2	cis-1,2-Dichloroethene	70	700	42100
000156-60-5	trans-1,2-Dichloroethene	100	1,000	59300
000078-87-5	1,2-Dichloropropane	5	50	3850
000100-41-4	Ethyl benzene	700	70,000	NOC
000106-93-4	Ethylene dibromide	0.05	5	NA
000075-09-2	Methylene chloride	5	500	77,000
000108-10-1	Methyl isobutyl ketone	220	22,000	NA
001634-04-4	Methyl-tert-butyl-ether	20	200	228000
000100-42-5	Styrene	100	10,000	NOC
000127-18-4	Tetrachloroethene	5	50	42400
000079-34-5	1,1,2,2-Tetrachloroethane	0.74	74	3680
000108-88-3	Toluene	1,000	100,000	491000
000079-01-6	Trichloroethylene	5	50	14300
000071-55-6	1,1,1-Trichloroethane	200	2,000	NOC
000079-00-5	1,1,2-Trichloroethane	5	50	5350
000075-01-4	Vinyl chloride	2	20	1,780
001330-20-7	Xylenes	10,000	**180,000**	57400

a/PA defaults using GWSCREEN.XLS version 2.3 03/01 PA Soils parameters; 15 cm to bottom of enclosed space; 150 cm to water table; RL = 10-5; HQ = 1

NOC - Not of concern

NA - Not available

Note: Bold face values indicate a COPIAC

Table 3 Groundwater Criteria/Screen (ug/L) for Protection of Indoor Air: Non-Residential (Commercial/Industrial)

	Chemical	Pennsylvania GW MSC Used Aquifer	Pennsylvania GW MSC Unused Aquifer	USEPA-PA Defaults Non-residential Volatilization to Indoor Air Criteria (a)	USEPA-PA Defaults Non-residential PELs Volatilization to Indoor Air Screen (b)
000067-64-1	Acetone	3,700	37,000	2,300,000,000 (NOC)	NOC
000107-13-1	Acrylonitrile	0.63	63	NA	NA
000078-93-3	2-Butanone (MEK)	2,800	280,000	NA	NA
000071-43-2	Benzene	5	500	9,600	NOC
000075-25-2	Bromoform	100	10,000	310,000	NOC
000056-23-5	Carbon Tetrachloride	5	50	2,400	NOC
000108-90-7	Chlorobenzene	55	5,500	44,000	NOC
000067-66-3	Chloroform	100	**1,000**	**610**	NOC
000124-48-1	Dibromochloromethane	100	**10,000**	**6,300**	NC
000095-50-1	1,2-Dichlorobenzene	600	60,000	720,000 (NOC)	NOC
000541-73-1	1,3-Dichlorobenzene	600	60,000	NA	NA
000106-46-7	1,4-Dichlorobenzene	75	7,500	2,400,000 (NOC)	NOC
000075-34-3	1,1-Dichloroethane	27	270	760,000	NOC
000107-06-2	1,2-Dichloroethane	5	50	4,600	NOC
000075-35-4	1,1-Dichloroethene	7	70	610	NOC
000156-59-2	cis-1,2-Dichloroethene	70	700	59,000	NOC
000156-60-5	trans-1,2-Dichloroethene	100	1,000	83,000	NOC
000078-87-5	1,2-Dichloropropane	5	50	9,500	NOC
000100-41-4	Ethyl benzene	700	70,000	1,800,000 (NOC)	NOC
000106-93-4	Ethylene dibromide	0.05	5	NA	NA
000075-09-2	Methylene chloride	5	500	130,000	NOC
000108-10-1	Methyl isobutyl ketone	220	22,000	NA	NA
001634-04-4	Methyl-tert-butyl-ether	20	200	NA	NA
000100-42-5	Styrene	100	10,000	2,700,000 (NOC)	NOC
000127-18-4	Tetrachloroethene	5	50	71,000	NOC
000079-34-5	1,1,2,2-Tetrachloroethane	0.74	74	6,200	NOC
000108-88-3	Toluene	1,000	100,000	690,000 (NOC)	NOC
000079-01-6	Trichloroethylene	5	50	24,000	NOC
000071-55-6	1,1,1-Trichloroethane	200	2,000	1,300,000 (NOC)	NOC
000079-00-5	1,1,2-Trichloroethane	5	50	9,000	NOC
000075-01-4	Vinyl chloride	2	20	5,800	2,300,000
001330-20-7	Xylenes	10,000	180,000	740,000 (NOC)	NOC

a/ "PA" defaults using USEPA J&E Version 2.3; 03/01 (Multichemical), Non-Residential receptor, RL = 10-5, HQ = 1
b/ "PA" defaults using USEPA J&E Version 2.3; 03/01 (Multichemical), Non-Residential receptor, PEL
>value indicates that risk-based target greater than constituent water solubility
NA Not available
NC Not calcuated
NOC Not of concern, value above constituent water solubility
Note: Bold face values indicate a COPIAC

Table 4 - Indoor Air Criteria & Odor Thresholds

CAS Number	Chemical	Residential MSC (mg/m^3)	Nonresidential MSC (mg/m^3)	EPA Region III RBC (mg/m^3)*	ACGIH TLV (mg/m^3)	OSHA PEL (mg/m^3	Odor Threshold (mg/m^3)
000067-64-1	Acetone	4.3E+01	9.1E+01	3.7E-01	1188	2400	237
000107-13-1	Acrylonitrile	3.1E-04	1.2E-03	2.6E-04	4.3	4.34	46.4
000078-93-3	2-Butanone (MEK)	1.4E+00	2.9E+00	1.0E+00	590	590	6
000071-43-2	Benzene	2.7E-03	1.1E-02	2.2E-03	1.6	3.19	2.7
000075-25-2	Bromoform	1.9E-02	7.4E-02	1.6E-02	5.2	5	13
000056-23-5	Carbon Tetrachloride	1.4E-03	5.5E-03	1.2E-03	31	62.9	135
000108-90-7	Chlorobenzene	2.4E-02	5.1E-02	6.2E-02	46	350	1.0
000067-66-3	Chloroform	4.4E-04	9.2E-04	3.1E-04	49		415
000124-48-1	Dibromochloromethane	7.8E-04	3.0E-03	7.5E-04			
000095-50-1	1,2-Dichlorobenzene	1.9E-01	4.1E-01	1.5E-01	150		12-24
000541-73-1	1,3-Dichlorobenzene			1.1E-01			0.12
000106-46-7	1,4-Dichlorobenzene	3.3E-03	1.3E-02	2.8E-03	60	450	180-360
000075-34-3	1,1-Dichloroethane	1.3E-02	5.0E-02	5.1E-01	405	400	490-810
000107-06-2	1,2-Dichloroethane	8.1E-04	3.1E-03	6.9E-04	40	202.5	24-160
000075-35-4	1,1-Dichloroethylene	4.2E-04	1.6E-03	3.6E-04	20		2000-4000
000156-59-2	cis-1,2-Dichloroethylene	4.9E-02	1.0E-01	3.7E-02	793	790	0.34
000156-60-5	trans-1,2-Dichloroethylene	9.7E-02	2.0E-01	7.3E-02	793	790	0.3357
000078-87-5	1,2-Dichloropropane	2.0E-03	7.9E-03	9.2E-04	347	350	231
000100-41-4	Ethyl benzene	1.4E+00	2.9E+00	1.1E+00	434	435	608
000106-93-4	Ethylene dibromide	9.5E-05	3.7E-04	8.2E-05		153.8	192
000075-09-2	Methylene chloride	4.4E-02	1.7E-01	3.8E-02	174	86.75	712-1070
000108-10-1	Methyl isobutyl ketone	9.7E-02	2.0E-01	7.3E-02	205	410	0.41
001634-04-4	Methyl-tert-butyl-ether	4.1E-02	1.6E-01	3.1E+00	144		0.19-0.69
000100-42-5	Styrene	1.4E+00	2.9E+00	1.0E+00	85	426	0.630
000127-18-4	Tetrachloroethylene	3.7E-02	1.4E-01	3.1E-02	170	678	31.7
000079-34-5	1,1,2,2-Tetrachloroethane	3.6E-04	1.4E-03	3.1E-04	6.9	35	3
000108-88-3	Toluene	5.6E-01	1.2E+00	4.2E-01	188	754	0.64
000079-01-6	Trichloroethylene	1.2E-02	4.8E-02	1.0E-02	269	537	115
000071-55-6	1,1,1-Trichloroethane	2.9E+00	6.1E+00	2.3E+00	1910	1900	545
000079-00-5	1,1,2-Trichloroethane	1.3E-03	5.1E-03	1.1E-03	55	45	
000075-01-4	Vinyl chloride	2.4E-03	9.5E-03	7.2E-04	2.5	2.56	664
001330-20-7	Xylenes	6.0E-01	1.3E+00	7.3E+00	434	435	2

* EPA Region III RBCs were adjusted to cancer risk of 1E-5 or HQ of 1.

Table 5 Soil Screening "Criteria" (mg/kg) for Protection of Indoor Air - Residential

	Chemical	Pennsylvania Soil-GW MSC Used Aquifer Residential	Pennsylvania Soil-GW MSC Unused Aquifer Residental	Pennsylvania Direct Contact 0-15 feet Residential	PA Defaults Residential Volatilization to Indoor Air Criteria (a)
000067-64-1	Acetone	370	3,700	10,000	112,000
000107-13-1	Acrylonitrile	0.06	6.30	4.70	NA
000078-93-3	2-Butanone (MEK)	280	10,000	10,000	NA
000071-43-2	Benzene	**0.5**	50	38	**0.37**
000075-25-2	Bromoform	**100**	10,000	290	**93.5**
000056-23-5	Carbon Tetrachloride	**0.5**	5	21	**0.0743**
000108-90-7	Chlorobenzene	5.5	550	4,400	**9.04**
000067-66-3	Chloroform	**10**	100	14	**0.0531**
000124-48-1	Dibromochloromethane	**10**	1,000	12	**1.32**
000095-50-1	1,2-Dichlorobenzene	60	6,000	3,800	145
000541-73-1	1,3-Dichlorobenzene	60	6,000	5,900	NA
000106-46-7	1,4-Dichlorobenzene	**7.5**	750	750	**7.52**
000075-34-3	1,1-Dichloroethane	**2.7**	27	12	**1.63**
000107-06-2	1,2-Dichloroethane	**0.5**	5	12	**0.494**
000075-35-4	1,1-Dichloroethene	**0.7**	7	6.40	**0.0128**
000156-59-2	cis-1,2-Dichloroethene	**7**	70	670	**5.4**
000156-60-5	trans-1,2-Dichloroethene	**10**	100	1,300	**4.57**
000078-87-5	1,2-Dichloropropane	**0.5**	5	16	**0.523**
000100-41-4	Ethyl benzene	70	7,000	10,000	108
000106-93-4	Ethylene dibromide	0.005	0.50	0.21	NA
000075-09-2	Methylene chloride	0.5	50	NA	7.54
000108-10-1	Methyl isobutyl ketone	22	2,200	1,500	-
001634-04-4	Methyl-tert-butyl-ether	2	20	10,000	31.2
000100-42-5	Styrene	10	1,000	10,000	717
000127-18-4	Tetrachloroethene	0.5	5	340	6.03
000079-34-5	1,1,2,2-Tetrachloroethane	0.074	7.4	5.50	1.18
000108-88-3	Toluene	**100**	10,000	7,600	**74.2**
000079-01-6	Trichloroethylene	1	5	190	1.32
000071-55-6	1,1,1-Trichloroethane	20	200	10,000	**124**
000079-00-5	1,1,2-Trichloroethane	0.5	5	20	1.44
000075-01-4	Vinyl chloride	**0.2**	2	3.80	**0.04**
001330-20-7	Xylenes	**1,000**	10,000	10,000	**174**

a/PA defaults using SL-SCREEN.XLS version 2.3 03/01 PA Soil parameters; 15 cm to bottom of enclosed space; 150 cm to top of contamination; RL = 10-5; HQ = 1

NA- not available

Note: Bold face values indicate a COPIAC

Table 6 Soil Criteria/Screen (mg/kg) for Protection of Indoor Air: Non-residential (Commercial/Industrial)

CAS	Chemical	Pennsylvania Soil-GW MSC Used Aquifer Non-residential	Pennsylvania Soil-GW MSC Unused Aquifer Non-residential	Pennsylvania Direct Contact 0-2 feet Non-Residential	Pennsylvania Direct Contact 2-15 feet Non-Residential	USEPA-PA Defaults Non-residential Volatilization to Indoor Air Criteria (a)	USEPA-PA Defaults Non-residential PELs Volatilization to Indoor Air Screen (b)
000067-64-1	Acetone	370	3,700	10,000	10,000	110,000 (NOC)	110,000 (Csat)
000107-13-1	Acrylonitrile	0.06	6.30	24.00	28.00	NA	NA
000078-93-3	2-Butanone (MEK)	280	10,000	10,000	10,000	NA	NA
000071-43-2	Benzene	0.5	50	200	230	1	470 (Csat)
000075-25-2	Bromoform	100	10,000	1,500	1,700	120	1,000
000056-23-5	Carbon Tetrachloride	**0.5**	5	110	120	**0.12**	440 (Csat)
000108-90-7	Chlorobenzene	5.5	550	10,000	10,000	16	310
000067-66-3	Chloroform	**10**	100	72	82	**0.079**	2000.000
000124-48-1	Dibromochloromethane	**10**	1,000	61	70	**2.20**	NA
000095-50-1	1,2-Dichlorobenzene	60	6,000	10,000	10,000	260	260 (Csat)
000541-73-1	1,3-Dichlorobenzene	60	6,000	10,000	10,000	NA	NA
000106-46-7	1,4-Dichlorobenzene	7.5	750	3,300	190,000	120	120 (Csat)
000075-34-3	1,1-Dichloroethane	2.7	27	1,000	1,200	63	1000 (Csat)
000107-06-2	1,2-Dichloroethane	**0.5**	5	63	73	**0.62**	1300 (Csat)
000075-35-4	1,1-Dichloroethene	**0.7**	7	33	38.00	**0.02**	710 (Csat)
000156-59-2	cis-1,2-Dichloroethene	7	70	1,900	2,100	**7.60**	840(Csat)
000156-60-5	trans-1,2-Dichloroethene	**10**	100	3,700	4,300	**6.40**	1500 (Csat)
000078-87-5	1,2-Dichloropropane	0.5	5	85	97	1.20	630 (Csat)
000100-41-4	Ethyl benzene	70	7,000	10,000	10,000	170	170 (Csat)
000106-93-4	Ethylene dibromide	0.005	0.50	0.93	8.60	NA	-
000075-09-2	Methylene chloride	0.5	50	3,500	4,000	13	1900 (Csat)
000108-10-1	Methyl isobutyl ketone	22	2,200	4,300	4,900	NA	NA
001634-04-4	Methyl-tert-butyl-ether	2	20	10,000	10,000	NA	NA
000100-42-5	Styrene	10	1,000	10,000	10,000	640	640 (Csat)
000127-18-4	Tetrachloroethene	0.5	5	1,500	3,300	10	180 (Csat)
000079-34-5	1,1,2,2-Tetrachloroethane	0.074	7.4	28	33.00	2.20	1000 (Csat)
000108-88-3	Toluene	100	10,000	10,000	10,000	110	230 (Csat)
000079-01-6	Trichloroethylene	1	5	970	1,100	3	590 (Csat)
000071-55-6	1,1,1-Trichloroethane	20	200	10,000	10,000	88	550 (Csat)
000079-00-5	1,1,2-Trichloroethane	0.5	5	100	120	1.90	1000 (Csat)
000075-01-4	Vinyl chloride	**0.2**	2	20	22.00	**0.12**	48.000
001330-20-7	Xylenes	**1,000**	10,000	10,000	10,000	**200 (99 = Csat)**	200,000 (99 = Csat)

a/ "PA" defaults using USEPA J&E Version 2.3; 03/01 (Multichemical), Non-Residential receptor, RL = 10-5, HQ = 1
b/ "PA" defaults using USEPA J&E Version 2.3; 03/01 (Multichemical), Non-Residential receptor, PEL as endpoint
>value indicates that risk-based target greater than constituent residual saturation
NA Not available
NC Not calcuated
NOC Not of concern
Note: Bold face values indicate a COPIAC

Table 7

Table

Inhalation of chemicals volatilized into indoor air from soil or groundwater
(Development of MSCs for Indoor Air -- MSC_{IAQ})

Non carcinogens

$$MSC(mg/m^3) = \frac{THQ \times RfD_i \times BW \times At_{nc} \times 365\ days/yr}{Abs \times ET \times EF \times ED \times IR}$$

Carcinogens

$$MSC\ (mg/m^3) = \frac{TR \times AT_c \times 365 days/yr}{CSF_i \times Abs \times ET \times EF \times IF_{adj}}$$

Recommended Exposure Assumptions				
Term		Residential: Non carcinogens[1]	Residential: Carcinogens[2]	Nonresidential (Onsite Worker)
THQ	Target Hazard Quotient	1	N/A	1
RfD_i	Inhalation Reference Dose (mg/kg-day)	Chemical-specific	N/A	Chemical-specific
BW	Body Weight (kg)	70	N/A	70
At_{nc}	Averaging Time for noncarcinogens (yr)	30	N/A	25
Abs	Absorption (unitless)	*	*	*
ET	Exposure Time (hr/day)	24	24	8
EF	Exposure Frequency (days/yr)	350	350	250
ED	Exposure Duration (yr)	30	N/A	25
IR	Inhalation Rate (m^3/hr)	0.625	N/A	1.25
TR	Target Risk	HQ = 1	1×10^{-5}	1×10^{-5}
CSF_i	Inhalation Cancer Slope Factor $(mg/kg\text{-}day)^{-1}$	N/A	Chemical-specific	Chemical-specific
AT_c	Averaging Time for carcinogens (yr)	N/A	70	70
IF_{adj}	Inhalation Factor [(3)] (m^3-yr/kg-hr)	N/A	0.4	0.4

Notes: Modified from USEPA (1995).
N/A = not applicable.
1 Residential exposure to noncarcinogens is based on adult exposure, consistent with USEPA (1991)
2 Residential exposure to carcinogens is based on combined childhood and adult exposure.
3 The inhalation factor for the residential scenario is calculated using the equation $IF_{adj} = ED_c x IR_c/BW_c + ED_a x IR_a/BW_a$, where ED_c= 6 yr. $IR_c = 0.5 m^3/hr$, BW_c = 15 kg, ED_a = 24 yr. $IR_a = 0.625\ m^3/hr$ and BW_a = 70 kg. The inhalation factor for the nonresidential scenario is calculated using the equation $IF_{adj} = ED x IR/BW$, where ED = 25 yr, IR = 1.25 m^3/hr and BW = 70 kg.
* Inhalation absorption factors *will be provided at a later date*. Default = 1. In cases where the inhalation RfD or CSF is based on absorbed dose, this factor *to be provided* can be applied in the exposure algorithm.

Appendix A

IAQ Subteam Personnel

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Appendix B - Comparison Tables (CT, MA, MI, ASTM, EPA)
Groundwater (Residential & Non-Residential)
Soil (Residential & Non-Residential)

Appendix C – Chemical-Specific Properties & Toxicity Values

Appendix D - TO-14 & TO-15 Analyte List

Appendix E - Johnson & Ettinger Vapor Intrusion Model

Appendix F - Indoor Air and Soil Gas Sampling Procedures

APPENDIX B - Comparison Table for Soil Residential

Summary of Soil Screening "Criteria" (mg/kg) for Protection of Indoor Air - Residential

Chemical	Pennsylvania Soil-GW MSC Used Aquifer Residential	Pennsylvania Soil-GW MSC Unused Aquifer Residental	Pennsylvania Direct Contact 0-15 feet Residential	PA Defaults Residential Volatilization to Indoor Air Criteria (a)	Michigan Residential Volatilization to Indoor Air Criteria (b)	ASTM Default Residential Volatilization to Indoor Air Criteria (c)
Acetone	370	3,700	10,000	112,000	110,000 (Csat)	-
Acrylonitrile	0.06	6.30	4.70	NA	6.60	-
2-Butanone (MEK)	280	10,000	10,000	NA	27,000 (Csat)	120
Benzene	0.5	50	38	0.37	2	0.02
Bromoform	100	10,000	290	93.5	150	-
Carbon Tetrachloride	0.5	5	21	0.07	0.190	0.008
Chlorobenzene	5.5	550	4,400	9.04	120	2
Chloroform	10	100	14	0.0531	7.2	0.006
Dibromochloromethane	10	1,000	12	1.32	3.9	-
1,2-Dichlorobenzene	60	6,000	3,800	145	210 (Csat)	65
1,3-Dichlorobenzene	60	6,000	5,900	NA	Not established	7
1,4-Dichlorobenzene	7.5	750	750	7.52	19	10
1,1-Dichloroethane	2.7	27	12	1.63	230	0.270
1,2-Dichloroethane	0.5	5	12	0.49	2	0.007
1,1-Dichloroethene	0.7	7	6.40	0.01	0.06	-
cis-1,2-Dichloroethene	7	70	670	5.40	23	-
trans-1,2-Dichloroethene	10	100	1,300	4.57	23	-
1,2-Dichloropropane	0.5	5	16	0.52	4	-
Ethyl benzene	70	7,000	10,000	108	140 (Csat)	87
Ethylene dibromide	0.005	0.50	0.21	NA	0.67	-
Methylene chloride	0.5	50		7.54	45	0.28
Methyl isobutyl ketone	22	2,200	1,500	-	2,700 (Csat)	-
Methyl-tert-butyl-ether	2	20	10,000	31.2	5,900 (Csat)	170
Styrene	10	1,000	10,000	717	250	240
Tetrachloroethene	0.5	5	340	6.03	11	0.22
1,1,2,2-Tetrachloroethane	0.074	7.4	5.50	1.18	4.30	0.02
Toluene	100	10,000	7,600	74.2	250 (Csat)	22
Trichloroethylene	1	5	190	1.32	7.10	0.07
1,1,1-Trichloroethane	20	200	10,000	124	250	54
1,1,2-Trichloroethane	0.5	5	20	1.44	4.60	0.08
Vinyl chloride	0.2	2	3.80	0.04	0.03	0.002
Xylenes	1,000	10,000	10,000	174	150 Csat)	480

a/PA defaults using SL-SCREEN.XLS version 2.3 03/01 PA Soil parameters; 15 cm to bottom of enclosed space; 150 cm to top of contamination; RL = 10-5; HQ = 1

b/ Michigan Department of Environmental Quality, Generic Cleanup Criteria and Screening Levels under Part 201 of the Natural Resources and Environmental Protection Act.

cb/ ASTM defaults using GSI software; Vadose zone 300 cm; Depth to GW 300 cm; Depth to bottom of foundation 150 cm; RL = 10-6 for A&B, 10-5 for C; HQ = 1

APPENDIX B Comparison Table for Soil Non-Residential

Summary of Soil Criteria/Screen (mg/kg) for Protection of Indoor Air: Non-residential (Commercial/Industrial)

	Chemical	Pennsylvania Soil-GW MSC Used Aquifer Non-residential	Pennsylvania Soil-GW MSC Unused Aquifer Non-residential	Pennsylvania Direct Contact 0-2 feet Non-Residential	Pennsylvania Direct Contact 2-15 feet Non-Residential	USEPA-PA Defaults Non-residential Volatilization to Indoor Air Criteria (a)	USEPA-PA Defaults Non-residential PELs Volatilization to Indoor Air Screen (b)	ASTM-PA Default Commercial Volatilization to Indoor Air Screen (c)	ASTM-PA Defaults TWA Volatilization to Indoor Air Screen (d)	Michigan Non-residential Volatilization to Indoor Air Criteria (e)
000067-64-1	Acetone	370	3,700	10,000	10,000	110,000 (NOC)	110,000 (Csat)	NC	NC	118,000 (Csat)
000107-13-1	Acrylonitrile	0.06	6.30	24.00	28.00	NA	NA	NA	NA	35
000078-93-3	2-Butanone (MEK)	280	10,000	10,000	10,000	NA	NA	1,100	>50,000	27,000 (Csat)
000071-43-2	Benzene	0.5	50	200	230	1	470 (Csat)	1.10	690.00	8
000075-25-2	Bromoform	100	10,000	1,500	1,700	120	1,000	240	>6,200	770
000056-23-5	Carbon Tetrachloride	0.5	5	110	120	0.12	440 (Csat)	0.580	2,700	1
000108-90-7	Chlorobenzene	5.5	550	10,000	10,000	16	310	13	>1,100	220
000067-66-3	Chloroform	10	100	72	82	0.079	2000.000	0.093	2,100	38
000124-48-1	Dibromochloromethane	10	1,000	61	70	2.20	?	NC	NC	21
000095-50-1	1,2-Dichlorobenzene	60	6,000	10,000	10,000	260	260 (Csat)	360	>3,100	210 (Csat)
000541-73-1	1,3-Dichlorobenzene	60	6,000	10,000	10,000	NA	NA	41	NC	Not established
000106-46-7	1,4-Dichlorobenzene	7.5	750	3,300	190,000	120	120 (Csat)	66	>3,100	100
000075-34-3	1,1-Dichloroethane	2.7	27	1,000	1,200	63	1000 (Csat)	1.600	>4,200	430
000107-06-2	1,2-Dichloroethane	0.5	5	63	73	0.62	1300 (Csat)	0.470	1,200	11
000075-35-4	1,1-Dichloroethene	0.7	7	33	38.00	0.02	710 (Csat)	NA	NA	0.33
000156-59-2	cis-1,2-Dichloroethene	7	70	1,900	2,100	7.60	840(Csat)	NC	NC	42
000156-60-5	trans-1,2-Dichloroethene	10	100	3,700	4,300	6.40	1500 (Csat)	NC	NC	43
000078-87-5	1,2-Dichloropropane	0.5	5	85	97	1.20	630 (Csat)	NA	NA	7
000100-41-4	Ethyl benzene	70	7,000	10,000	10,000	170	170 (Csat)	490	>640	140 (Csat)
000106-93-4	Ethylene dibromide	0.005	0.50	0.93	8.60	NA	-	-	-	4
000075-09-2	Methylene chloride	0.5	50	3,500	4,000	13	1900 (Csat)	19.00	>3,400	240
000108-10-1	Methyl isobutyl ketone	22	2,200	4,300	4,900	NA	NA	23	>2,800	2,700 (Csat)
001634-04-4	Methyl-tert-butyl-ether	2	20	10,000	10,000	NA	NA	1,200	>12,000	5,900 (Csat)
000100-42-5	Styrene	10	1,000	10,000	10,000	640	640 (Csat)	>240	>240	520 (Csat)
000127-18-4	Tetrachloroethene	0.5	5	1,500	3,300	10	180 (Csat)	11.00	>350	60
000079-34-5	1,1,2,2-Tetrachloroethane	0.074	7.4	28	33.00	2.20	1000 (Csat)	0.15	>110	23
000108-88-3	Toluene	100	10,000	10,000	10,000	110	230 (Csat)	120	>780	250 (Csat)
000079-01-6	Trichloroethylene	1	5	970	1,100	3	590 (Csat)	51.00	>1,400	37
000071-55-6	1,1,1-Trichloroethane	20	200	10,000	10,000	88	550 (Csat)	310	>3,800	460
000079-00-5	1,1,2-Trichloroethane	0.5	5	100	120	1.90	1000 (Csat)	0.55	>880	24
000075-01-4	Vinyl chloride	0.2	2	20	22.00	0.12	48.000	0.100	>2,400	0.15
001330-20-7	Xylenes	1,000	10,000	10,000	10,000	200 (99 = Csat)	200,000 (99 = Csat)	>510	>510	150 (Csat)

a/ "PA" defaults using USEPA J&E Version 2.3; 03/01 (Multichemical), Non-Residential receptor, RL = 10-5, HQ = 1
b/ "PA" defaults using USEPA J&E Version 2.3; 03/01 (Multichemical), Non-Residential receptor, PEL as endpoint
c/ "PA" defaults using GSI-ASTM software; Contaminated Soil 150-300cm;Commercial receptor, RL = 10-5, HQ = 1
d/ "PA" defaults using GSI-ASTM software; Contaminated Soil 150-300cm; OSHA-TWA endpoint
e/ Michigan Department of Environmental Quality, Generic Cleanup Criteria and Screening Levels under Part 201 of the Natural Resources and Environmental Protection Act.Attachment A to Operations Memo 18
>value indicates that risk-based target greater than constituent residual saturation
NA Not available
NC Not calcuated
NOC Not of concern

APPENDIX B - Comparison Table for Groundwater Residential
Summary of Groundwater Srceening "Criteria" (ug/L) for Protection of Indoor Air - Residential

Chemical	Pennsylvania GW MSC Used Aquifer	Pennsylvania GW MSC Unused Aquifer	PA Defaults Residential Volatilization to Indoor Air Criteria (a)	Connecticut Residential Volatilization Criteria (b)	Massachusetts GW-2 Standards (c)	Michigan Residential Volatilization to Indoor Air Criteria (d)	ASTM Default Residential Volatilization to Indoor Air Criteria (e)	EPA Defaults (1998) Residential Volatilization to Indoor Air Criteria (f)
Acetone	3,700	37,000	NOC	50,000	50,000	1,000,000,000(s)	-	
Acrylonitrile	0.63	63	NA	Not established	Not established	34,000		
2-Butanone (MEK)	2,800	280,000		50,000	50,000	240,000,000 (s)	1,600,000	
Benzene	5	500	5,500	215	2,000	5,600	19	1,280
Bromoform	100	10,000	182,000	920	800	480,000	-	157,000
Carbon Tetrachloride	5	50	1,400	16	20	2,400	3	126
Chlorobenzene	55	5,500	27,400	1,800	1,000	470,000	2,100	15,600
Chloroform	100	1,000	114	287	400	180,000	9	595
Dibromochloromethane	100	10,000	3,750	Not established	Not established	15,000		
1,2-Dichlorobenzene	600	60,000	NOC	30,500	10,000	160,000	5,600	
1,3-Dichlorobenzene	600	60,000	NA	24,200	10,000	Not established	890	
1,4-Dichlorobenzene	75	7,500	8090	50,000	30,000	16,000	890	
1,1-Dichloroethane	27	270	15600	34,600	9,000	1,000,000	160	
1,2-Dichloroethane	5	50	2,770	21	20	9,600	17	2,040
1,1-Dichloroethene	7	70	362	1	1	200	-	37
cis-1,2-Dichloroethene	70	700	42100	Not established	Not established	96,000	-	
trans-1,2-Dichloroethene	100	1,000	59300	Not established	Not established	85,000	-	
1,2-Dichloropropane	5	50	3850	14	9	16,000	-	3,650
Ethyl benzene	700	70,000	NOC	50,000	30,000	170,000	59,000	
Ethylene dibromide	0.05	5	NA	4	3	2,400	-	
Methylene chloride	5	500	77,000	50,000	50,000	220,000	590	
Methyl isobutyl ketone	220	22,000	NA	50,000	50,000	20,000,000 (S)	-	
Methyl-tert-butyl-ether	20	200	228000	50,000	50,000	47,000,000 (S)	1,100,000	
Styrene	100	10,000	NOC	580	900	170,000	19,000	310,000
Tetrachloroethene	5	50	42400	1,500	3,000	25,000	120	6,420
1,1,2,2-Tetrachloroethane	0.74	74	3680	23	20	12,000	72	3,120
Toluene	1,000	100,000	491000	23,500	6,000	530,000	25,000	
Trichloroethylene	5	50	14300	219	300	15,000	32	3,440
1,1,1-Trichloroethane	200	2,000	NOC	20,400	4,000	660,000	29,000	
1,1,2-Trichloroethane	5	50	5550	8,000	20,000	17,000	520	4,170
Vinyl chloride	2	20	1,780	2	2	110	0.13	345
Xylenes	10,000	180,000	57,400	21,300	6,000	190,000	200,000	

a/PA defaults using GWSCREEN.XLS version 2.3 03/01 PA Soils parameters; 15 cm to bottom of enclosed space; 150 cm to water table; RL = 10-5; HQ = 1
b/ RCSA 22a-133k, CT Remediation Standards Regulations, Appendix E.
c/310 CMR 40.0974(2), MA Contingency Plan, Table 1.
d/ Michigan Department of Environmental Quality, Generic Cleanup Criteria and Screening Levels under
Part 201 of the Natural Resources and Environmental Protection Act. Attachment A of Operations Memo 18
e/ ASTM defaults using GSI software; Vadose zone 300 cm; Depth to GW 300 cm; Depth to bottom of foundation 150 cm; RL = 10-6 for A&B, 10-5 for C; HQ = 1
f/EPA defaults using GWSCREEN.XLS version 1.2 09/98 EPA soil parameters; 200 cm to bottom of enclosed space; 400 cm to water table; RL = 10-5; HQ = 1
NA: Not available in model
NOC: Not of concern - from model run

APPENDIX B - Comparison Table for Groundwater Non-Residential

Summary of Groundwater Screening "Criteria" (ug/L) for Protection of Indoor Air - Non-Residential

Chemical	Pennsylvania GW MSC Used Aquifer	Pennsylvania GW MSC Unused Aquifer	USEPA-PA Defaults Non-residential Volatilization to Indoor Air Criteria (a)	USEPA-PA Defaults Non-residential PELs Volatilization to Indoor Air Screen (b)	ASTM-PA Defaults Non-residential Volatilization to Indoor Air Screen (c)	ASTM-PA Defaults TWA Volatilization to Indoor Air Screen (d)	Connecticut Non-residential Volatilization Criteria (e)	Michigan Non-residential Volatilization to Indoor Air Criteria (f)	ASTM Default Residential Volatilization to Indoor Air Criteria (d)	EPA Defaults (1998) Residential Volatilization to Indoor Air Criteria (e)	PA Defaults Residential Volatilization to Indoor Air Criteria (f)
Acetone	3,700	37,000	2,300,000,000 (NOC)	NOC	NC	NC	50,000	1,000,000,000 (S)	-		NOC
Acrylonitrile	0.63	63	NA	NA	NA	NA	Not established	190,000			NA
2-Butanone (MEK)	2,800	280,000	NA	NA	7,800,000	>320,000,000	50,000	-	1,600,000		
Benzene	5	500	9,600	NOC	2,100	1,400,000	530	36,000	19	1,280	3,500
Bromoform	100	10,000	310,000	NOC	130,000	>3,200,000	3,800	240,000,000 (S)	-	157,000	182,000
Carbon Tetrachloride	5	50	2,400	NOC	340	>760,000	40	2,400	3	126	1,400
Chlorobenzene	55	5,500	44,000	NOC	19,000	>470,000	6,150	470,000 (S)	2,100	15,600	27,400
Chloroform	100	1,000	610	NOC	230	5,100,000	710	180,000	9	595	414
Dibromochloromethane	100	10,000	6,300	NC	NC	NC	Not established	110,000			3,750
1,2-Dichlorobenzene	600	60,000	720,000 (NOC)	NOC	44,000	>150,000	50,000	160,000 (S)	5,600		NOC
1,3-Dichlorobenzene	600	60,000	NA	NA	7,700	NC	50,000	-	890		NA
1,4-Dichlorobenzene	75	7,500	2,400,000 (NOC)	NOC	7,300	>150,000	50,000	74,000(S)	800		8090
1,1-Dichloroethane	27	270	760,000	NOC	1,600	>5,500,000	50,000	23,000,000	160		15600
1,2-Dichloroethane	5	50	4,600	NOC	1,500	3,800,000	90	59,000	17	2,040	2,770
1,1-Dichloroethene	7	70	610	NOC	NA	NA	6.00	1,300	-	37	362
cis-1,2-Dichloroethene	70	700	59,000	NOC	NC	NC	Not established	220,000	-		42100
trans-1,2-Dichloroethene	100	1,000	83,000	NOC	NC	NC	Not established	200,000	-		59300
1,2-Dichloropropane	5	50	9,500	NOC	NA	NA	60	36,000	-	3,650	3850
Ethyl benzene	700	70,000	1,800,000 (NOC)	NOC	>170,000	>170,000	50,000	170000 (S)	59,000		NOC
Ethylene dibromide	0.05	5	NA	NA	NA	NA	16	15,000	-		NA
Methylene chloride	5	500	130,000	NOC	57,000	>13,000,000	50,000	1,400,000	590		77,000
Methyl isobutyl ketone	220	22,000	NA	NA	160,000	>19,000,000	50,000	20,000,000 (S)	-		NA
Methyl-tert-butyl-ether	20	200	NA	NA	4,800,000	>48,000,000	50,000	47,000,000 (S)	1,100,000		228000
Styrene	100	10,000	2,700,000 (NOC)	NOC	>19,000	>19,000	2,065	310,000 (S)	19,000	310,000	NOC
Tetrachloroethene	5	50	71,000	NOC	10,000	>200,000	3,820	170,000	120	6,420	42400
1,1,2,2-Tetrachloroethane	0.74	74	6,200	NOC	690	>720,000	100	77,000	72	3,120	3680
Toluene	1,000	100,000	690,000 (NOC)	NOC	230,000	>520,000	50,000	530,000 (S)	25,000		491000
Trichloroethylene	5	50	24,000	NOC	2,800	>1,000,000	540	97,000	32	3,440	14300
1,1,1-Trichloroethane	200	2,000	1,300,000 (NOC)	NOC	290,000	>1,300,000	50,000	1,300,000 (S)	29,000		NOC
1,1,2-Trichloroethane	5	50	9,000	NOC	4,000	>5,900,000	19,600	110,000	520	4,170	5350
Vinyl chloride	2	20	5,800	2,300,000	16	440,000	2	690	0.13	345	1,780
Xylenes	10,000	180,000	740,000 (NOC)	NOC	>200,000	>200,000	50,000	190,000 (S)	200,000		57400

a/ "PA" defaults using USEPA J&E Version 2.3; 03/01 (Multichemical), Non-Residential receptor, RL = 10-5, HQ = 1
b/ "PA" defaults using USEPA J&E Version 2.3; 03/01 (Multichemical), Non-Residential receptor, PEL
c/ "PA" defaults using GSI-ASTM software; GW at 150 cm, Non-residential receptor, RL = 10-5, HQ = 1
d/ "PA" defaults using GSI-ASTM software; GW at 150 cm, Non-residential receptor; OSHA-TWA endpoint
e/ RCSA 22a-133k, CT Remediation Standards Regulations, Appendix E.
f/ Michigan Department of Environmental Quality, Generic Cleanup Criteria and Screening Levels under
Part 201 of the Natural Resources and Environmental Protection Act.Attachment A to Operations Memo 18
>value indicates that risk-based target greater than constituent water solubility
NA Not available
NC Not calcuated
NOC Not of concern, value above constituent water solubility

APPENDIX C - Chemical-Specific Properties and Toxicity Values

CAS Number	Chemical	Aqueous Solubility (mg/L)	Koc	RfDo (mg/kg/day)	Source RfDo	RfDi (mg/kg/day)	Source RfDi	CSFo (mg/kg/day)^-1	Source CSFo	CSFi (mg/kg/day)^-1	Source CSFi
000067-64-1	Acetone	1000000	0.31	1.0E-01	I	8.9E+00	D				
000107-13-1	Acrylonitrile	73500	11	1.0E-03	H	5.7E-04	I	5.4E-01	I	2.4E-01	I
000078-93-3	2-Butanone (MEK)	275000	32	6.0E-01	I	2.9E-01	I				
000071-43-2	Benzene	1780.5	58	3.0E-03	N	1.7E-03	N	2.9E-02	I	2.7E-02	I
000075-25-2	Bromoform	3050	130	2.0E-02	I	2.0E-02	I r-r	7.9E-03	I	3.9E-03	I
000056-23-5	Carbon Tetrachloride	795	160	7.0E-04	I	5.7E-04	N	1.3E-01	I	5.3E-02	I
000108-90-7	Chlorobenzene	490	200	2.0E-02	I	5.0E-03	H				
000067-66-3	Chloroform	8000	56	1.0E-02	I	9.0E-05	N		I [A dose of 0.01 mg/kg/day (equal to the RfD) can be considered protective against cancer risk.]	8.1E-02	I
000124-48-1	Dibromochloromethane	4200	83	2.0E-02	I	2.0E-02	I r-r	8.4E-02	I	9.4E-02	C
000095-50-1	1,2-Dichlorobenzene	147	350	9.0E-02	I	4.0E-02	H				
000541-73-1	1,3-Dichlorobenzene	106	360	3.0E-02	N		N r-r is not appropriate.				
000106-46-7	1,4-Dichlorobenzene	82.9	510	3.0E-02	N	2.3E-01	I	2.4E-02	H	2.2E-02	N
000075-34-3	1,1-Dichloroethane	5000	52	1.0E-01	H	1.0E-01	H	5.7E-03	C	5.7E-03	C
000107-06-2	1,2-Dichloroethane	8412	38	3.0E-02	N	2.0E-01	D	9.1E-02	I	9.1E-02	I
000075-35-4	1,1-Dichloroethylene	2500	65	9.0E-03	I	9.0E-03	I r-r	6.0E-01	I	1.8E-01	I
000156-59-2	cis-1,2-Dichloroethylene	3500	49	1.0E-02	H	1.0E-02	H r-r				
000156-60-5	trans-1,2-Dichloroethylene	6300	47	2.0E-02	I	2.0E-02	I r-r				
000078-87-5	1,2-Dichloropropane	2700	47	9.0E-02	D	1.1E-03	I	6.8E-02	H	3.6E-02	C
000100-41-4	Ethyl benzene	161	220	1.0E-01	I	2.9E-01	I				
000106-93-4	Ethylene dibromide	4150	54	5.7E-05	H r-r	5.7E-05	H	8.5E+01	I	7.7E-01	I
000075-09-2	Methylene chloride	20000	16	6.0E-02	I	8.6E-01	H	7.5E-03	I	1.7E-03	I
000108-10-1	Methyl isobutyl ketone	19550	17	8.0E-02	H	2.0E-02	H				
001634-04-4	Methyl-tert-butyl-ether	45000	12	8.6E-01	I r-r	8.6E-01	I	1.8E-03	C	1.8E-03	C
000100-42-5	Styrene	300	910	2.0E-01	I	2.9E-01	I				
000127-18-4	Tetrachloroethylene	162	300	1.0E-02	I	1.4E-01	N	5.2E-02	N	2.0E-03	N
000079-34-5	1,1,2,2-Tetrachloroethane	2860	79	6.0E-02	N	6.0E-02	N r-r	2.0E-01	I	2.0E-01	I
000108-88-3	Toluene	532.4	130	2.0E-01	I	1.1E-01	I				
000079-01-6	Trichloroethylene	1100	93	6.0E-03	N	1.4E-01	D	1.1E-02	N	6.0E-03	N
000071-55-6	1,1,1-Trichloroethane	1495	100	2.8E-01	N	6.0E-01	N				
000079-00-5	1,1,2-Trichloroethane	4420	76	4.0E-03	I	4.0E-03	I r-r	5.7E-02	I	5.6E-02	I
000075-01-4	Vinyl chloride	2700	10	3.0E-03	I	3.0E-02	I	1.5E+00	I	3.0E-02	I
001330-20-7	Xylenes	175	350	2.0E+00	I	1.2E-01	D				

Toxicity Value Sources:
C = California EPA Cancer Potency Factor
D = ATSDR Minimal Risk Level
H = Health Effects Assessment Summary Table (HEAST)
I = Integrated Risk information System (IRIS)
M = EPA Drinking Water Regulations and Health Advisories
N = EPA NCEA Provisional Values
r-r = route-to-route extrapolation

Appendix D TO-14 & TO-15 Analyte List

TO-14 Target Analytes	TO-15 Target Analytes
Dichlorodifluoromethane	Dichlorodifluoromethane
Chloromethane	Dichlorotetrafluoroethane
Dichlorotetrafluoroethane	Trichlorofluoromethane
Vinyl Chloride	Isopropyl Alcohol
Bromomethane	1,1-Dichloroethene
Chloroethane	Methylene Chloride
Trichlorofluoromethane	3-Chloropropene
1,1-Dichloroethene	Carbon Disulfide
Methylene Chloride	Trichlorotrifluoroethane
Trichlorotrifluoroethane	Trans-1,2-Dichloroethene
1,1-Dichloroethane	1,1-Dichloroethane
Cis-1,2-Dichloroethene	Methyl-tertiary-butyl ether
Chloroform	Methyl Ethyl Ketone
1,2-Dichloroethane	Cis-1,2-Dichloroethene
1,1,1-Trichloroethane	1,2-Dichloroethane
Benzene	1,1,1-Trichloroethane
Carbon Tetrachloride	Carbon Tetrachloride
1,2-Dichloropropane	1,2-Dichloropropane
Trichloroethene	Bromodichloromethane
Cis-1,3-Dichloropropene	2,2,4-Trimethylpentane
Trans-1,3-Dichloropropene	Cis-1,3-Dichloropropene
1,1,2-Trichloroethane	Trans-1,3-Dichloropropene
Toluene	Methyl Isobutyl Ketone
1,2-Dibromomethane	1,1,2-Trichloroethane
Tetrachloroethene	Methyl Butyl Ketone
Chlorobenzene	Dibromochloromethane
Ethylbenzene	1,1,2,2-Tetrachloroethane
Styrene	1,3,5-Trimethylbenzene
1,1,2,2-Tetrachloroethane	1,2,4-Trimethylbenzene
Xylenes(m,p,o)	Vinyl Chloride
1,3,5-Trimethylbenzene	Chloromethane
1,2,4-Trimethylbenzene	1,3-Butadiene
1,3-Dichlorobenzene	Bromomethane
1,4-Dichlorobenzene	Chloroethane
1,2-Dichlorobenzene	Bromoethene
1,2,4-Trichlorobenzene	Acetone
	Hexane
	Chloroform
	Tetrahydrofuran
	Benzene
	Cyclohexane
	1,4-Dioxane
	n-Heptane
	Toluene
	Tetrachloroethene
	Chlorobenzene
	Ethylbenzene
	Xylenes(m,p,o)
	Trichloroethene
	Bromoform
	Styrene
	2-Chlorotoluene
	4-Ethyltoluene
	1,2-Dibromomethane
	1,3-Dichlorobenzene
	1,4-Dichlorobenzene
	1,2-Dichlorobenzene

Appendix E

Johnson and Ettinger Vapor Intrusion Model

History: The model was developed in 1991, and it has been in use formally as USEPA guidance since 1997. It has been used under the site-specific standard of Act 2. We are using version 2.3 for this effort.

Application: The model is typically applied to augment analysis of cases at which volatile constituents are present in or migrating toward soil or groundwater beneath a building, or a proposed building. The Johnson and Ettinger model incorporates both convective and diffusion mechanisms, as well as chemical, soil, and building foundation properties to estimate indoor air concentrations of constituents. The model may employ data from environmental samples beneath the structure, or it may be coupled with groundwater flow modeling to provide a predicted concentration of constituents beneath the building for use in the model. This model does lend itself to use as a screening tool and as a sophisticated site-specific tool, provided it is used thoughtfully.

Model Output: The model will provide a steady-state indoor air concentration from data on a chemical that is present in subsurface soil or groundwater beneath the building. It is useful to note that software is included with the User's Guide to allow use of the model without any programming on a standard computer.

The model will also calculate a potential risk to a hypothetical receptor in the indoor setting. This aspect of the calculation allows the greatest potential for misuse, since the exposure area is a basement (often an industrial basement) and the potential for exposure should be assessed site-specifically, rather than as default residential living space. This is easy to do.

Critical Sensitivities: This model can be misused to arrive at entirely erroneous results. It is critical in the application of this model that site-specific data be used, such as at a minimum (a) the concentrations of specific soil components such as organic matter, (b) the area of the building, and (c) the crack area of the basement floor. These are all typically readily available or can be easily calculated.

Web Link for J-E Model:
(http://www.epa.gov/superfund/programs/risk/airmodel/johnson_ettinger.htm)

APPENDIX F: SAMPLING INDOOR AIR AND SOIL GAS

There are significant difficulties with sampling indoor air and soil gas. Therefore, it is beyond the scope of this document to fully define processes for sampling these media. The intent of this Appendix is to identify a few key issues/considerations for each area and provide references that could serve as protocols or be useful in addressing these key issues.

Indoor air sampling

Indoor air sampling provides the most direct measure of whether there is (or is not) an indoor air quality (IAQ) concern. However, it is recognized that there can significant ambient (general outdoor) and indoor (from consumer products) sources that can make it difficult to definitively conclude that the source of the IAQ concern is actually from a contaminated site. Indeed, particularly in urban areas, ambient sources may be well above the calculated "unacceptable" risk levels and indoor sources from use of consumer products are sometimes much higher than outdoor sources. Further, IAQ is subject to building conditions and spatial and temporal variability.

Sampling to address vapor intrusion should be design to identify incremental exposures. Therefore, background concentrations should be characterized and subtracted from the indoor air concentrations to limit the assessment to only those vapors that may be attributable to subsurface vapor sources. This is typically very challenging and may require an extensive monitoring program (USEPA, 2001)

The Massachusetts Department of Environmental Protection has developed a comprehensive guide to address sampling IAQ. This document suggests the following steps in designing and implementing a sampling plan for IAQ.

1. Define Study Objective
2. Identify Chemicals of Concern
3. Identify Required Sampling Duration
4. Choose Sampling Method
5. Check if Adequate Limit of Detection
6. Define QA/QC Indicators for Sampling/Analysis
7. Do Pre-Sampling Investigation
8. Establish Appropriate Sampling Conditions and Conduct Sampling
9. Analyze Samples
10. Evaluate Data and Calculate Health Risks

The guide is available for free download at: http://www.state.ma.us/dep/new.htm

Useful guides are available from the New Jersey Department of Environmental Protection (NJDEP, 1999) and New York Department of Health (NY DOH, 2001).

Soil gas sampling

Soil gas sampling can be used both as an alternative to sampling indoor air and to better determine the source term for the Johnson and Ettinger model.

The mobility of volatile chemicals in soil primarily depends on soil porosity, i.e., the most significant determining factor is available connected air-filled porosity. Thus, even small changes in soil lithology can result in changes in vapor transport. This presents a major difficulty in getting representative vapor concentration. In addition, environmental conditions that can fluctuate significantly with time (such as seasonal variation in moisture content, time since the last rainfall and atmospheric pressure) are also important determinants of vapor concentrations. This means that multiple concentration measurement events are typically needed to develop a representative soil vapor concentration.

The typical method to collect soil gas is with narrow diameter probes that are installed in the ground for multiple sampling events. The American Petroleum Institute (API, 1998) is developing a resource on the issue. Some of the recommendations include:

- sampling devices should intersect small vertical sections of the vadose zone
- sampling devices should be sealed from short-circuiting from the surface
- probes may be installed in nested groups at various elevations
- samples should be collected periodically (e.g., four quarterly samples over a year)
- the soil vapor sampling point should be purged of stagnant air before the samples are acquired
- sampling equipment is appropriately contaminant-free
- samples to be sent to a laboratory for analysis should be collected in SUMMA canisters
- Tedlar bags may be used if an onsite laboratory will analyze the samples.

In addition to concentrations of chemicals of concern, concentrations of oxygen and carbon dioxide are often measured to develop the information needed to support biodegradation demonstrations. So, field analyzers may be used for some parameters such as oxygen and carbon dioxide.

References:

API 1998. Assessing the Significance of Subsurface Contaminant Vapor Migration to Enclosed Spaces, Site-Specific Alternatives to Generic Estimates. Health and Environmental Sciences Department, Publication Number 4674. Washington, D.C.

Massachusetts Department of Environmental Protection - Office of Research and Standards. Indoor Air Sampling and Evaluation Guide. Draft Version. February 1, 2001. http://www.state.ma.us/dep/new.htm

New Jersey Department of Environmental Protection. 1999. Indoor Air Sampling Guide for Volatile Organic Chemicals.

New York Department of Health (2001) : Sampling Indoor Air and Analysis Guidance, August.

USEPA. 1992. Air/Superfund National technical Guidance Study Series. Assessing Potential Indoor Air Impacts from Superfund Sites. EPA-451/R-92-002

USEPA. 2001. Supplemental guidance for evaluating the vapor intrusion to indoor air pathway. Partial response to question 3 of 02/05/99 RCRA Corrective Action Environmental Indicator RCRIS Code (CA725). Draft for comment. 10/23/01.