DEPARTMENT OF ENVIRONMENTAL PROTECTION
Bureau of Land Recycling and Waste Management

DOCUMENT NUMBER: 253-0300-100

TITLE: Land Recycling Program Technical Guidance Manual- Section IV.A.4. Vapor Intrusion into Buildings from Groundwater and Soil under the Act 2 Statewide Health Standard.

ANTICIPATED EFFECTIVE DATE: October 26, 2002

AUTHORITY:

The Land Recycling and Environmental Remediation Standards Act (Act 2 of 1995) (35 P.S. §§6026.101 et seq.) and the regulations issued pursuant to that legislation at 25 PA Code Chapter 250.

POLICY:

It is the policy of the Department to implement Act 2 in accordance with the regulations contained in Chapter 250 of the PA Code and as described in this guidance manual.

PURPOSE:

The Department has developed a technical guidance manual to assist remediators in satisfying the requirements of Act 2 and the regulations published in Chapter 250 of the PA Code. This specific guidance, which is to be incorporated into the technical manual, is to provide additional attainment screening requirements in some cases, to prevent risk of unacceptable risk being present as result of vapor intrusion of contaminants from soil and/or groundwater into indoor structures.

APPLICABILITY:

The guidance is applicable to any person or persons conducting a site remediation under Act 2 under the Statewide Health Standard.

DISCLAIMER:

The policies and procedures outlined in this guidance document are intended to supplement existing requirements. Nothing in the policies or procedures will affect regulatory requirements.

The policies and procedures herein are not an adjudication or a regulation. There is no intent on the part of the Department to give these rules that weight or deference. This document establishes the framework, within which DEP will exercise its administrative discretion in the future. DEP reserves the discretion to deviate from this policy statement if circumstances warrant.

PAGE LENGTH: 24 pages

LOCATION: Volume 5 Tab 32

DEFINITIONS: See 25 Pa. Code Chapter 250

Introduction

Indoor air quality from the vapor intrusion of contaminants into buildings from groundwater and soil is not specifically detailed in the Act 2, Chapter 250 regulations. This document provides guidance for assessing the potential for indoor vapor intrusion pathways under Statewide health standard (SHS) .

This document provides guidance for assessing subsurface vapor intrusion of volatile and semivolatile contaminants into buildings from contaminated groundwater and soils. When releases occur near buildings, volatilization of contaminants from the dissolved or pure phases in the subsurface can result in the intrusion of vapor-phase contaminants into indoor air.

Decision matrices for consideration of indoor air quality were developed for groundwater and soil under a Statewide health or generic approach. In these matrices, several options are provided for determining if indoor air quality (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 (see Tables 1-2, Groundwater; Tables 4-5, Soil). Specifically, with the exception of three compounds, none of the regulated substances for which a nonuse aquifer standard is listed in Chapter 250 would be a concern in groundwater if the MSCs for nonuse aquifers are met. The same is true for soil meeting a used aquifer standard, with only a few regulated substances being a concern at levels below the used aquifer standards published in Chapter 250.
- Comparison to conservative default screening values for soil and groundwater (see Tables 1-2 and Tables 4-5) calculated using Pennsylvania-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 residential screening value for chloroform in groundwater is 414 μg/L (see Table 1). 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 μg/L (including groundwater that meets the nonuse 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 estimated levels inside the building. See Table 3.
- Comparison to MSC developed for IAQ (MSC_{IAQ}) using measured indoor air concentrations. See Table 3.

If indoor air quality 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.

General Considerations

Evaluating the vapor intrusion pathway into buildings, on a generic basis, is extremely difficult. For example, even though **reasonable Pennsylvania-specific assumptions (Table 8)** 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. It was decided 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. A remediator should use caution when making decisions based on both indoor air and soil gas analyses.

If a property does not currently have dwellings (non-residential) and it is possible that future development will consist of occupied buildings (residential), the deed acknowledgment requirements shall apply pursuant to Chapter 250.303(g).

Process for Groundwater

In the Groundwater IAQ Decision Matrix for SHS (Figure 1), the receptor location and type of soil are critical. Under SHS, if separate phase liquid (SPL – see SHS definitions) is encountered beneath the site or within 100 feet of the receptor at or above the water table, soil gas sampling or indoor air sampling is required**. If a site has SPL within 100 feet of the receptor and samples collected at 50 feet from the receptor indicate no SPL, then further soil gas sampling would not be required at the receptor. If SPL is found within 50 feet of the receptor, soil gas would be required at the receptor.** In addition, the presence of preferential exposure pathways (see SHS definitions) limits the further use of the matrix. Hence, additional sampling is required to meet the SHS if preferential exposure pathways are present and pass through the source or occur within 30 feet of the source.

For residential receptors, if the levels of chloroform, dibromochloromethane and xylenes do not exceed the residential groundwater MSC (MSCgw) for used aquifers, and other regulated substances in groundwater do not exceed the residential MSCgw for a nonuse aquifer, no further site evaluation is required. See Table 1 for groundwater residential values.

For nonresidential receptors, if the levels of chloroform and dibromochloromethane do not exceed the nonresidential MSCgw for used aquifers and other regulated substances do not exceed the nonresidential MSCgw for nonuse aquifers, no further site evaluation is required. No regulated substances were identified as of concern when Occupational Safety and Health (OSHA) endpoints (i.e., permissible exposure limits or PELs) were used with standard worker exposure assumptions. The OSHA-derived screen (USEPA-PA defaults) may be used as an alternate to the default EPA-derived screen when OSHA regulations are fully implemented (e.g., notification, monitoring) and documented in a workplace building. In addition, the permissible exposure limits (PELs) prescribe concentrations that cannot be exceeded during a workday. See Table 2 for groundwater nonresidential values.

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

- Within 100 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).

For a potentially complete pathway, if the groundwater concentrations are less than the J&E PA default screening levels (Table 1 – residential, Table 2 – nonresidential) <u>and</u> the groundwater is greater than or equal to 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 or if groundwater 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}).

The MSC_{IAQ} are found in Table 3 and MSC_{SG} (see SHS definition - soil gas) is a function of the MSC_{IAQ} and a transfer (or attenuation) factor of 0.01, from outside to inside the building.

If MSC_{SG} or MSC_{IAQ} is exceeded for these SHS evaluations, 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} is not exceeded, then no further activity for groundwater is warranted.

<u>Process for Soil</u>

In the Soil IAQ Decision Matrix for SHS (Figure 2), if SPL is encountered beneath or within 100 feet of an inhabited building or below grade occupied space at or above the water table, this moves the process to soil gas sampling or indoor air sampling**. If a site has SPL within 100 feet of the receptor and samples collected at 50 feet from the receptor indicate no SPL, then further soil gas sampling would not be required at the receptor. If SPL is found within 50 feet of the receptor, soil gas would be required at the receptor.** Also, if preferential exposure pathways are present and pass through the source or occur within 30 feet of the source, then the decision matrix requires that soil gas or indoor air sampling be performed.

The following chemicals were identified as COPIACs because their presence in soil even below the $MSC_{soil\ to\ gw}$ for used aquifers may lead to indoor air concerns. **A responsible party needs only to sample and analyze for those constituents pertaining to the particular release at the site that are on the COPIAC list or in Tables 1, 2, 4, 5. If the**

constituent is not listed in the tables and it is found to be a concern at a particular site, then a site-specific analysis should be used. The COPIACs identified in soil based on specific receptors are as follows:

Residential	Nonresidential (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	Carbon tetrachloride Chloroform Dibromochloromethane 1,2-dichloroethane 1,1–dichloroethene (EDC) cis–1,2–dichloroethene trans–1,2–dichloroethene Xylenes Vinyl chloride	None

* The OSHA-derived screen may be used as an alternate to the default EPA-derived screen when OSHA regulations are fully implemented (e.g., notification, monitoring) and documented in a workplace building.

If any of these COPIACs are present at the site or if other volatile constituents exceed the $\text{MSC}_{\text{soil to gw}}$ (Tables 4 & 5) for a used aquifer, a potentially complete pathway exists if an inhabited building is:

- Within 100 feet of a source horizontally, and
- not separated vertically from the source by at least 10 feet of sand or soil-like[1] (fill) 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 nonuse aquifer 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 4 – residential, Table 5 – nonresidential) <u>and</u> the contamination is greater than or equal to five feet from the receptor, then no further IAQ activity for soil is required. The OSHA-derived screen (USEPA-PA defaults) may be

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[1] Soil-like material is defined as a conglomeration of soils and residuals such as ash from the residential burning of wood or coal, incinerator ash, coal ash, slag and dredged material and other similarly sized solid inert material.

used when OSHA regulations are fully implemented and documented in a workplace building. In addition, the permissible exposure limits (PELs) would also prescribe concentrations that cannot be exceeded during a workday.

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}).

The MSC_{IAQ} are found in Table 3 and MSC_{SG} (see SHS definition- soil gas) is a function of the MSC_{IAQ} and a transfer (or attenuation) factor of 0.01, from outside to inside the building.

If MSC_{SG} or MSC_{IAQ} is exceeded for these SHS evaluations, 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} is not exceeded, then no further activity for soil is warranted.

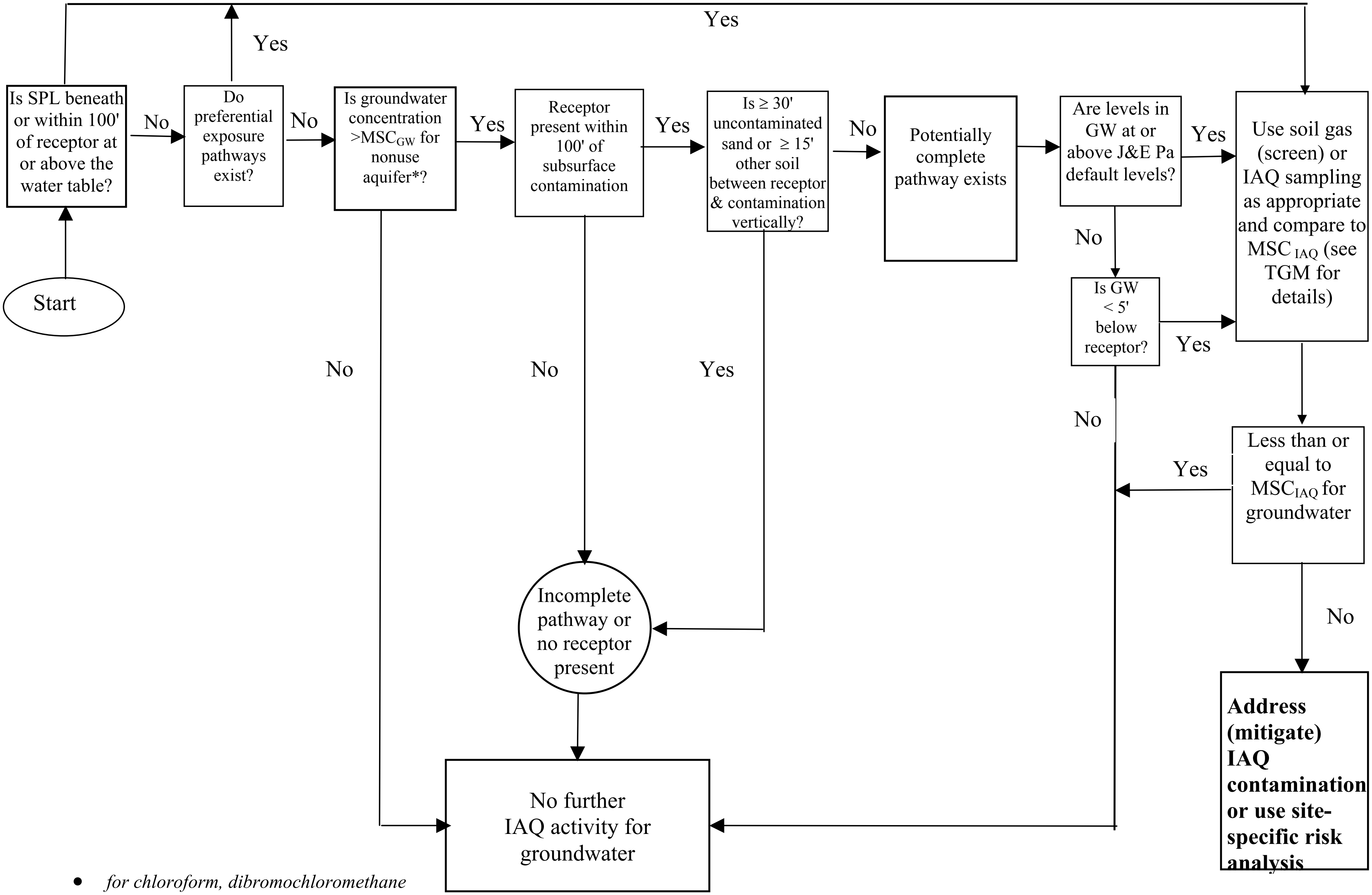
Sampling

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 Table 6. 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). Use caution in taking indoor air samples and interpreting the results in this context.
- Sampling soil gas and indoor air is complex and should be approached with caution. A plan should be developed to assist in addressing data quality objectives before beginning sampling.

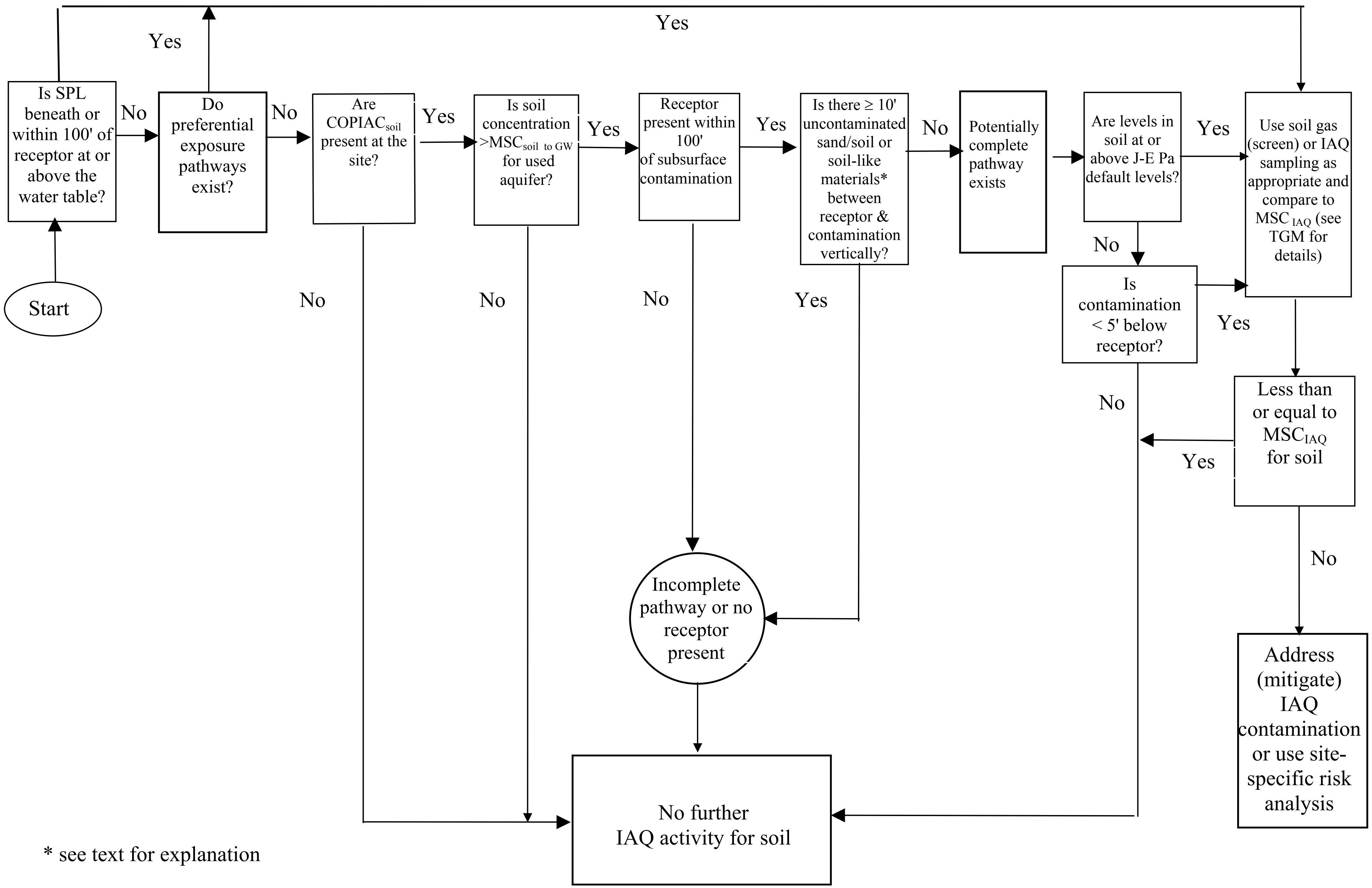
Odors

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}). A comparison of the odor thresholds from literature sources to the corresponding MSC_{IAQ} was done. Except for styrene and toluene, odor thresholds were higher than 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 3).



- *for chloroform, dibromochloromethane and xylene, use MSC$_{GW}$ for used aquifer*

Figure 1. Groundwater IAQ Decision Matrix for SHS



* see text for explanation

Figure 2. Soil IAQ Decision Matrix for SHS

Table 1
Groundwater Screening Criteria (µg/L) for Protection of Indoor Air - Residential

CAS Number	Regulated Substance	Pennsylvania GW MSC Used Aquifer	Pennsylvania GW MSC Nonuse Aquifer	PA Defaults Residential Volatilization to Indoor Air Criteria*
67-64-1	Acetone	3,700	37,000	NOC
107-13-1	Acrylonitrile	0.63	63	NA
78-93-3	2-Butanone (MEK)	2,800	280,000	NA
71-43-2	Benzene	5	500	3,500
75-25-2	Bromoform	100	10,000	182,000
56-23-5	Carbon Tetrachloride	5	50	1,400
108-90-7	Chlorobenzene	55	5,500	27,400
67-66-3	Chloroform	100	**1,000**	**414**
124-48-1	Dibromochloromethane	100	**10,000**	**3,750**
95-50-1	1,2-Dichlorobenzene	600	60,000	NOC
541-73-1	1,3-Dichlorobenzene	600	60,000	NA
106-46-7	1,4-Dichlorobenzene	75	7,500	8090
75-34-3	1,1-Dichloroethane	27	270	15600
107-06-2	1,2-Dichloroethane	5	50	2,770
75-35-4	1,1-Dichloroethene	7	70	362
156-59-2	cis-1,2-Dichloroethene	70	700	42100
156-60-5	trans-1,2-Dichloroethene	100	1,000	59300
78-87-5	1,2-Dichloropropane	5	50	3850
100-41-4	Ethyl benzene	700	70,000	NOC
106-93-4	Ethylene dibromide	0.05	5	NA
75-09-2	Methylene chloride	5	500	77,000
108-10-1	Methyl isobutyl ketone	220	22,000	NA
1634-04-4	Methyl-tert-butyl-ether	20	200	228000
100-42-5	Styrene	100	10,000	NOC
127-18-4	Tetrachloroethylene (PCE)	5	50	42400
79-34-5	1,1,2,2-Tetrachloroethane	0.74	74	3680
108-88-3	Toluene	1,000	100,000	491000
79-01-6	Trichloroethylene	5	50	14300
71-55-6	1,1,1-Trichloroethane	200	2,000	NOC
79-00-5	1,1,2-Trichloroethane	5	50	5350
75-01-4	Vinyl chloride	2	20	1,780
1330-20-7	Xylenes	10,000	**180,000**	**57400**

* 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 2
Groundwater Criteria/Screen (µg/L) for Protection of Indoor Air: Nonresidential (Commercial/Industrial)

CAS Number	Regulated Substance	PA GW MSC Used Aquifer	PA GW MSC Nonuse Aquifer	USEPA-PA Defaults Nonresidential Volatilization to Indoor Air Criteria [1]	USEPA-PA Defaults Nonresidential PELs Volatilization to Indoor Air Screen [2]
67-64-1	Acetone	3,700	37,000	2,300,000,000 (NOC)	NOC
107-13-1	Acrylonitrile	0.63	63	NA	NA
78-93-3	2-Butanone (MEK)	2,800	280,000	NA	NA
71-43-2	Benzene	5	500	9,600	NOC
75-25-2	Bromoform	100	10,000	310,000	NOC
56-23-5	Carbon Tetrachloride	5	50	2,400	NOC
108-90-7	Chlorobenzene	55	5,500	44,000	NOC
67-66-3	Chloroform	100	**1,000**	**610**	NOC
124-48-1	Dibromochloromethane	100	**10,000**	**6,300**	NC
95-50-1	1,2-Dichlorobenzene	600	60,000	720,000 (NOC)	NOC
541-73-1	1,3-Dichlorobenzene	600	60,000	NA	NA
106-46-7	1,4-Dichlorobenzene	75	7,500	2,400.000 (NOC)	NOC
75-34-3	1,1-Dichloroethane	27	270	760,000	NOC
107-06-2	1,2-Dichloroethane	5	50	4,600	NOC
75-35-4	1,1-Dichloroethene	7	70	610	NOC
156-59-2	cis-1,2-Dichloroethene	70	700	59,000	NOC
156-60-5	trans-1,2-Dichloroethene	100	1,000	83,000	NOC
78-87-5	1,2-Dichloropropane	5	50	9,500	NOC
100-41-4	Ethyl benzene	700	70,000	1,800,000 (NOC)	NOC
106-93-4	Ethylene dibromide	0.05	5	NA	NA
75-09-2	Methylene chloride	5	500	130,000	NOC
108-10-1	Methyl isobutyl ketone	220	22,000	NA	NA
1634-04-4	Methyl-tert-butyl-ether	20	200	NA	NA
100-42-5	Styrene	100	10,000	2,700,000 (NOC)	NOC
127-18-4	Tetrachloroethylene (PCE)	5	50	71,000	NOC
79-34-5	1,1,2,2-Tetrachloroethane	0.74	74	6,200	NOC
108-88-3	Toluene	1,000	100,000	690,000 (NOC)	NOC
79-01-6	Trichloroethylene	5	50	24,000	NOC
71-55-6	1,1,1-Trichloroethane	200	2,000	1,300,000 (NOC)	NOC
79-00-5	1,1,2-Trichloroethane	5	50	9,000	NOC
75-01-4	Vinyl chloride	2	20	5,800	2,300,000
1330-20-7	Xylenes	10,000	180,000	740,000 (NOC)	NOC

[1] PA defaults using USEPA J&E Version 2.3; 03/01, Nonresidential receptor, RL = 10-5, HQ = 1

[2] PA defaults using USEPA J&E Version 2.3; 03/01, Nonresidential receptor, PEL>value indicates that risk-based target greater than constituent water solubility; Use this OSHA-derived Screen when OSHA regulations are fully implemented and documented inside a workplace building.

NA Not available
NC Not calculated
NOC Not of concern, value above constituent water solubility

Note: Bold face values indicate a COPIAC

Table 3
Indoor Air Criteria & Odor Thresholds

CAS Number	Regulated Substance	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)
67-64-1	Acetone	43	91	0.37	1188	2400	237
107-13-1	Acrylonitrile	0.00031	0.0012	0.00026	4.3	4.34	46.4
78-93-3	2-Butanone (MEK)	1.4	2.9	1.0	590	590	6
71-43-2	Benzene	0.0027	0.011	0.0022	1.6	3.19	2.7
75-25-2	Bromoform	0.019	0.074	0.016	5.2	5	13
56-23-5	Carbon Tetrachloride	0.0014	0.0055	0.0012	31	62.9	135
108-90-7	Chlorobenzene	0.024	0.051	0.062	46	350	1.0
67-66-3	Chloroform	0.00044	0.00092	0.00077	49		415
124-48-1	Dibromochloromethane	0.00078	0.003	0.00075			
95-50-1	1,2-Dichlorobenzene	0.19	0.41	0.15	150		12-24
541-73-1	1,3-Dichlorobenzene			0.11			0.12
106-46-7	1,4-Dichlorobenzene	0.0033	0.013	0.0028	60	450	180-360
75-34-3	1,1-Dichloroethane	0.013	0.05	0.51	405	400	490-810
107-06-2	1,2-Dichloroethane	0.00081	0.0031	0.00069	40	202.5	24-160
75-35-4	1,1-Dichloroethylene	0.000061	0.00024	0.00036	20		2000-4000
156-59-2	cis-1,2-Dichloroethylene	0.049	0.1	0.037	793	790	0.34
156-60-5	trans-1,2-Dichloroethylene	0.097	0.2	0.073	793	790	0.3357
78-87-5	1,2-Dichloropropane	0.002	0.0079	0.00092	347	350	231
100-41-4	Ethyl benzene	0.019	0.073	0.016	434	435	608
106-93-4	Ethylene dibromide	0.000095	0.00037	0.000082		153.8	192
75-09-2	Methylene chloride	0.044	0.17	0.038	174	86.75	712-1070
108-10-1	Methyl isobutyl ketone	0.097	0.2	0.073	205	410	0.41
1634-04-4	Methyl-tert-butyl-ether	0.041	0.16	0.016	144		0.19-0.69
100-42-5	Styrene	1.4	2.9	1.0	85	426	0.630
127-18-4	Tetrachloroethylene (PCE)	0.0073	0.029	0.0063	170	678	31.7

Table 3
Indoor Air Criteria & Odor Thresholds

CAS Number	Regulated Substance	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)
79-34-5	1,1,2,2-Tetrachloroethane	0.00036	0.0014	0.00031	6.9	35	3
108-88-3	Toluene	0.56	1.2	0.42	188	754	0.64
79-01-6	Trichloroethylene	0.00018	0.00072	0.00016	269	537	115
71-55-6	1,1,1-Trichloroethane	2.9	6.1	2.3	1910	1900	545
79-00-5	1,1,2-Trichloroethane	0.0013	0.0051	0.0011	55	45	
75-01-4	Vinyl chloride	0.0024	0.0095	0.00072	2.5	2.56	664
1330-20-7	Xylenes	0.6	1.3	7.3	434	435	2

* EPA Region III RBCs were adjusted to cancer risk of 10^{-5} or HQ of 1.

Table 4
Soil Screening "Criteria" (mg/kg) for Protection of Indoor Air - Residential

	Chemical	Pennsylvania Soil-GW MSC Used Aquifer Residential	Pennsylvania Soil-GW MSC Nonuse Aquifer Residential	Pennsylvania Direct Contact 0-15 feet Residential	PA Defaults Residential Volatilization to Indoor Air Criteria*)
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	Tetrachloroethylene (PCE)	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**

*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 5
Soil Criteria/Screen (mg/kg) for Protection of Indoor Air: Nonresidential (Commercial/Industrial)

	Regulated Substance	PA Soil-GW MSC Used Aquifer Nonresidential	PA Soil-GW MSC Nonuse Aquifer Nonresidential	PA Direct Contact 0-2 feet Nonresidential	PA Direct Contact 2-15 feet Nonresidential	USEPA-PA Defaults Nonresidential Volatilization to Indoor Air Criteria[1]	USEPA-PA Defaults Nonresidential PELs Volatilization to Indoor Air Screen[2]
67-64-1	Acetone	370	3,700	10,000	10,000	110,000 (NOC)	110,000 (Csat)
107-13-1	Acrylonitrile	0.06	6.30	24.00	28.00	NA	NA
78-93-3	2-Butanone (MEK)	280	10,000	10,000	10,000	NA	NA
71-43-2	Benzene	0.5	50	200	230	1	470 (Csat)
75-25-2	Bromoform	100	10,000	1,500	1,700	120	1,000
56-23-5	Carbon Tetrachloride	**0.5**	5	110	120	**0.12**	440 (Csat)
108-90-7	Chlorobenzene	5.5	550	10,000	10,000	16	310
67-66-3	Chloroform	**10**	100	72	82	**0.079**	2000.000
124-48-1	Dibromochloromethane	**10**	1,000	61	70	**2.20**	NA
95-50-1	1,2-Dichlorobenzene	60	6,000	10,000	10,000	260	260 (Csat)
541-73-1	1,3-Dichlorobenzene	60	6,000	10,000	10,000	NA	NA
106-46-7	1,4-Dichlorobenzene	7.5	750	3,300	190,000	120	120 (Csat)
75-34-3	1,1-Dichloroethane	2.7	27	1,000	1,200	63	1000 (Csat)
107-06-2	1,2-Dichloroethane	**0.5**	5	63	73	**0.62**	1300 (Csat)
75-35-4	1,1-Dichloroethene	**0.7**	7	33	38.00	**0.02**	710 (Csat)
156-59-2	cis-1,2-Dichloroethene	**7**	70	1,900	2,100	**7.60**	840(Csat)
156-60-5	trans-1,2-Dichloroethene	**10**	100	3,700	4,300	**6.40**	1500 (Csat)
78-87-5	1,2-Dichloropropane	0.5	5	85	97	1.20	630 (Csat)
100-41-4	Ethyl benzene	70	7,000	10,000	10,000	170	170 (Csat)
106-93-4	Ethylene dibromide	0.005	0.50	0.93	8.60	NA	-
75-09-2	Methylene chloride	0.5	50	3,500	4,000	13	1900 (Csat)
108-10-1	Methyl isobutyl ketone	22	2,200	4,300	4,900	NA	NA
1634-04-4	Methyl-tert-butyl-ether	2	20	10,000	10,000	NA	NA

Table 5
Soil Criteria/Screen (mg/kg) for Protection of Indoor Air: Nonresidential (Commercial/Industrial)

	Regulated Substance	**PA Soil-GW MSC Used Aquifer Nonresidential**	**PA Soil-GW MSC Nonuse Aquifer Nonresidential**	**PA Direct Contact**		**USEPA-PA Defaults Nonresidential Volatilization to Indoor Air Criteria[1]**	**USEPA-PA Defaults Nonresidential PELs Volatilization to Indoor Air Screen[2]**
				0-2 feet	**2-15 feet**		
				Nonresidential	**Nonresidential**		
100-42-5	Styrene	10	1,000	10,000	10,000	640	640 (Csat)
127-18-4	Tetrachloroethylene (PCE)	0.5	5	1,500	3,300	10	180 (Csat)
79-34-5	1,1,2,2-Tetrachloroethane	0.074	7.4	28	33.00	2.20	1000 (Csat)
108-88-3	Toluene	100	10,000	10,000	10,000	110	230 (Csat)
79-01-6	Trichloroethylene	1	5	970	1,100	3	590 (Csat)
71-55-6	1,1,1-Trichloroethane	20	200	10,000	10,000	88	550 (Csat)
79-00-5	1,1,2-Trichloroethane	0.5	5	100	120	1.90	1000 (Csat)
75-01-4	Vinyl chloride	**0.2**	2	20	22.00	**0.12**	48.000
1330-20-7	Xylenes	**1,000**	10,000	10,000	10,000	**200 (99 = Csat)**	200,000 (99 = Csat)

[1] PA defaults using USEPA J&E Version 2.3; 03/01 , Nonresidential receptor, RL = 10-5, HQ = 1

[2] PA defaults using USEPA J&E Version 2.3; 03/01, Nonresidential receptor, PEL as endpoint>value indicates that risk-based target greater than constituent residual saturation; Use this OSHA-derived screen when OSHA regulations are fully implemented and documented inside a workplace building.

NA - Not available
NC - Not calculated
NOC - Not of concern

Note: Bold face values indicate a COPIAC

TABLE 6

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 be 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 designed 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).

A plan should be developed to assist in addressing data quality objectives before beginning sampling. In a typical sampling plan, multiple samples should be collected over a target time period (e.g., 2 hours to 3 weeks) to determine indoor air concentrations. It is recommended that samples be collected using either a pumped air collection method with adsorbent media tubes or evacuated canisters. For longer term duration (e.g., three weeks), passive diffusion badges suitable for the COPIACs targeted in the study may be used. Tedlar bags are not recommended for sampling of indoor air.

To meet minimum data quality, a field blank and at least one duplicate sample will be needed with each data set submitted for laboratory analysis. Analysis using laboratory equipment (e.g., GC – GC/MS) will be needed to attain the required specificity and sensitivity.

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.

- Define Study Objective
- Identify Chemicals of Concern
- Identify Required Sampling Duration
- Choose Sampling Method

- Check if Adequate Limit of Detection
- Define QA/QC Indicators for Sampling/Analysis
- Do Pre-Sampling Investigation
- Establish Appropriate Sampling Conditions and Conduct Sampling
- Analyze Samples
- 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
- **at least 2 quarterly samples (spring & winter to account for seasonal variations) must be collected during evening hours**
- 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.

Table 7

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		Nonresidential (Onsite Worker)
		Non carcinogens[1]	Carcinogens[2]	
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} = EDxIR/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.

TABLE 8

Summary of Selected PA Input Parameters
EPA's Johnson and Ettinger Model (Version 2.3, 2001)

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
Vadose 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

SHS Definitions for IAQ Decision Matrix

(see Figures 1 and 2)

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 **Nonresidential** 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 do 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 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 <u>Management of Manufactured Gas Plant Sites</u>, 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. 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) 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 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 nonresidential 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.