Vapor-Intrusion Management Plan
Lockheed Martin Middle River Complex
2323 Eastern Boulevard
Middle River, Maryland

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Lockheed Martin Corporation

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ACRONYMS

$\mu g/m^3$	micrograms per cubic meter
AF	attenuation factor
atm-m^3/mol	atmospheres per cubic meter/mole
ca	carcinogenic
DTSC	California Department of Toxic Substances Control
ESH	environment, safety, and health
FID	flame-ionization detectors
HQ	hazard quotient
HVAC	heating, ventilation, and air conditioning
IAQ	indoor air quality
Lockheed Martin	Lockheed Martin Corporation
MDE	Maryland Department of the Environment
MRC	Middle River Complex
MSDS	material safety data sheet
nc	non-carcinogenic
OSHA	Occupational Safety and Health Administration
PCE	tetrachloroethene
PID	photoionization detector
ppm	parts per million
SSD	sub-slab depressurization
STEL	short-term exposure limit
SV	sub-slab vapor
TCE	trichloroethene
TWA	time-weighted average
USEPA	United States Environmental Protection Agency
VI	vapor intrusion
VOC	volatile organic compound

Section 1
Introduction

Vapor intrusion (VI) is the migration of volatile chemicals from the subsurface into the indoor air of buildings above the location of chemical contamination. This document was developed as a resource for personnel at the Lockheed Martin Middle River Complex (MRC) who that need to manage known VI pathways and/or investigate as yet unknown potential VI pathways at the site that may adversely affect facility indoor air quality (IAQ). This document provides a general framework for addressing VI from a program management, technical management, and risk management perspective.

VI should be evaluated as a potential human exposure pathway whenever volatile chemicals are present in soil, soil gas, or groundwater underlying existing structures or has the potential to underlie future buildings. The physical properties of volatile chemicals can result in their migration through unsaturated soil into the indoor air of buildings near zones of subsurface contamination. The United States Environmental Protection Agency (USEPA) defines a chemical as volatile if its Henry's Law constant is 1×10^{-5} atmospheres per cubic meter/mole (atm-m^3/mol) or greater (USEPA, 2002). (Henry's Law constants are calculated to characterize the equilibrium distribution of concentrations of volatile, soluble chemicals between gas and liquid; i.e., the solubility of a gas in a liquid at a particular temperature is proportional to the pressure of that gas above the liquid.)

Volatile organic compounds (VOCs) including such common chemicals as petroleum hydrocarbons (e.g., benzene) and chlorinated solvents (e.g., trichloroethylene [TCE]) are the class of chemicals of greatest interest for this pathway. The USEPA has identified more than 100 chemicals with sufficient volatility and toxicity to pose a theoretical VI hazard (USEPA, 2002). These chemicals should thus be included in any VI investigation or program if they are known to have been used or released at a site, or it might reasonably be assumed that they may have been used or released at a site. Typically, the potential for VI is evaluated during a site investigation.

The site-specific VI risk assessment for the MRC indicates the possible presence of regulatorily unacceptable risks associated with VI; appropriate response actions were implemented to mitigate these risks. Reasonable alternatives are considered when selecting response actions, including passive or active ventilation systems, floor sealants, or other mitigation measures. The potential for VI in future structures should be addressed during design, and any necessary measures to reduce VI included in the design as well as in subsequent construction costs. A typical approach for assessing potential risks posed by the VI pathway, as well as mitigation and remediation options, is summarized below:

Evaluate whether exposure to the vapors poses an acute (immediate) risk to building occupants: This can include both acute health risks and the risk of explosion. For acute risks, field instruments will be used and comparisons made to Occupational Safety and Health Administration (OSHA) short-term and ceiling exposure levels (see Section 4.1). If acute risks from VI are identified, the affected area may need to be evacuated until the risks are mitigated. If no acute risks are identified, a screening level VI evaluation may be conducted.

Conduct a screening level assessment of site contaminants: This evaluation typically involves comparing site soil gas or groundwater data to conservative risk based screening values. If site concentrations are below the screening levels, a low potential for VI risk exists. If contaminant concentrations in affected media exceed risk based screening values, then a site-specific VI model may be evaluated.

Conduct a site-specific VI pathway evaluation: Site-specific data are collected that may include sub-slab soil gas and/or indoor air samples. Multiple lines of evidence may be used to evaluate the magnitude and extent of VI. Depending on the results of the investigation and comparison to site-specific action levels, no further action might be deemed necessary, or perhaps mitigation may be warranted.

Evaluate mitigation/remediation options, if necessary: Mitigation involves techniques that prevent (or minimize) subsurface vapors from entering a building's indoor air from subsurface contamination. Common mitigation measures include installation of a passive venting system, sub-slab depressurization or pressurization devices, sealing cracks, sumps, and other potential preferential pathways, and installing vapor proof membranes. At active facilities, land (or building) use-controls may also be an option to control exposure. Remediation treats and removes chemicals from contaminated subsurface media, such as soil and groundwater. Common remediation options include soil removal, soil gas extraction, and groundwater treatment. Mitigation and remediation may be performed concurrently or individually, depending on site needs.

Section 2
Program Management

As part of VI management at the Middle River Complex, Tetra Tech developed VI-specific action levels and policies/protocols. Similar policies/protocols may already be in effect at the MRC that can be modified or adapted to meet VI management needs. These steps can then be integrated into the facility-level operations program and policies**.**

2.1 SITE VI MANAGER

An on-site person will be assigned as the VI manager at the MRC and provided with sufficient authority to implement the comprehensive VI management plan. Appropriate training and other steps will ensure that the VI manager is familiar with the principles of VI, IAQ, and the elements of the VI management plan. The VI manager will be responsible for the following:

- ensuring that building drawings and records are up to date
- training staff, as necessary
- coordinating monthly building walk-through with tenants
- reviewing with tenants, before work begins, any maintenance and housekeeping plans for their potential VI effects
- reviewing contracts and negotiations with contractors for anything that might increase potential VI, such as drilling through the slab, ventilation changes, and running of conduit from basement locations
- communicating with tenants/occupants about building activities and occupant/tenant responsibilities in managing VI

Key Lockheed Martin personnel, as well as tenant staff, should be identified and assigned clearly defined VI responsibilities. We recommend that each tenant identify their own VI manager(s) so the site VI manager will have specific individuals within the tenant organization to coordinate and communicate. All personnel associated with VI management should understand the fundamentals of both VI and indoor air quality, and be trained as necessary to incorporate management thereof as part of their daily responsibilities. Key Lockheed Martin and tenant personnel who may assist with VI management may include the following parties:

- building managers
- building engineers
- environmental, health, and safety personnel
- heating, ventilation, and air conditioning (HVAC) personnel
- building maintenance personnel

All contractors working on-site will have their proposed work evaluated by VI management personnel at least one month in advance to assess how their proposed tasks might affect potential VI.

2.2 RECORDS

An organized system should be developed to collect and maintain the following building records:

- "as built" blueprints, including modifications to reflect current conditions
- up-to-date drawings of all tenants' build outs and interior renovations
- records of major changes in space use not reflected in original design
- drawings of pressure relationships (i.e. pressurized versus non-pressurized areas)
- operating and maintenance plans and schedules
- inventory of any products or materials that are a potential source of VOCs

Documents that may be useful in organizing these records include:

- construction documents
- commissioning reports
- operating manuals
- HVAC maintenance records
- remodeling and renovation records
- records of equipment modifications/replacements

2.3 SITE WALKS AND THE BASELINE BUILDING AUDIT

As part of VI management, baseline building conditions will be documented, and these records will be updated periodically. A whole-building walk through will be conducted by the site VI manager and tenant representatives to record the status of existing, as well as potential, conduits for sub-slab vapor. Simple measurements of pressure relationships and airflow patterns may help identify locations that may be more susceptible to VI. These measurements will be recorded and kept as a baseline for future comparison. If appropriate, areas where more detailed information may be needed to complete the basic profile can be identified and placed in the baseline audit at a later date. The basic conditions of the building exterior, its mechanical systems, the HVAC design, and occupied spaces will be documented.

Potential problems identified in the baseline audit that might facilitate VI should be rectified as soon as possible (see Section 3). The site VI manager will ask Lockheed Martin to issue appropriate work orders so that the problems can be corrected. Managers should plan and budget for the remediation of major problems requiring significant expenditure. Site walks and audits will be repeated monthly and the results recorded. Any changes in the facility that may affect VI, such as uncovering an area of flooring with cracks or holes, will be documented and reported to the designated site VI manager within 24 hours of discovery.

2.4 WRITTEN POLICY, PLANS, AND PROTOCOLS

Written policies, plans, and protocols are important because they are conducive to minimizing VI and establishing and maintaining good IAQ. Policies can be used to train and guide building personnel as well as guide housekeeping, maintenance, and construction or remodeling activities.

2.4.1 Source Management Protocols

For locations where a source or potential source of VI has been identified, specific written protocols will be established to manage those sources and prevent the creation of possible conduits from the subsurface that might increase potential exposures to sub-slab contaminants through VI. Current known source locations include beneath the Building A Plating Shop and beneath the southern part of the Building C Basement. These protocols are in addition to the ongoing operation and maintenance programs for the sub-slab depressurization (SSD) systems operating at these locations.

Protocols that may be implemented include:

- protocols to provide adequate exhaust ventilation, either localized (e.g. fans and/or venting) or centralized, at all areas with identified or potential sources of VI emissions, to reduce potential airborne concentrations of VI contaminants
- protocols to move personnel away from known source areas or suspected source areas if localized exhaust or additional ventilation cannot be provided to reduce airborne concentrations of VI contaminants below action levels
- protocols to provide for "circulation" of adequate outside air during winter months when doors and windows are closed
- protocols to review all proposed operations to be performed by tenants and contractors near known or suspected source areas by the site VI manager
- protocols to prevent work from being performed in locations with known or suspected VI without authorization by the VI manager
- protocols to ensure that all necessary steps will be taken to prevent breaching of the slab in areas of known or suspected sub-slab sources of contaminants
- protocols to collect IAQ and sub-slab vapor data semi-annually
- protocols to communicate VI information to tenants, contractors, and other site personnel

These protocols can be included as appendices to this document.

2.4.2 Maintenance and Housekeeping Plans

Written maintenance and housekeeping plans will be reviewed to ensure that they include practices to maintain good IAQ and minimize potential VI. Examples of housekeeping protocols include such tasks as prompt clean up of spills and trash, and keeping the areas around mitigation equipment unobstructed and clean. Material safety data sheets (MSDS) for all chemicals used in housekeeping will be reviewed to ensure that they do not contain any of the target compounds associated with VI. The presence of these compounds in the work environment might affect the results of routine sub-slab vapor and indoor air sampling. Examples of maintenance protocols may include such tasks as scheduled maintenance/evaluation of HVAC functions (including equipment, fans, and filters), prompt repair of faulty equipment, and steps to prevent compromising the function of SSD systems.

2.5 COMMUNICATIONS PROGRAM

A communications program will be developed or the current communications program modified to address VI. Specifically, a VI communication program for the MRC site will:

- clarify the responsibilities of facility managers, staff, tenants, and contractors in maintaining a safe and comfortable indoor environment
- respond effectively to potential VI issues and prevent situations that may result in mistrust and misunderstandings
- prevent disruptive and costly remedies by reacting before problems arise
- help occupants improve their work environment through positive contributions

To identify critical areas of responsibility and communication, an understanding of site-specific general responsibilities and communication needs will be developed. Personnel will be provided with information about what they can do to minimize known or potential VI.

2.5.1 Notification of Remodeling and Renovation

As part of the lease agreement, the tenant must notify the site VI manager and Lockheed Martin of any proposed remodeling or renovation in the building at least two weeks before the work begins. Likewise, Lockheed Martin will notify the tenant contact of any major renovation, remodeling, or maintenance that will be performed on site. In each case, the notification should be submitted in writing. It must include the proposed work plan and associated mitigation measures that will be undertaken to minimize potential VI and maintain good IAQ during construction.

2.5.2 Notification of Short-Term Activities Affecting IAQ

Notification procedures will be developed for any activities that could affect VI. Examples of short-term activities include interruption of electrical service that shuts down SSD systems, disruption of HVAC operations that might reduce positive pressures (thereby increasing the potential for VI), and drilling through the slab to install electrical conduit or ventilation ductwork. Tenants and occupants will also be notified about the measures that will be taken during these activities to minimize VI and maintain IAQ.

2.5.3 Feedback

To coordinate and cooperate with tenant operations, tenants will receive advance notice of any VI activities that may occur on-site. These include on-site sampling of environmental media, or the assessment, installation, or expansion of the existing VI-mitigation systems. This advance notice will allow the tenant to shift on-site processes to other locations, to minimize disruption of overall site operations and production.

A procedure to keep the tenant informed of work associated with VI-related activities will be developed. It should describe the activity and the area in which it will be performed. Contact persons and their telephone numbers, as well as the names and phone numbers of individuals to call for more detailed information, will be provided. Progress and the expected length of any on-site work should be identified and included in the notification.

Section 3
Technical Management

3.1 BACKGROUND

This section of the VI management plan addresses the development and application of site-specific risk based action levels that will be used to assess the potential for VI at the MRC, as well as to evaluate when mitigation may be needed or discontinued. These action levels will guide:

- whether additional IAQ and SV monitoring are indicated
- whether mitigation is required
- emergency response

USEPA and Maryland Department of the Environment (MDE) accept that chemical concentrations above a screening/action level do not automatically designate a site as “dirty” or necessarily trigger a response action; however, exceeding a screening/action level suggests that further evaluation of the potential risks posed by site contaminants is appropriate. As such, the action levels to be discussed represent values that will be used to make management decisions regarding the need for additional actions to address potential VI concerns.

3.2 DEVELOPMENT OF VI AND IAQ ACTION LEVELS

The default screening levels for industrial air set forth in EPA’s *Regional Screening Levels for Chemical Contaminants at Superfund Sites* (USEPA, 2009) are currently used to evaluate chemical contaminants in indoor air at the MRC, except for TCE. A summary of the EPA default screening levels for the VI contaminants of concern at the MRC is presented in Table 3-1. The lowest carcinogenic (*ca*) or noncarcinogenic (*nc*) screening level is used to screen the contaminants identified in sub-slab vapor in the semi-annual sub-slab vapor and indoor air sampling event. Although EPA screening levels are defined for a carcinogenic-risk of 1×10^{-6} (one in 1,000,000), carcinogenic risk is evaluated at the 1×10^{-5} risk level at this site in accordance with MDE requirements. For TCE, MDE has specified a screening level of 25 $\mu g/m^3$, at a risk level of 1×10^{-5} (MDE, 2009). A summary of the indoor air screening levels used at this site is presented in Table 3-2.

In the past, these default screening values were used to evaluate historical data collected as part of ongoing investigations at Block I. Sub-slab vapor sampling results were compared to sub-slab vapor screening values, which were derived in accordance with methods discussed in Appendix D of USEPA, 2002. SV screening values were calculated by dividing the default indoor air screening levels (Table 3-2) by a conservative attenuation factor (AF) of 0.1, obtained from USEPA, 2002. An AF represents the factor by which subsurface-vapor concentrations migrating into indoor air spaces are reduced due to diffusive, advective, and/or other attenuating mechanisms.

Exceedance of a screening level indicates a potential risk from VI and that further evaluation is needed. Sub-slab vapor screening values may not reflect actual site conditions because they are based on a default attenuation factor. Site-specific attenuation factors may be higher or lower, which in turn may overestimate or underestimate potential risks. To address this uncertainty and provide the site VI manager with a tool to address potential VI before it reaches levels of potentially regulatorily unacceptable risk, new site-specific action levels for the MRC were developed.

These new action levels incorporate site-specific factors that the existing screening levels lacked. They reflect site conditions at the MRC, since they are based on co-located sub-slab vapor and IAQ sampling data. Where these data are adequate, the new action levels incorporate attenuation factors derived from the co-located data. These site-specific attenuation factors reflect both the characteristics of the chemicals that affect potential VI (i.e., vapor pressure, molecular weight, Henry's Law constant, etc.), as well as the particular building characteristics, such as slab thickness, porosity, ventilation, etc. To calculate the new site-specific action levels for the MRC, EPA and MDE screening values were used in conjunction with chemical- and site-specific attenuation factors. Note that the new action levels are specific to the MRC, and may not be applicable at other locations due to differences in geology, hydrogeology, building characteristics, etc.

3.2.1 Attenuation Factor Calculations

To calculate site-specific action levels for sub-slab vapor and indoor air at the MRC, site-specific attenuation factors (AFs) were calculated (where possible). AFs were calculated using chemical concentrations measured in co-located sub-slab vapor and indoor air samples from the first three rounds of sampling at the MRC. This sample set represents conditions at the MRC before activation of the SSD systems. Since the action levels will ultimately be used to determine whether to shut down the SSD system (and then whether it needs to be reactivated), AFs should represent the site without the influence of a mitigation system. AFs are valid only when migration from SV to indoor air is occurring. An SSD system is designed to minimize this migration.

AFs were calculated by dividing the measured indoor air concentration by the sub-slab vapor concentration for each co-located sample in sampling rounds 1–3. The data sets for all buildings were combined to provide as large a data set as possible to determine site-specific AFs. Table 3-1 presents a summary of the AFs for each chemical. Figure 3-1 includes a flow chart illustrating AF calculation.

The data set from sampling rounds 1–3 was evaluated for possible background effects that might bias the attenuation factors. Indoor air concentrations versus sub-slab vapor concentrations were plotted along with average background concentrations for each chemical. These are shown in Appendix A. For some chemicals, the influence of background concentrations is significant; these are noted in Table 3-3. Also noted in this table is the number of samples where the AF was greater than 1, which indicates a background source of that chemical.

When an AF is greater than 1, the indoor air concentration is greater than the sub-slab vapor concentration. This indicates the presence of some other contributor to the indoor air concentration (e.g., ambient levels in outdoor air or an indoor source of the chemical). Co-located samples with AFs greater than 1 were excluded from the calculations because these samples do not accurately represent vapor intrusion from sub-slab to indoor air. No further adjustments were made to the AFs due to the influence of background concentrations.

Data from sampling rounds 6–8 were evaluated for inclusion in the AF calculations, because data from sampling rounds 1–3 were limited. During rounds 6–8, co-located samples were taken while the SSD system was operational. Although rounds 6–8 had considerably more data, concentrations in the sub-slab vapor were generally several orders of magnitude lower than those observed in sampling rounds 1–3 because the SSD system was operating. The indoor air concentrations measured in rounds 6–8, however, were generally one to two orders of magnitude lower than those measured in rounds 1–3. This resulted in higher AFs (greater than 0.1) for most chemicals. These AFs are not considered representative of vapor intrusion from sub-slab vapor to indoor air, since operation of the SSD system may be influencing the measured concentrations; therefore, data from rounds 6–8 were not used in the site-specific AF calculations.

Results from sampling rounds 1–3 data (Table 3-3) provided sufficient data (i.e., a minimum of five AFs less than 1) to calculate site-specific AFs for only four chemicals: *cis*-1,2-dichloroethene, tetrachloroethene (PCE), TCE, and toluene. Five AFs less than 1 was considered a reasonable minimum number to perform statistical calculations, as fewer AFs would likely result in no differences between the percentiles of the calculated AFs for each chemical. Cumulative distribution functions of the AFs for these chemicals are provided in Appendix A. The 90th percentile AF was selected to calculate the site-specific SV action levels for this site.

For the remaining chemicals, the absence of adequate co-located data (non-detected, blank contaminated, estimated below detection-limits) or other uncertainties and/or lack of quantification in the data set prevented calculation of a site-specific AF. A default AF of 0.01 was assigned to these chemicals. This is a conservative assumption, as an AF of 0.01 is the maximum AF recommended by California Department of Toxic Substances Control (DTSC) (2005) (representing sub-slab to basement vapor intrusion for residential buildings). An AF of 0.01 is also a factor of two greater than the median AF of 0.005 for sub-slab vapor to indoor air in EPA's *Vapor Intrusion Database* (2008).

A range of site-specific AFs (based on comparisons of SV and IAQ contaminant concentrations) was calculated for each contaminant for which sufficient data above method-detection limits were available for both SV and IAQ measurements. The resulting variability in AFs is understandable, given that the samples were collected in several large adjoining buildings with different foundation types, potential pathways for VI, ventilation dynamics, and building sizes, allowing for variation in vapor migration and dispersion within the buildings. Therefore, uncertainty exists in determining a specific correlation between the sub-slab vapor data set and the indoor air data set. Nevertheless, a relationship is expected to exist between the two, since for chemicals such as TCE and cis-1,2-DCE, no other indoor air sources (other than sub-slab vapor intrusion) are known, and because these chemicals appear above detection limits in both media. However, any relationship between SV and IAQ concentrations would be mathematically complex due to the variety of contributing factors; the observed range of ratios between the co-located sub-slab and indoor air samples is consistent with this observation.

To address this inherent variability, the 90th percentile AF was selected for chemicals where the database was considered adequate for such calculations. Using conservative factors to offset uncertainty is a standard practice in risk assessment and risk based decision-making, where assurances that potential risks will not be underestimated are necessary. Notably, the AF selected for TCE (0.008) is essentially comparable to the default value (0.01) selected for evaluating other chemicals for which data are insufficient to allow calculation of site-specific AFs. Consequently, this determination supports the health-protective nature of using an upper percentile of the calculated site-specific AFs.

3.2.2 Sub-Slab Vapor Action Level Calculations

Table 3-4 summarizes the sub-slab vapor action levels and indoor air action levels for all chemicals. Figure 3-1 illustrates the decision logic used to calculate action levels. The sub-slab vapor action levels were calculated by dividing the indoor air action level by the AF.

Site-specific indoor air action levels assume a regulatorily acceptable risk probability of 1×10^{-6} (one in 1,000,000) for carcinogens and a hazard quotient (HQ) of 0.1 for non-carcinogens. These action levels provide an order of magnitude safety factor below the basis on which current health-based screening values were derived (i.e., a factor of 10 below a risk probability of 1×10^{-5}, or a HQ of 1). Sub-slab vapor action levels for this site were determined conservatively by using the 90th percentile AF. This would, in turn, result in sub-slab vapor action levels equal to a regulatorily acceptable risk probability of 1×10^{-6} for carcinogens and a HQ of 0.1 for non-carcinogens. The intent is to calculate sub-slab vapor and indoor air screening values that are sufficiently low so that decisions regarding possible intervention can be made before concentrations reach regulatory thresholds.

3.2.3 Application of Action Levels

As previously discussed, action levels provide site managers with a tool to evaluate the potential for sub-slab vapor intrusion before either sub-slab or indoor air contaminant concentrations could possibly reach a level of concern. Table 3-5 provides a decision matrix for using the action levels. When sub-slab vapor and/or indoor air concentrations exceed the action levels, steps should be taken to further evaluate whether a potentially complete VI pathway exists. Source-management protocols such as those discussed in Section 2 may be implemented, as appropriate, to reduce potential employee exposures.

After further evaluation, any identified areas of concern can be considered for mitigation measures, as further discussed in Section 4. The VI manager will receive the most recent data from semi-annual sub-slab vapor and IAQ sampling, SSD-system monitoring, and any other sampling of sub-slab vapor or IAQ at the MRC, with comparisons to the action levels included so areas of potential concern may be identified and actions taken as necessary. When sub-slab and indoor air concentrations fall below the action levels, decisions can be made regarding cessation of sub-slab depressurization or other modification of active and passive mitigation methods, because the action levels incorporate conservative safety factors.

3.3 SSD SYSTEM SHUTDOWN

When a SSD system has reduced sub-slab contaminant concentrations below the previously discussed sub-slab action levels, and no IAQ samples demonstrate concentrations greater than or equal to the IAQ action levels within the system’s radius of influence, the site VI manager can evaluate shutting down the SSD system. To be eligible for shutdown, a system must demonstrate consistent reduction of sub-slab and indoor air contaminant concentrations within its radius of influence. Sub-slab vapor contaminant concentrations must remain under the action levels for at least one year before the system can be shut down and rebound testing performed.

Measurement of sub-slab vapor while the mitigation system is operating may not adequately indicate what potential sub-slab concentrations will be when the system is turned off. To evaluate the reduction of sub-slab contamination, the semi-annual sub-slab vapor and indoor air quality data will be examined in conjunction with samples of sub-slab vapor collected from the SSD-system influent. Measurement of system influent will provide an average sub-slab vapor contaminant concentration, as it is being drawn from all extraction points and is less likely to be biased by a sample with a highly elevated or highly depressed result. Influent samples may include ambient air, which could dilute contaminant concentrations in the system stream. Once the results of the influent monitoring and sub-slab vapor and IAQ sampling meet the action levels/performance criteria previously described, the system may be shut down to undergo rebound testing.

To perform a rebound test, the SSD system must be shut off and not turned on for a period of three to six months. The objective is to see whether sub-slab vapor and indoor air contaminant concentrations increase (i.e., rebound) after the system is turned off. The actual length of time the system remains dormant depends on site-specific conditions that might reduce the flow of vapor. Thus, at locations with high clay content or tight soils, a longer dormant period may be needed.

At the beginning of the test, samples of sub-slab vapor are collected from background air and from the permanent vapor-monitoring points, along with collection of their co-located IAQ samples. These samples document baseline conditions. After the system has remained off for the test period, samples of sub-slab vapor, indoor air, and background air are collected from the same locations.

If the concentrations of contaminants in sub-slab vapor and indoor air have not increased and are still below action levels, then a decision may be made to remove the system. If the concentrations of contaminants in sub-slab vapor or indoor air have increased from baseline conditions but are still below action levels, then the rebound test should be allowed to continue, as concentrations may continue to increase or merely fluctuate with more time. If the concentrations of contaminants in sub-slab vapor and indoor air have increased and are above action levels, rebound has occurred and the system will need to be reactivated. In this case, monitoring should continue, and the rebound test performed again after monitoring of sub-slab and/or indoor air concentrations produces results below the action levels and demonstrates asymptotic behavior, indicating that the system has reached its maximum removal efficiency.

TABLE 3-1

INDOOR WORKER RISK-BASED SCREENING LEVELS FOR AMBIENT AIR
LOCKHEED MARTIN MIDDLE RIVER COMPLEX
MIDDLE RIVER, MARYLAND

Chemical	CAS Number	Inhalation Unit Risk $(ug/m3)^{-1}$	IUR Ref	Chronic RfC (mg/m^3)	RfC Ref	Carcinogenic SL TR=1.0E-6 (ug/m3)	Noncarcinogenic SL HI=1 (ug/m3)	Screening Level (ug/m^3)
Benzene	71-43-2	7.80E-06	I	3.00E-02	I	1.57E+00	1.31E+02	1.57E+00 ca*
Carbon Tetrachloride	56-23-5	6.00E-06	I	1.00E-01	I	2.04E+00	4.38E+02	2.04E+00 ca
Chlorodifluoromethane	75-45-6	-		5.00E+01	I	-	2.19E+05	2.19E+05 max
Chloroform	67-66-3	2.30E-05	I	9.77E-02	A	5.33E-01	4.28E+02	5.33E-01 ca
Dichlorodifluoromethane	75-71-8	-		2.00E-01	H	-	8.76E+02	8.76E+02 nc
Dichloroethane, 1,1-	75-34-3	1.60E-06	C	-		7.67E+00	-	7.67E+00 ca**
Dichloroethane, 1,2-	107-06-2	2.60E-05	I	2.43E+00	A	4.72E-01	1.06E+04	4.72E-01 ca
Dichloroethylene, 1,1-	75-35-4	-		2.00E-01	I	-	8.76E+02	8.76E+02 nc
Dichloroethylene, 1,2-cis-	156-59-2	-		-		-	-	-
Dichloroethylene, 1,2-trans-	156-60-5	-		6.00E-02	P	-	2.63E+02	2.63E+02 nc
Ethylbenzene	100-41-4	2.50E-06	C	1.00E+00	I	4.91E+00	4.38E+03	4.91E+00 ca
Methyl tert-Butyl Ether (MTBE)	1634-04-4	2.60E-07	C	3.00E+00	I	4.72E+01	1.31E+04	4.72E+01 ca
Methylene Chloride	75-09-2	4.70E-07	I	1.04E+00	A	2.61E+01	4.56E+03	2.61E+01 ca
Naphthalene	91-20-3	3.40E-05	C	3.00E-03	I	3.61E-01	1.31E+01	3.61E-01 ca*
Tetrachloroethylene	127-18-4	5.90E-06	C	2.71E-01	A	2.08E+00	1.19E+03	2.08E+00 ca
Toluene	108-88-3	-		5.00E+00	I	-	2.19E+04	2.19E+04 nc
Trichlorobenzene, 1,2,4-	120-82-1	-		2.00E-03	P	-	8.76E+00	8.76E+00 nc
Trichloroethane, 1,1,1-	71-55-6	-		5.00E+00	I	-	2.19E+04	2.19E+04 nc
Trichloroethane, 1,1,2-	79-00-5	1.60E-05	I	-		7.67E-01	-	7.67E-01 ca**
Trichloroethylene	79-01-6	2.00E-06	C	-		6.13E+00	-	6.13E+00 ca**
Vinyl Chloride	75-01-4	4.40E-06	I	1.00E-01	I	2.79E+00	4.38E+02	2.79E+00 ca
Xylene, P-	106-42-3	-		7.00E-01	C	-	3.07E+03	3.07E+03 nc
Xylene, m-	108-38-3	-		7.00E-01	C	-	3.07E+03	3.07E+03 nc
Xylene, o-	95-47-6	-		7.00E-01	C	-	3.07E+03	3.07E+03 nc

Source: USEPA Regional Screening Level (RSL) Summary Table May 2010

Notes:

ca=Cancer, nc=Noncancer, ca* (Where nc SL < 100 x ca SL),

ca** (Where nc SL < 10 x ca SL),

IUR = inhalation unit risk

max = SL exceeds ceiling limit (see User's Guide), sat=SL exceeds csat

ug/m3 = micrograms per cubic meter

$(ug/m3)^{-1}$ = risk per microgram per cubic meter

RfC = reference concentration

Ref (reference) sources: A = ATSDR; C = California; H = HEAST; I = IRIS; P = PPRTV

SL = screening level; TR= 1.0E-06 is a target cancer risk of 1E-06; HI = 1 is a hazard index of 1.

Starting in Spring of 2008, Region III now relys for its RBC Table updates on the Regional Screening table developed by Oak Ridge National Laboratory under an Interagency Agreement with EPA.

TABLE 3-2

**INDOOR AIR SCREENING LEVELS FOR MRC
LOCKHEED MARTIN MIDDLE RIVER COMPLEX
MIDDLE RIVER, MARYLAND**

Chemical	Screening Level (ug/m^3)	Source
Benzene	1.57E+01	EPA 2010, adjusted for 10^{-5} risk level
Carbon Tetrachloride	2.04E+01	EPA 2010, adjusted for 10^{-5} risk level
Chlorodifluoromethane	2.19E+05	EPA 2010
Chloroform	5.33E+00	EPA 2010, adjusted for 10^{-5} risk level
Dichlorodifluoromethane	8.76E+02	EPA 2010
Dichloroethane, 1,1-	7.67E+01	EPA 2010, adjusted for 10^{-5} risk level
Dichloroethane, 1,2-	4.72E+00	EPA 2010, adjusted for 10^{-5} risk level
Dichloroethylene, 1,1-	8.76E+02	EPA 2010
Dichloroethylene, 1,2-cis-	2.63E+02	Trans-1,2-dichloroethylene used as surrogate
Dichloroethylene, 1,2-trans-	2.63E+02	EPA 2010
Ethylbenzene	4.91E+01	EPA 2010, adjusted for 10^{-5} risk level
Methyl tert-Butyl Ether (MTBE)	4.72E+02	EPA 2010, adjusted for 10^{-5} risk level
Methylene Chloride	2.61E+02	EPA 2010, adjusted for 10^{-5} risk level
Naphthalene	3.61E+00	EPA 2010, adjusted for 10^{-5} risk level
Tetrachloroethylene	2.08E+01	EPA 2010, adjusted for 10^{-5} risk level
Toluene	2.19E+04	EPA 2010
Trichlorobenzene, 1,2,4-	8.76E+00	EPA 2010
Trichloroethane, 1,1,1-	2.19E+04	EPA 2010
Trichloroethane, 1,1,2-	7.67E+00	EPA 2010, adjusted for 10^{-5} risk level
Trichloroethylene	2.50E+01	EPA 2010
Vinyl Chloride	2.79E+01	EPA 2010, adjusted for 10^{-5} risk level
Xylene, P-	3.07E+03	EPA 2010
Xylene, m-	3.07E+03	EPA 2010
Xylene, o-	3.07E+03	EPA 2010

TABLE 3-3

SUMMARY OF ATTENUATION FACTORS BASED ON CO-LOCATED SAMPLING ROUNDS 1-3 (PRE-SSD)[1]
LOCKHEED MARTIN MIDDLE RIVER COMPLEX
MIDDLE RIVER, MARYLAND

Chemical	Number of Co-Located Samples Where Detected in Both Media	Attenuation Factors (AF)				Number of Samples with AF>1[2]	Notes
		Min	Max	50th percentile	90th percentile		
Benzene	6	0.034	0.044	0.041	0.043	3	
Carbon tetrachloride	3	0.095	0.94	0.45	0.845	0	All indoor air concentrations below background levels
Chloroform	4	7.90E-03	0.78	0.21	0.673	0	All indoor air samples J qualified (near detection limit)
Chlorodifluoromethane	*Not analyzed in Rounds 1-3 sampling*						
Dichlorodifluoromethane	2	0.187	0.654	0.420	0.607	0	All indoor air concentrations below background levels
1,1-Dichloroethane	1	1.90E-04	1.90E-04	1.90E-04	1.90E-04	0	
1,1-Dichloroethene	*Not analyzed in Rounds 1-3 sampling*						
1,2-Dichloroethane	*Not analyzed in Rounds 1-3 sampling*						
cis-1,2-Dichloroethene	6	1.30E-06	2.45E-04	4.50E-06	1.68E-04	0	
Trans-1,2-Dichloroethene	0	NA	NA	NA	NA	NA	
Ethylbenzene	5	2.14E-03	0.277	0.081	0.212	0	Indoor air concentrations within 2X background levels
MTBE	4	3.80E-04	0.028	0.002	0.02	0	
Methylene chloride	*Not analyzed in Rounds 1-3 sampling*						
Naphthalene	*Not analyzed in Rounds 1-3 sampling*						
Tetrachloroethene	5	2.31E-03	0.071	0.016	0.07	0	
Toluene	9	0.0379	0.328	0.066	0.232	4	
1,2,4-Trichlorobenzene	0	NA	NA	NA	NA	NA	
1,1,1-Trichloroethane	*Not analyzed in Rounds 1-3 sampling*						
1,1,2-Trichloroethane	*Not analyzed in Rounds 1-3 sampling*						
Trichloroethene	12	1.91E-07	0.655	1.68E-05	0.008	0	
Vinyl chloride	0	NA	NA	NA	NA	NA	
Total Xylenes	3	1.40E-03	0.088	0.017	0.074	1	Concentrations in indoor air at or below background levels.

Notes:

(1) Shaded chemicals have sufficient data (i.e., 5 or more co-located samples) to calculate a site-specific AF.

(2) Samples with AF>1 were excluded from the AF calculations.

TABLE 3-4

SUMMARY OF ACTION LEVELS
LOCKHEED MARTIN MIDDLE RIVER COMPLEX
MIDDLE RIVER, MARYLAND

Chemical	Attenuation Factor (AF)	Sub-Slab Vapor Action Level (ug/m^3)	Indoor Air Action Level (ug/m^3)	Basis for Attenuation Factor
Benzene	0.01	157	1.57	Default
Carbon tetrachloride	0.01	204	2.04	Default
Chlorodifluoromethane	0.01	2,190,000	21,900	Default
Chloroform	0.01	53.3	0.53	Default
Dichlorodifluoromethane	0.01	8,760	87.6	Default
1,1-Dichloroethane	0.01	767	7.67	Default
1,1-Dichloroethene	0.01	47.2	0.47	Default
1,2-Dichloroethane	0.01	8,760	87.6	Default
cis-1,2-Dichloroethene	1.68E-04	156,717	26.3	90th percentile AF from Sampling Rounds 1-3 Data
Trans-1,2-Dichloroethene	0.01	2,630	26.3	Default
Ethylbenzene	0.01	491	4.91	Default
MTBE	0.01	4,720	47.2	Default
Methylene chloride	0.01	2,610	26.1	Default
Naphthalene	0.01	36.1	0.36	Default
Tetrachloroethene	0.07	29.7	2.08	90th percentile AF from Sampling Rounds 1-3 Data
Toluene	0.23	9,522	2,190	90th percentile AF from Sampling Rounds 1-3 Data
1,2,4-Trichlorobenzene	0.01	87.6	0.88	Default
1,1,1-Trichloroethane	0.01	219,000	2,190	Default
1,1,2-Trichloroethane	0.01	76.7	0.77	Default
Trichloroethene	8.05E-03	310	2.50	90th percentile AF from Sampling Rounds 1-3 Data
Vinyl chloride	0.01	279	2.79	Default
Total Xylenes	0.01	30,700	307	Default

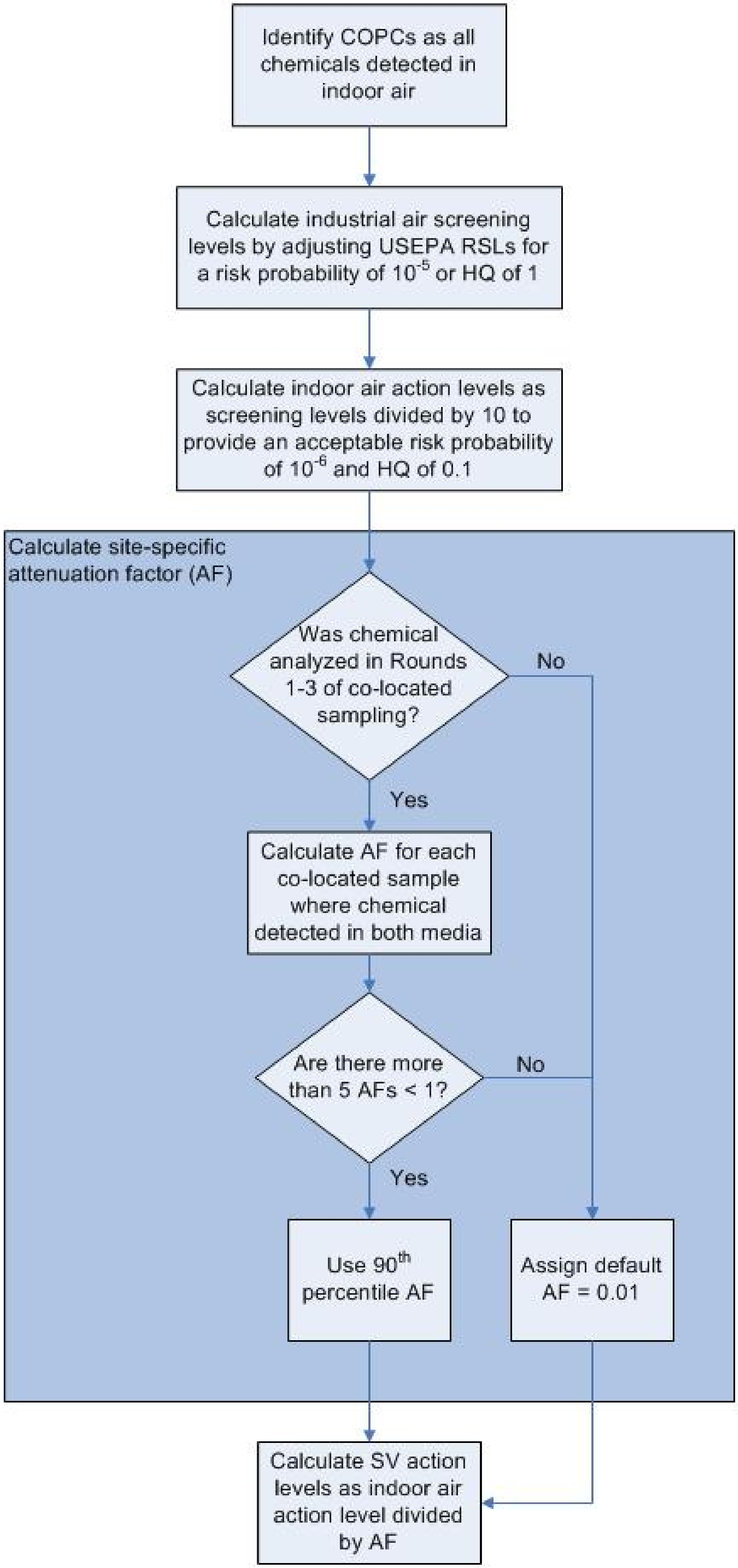
TABLE 3-5

ACTION LEVEL DECISION MATRIX
LOCKHEED MARTIN MIDDLE RIVER COMPLEX
MIDDLE RIVER, MARYLAND

Indoor Air Sampling Results		Sub-Slab Vapor Sampling Results	Response	Activities
Concentrations below Action Levels: Carcinogenic Risk $< 10^{-6}$ Hazard Quotient <1	**AND**	Concentrations below Action Levels: Carcinogenic Risk $< 10^{-5}$ Hazard Quotient <1	None*	Determine sub-slab vapor plume is stable
Concentrations at or slightly above Action Levels: Carcinogenic Risk $\geq 10^{-6}$ but $< 10^{-5}$ Hazard Quotient ≥ 1 but < 3	**OR**	Concentrations at or slightly above Action Levels: Carcinogenic Risk $\geq 10^{-5}$ but $< 10^{-4}$ Hazard Quotient ≥ 1	Semi- Annual Monitoring	Collect additional data: sub-slab vapor, indoor air samples
Concentrations much higher than Action Levels: Carcinogenic Risk $> 10^{-5}$ Hazard Quotient >3	**OR**	Concentrations much higher than Action Levels: Carcinogenic Risk $> 10^{-4}$ Hazard Quotient >3	Mitigation	Institute engineering controls and continue monitoring

* Based on two consecutive semi-annual rounds with all results below action levels.

Figure 3-1
Action Level Calculation Flow Chart
Lockheed Middle River Complex
Middle River, Maryland



Section 4
Management of Potential Vapor-Intrusion Risks

If potentially regulatorily unacceptable risk from VI is identified, it must be appropriately managed. Early planning for this will assist in making informed site-management decisions. In managing potential risk from VI, the results of indoor air and sub-slab investigations are integrated with other considerations, such as economic or legal concerns, to identify the need for mitigation, a remedial action, or to implement other risk reduction activities. Additional factors such as regulatory requirements, technical implementability, and employee/tenant acceptance must also be considered when making risk management decisions.

An important distinction needs to be made between *remediation* and *mitigation*. *Remediation* refers to the treatment, removal, and reduction in the amount of contaminants at a site. *Mitigation* means taking measures to minimize or reduce exposure to the conditions as they currently exist. Mitigation, by itself, typically does not have any direct effect on the contaminant source area.

4.1 MANAGEMENT OF POTENTIAL ACUTE RISKS

Acute risks are those that may result in immediate harmful effects. At the MRC, the potential for acute risks from VI may be increased through a number of possible scenarios, including the intentional breaching of the facility slab in areas where sub-slab contamination is present, or through incidental cracking. Under such circumstances, the VI manager should contact ESH personnel to determine the best course of action.

By its nature, management of acute risk from VI requires a rapid response. Possible responses for acute risk include vacating the premises to eliminate exposure or providing additional localized ventilation. Immediate action is especially important when potentially explosive gases are present, such as petroleum hydrocarbons. Where the possibility of explosive hazards exists, facility security, facility firefighting, the local fire department, and/or regulatory authorities should be alerted.

Monitoring programs to manage potential acute risks will rely on direct reading instruments such as photoionization detectors (PIDs) and/or flame ionization detectors (FIDs). (If a PID is used, make sure that a lamp of appropriate photon energy is selected for the sub-slab vapor and indoor air chemicals of concern.) The direct reading instruments cited have varying degrees of response to different chemicals, so action levels must be developed accordingly based on instrument response.

Table 4-1 contains action levels to be used during acute events. These levels are based on federal Occupational Safety and Health Administration (OSHA) short-term exposure limits (STELs) and 8-hour time-weighted averages (TWAs), which are more appropriate for screening acute exposures than the EPA screening levels, which are based on chronic exposure scenarios. (Note that the units in Table 4-1 are in parts per million [ppm] and not micrograms per cubic meter as ppm is the concentration unit most commonly used in field instruments.)

The location(s) where the slab has been compromised should be monitored to identify whether sub-slab contamination is migrating into the occupied space. The occupied space should also be monitored to assess airborne (breathing zone) concentrations of sub-slab vapor contaminants. If action levels are exceeded, then the area will need to be vacated until mitigation measures (localized ventilation) are implemented.

4.2 MANAGEMENT OF POTENTIAL CHRONIC RISKS

If the results of sub-slab vapor and/or indoor air monitoring indicate that potential chronic risks are regulatorily unacceptable, steps will be taken as part of a risk management strategy to address these potential risks. Steps that may be taken range from mitigation of building parameters to remediation of groundwater and soil contamination. Several options for mitigation of potential chronic risks include:

- ***Sealing cracks/annular spaces around utilities, the floor/wall intersection, and/or cracks in basement floor:*** This is done using epoxy-based sealants that are impenetrable to vapors. Although this approach may help reduce the flux rate at specific locations, it may be inadequate to eliminate vapor intrusion over a large slab.

- ***Sealing and venting groundwater sumps:*** Many buildings with basements have sumps intended to capture any unexpected water release (flooding, burst hose, etc.). These sumps are dug into the ground below the rest of the foundation and may serve as an easy access point for vapors. Sealing and venting them maintains their function while preventing VI.

- ***Vapor barriers beneath the building:*** Vapor barriers can be plastic or geotextile sheeting or perhaps a sealant applied directly to the foundation or basement wall. Barriers are more easily installed during building construction than during a retrofit. This technique is often used in conjunction with active mitigation systems at sites with known contamination. Damage to even a small portion of the barrier during installation can result in significant leakage across the barrier.

- ***Reducing basement depressurization by ducting in outside air for furnace combustion:*** For furnaces in basements, bringing outside air into the furnace decreases the pressure differential across the slab. Lowering the pressure in a basement lessens the pull on subsurface vapors.

- ***Over-pressurization of the building using air/air heat exchangers:*** This technique creates a positive pressure in the building by supplying more outdoor air to the inside than the amount of air exhausted. To work effectively, buildings should be tightly sealed and have a ventilation system capable of producing the output needed to maintain the pressure differential. This may only be viable for limited portions of the Block I at the MRC due to the high use of natural ventilation through open doors and bays.

- ***Passive or active sub-slab depressurization systems:*** This technique creates a relatively low pressure beneath the building foundation; this low pressure is greater in strength than the pressure differential that exists between the building and the soil. Low-pressure zones created beneath the slab reverse the flow direction so that air is drawn from inside the building and into the soil, thus preventing vapors from migrating into the structure. Passive and active systems are very similar in design; the only real difference is inclusion of a powered fan to create a low-pressure zone for the active system. A passive depressurization system may not be particularly effective because it lacks any means of actively moving vapors, relying instead on natural thermal and wind effects to move the soil gas from the collection zone to the external vent.

Mitigation techniques may be used individually or they may be used in combination as part of an overall plan.

Monitoring programs to assess potential chronic risks from VI are similar to the current semi-annual sampling and analysis of sub-slab vapor and indoor air. The existing program can be expanded to address any newly identified areas of concern. Should mitigation steps not meet the goal of reducing sub-slab and indoor air contaminant concentrations to regulatorily acceptable levels, remediation of affected media will be required.

Removing the source of vapors is often the preferred remediation strategy at VI sites. Greater short-term effects may be seen with soil removal and soil vapor extraction, as they either eliminate or reduce the source of contamination or intercept the contaminated soil gas, thereby reducing potential exposure. Groundwater remediation is a long-term option that typically takes years or decades before cleanup goals are met.

Implementing both a remediation and a mitigation strategy at the site may be necessary. For example, if potential risks are high enough in currently occupied spaces, then some kind of mitigation measure is needed to immediately reduce exposure. However, since mitigation does not affect the source concentration, a remediation strategy may also be needed so that the source mass and long-term risks can be reduced.

The possible effects of remedial alternatives on VI should also be considered. Certain groundwater remedies may change the chemical conditions of the subsurface, which may in turn increase the possibility of VI. Degradation products may be produced that have more stringent risk screening levels than their parent compounds. These possibilities should be considered as part of risk management project planning.

In addition to mitigation and remediation, other risk management strategies, including land use and building use controls, may be implemented. If possible, areas of high potential risk should be vacated and personnel moved to locations where potential risks are lower. Similarly, property that is located over a contaminant plume should not be developed unless mitigation measures are included to address potential future risks from VI.

Land-use controls and institutional controls are common tools for limiting access and/or development. Institutional controls may be applied at undeveloped sites or sites where land use may change in the future. Institutional controls may be necessary to ensure that the VI pathway is effectively addressed in the future. Institutional controls may include requirements to install engineering controls on buildings to mitigate potential VI pathways. Institutional controls might also limit certain kinds of land use (such as residential use) that might be associated with regulatorily unacceptable health risks. Engineering controls implemented as a part of institutional controls will require operations and maintenance to retain their effectiveness.

4.3 EXIT STRATEGY

An exit strategy is an important component of the VI management plan. An exit strategy is a plan for reducing potential risk from VI to a level where no further remedial action or mitigation is needed. Monitoring may continue to verify that response actions were effective in reducing potential risks to regulatorily acceptable levels. When this status is achieved, the site will no longer require active management.

The exit strategy will incorporate the previously discussed action levels to clearly identify that the site no longer poses a regulatorily unacceptable VI risk. An exit strategy should be developed early in a VI project so site management and regulators can agree as to when potential risks at a site have been adequately mitigated. Factors to be considered in an exit strategy include mitigation and/or remediation techniques, final cleanup goals, land use, and possible future building construction or land use.

4.4 COMMUNICATION OF POTENTIAL RISK

A critical aspect of VI projects/management is to communicate information regarding potential risks with building occupants as well as with management and regulatory agencies. VI is a relatively new and unfamiliar concept and with considerable potential to raise concerns among site occupants. Factors associated with VI contribute to the likelihood that workers will perceive a high level of risk, such as the unfamiliarity of the pathway and potential risks, an assumed lack of control over the potential risk, and potential harm from the exposure, no matter what investigations and monitoring may find.

Sampling for VI and remedial actions can be invasive to building occupants because it can involve drilling through floors, the presence of obtrusive equipment, and excavation. This has the potential to alarm building occupants and may raise health concerns. VI issues occur indoors, where people work, so workers' input, understanding, and cooperation can significantly affect assessment or mitigation activities.

Risk communication practices and principles should be followed at every step throughout a project, from planning to follow up communication after the project concludes. Effective risk communication is based on building, maintaining, and/or repairing relationships with potentially affected individuals that can influence program success. Early involvement of workers and tenants is critical.

Too often, risk communication is seen as something that takes place after the fact, when all the important decisions have already been made. This approach often produces negative outcomes, because affected individuals feel that they were not informed and involved early on, and can create unnecessary difficulties in completing assessments and implementing solutions. If tenants and employees are not informed of the steps leading to conclusions, they are very likely to regard study conclusions skeptically, and trust and credibility will be lost.

Such a scenario may lead to protracted disagreement about what was done at the site, what the results mean, and the correct path forward. Corporate or outside communication staff shall be consulted before any meeting or presentation to facility employees or tenants. Educational materials that incorporate risk management principles may be generated by communications personnel to assist in delivering a consistent message and providing clear, effective responses to questions from interested parties.

TABLE 4-1

ACTION LEVELS FOR ACUTE EXPOSURE
LOCKHEED MARTIN MIDDLE RIVER COMPLEX
MIDDLE RIVER, MARYLAND

Chemical	CAS #	Occupational Exposure Limit (OEL)	OEL Reference	Can this chemical be monitored by a FID?	Can this chemical be monitored by a PID (RAE)?	Lamp strength for PID (eV)	# of Exposures allowed in any one work day	Time per Exposure (mins)	PID ACTION LEVEL/ INSTRUMENT READING (ppm)	FID ACTION LEVEL/ INSTRUMENT READING (ppm)
1,1,1-Trichloroethane	71-55-6	450	ACGIH 15 min STEL	yes	yes	11.7	1	3	2250	350
1,1-Dichloroethane	75-34-3	100	OSHA TWA8	yes	no	NA	1	3	NA	3750
1,1-Dichloroethene	75-35-4	5	ACGIH TWA8	yes	yes	10.6	1	3	650	45
1,2-Dichloroethane	107-06-2	100	OSHA Ceiling	yes	yes	11.7	1	any	60	80
1,2-Dichloroethene - cis	156-59-2	200	OSHA TWA8	yes	yes	10.6	1	3	22000	2400
1,2-Dichloroethene - trans	156-60-5	200	OSHA TWA8	yes	yes	10.6	1	3	14000	2400
Benzene	71-43-2	2.5	ACGIH STEL	yes	yes	10.6	1	3	6.5	2.75
Carbon Tetrachloride	56-23-5	25	OSHA Ceiling	yes	yes	11.7	1	any	42	2.5
Chlorodifluoromethane	75-45-6	1000	ACGIH TWA8	yes	no	NA	1	3	NA	64000
Chloroform	67-66-3	50	OSHA Ceiling	yes	yes	11.7	1	3	175	32
Dichlorodifluoromethane	75-71-8	1000	OSHA TWA8	yes	no	NA	1	3	NA	24000
Ethylbenzene	100-41-4	125	ACGIH STEL	yes	yes	10.6	1	3	325	625
Methyl tert-Butyl Ether (MTBE)	1634-04-4	40	ACGIH TWA8	no	yes	10.6	1	3	5575	NA
Methylene Chloride	75-09-2	125	OSHA 15 minute STEL	yes	yes	11.7	1	3	445	90
Naphthalene	91-20-3	100	OSHA TWA8	no	yes	10.6	1	3	6500	N/A
Tetrachloroethylene	127-18-4	200	OSHA Ceiling	yes	yes	10.6	1	any	114	140
Toluene	108-88-3	300	OSHA Ceiling	yes	yes	10.6	1	any	150	330
Trichlorobenzene, 1,2,4-	120-82-1	5	ACGIH Ceiling	no	yes	10.6	1	any	2.3	NA
Trichloroethane, 1,1,2-	79-00-5	10	OSHA TWA8	yes	yes	11.7	1	3	1400	1300
Trichloroethene	79-01-6	200	OSHA Ceiling	yes	yes	10.6	1	any	108	140
Vinyl Chloride	75-01-4	5	OSHA 15 minute Ceiling	yes	yes	10.6	1	3	50	1.25
Xylene	106-42-3	150	OSHA 15 minute STEL	yes	yes	10.6	1	3	290	120

ACGIH - American Conference of Governmental Industrial Hygienists
15 min STEL - 15 Minute Short Term Exposure Limit
OSHA Occupational Safety and Health Adminstration Eight Hour Time Weighted Average
TWA 8 -Eight Hour Time Weighted Average
Ceiling - Ceiling Limit
FID - flame ionization detector
PID - photo ionization detector
any - instantaneous exposure requiring immediate exit

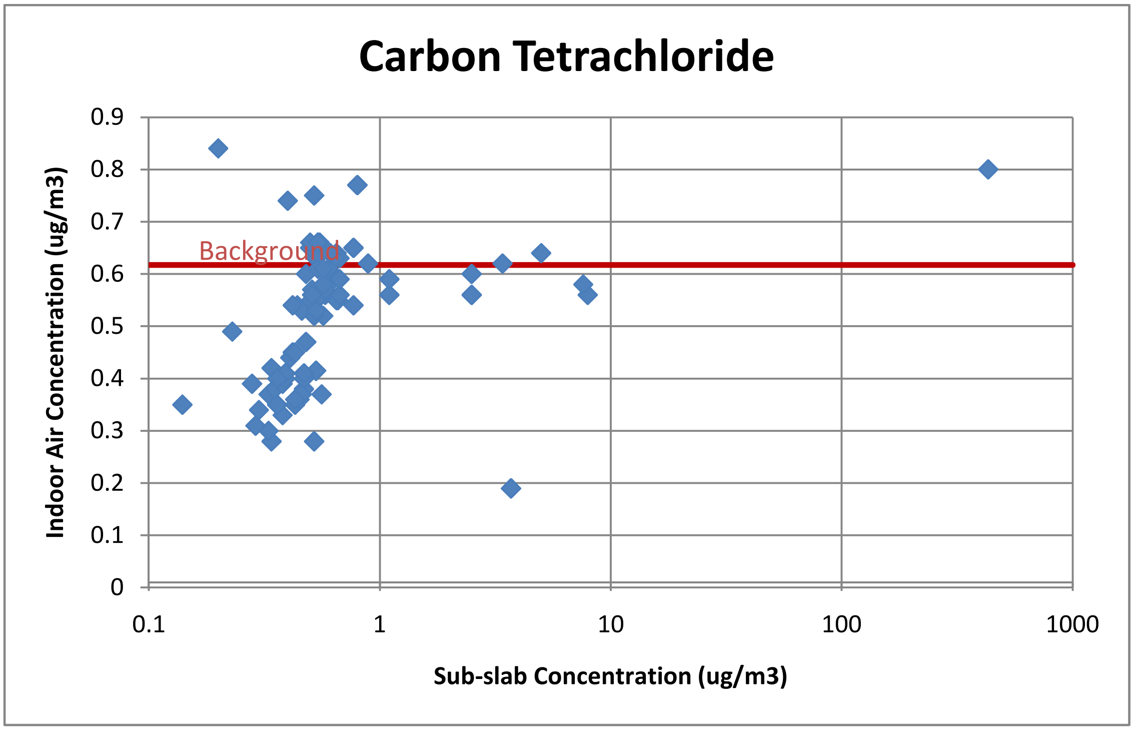
Section 5
References

1. MDE (Maryland Department of the Environment), 2009. Conversation among Mark Mank (MDE), Tetra Tech, and Lockheed Martin. June.

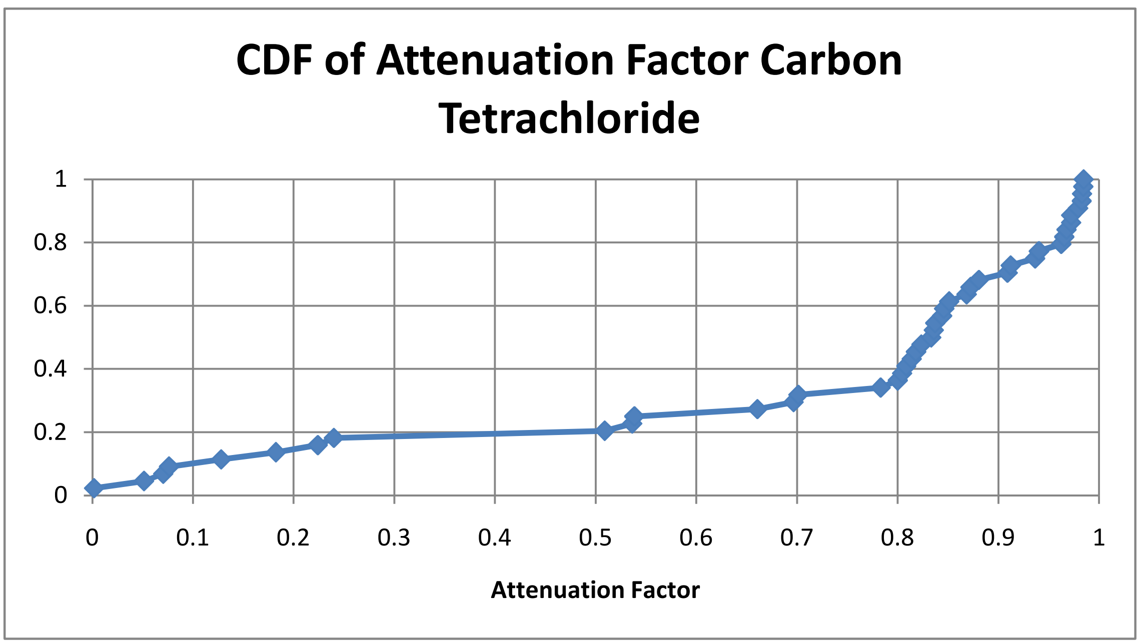
2. USEPA (United States Environmental Protection Agency), 2002. "Draft Guidance for Evaluating the VI to Indoor Air Pathway from Groundwater and Soils (Docket ID No. RCRA-2002-0033)," *Federal Register*: November 29, 2002 (Volume 67, Number 230).

3. USEPA (United States Environmental Protection Agency), 2010. *Regional Screening Levels for Chemical Contaminants at Superfund Sites*. EPA Office of Superfund and Oak Ridge National Laboratory. May.

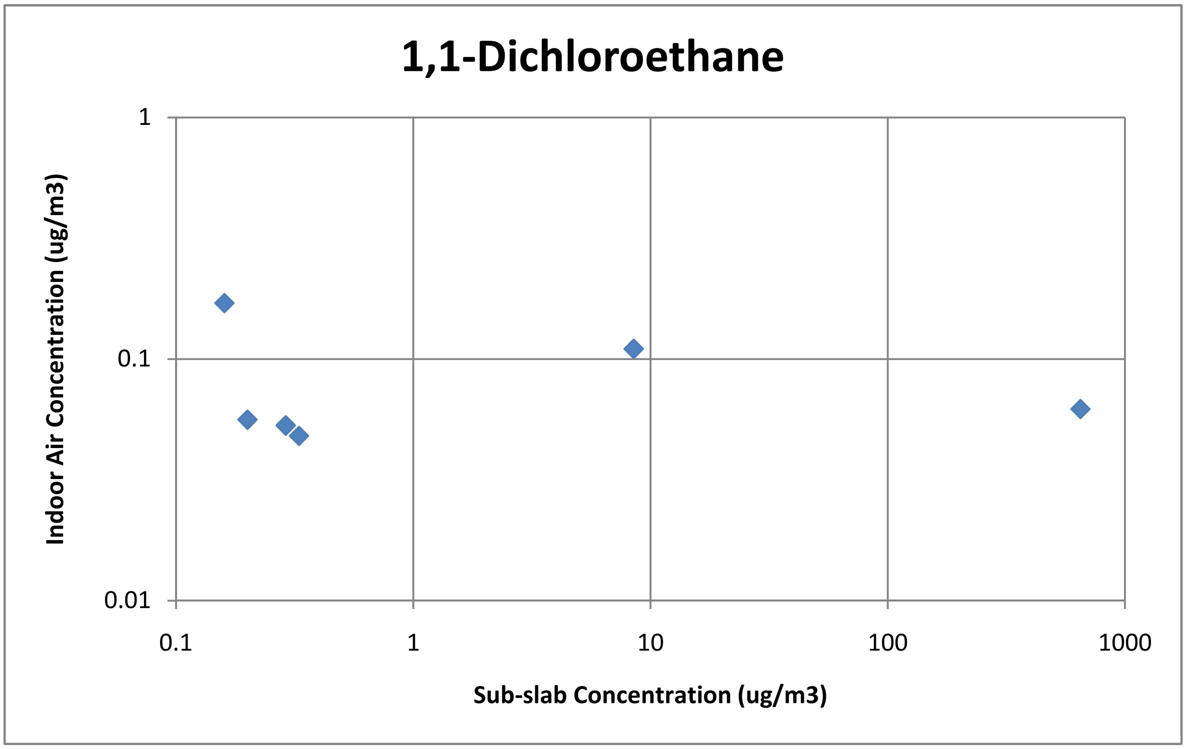
APPENDIX A—SUPPORTING PLOTS FOR ATTENUATION FACTOR CALCULATIONS

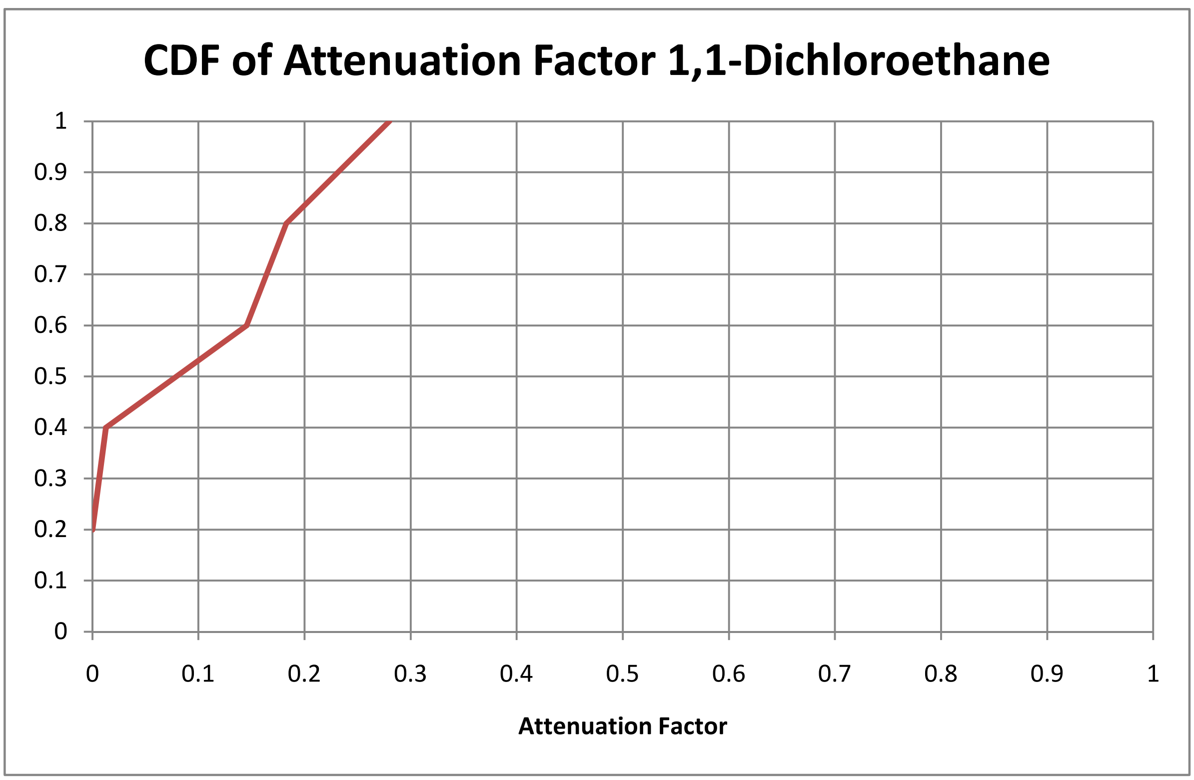


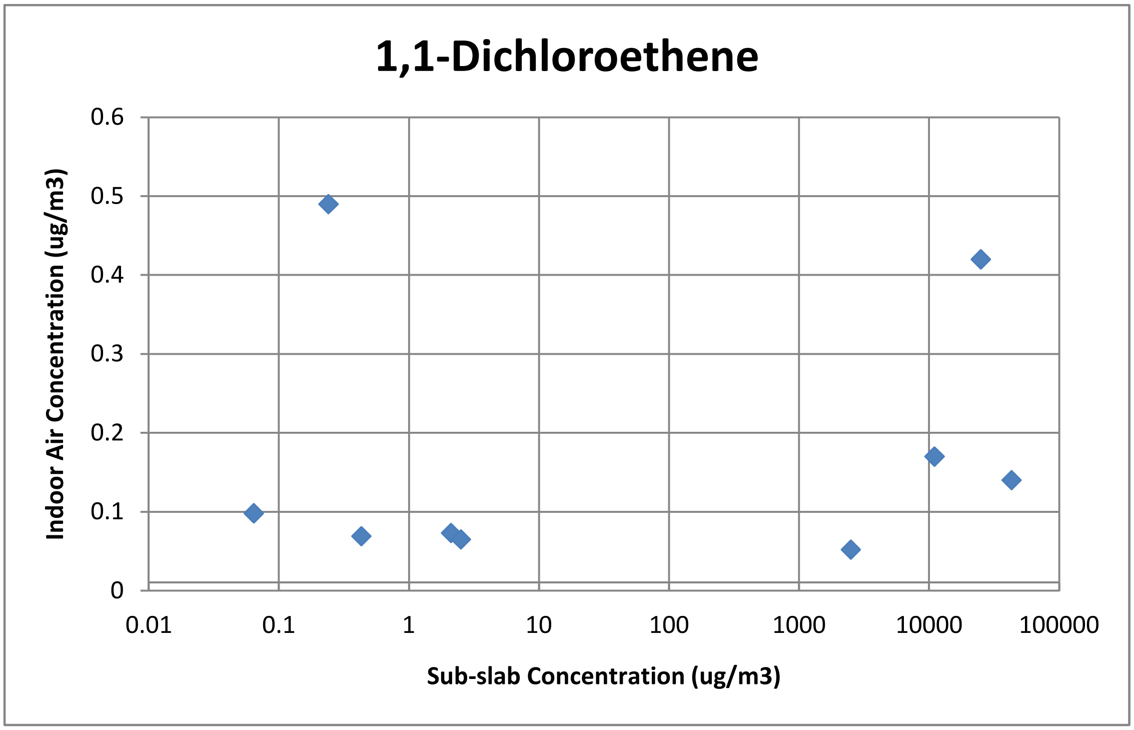
Carbon Tetrachloride
Indoor Air Concentration (ug/m3)
Background
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0.1
1
10
100
1000
Sub-slab Concentration (ug/m3)

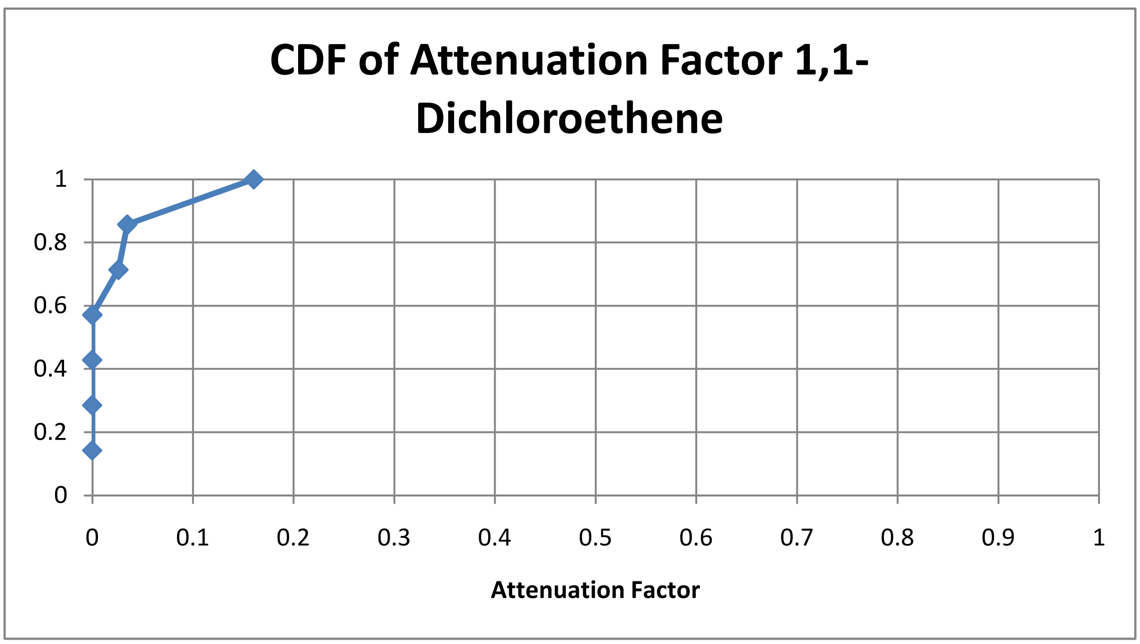


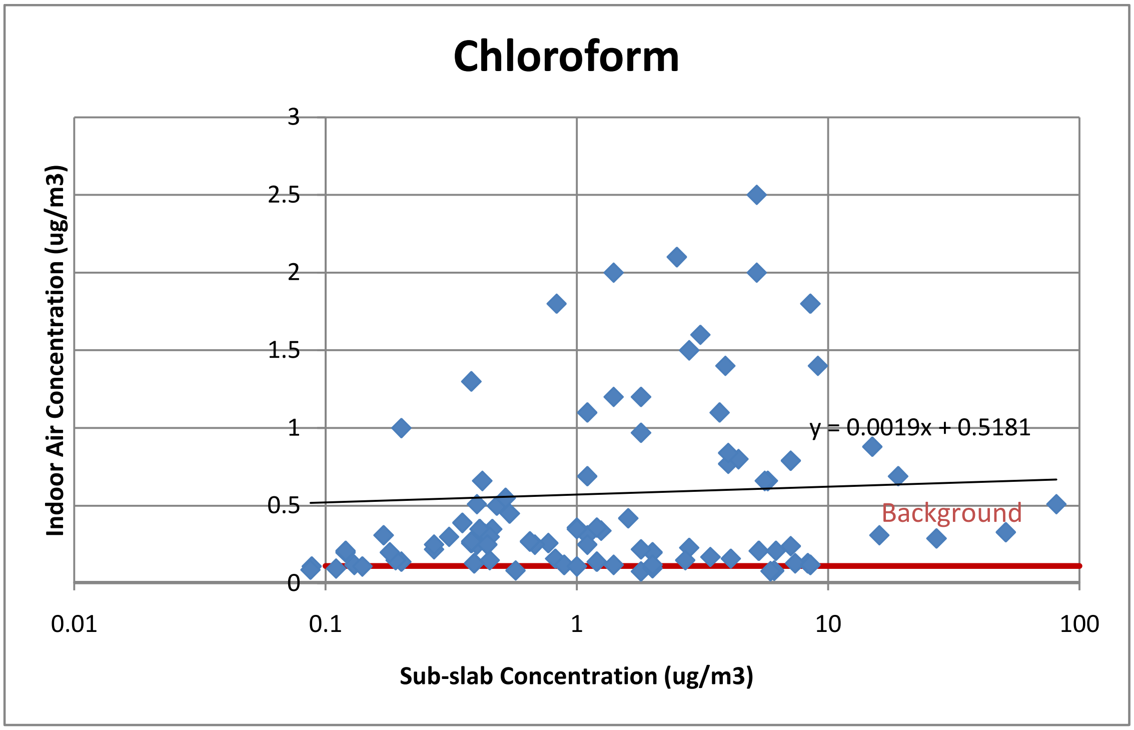
CDF of Attenuation Factor Carbon Tetrachloride
1
0.8
0.6
0.4
0.2
0
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Attenuation Factor

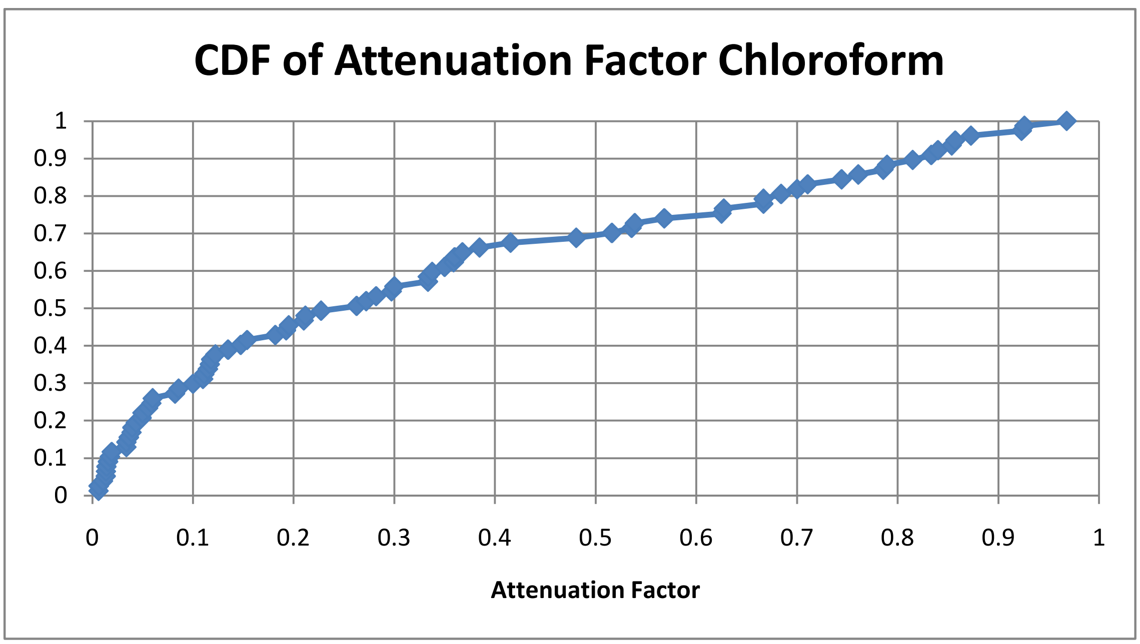

1,1-Dichloroethane
Indoor Air Concentration (ug/m3)
1
0.1
0.01
0.1
1
10
100
1000
Sub-slab Concentration (ug/m3)

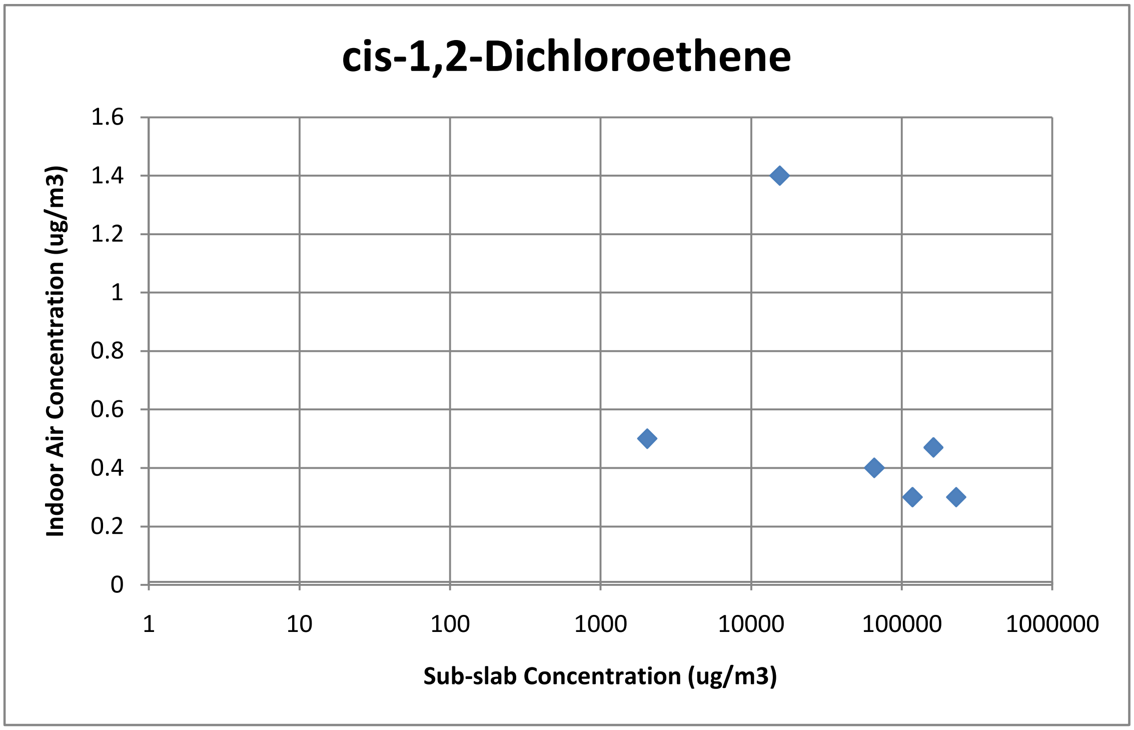

CDF of Attenuation Factor 1,1-Dichloroethane
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Attenuation Factor


1,1-Dichloroethene
Indoor Air Concentration (ug/m3)
0.6
0.5
0.4
0.3
0.2
0.1
0
0.01
0.1
1
10
100
1000
10000
100000
Sub-slab Concentration (ug/m3)

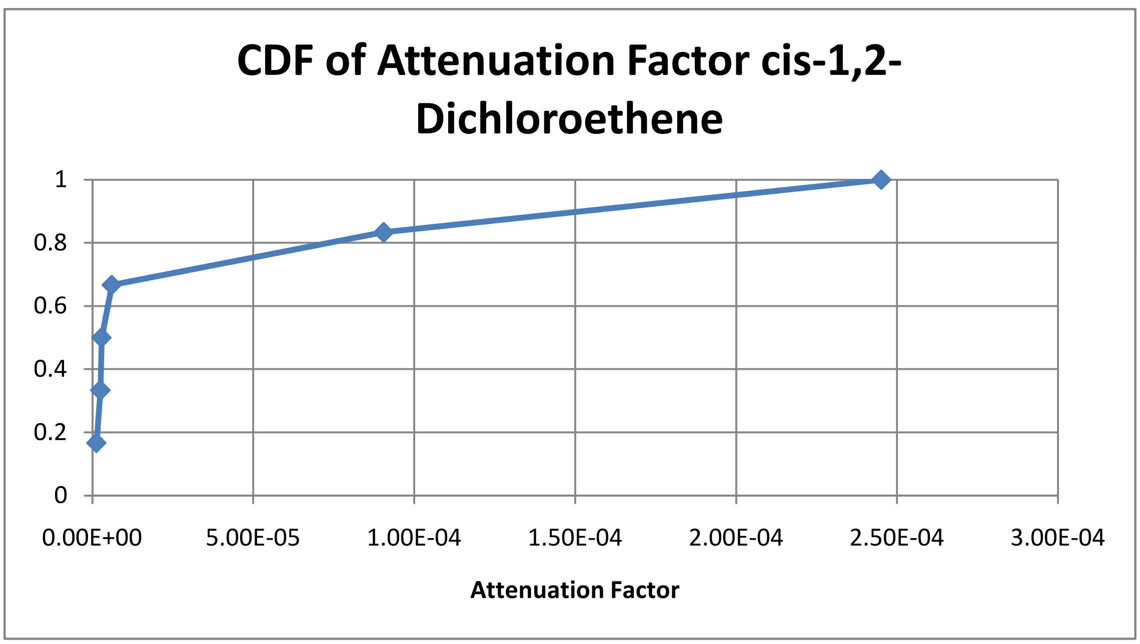

CDF of Attenuation Factor 1,1-Dichloroethene
1
0.8
0.6
0.4
0.2
0
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Attenuation Factor


Chloroform
Indoor Air Concentration (ug/m3)
Sub-slab Concentration (ug/m3)
y = 0.0019x + 0.5181
Background
0
0.5
1
1.5
2
2.5
3
0.01
0.1
1
10
100

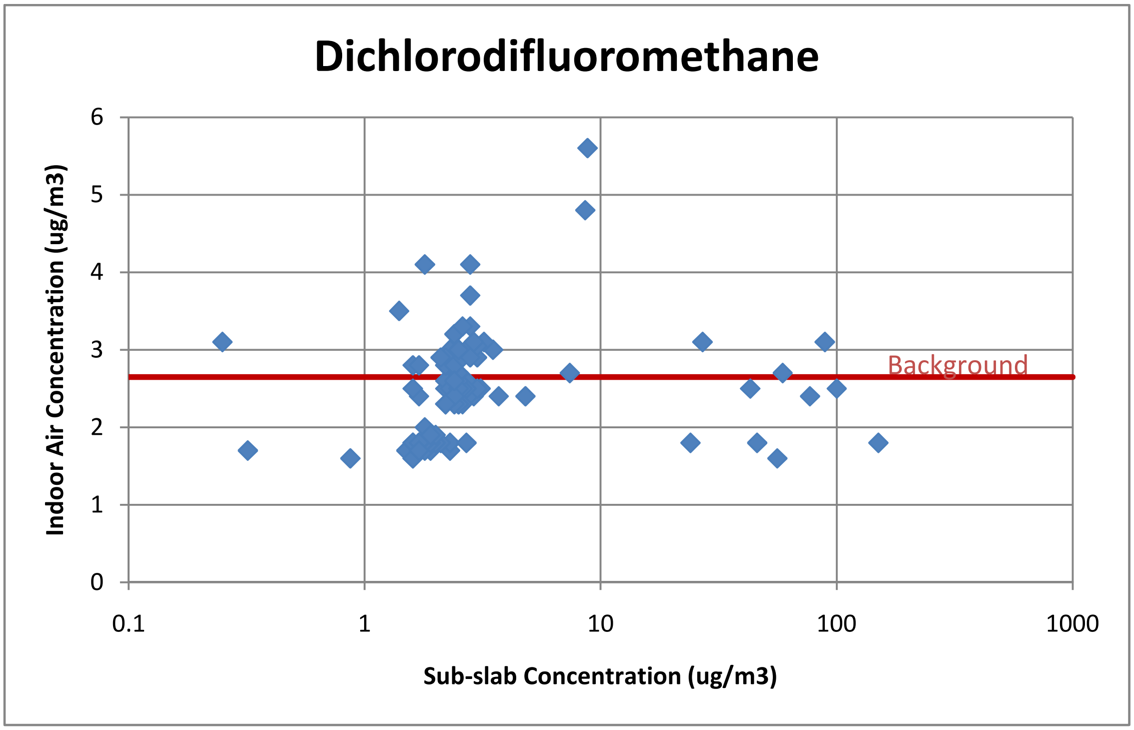

CDF of Attenuation Factor Chloroform
Attenuation Factor
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1



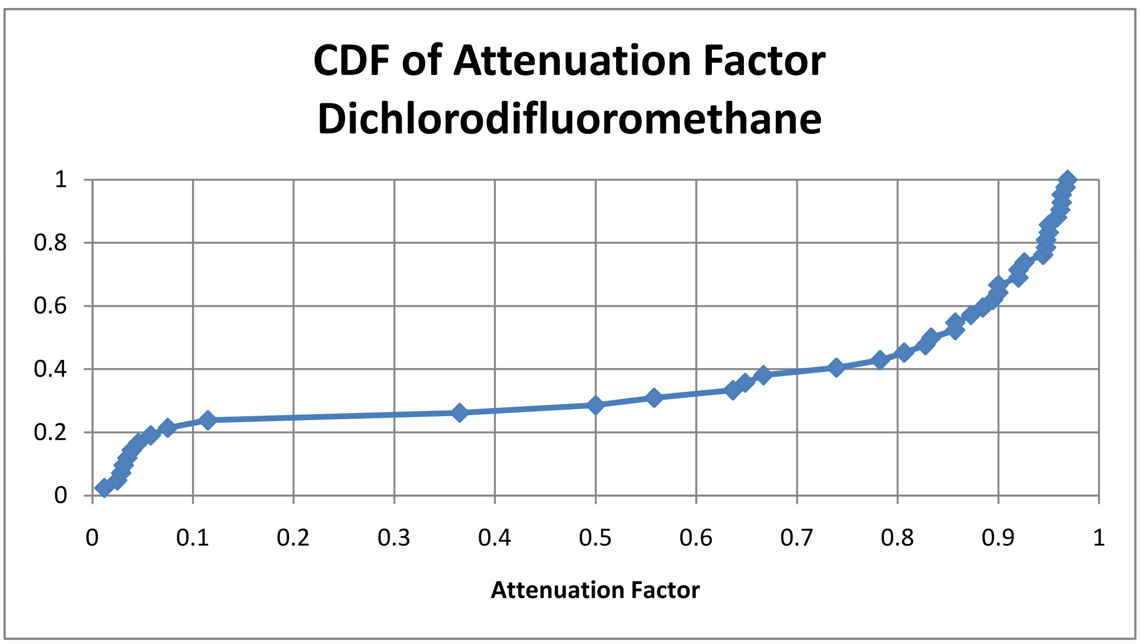
cis-1,2-Dichloroethene
Indoor Air Concentration (ug/m3)
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1
10
100
1000
10000
100000
1000000
Sub-slab Concentration (ug/m3)



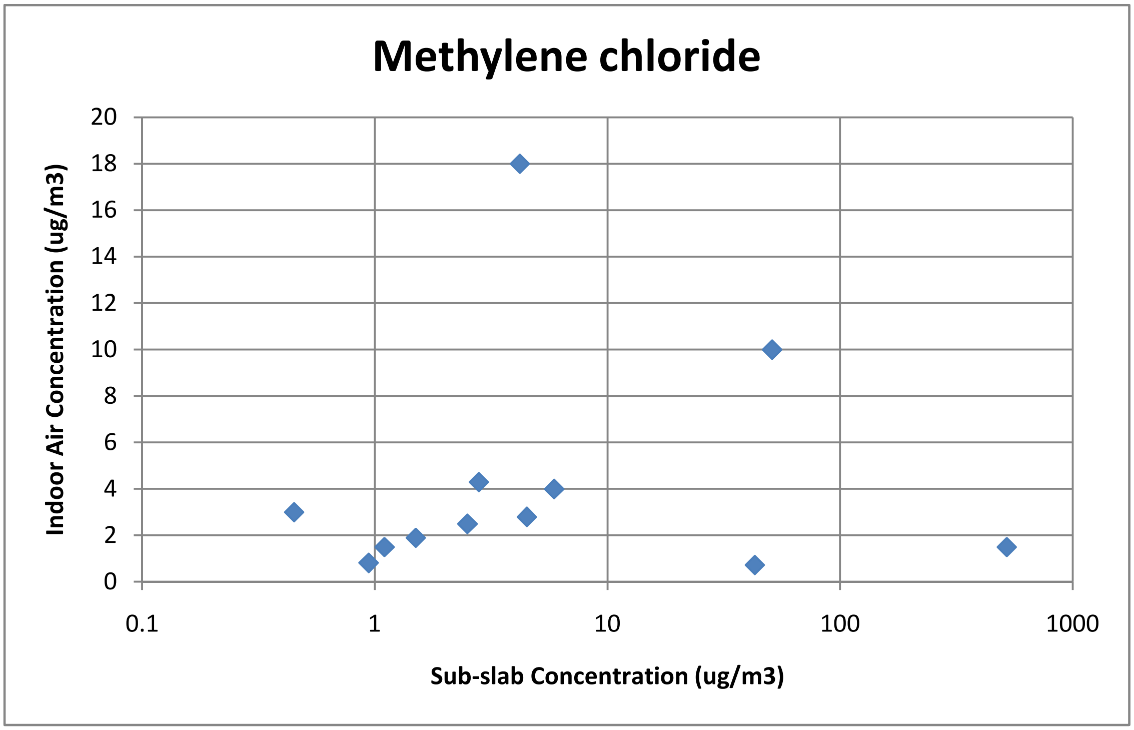
CDF of Attenuation Factor cis-1,2-Dichloroethene
1
0.8
0.6
0.4
0.2
0
0.00E+00
5.00E-05
1.00E-04
1.50E-04
2.00E-04
2.50E-04
3.00E-04
Attenuation Factor



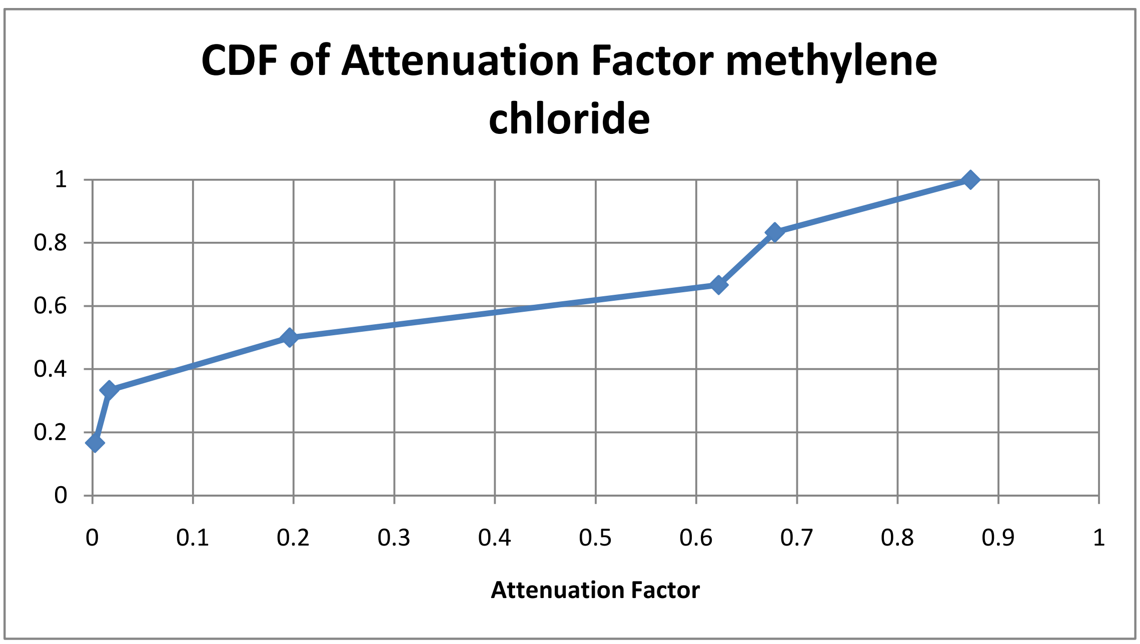
Dichlorodifluoromethane
Indoor Air Concentration (ug/m3)
Sub-slab Concentration (ug/m3)
Background
0
1
2
3
4
5
6
0.1
1
10
100
1000



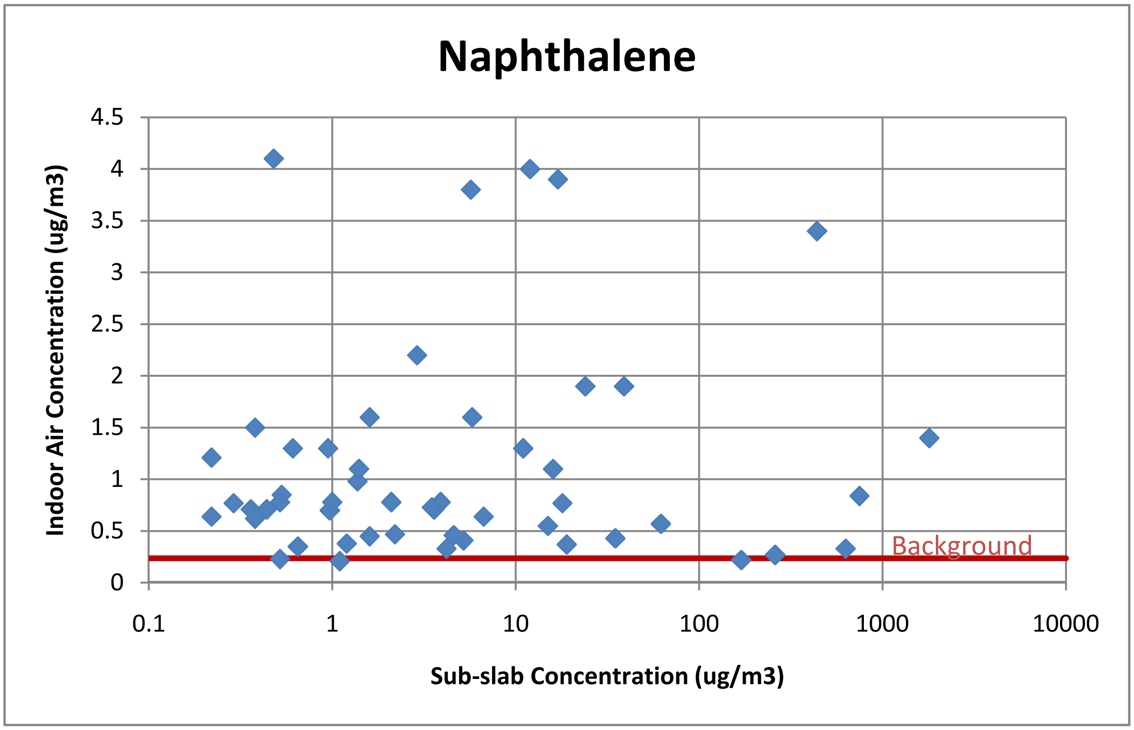
CDF of Attenuation Factor
Dichlorodifluoromethane
Attenuation Factor
0
0.2
0.4
0.6
0.8
1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1

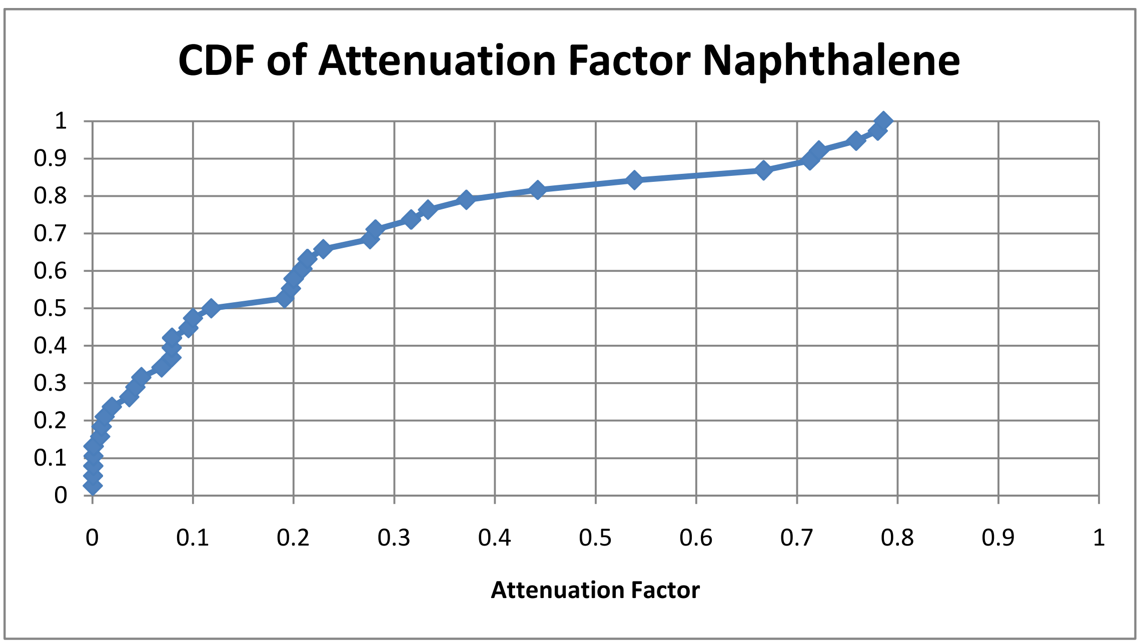


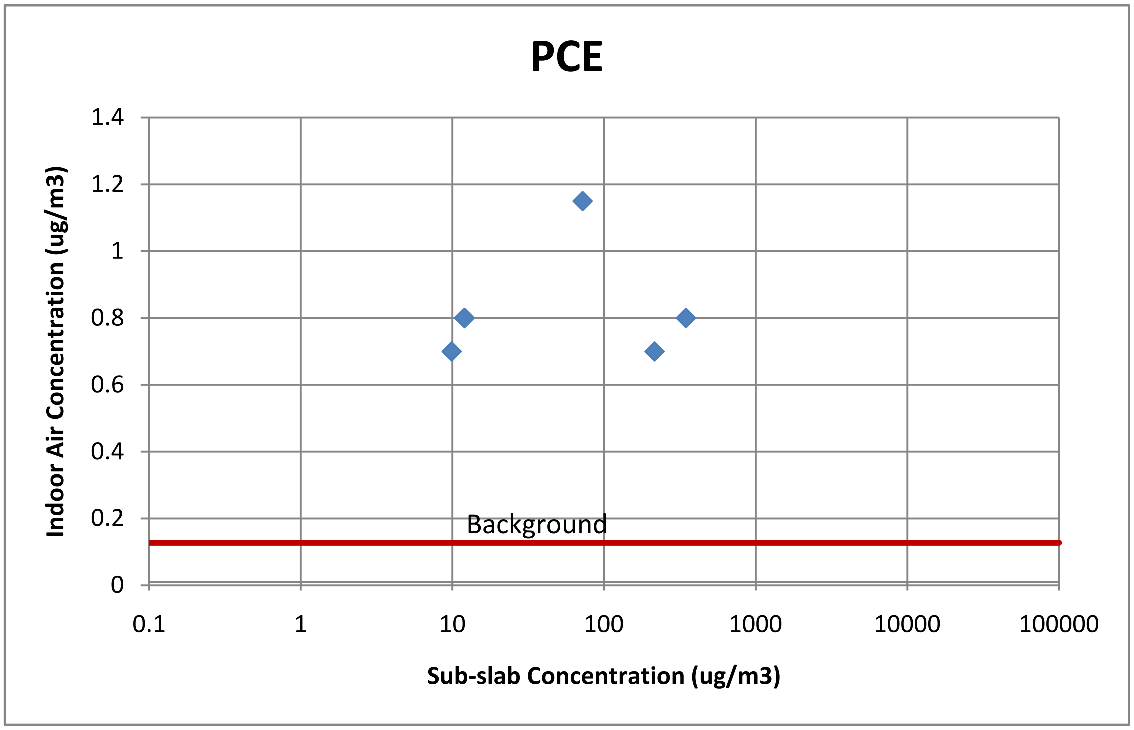
Methylene chloride
Indoor Air Concentration (ug/m3)
Sub-slab Concentration (ug/m3)
0
2
4
6
8
10
12
14
16
18
20
0.1
1
10
100
1000

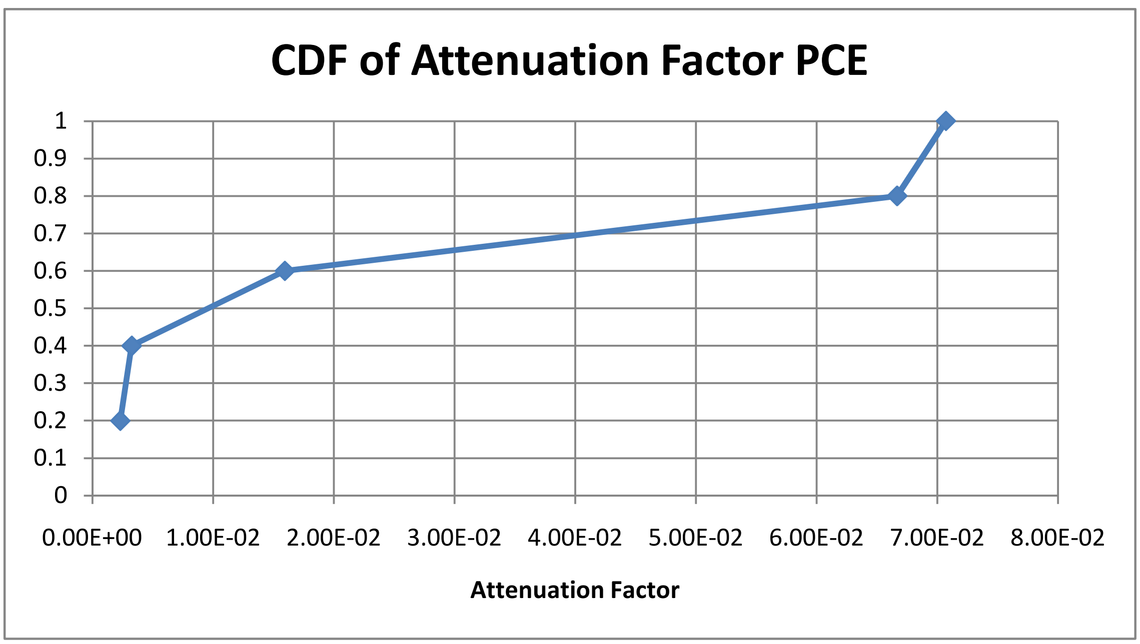


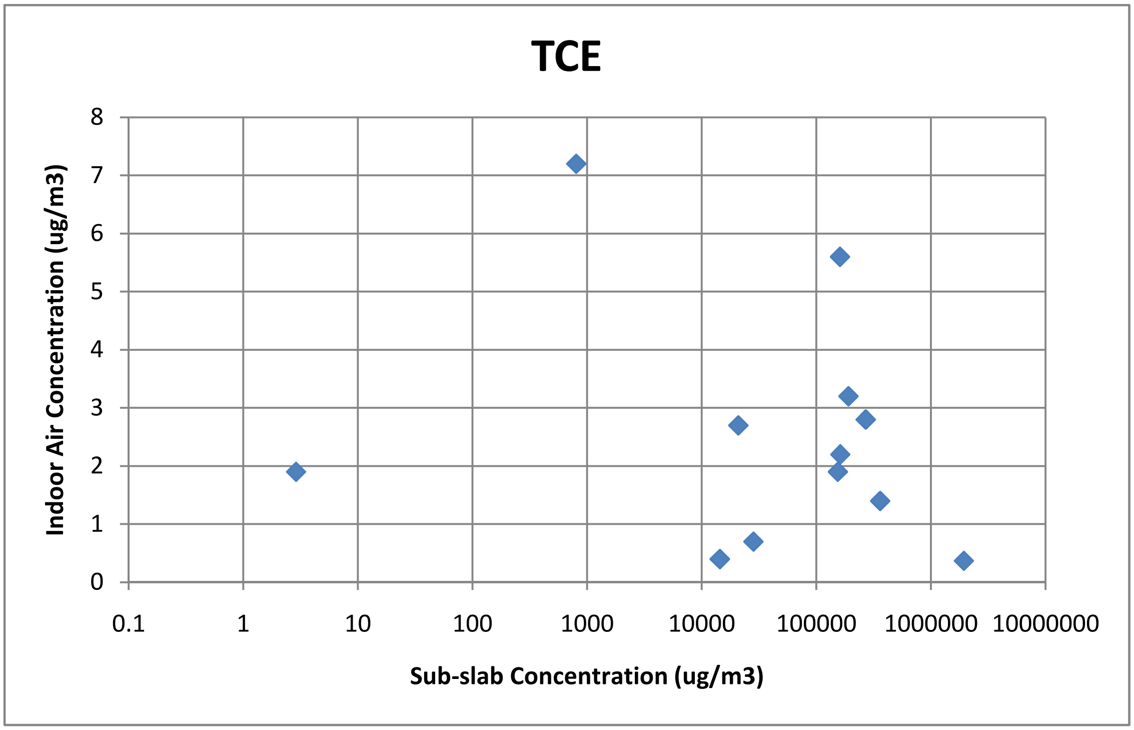
CDF of Attenuation Factor methylene chloride
Attenuation Factor
0
0.2
0.4
0.6
0.8
1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1

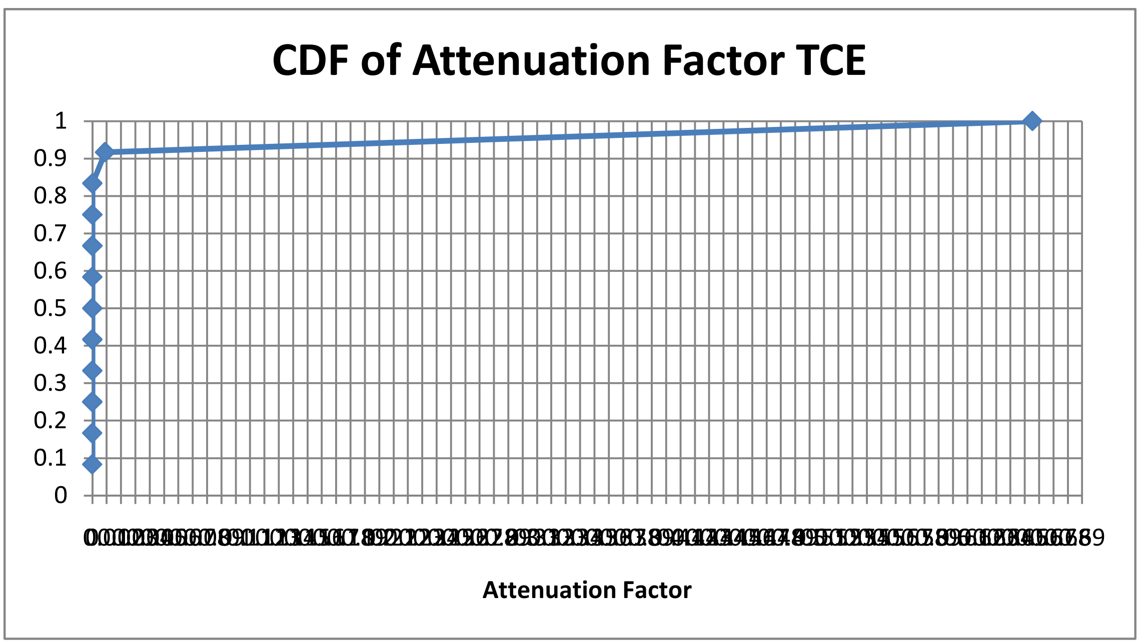

Naphthalene
Indoor Air Concentration (ug/m3)
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
0.1
1
10
100
1000
10000
Background
Sub-slab Concentration (ug/m3)


CDF of Attenuation Factor Naphthalene
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Attenuation Factor


PCE
1.4
1.2
1
0.8
0.6
0.4
0.2
0
Indoor Air Concentration (ug/m3)
Background
0.1
1
10
100
1000
10000
100000
Sub-slab Concentration (ug/m3)


CDF of Attenuation Factor PCE
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0.00E+00
1.00E-02
2.00E-02
3.00E-02
4.00E-02
5.00E-02
6.00E-02
7.00E-02
8.00E-02
Attenuation Factor


TCE
Indoor Air Concentration (ug/m3)
Sub-slab Concentration (ug/m3)
0
1
2
3
4
5
6
7
8
0.1
1
10
100
1000
10000
100000
1000000
10000000


CDF of Attenuation Factor TCE
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Attenuation Factor