MAINE DEPARTMENT OF ENVIRONMENAL PROTECTION
BUREAU OF REMEDIATION

VAPOR INTRUSION EVALUATION GUIDANCE

January 13, 2010

Effective Date: January 15, 2010

Approved: ______________________________
Mark Hyland, Director, Bureau of Remediation & Waste Mgmt.

Date: January 14, 2010

Table of Contents

List of Appendices

List of Tables

[1] http://www.maine.gov/dep/rwm/publications/guidance/index.htm

1. INTRODUCTION:

1.1 Vapor Intrusion Definition[2]

Vapor intrusion (VI) is the migration of volatile chemicals from the subsurface into overlying buildings. Volatile chemicals may include volatile organic compounds, select semivolatile organic compounds, and some inorganic analytes, such as elemental mercury and hydrogen sulfide. VI requires three components: a source, an inhabited building, and a pathway from the source to the building interior.[3]

VI is typically conceptualized as follows. Chemicals volatilize from impacted soil and/or groundwater into soil vapor which diffusively flows toward regions of lower chemical concentration (e.g., the atmosphere, conduits, basements). Soil vapor can flow into a building due to a number of factors, including barometric pressure changes, wind load, thermal currents, or depressurization from building exhaust fans. In addition to diffusive transport, advective flow through soil and along/within preferential pathways such as utilities and bedrock can facilitate soil gas migration to a receptor. The rate of movement of the vapors into the building is a difficult value to quantify and depends on soil type, chemical properties, building design and condition, and the pressure differential. Upon entry into a structure, soil gas mixes with the existing air through the natural or mechanical ventilation of the building.[4]

1.2 Vapor Intrusion Guidance Application and Limitations

<u>1.2.1 General</u>

This document presents the Department's process for evaluating a site's potential for vapor intrusion, and should be used as guidance by 3rd parties conducting and reporting upon a vapor investigation in Maine. It includes and references techniques to collect and analyze samples from soil gas, subslab gas, indoor air and ambient air, and presents risk based target levels in indoor air and soil gas to determine whether additional investigation and/or mitigation is necessary.

VI is most often associated with petroleum and chlorinated cleaning solvent operations (dry cleaners and degreasers) and this guidance is primarily developed with those facilities in mind. The Department has not consistently evaluated VI, but recent experience at Maine sites suggests that the pathway may often be overlooked, resulting in unaddressed public health impacts.

Vapor intrusion is a complicated pathway that involves relational properties (time, distance and concentration) between the source and receptor as well as physical properties of the VI chemicals, soil, groundwater, and building/utilities. Assessment of the VI pathway is further complicated by the fact that many of the VI chemicals of potential concern (COPCs) are used,

[2] Note that Acronyms and Definitions are provided in Appendix C
[3] ITRC Vapor Intrusion Pathway A Practical Guideline, 2007
[4] ibid

stored or generated within households and are often present as a background condition unrelated to vapor intrusion.

The goal of establishing a process to evaluate the vapor intrusion pathway is to ensure a consistent, cost effective approach to protect public health from vapor intrusion while avoiding false positives. This is goal is met by systematically identifying complete exposure pathways from the contamination source, then measuring indoor air concentrations, and then determining appropriate mitigation and remediation actions. When appropriate, mitigation includes stopping infiltration or increasing indoor ventilation to prevent deleterious health effects associated with long term inhalation exposure to volatile and toxic chemicals. Remediation includes removal, treatment or control of the highly contaminated soil or groundwater that is the source of the vapor.

This guidance does not address or protect against potentially explosive conditions associated with high concentrations of vapors or methane gas from landfills . Defer to Emergency First Responders when potentially hazardous atmospheres are suspected in utilities or buildings.

This guidance is specific to the vapor intrusion pathway. Other exposure pathways (ingestion, dermal, outside inhalation) should be evaluated in accordance with the following guidelines (available at: http://www.maine.gov/dep/rwm/publications/guidance/index.htm), as applicable:

1. For Petroleum sites, “Remediation Guidelines for Petroleum Contaminated Sites in Maine” dated November 20, 2009 and effective December 1, 2009.
2. For Hazardous Substance Sites, “Implementation of Maine Remedial Action Guidelines for Soil” effective November, 2009; or
3. “Guidance for Human Health Risk Assessments for Hazardous Substance Site in Maine”, July, 2009 draft

This document provides general guidelines for the investigation of vapor intrusion potential at petroleum and hazardous substance contaminated sites in Maine. These guidelines are not rules or regulations, and are not intended to have the force of law. This document does not create or affect the legal rights of any person which are determined by applicable statutes or law.

1.2.2 Alternatives to a VI Evaluation

At the start and throughout the VI evaluation, the cost and effectiveness of a VI investigation need to be weighed against cost and effectiveness of alternatives including source removal and direct measurement of indoor air.

When a spill is recent, clean-up is prompt (within 30 days of the approximate date of the beginning of the discharge) and virtually all the release is recovered because the spill is accessible and limited in depth and extent, investigation of the VI pathway is not necessary. Transportation, surface discharges and exterior residential spills of petroleum products may qualify in this regard.

At least two rounds of direct indoor air measurement collected from at least two locations within the building along with concurrent point of entry foundation samples and concurrent upgradient outside ambient air samples can be an effective and acceptable alternative to the approach outlined in this guidance. Multiple rounds and multiple sample locations are important aspects of direct measurement in order to capture the temporal and spatial variability in vapor samples. Concurrent point of entry samples and building occupant/owner participation in the removal/isolation of background sources are also important aspects of direct measurement in order to identify and control potential background influence on indoor air quality (see section 2.4.2 “Considerations in the Establishment of DQOs”). The relationship between indoor air and outdoor air is extremely complex and in situations where an ambient source may influence indoor air quality, upgradient, outside ambient air samples may be useful interpreting indoor air sample results.

1.2.3 Risk Management

In addition to residential buildings, the Department recommends using this guidance for workers within commercial/industrial buildings who may be exposed to COPCs through the VI pathway at their workplace. However, this guidance should not be applied to buildings on the same parcel as the VI source when:

- The contamination is attributed to operations at the subject facility
- The commercial/industrial operation involves the VI COPCs so that the indoor air monitoring and quality for the VI COPCs is governed by OSHA regulations
- And the employer is required by OSHA regulations to train their employees in protection from and awareness of the inhalation route of exposure due to workplace exposure of the same COPCs.

Risk management decisions are considered separate from decisions regarding responsibility/funding for costs associated with the VI investigation, mitigation or remediation of facility derived contamination.

This guidance is intended to evaluate risks associated with current development conditions and it is not intended to evaluate VI risk posed by future development. However, changes to the subsurface infrastructure or future development in the area may warrant a re-examination of the VI pathway. Options to address changes in VI potential arising from future development include:

- Re-assess the pathway when the development occurs
- Use existing site characteristics to model the impact of future development
- Plan to install mitigation systems as a component of future construction
- Require environmental covenants at properties considered vulnerable to VI as a result of development

1.2.4 Analysis Method

The recommended analytical method for assessing VI is EPA Method TO-15 and modifications to that method as in the Massachusetts APH[5] method. See section 2.4.

[5] METHOD FOR THE DETERMINATION OF AIR-PHASE PETROLEUM HYDROCARBONS (APH) http://www.mass.gov/dep/cleanup/laws/aphsop08.doc

1.2.5 Remediation

For the purpose of this document, remediation addresses the source of contamination through removal/reduction/control approaches. Mitigation is considered a pathway or point of entry control measure. The VI pathway may be associated with large groundwater plumes, extensive soil contamination and complex infrastructure. Due to the possible high cost and questionable reliability of a remediation to eliminate VI potential, the current convention is to first assess the pathway and risk and that is the focus of this guidance. If the assessment determines that the pathway is complete, source remediation can then be considered as an alternative to conventional mitigation strategies such as sub-slab depressurization at the receptor. Since remedial and mitigation investigations and strategies are site and contaminant specific and as they are addressed elsewhere[6], site remediation and mitigation are not developed in this guidance.

1.2.6 Home Heating Oil Spills

Releases at home heating oil sites are a unique form of VI. Releases are commonly due to tank corrosion, filter breakage, leakage in the copper line between tank and furnace, and tank overfills. Due to the location of the tank and piping, the release is typically within the building or the building envelope (area around and beneath the building foundation that may interact with the interior building environment). Many constituents of home heating oil have strong, distinctive odors and therefore detecting the completed pathway is often obvious due to these odors. In addition to odors, indicators of a complete pathway include oil stained material within the home, neat material or contaminated groundwater within the building envelope or basement drainage, PID readings attributed to the release within the building, and PID readings in cracks and openings in the floor, walls and bedrock intrusions.

Evidence of a complete pathway warrants remedial and/or mitigation measures to remove and control the source of vapors. Guidance on clean-up of home heating oil spills is provided in the Department's "Remediation Guidelines for Petroleum Contaminated Sites in Maine" dated November 20, 2009 and effective December 1, 2009.

When there is no sensory or PID evidence of a VI pathway at home heating oil spills; the spill is known to be recent (little time to spread in the environment); and virtually all of the spilled product is removed from soil and groundwater, it is not necessary to further evaluate VI at the subject or surrounding properties as described in this document. However, the indoor air sampling and analytical methods as well as the MECDCs Indoor Air Targets do apply when evaluating the effectiveness of a home heating oil spill mitigation or when a distinction between a nuisance odor and a health threat is necessary.

[6] ITRC "Vapor Intrusion Pathway: A Practical Guideline" Technical and Regulatory Guidance, January, 2007, Chapter 4 and Appendix D
http://www.itrcweb.org/Documents/VI-1.pdf

2. EVALUATING VAPOR INTRUSION POTENTIAL:

Evaluating a site for vapor intrusion potential takes the same approach as with any site investigation and typically includes the following components:

2.1: Development of a Conceptual Site Model
2.2: Establishment of VI Investigation Objectives
2.3: Development of a VI Investigation Plan
2.4: Establishment of Data Quality Objectives

2.1 Development of a Conceptual Site Model:

The first step in evaluating a site for vapor intrusion potential is to develop a conceptual site model (CSM). For vapor sites the CSM is particularly important because vapors do not always act like other contaminants released into the environment in liquid form; the migration pathways are influenced by many additional factors. ASTM defines a CSM as "*a written or pictorial representation of an environmental system and the biological, physical and chemical processes that determine the transport of contaminants from sources through environmental media to environmental receptors within the system.*[7]" The CSM is a dynamic tool to be updated as new information becomes available, and therefore it should be amended, as appropriate, after each stage of investigation. **It is especially important that the site be reasonably well characterized to confidently evaluate the VI potential at a site.**

The CSM for vapor sites should be site-specific and take into consideration the following information:

- Facility Use/storage characteristics: Consider chemical and petroleum storage and use areas, and storage/collection areas for rags or other wastes that might be contaminated with petroleum, solvents or other volatile chemicals. Consider the historical property use: did it have multiple generations of underground tanks and did the property use/store other hazardous materials in the past? Consider the location of the equipment used in operations at the facility including dry cleaning machines, parts cleaners, solvent recovery devices (such as dry cleaner distillation units). Consider potential conduits between the building foundation and the subsurface including but not limited to floor drains and vents. Consider the potential for a capped surface (paved, concrete or frozen) inducing additional migration of soil gas.
- Release characteristics: When was the release? How much was discharged? Was the release catastrophic or overtime? **Where was the release and where are the remaining sources located – is there neat material?** What was the release mechanism: surface spill of a liquid, a subsurface spill from piping or a tank, improper storage of materials such as chemical soaked filters at a drycleaner, through a floor drain to the subsurface beneath a building, or through a floor drain to a surface location? Was the release related to high or low concentrated dissolved phase (such as at a condenser hood)?

[7] ASTM E 1689-95 Standard Guide For Developing Conceptual Site Models for Contaminated Sites., 1995

- Chemical characteristics: What is the chemical or mixture released and what are the chemicals of potential concern (COPCs) associated with the release. What are the properties of the COPCs that influence migration: solubility, volatility and partitioning?
- Pathway / subsurface characteristics: How do the geology, soil type, preferential pathways, groundwater flow, depth to groundwater, proximity to impermeable surfaces, and chemical attenuation influence contaminant migration and soil vapor movement? Note that soil gas vapors can migrate against the direction of groundwater flow when drafted along or through a subsurface utility
- Existing data: Is the existing site subsurface characterization data adequate in the zone of transport, typically the vadose zone? Data from traditional site characterization is typically focused on the saturated zone and may not be sufficient to screen for VI potential.
- Environmental characteristics: How do atmospheric and seasonal changes in groundwater level, frost layers, and building heating ventilating and air conditioning (HVAC) operation impact soil gas migration and concentrations? Are there sources of ambient air pollution (combustion sources (particularly burning wood or other biomass), traffic, filling stations, industry).
- Receptor characteristics: What is the receptor like, in terms of proximity to source areas, building type, building HVAC, foundation type, foundation drainage/sumps, foundation/floor penetrations, foundation/floor condition, bedrock intrusion, underground utility services, future development? Consider the potential for a capped surface (paved or concrete) influencing migration of soil gas.

2.2 Establishment of VI Investigation Objectives:

2.2.1 Introduction to VI Investigation Objectives:

Depending upon the level of understanding presented in the CSM, the objective of the VI investigation can vary. A primary VI investigation objective throughout the process is to collect the information necessary to "screen out" a site or a potential receptor. The objective needs to be developed and reviewed by the project team and clearly communicated to stakeholders, responsible parties and the project team. The CSM is helpful in communicating the current understanding and calling out aspects of the site characteristics and risk that aren't understood well enough to make decisions. Objectives can be generally classified according to one or several of the following stages:

- preliminary screening
- site and receptor characterization
- remedial investigation mitigation evaluation or follow on monitoring.

2.2.2 Preliminary Screening Objective:

Preliminary screening is typically the first look at a site with VI in mind. All sites storing and using volatile petroleum and hazardous substances are considered to have a VI potential if released to the subsurface. Therefore a primary goal of the preliminary screening is to "screen out" sites that do not have all three of the following elements of VI:

1. evidence of a release of volatile and toxic chemicals,
2. a pathway to a receptor and
3. a receptor.

If a site cannot be screened out, preliminary screening may be used to prioritize sites by assigning weights to indicators of VI risk such as source type and source proximity to receptors and utilities. A preliminary screening objective may also be to develop the risk scenario associated with the site. The risk scenario includes identification of the most sensitive receptor (residential versus commercial property or both) and identification of COPCs in subsurface (single versus multiple contaminant risk).

Preliminary screening is presumed to be accomplished without the benefit of vapor samples from soil gas, subslab or indoor air. Information used in a preliminary screening includes a review of records from: the spill file, environmental databases, GIS records, Town records; interviews with staff and property owner; and a site visit to observe and record factors influencing the VI pathway. A site visit can involve evaluation of potential pathways (PID screening of utility valve boxes and manholes) and inspection of potential receptors (building proximity, type, age, foundation construction, foundation drainage and PID screening of basements). Considerations of preliminary screening are outlined in the following Table 1 – "Preliminary Screening Evaluation Criteria".

<table>
<tr><th>TABLE 1: PRELIMINARY SCREENING EVALUATION CRITERIA</th><th>YES</th><th>NO</th></tr>
<tr><td colspan="3">1. Chemical Characteristics:
If the answer to the following question is yes continue to #2. If the answer is no then a vapor intrusion investigation is not needed.</td></tr>
<tr><td>A) Are any of the contaminants of concern at the site volatile and toxic?
▪ Volatile chemicals are defined as chemicals having a Henry's law constant greater than 10^{-5} atm m^3 mol^{-1} and a vapor pressure greater than 1 mm Hg at room temperature.[8]
▪ Toxic chemicals are defined as maximum pure component vapor concentration greater than an indoor air concentration corresponding to the chemicals ILCR of 1x10-6 or 1/5th of its RfC for multi contaminant sites.
▪ Volatile and toxic chemicals include but are not limited to all compounds listed on the MECDC 6/25/09 Draft IAT Tables B1 through B8 located on the Department's BRWM web page.
▪ Some inorganic chemicals may be volatile such as elemental mercury and hydrogen sulfide.</td><td></td><td></td></tr>
<tr><td colspan="3">2. Environmental Release:
If the answer to either question is yes continue to #3. If the answer to both questions is no then a vapor intrusion investigation is not needed</td></tr>
<tr><td>A) Is there evidence of a release of contaminants at the site ?
▪ Analytical data showing groundwater contamination,
▪ Analytical data showing soil contamination or,
▪ Visual evidence of a release (e.g. leaking tank, leaking containers, stained soil).
▪ Record of a release or contamination that was not completely recovered within 30-days of the beginning of the spill</td><td></td><td></td></tr>
<tr><td>B) If there is no evidence of a release is it likely that chemicals have been released? Review data collected during the Phase I investigation to determine if a release is likely.
▪ Operational years predate regulations.
▪ General chemical handling practices are sloppy.
General industry practices (such as dry cleaners) lead to vaporization of the chemicals which could lead to subsurface vapor problems.</td><td></td><td></td></tr>
<tr><td colspan="3">3. Receptor / Pathway Migration Potential:
If the answer to any of the following questions is yes there is a potential for vapor intrusion and an investigation is needed (See Section 2.3on Investigations). If the answer is unknown the answer is assumed to be yes. If the answer is no to all questions then a vapor intrusion investigation is not needed.</td></tr>
<tr><td>A. Are there buildings (intended for human occupancy), utilities or other preferential pathways within 30[9] feet (horizontally or vertically) from petroleum contaminated media (soil, groundwater, soil gas) or within 100[10] feet (horizontally or vertically) from non petroleum contaminated media (chlorinated hydrocarbons in soil, groundwater, soil gas)? Preferential pathways are features that exist below ground such as a fracture, utility line, or pipeline through which migration may be facilitated. Note that building draft (chimney effect) can draw vapors into a building, in the opposite direction of gravity flow.
Examples of preferential pathways include but are not limited to:
▪ Underground drainage features such as culverts or storm drains
▪ Public utilities (sewer, water, natural gas)
▪ Fractured bedrock
▪ Permeable backfill around subsurface piping
B. Is the ground surface around the source and nearby buildings significantly covered by an impervious material such as pavement, concrete or frost?
Note that releases that are completely recovered within 30-days of the beginning of the spill can be an exception to the 30 foot setback (see sections 1.2.2 and 1.2.6)</td><td></td><td></td></tr>
</table>

[8] ASTM E 2600-08
[9] New Hampshire DES " Vapor Intrusion Guidance", July 2006

[10] EPA "OSWER Draft Guidance for Evaluating the Vapor Intrusion to Indoor Air Pathway from Groundwater and Soils (Subsurface Vapor Intrusion Guidance)", November, 2002

2.2.3 Site and Receptor Characterization Objectives

In the characterization phase, the 3 elements of VI are suspected or present, however the magnitude and influence of variables impacting VI are undetermined. **An objective for a VI characterization is to determine many of the parameters typically assessed in a hydrogeological study such as soil type and groundwater depth**. Additional objectives to consider that are germane to a VI characterization include the following:

- Determine presence of COPC in soil gas.
- Quantify COPC levels in soil, groundwater and soil gas,
- Locate source and source type responsible for vapors
- Delineate source areas and plume areas with respect to receptors and pathways
- Determine vapor source (vapors from neat material, soil, groundwater, air)
- Evaluate potential for offsite migration (contaminant levels at subject property boundaries)
- Expand understanding based upon results of prior investigations
- Determine receptor characteristics
- Identify migration pathways (utility related, subslab intrusion)
- Identify Possible Points Of Entry (basement walls, slab, utility penetrations, etc.)
- Determine whether suspected pathways are complete or not
- Determine relative contributions between soil gas/indoor air background and/or ambient air by concurrent sampling
- Evaluate relative ratios of COPCs in soil gas, subslab, indoor air and ambient air by concurrent sampling

2.2.4 Remedial Investigation, Mitigation Evaluation or Follow-on Monitoring Objectives

A VI investigation objective is to evaluate remedial and/or mitigation options, evaluate performance and effectiveness of an implemented corrective action, and to comply with monitoring requirements imposed to evaluate atmospheric, seasonal and property development influences on VI as well as natural attenuation.

2.3 Develop a VI Investigation Plan

2.3.1 VI Investigation Approach:

The objectives of VI investigations can vary widely based upon the stage of development of the CSM. Also, VI investigations are highly site specific considering all the factors influencing the VI pathway. Consequently, the first investigation plan recommended is considered a “baseline” VI characterization for sites that pass through (screened in) during the preliminary screening process. Following the baseline characterization, the recommended VI investigation approach is a “stepped” process from the source to the receptor that progressively captures data, site information and “lines of evidence” that coincide with decision points in the VI evaluation process. One step in an investigation may involve several iterations as it may be necessary to collect samples from multiple locations over several events to capture temporal and spatial variations. In the following sections, the stepped investigations are referred to as:

- VI Preliminary Screening (review of existing records, site observations and interviews)
- VI Baseline Characterization (soil gas survey)
- VI Step Out Investigation (off property, perhaps receptor)
- VI Indoor Air Investigation (receptor)

The recommended approach is linear from the source to the receptor and the steps are progressively more involved in terms of design, time and level of effort. There are sites where immediate, direct indoor air measurement (see Section 1.2.2) and/or mitigation is prudent and/or presents a cost effective alternative to investigation. Immediate indoor air measurement and/or mitigation may be appropriate for receptors considered at high risk due to characteristics of the discharge, vulnerability of the pathway and/or receptor due to construction and/or condition, or sensitivity of the occupants.

Because of the complex nature of VI sites, involvement of an experienced VI professional (such as a Maine Certified Geologist or a Maine Professional Engineer experienced with VI investigations) is recommended in the development of the CSM, establishment of objectives and the development of a sampling plan. Ongoing communication and partnering with the Department project manager, laboratory chemist, contractors and consultants is also extremely important to ensure investigation and data quality objectives can be satisfied. The scope, timing and objectives of the investigation must be clear to avoid an expectation of a conclusion on the VI pathway when multiple sample rounds and/or locations are necessary to complete the VI evaluation. The Department requires submittal of a VI workplan, budget (where Department funding or reimbursement is secured or possible) and schedule for approval prior to proceeding with a VI investigation.

2.3.2 VI Baseline Characterization Objectives

Baseline characterization objectives are directed toward identifying COPCs in the soil gas, assessing the extent of the soil gas plume, and determining COPC gradients between the source and potential receptors and potential pathways. Another objective is to evaluate the soil gas transport mechanisms of diffusive (concentration gradient) and advective (pressure gradient) flow of soil gas contaminants within the soil matrix and utility bedding. A third objective is to evaluate attenuation of COPCs over lateral distance. **Hydrogeologic influences on the VI pathway (such as soil type, depth to groundwater and extent of a groundwater plume), require an understanding of the local hydrogeology in order to design and interpret the results of a soil gas investigation.**

A site passing (screened in) the preliminary screening phase has the possibility of: toxic and volatile contaminants in the subsurface, a pathway from the source of contamination to a receptor, and a receptor. The soil gas information collected during the baseline characterization will be used to confirm or refute the possibility of toxic and volatile contaminants in the subsurface as well as evaluate potential pathways to receptor. If contaminants are not detected or pathways can be eliminated, the site can be screened out from further VI evaluation. If contaminants are detected, the detected contaminants, their concentration, and location can be used to target chemicals of concern, pathways and potential receptors in step out investigations.

2.3.3 VI Baseline Characterization Approach

In order to satisfy the objectives, collect soil gas samples at the suspected source, within the bedding of the nearest utility, 30 feet from the source in the hydraulically downgradient direction and at the property line in the hydraulically downgradient direction. The sample locations are respectively selected to assess the source strength and identify COPCs, assess potential preferential pathways, assess lateral attenuation and extent [11] of the source, and evaluate potential for off-site impacts. Selection of the utility sample point and the presumed "downgradient" direction merit deliberation as gravity draining utilities (storm water and sewer) can serve as chimneys and draft vapors in the hydraulically upgradient direction through advection. The source sample point should be driven deep enough to assess groundwater depth and quality if groundwater depth and impact is unknown.

Site specific characteristics may allow capturing two locations with one sample (such as a small property where the 30 foot distance is equal to or greater than the property line distance). Additional sample locations and/or vertical profiling may be necessary depending upon the number of source areas, the differing source media (soil, groundwater or both), the size of the source area, the depth of the source, and the number of pathways present. Soil gas sample point construction and sample procedures as well as a sheet to log a soil gas sample event are provided on the BRWM's web page.

Sample point construction and sample collection methods need to consider the analytical methods. The analytical methods during the baseline characterization phase should be comprehensive to identify potential contaminants of concern (EPA method TO-15 for chlorinated hydrocarbon sites and MA APH method for petroleum hydrocarbon sites).

2.3.4 Alternate Site Characterization Screening Criteria

Analytically supported documentation of a clean-up where residual contamination in groundwater is considered protective of VI may be used to screen out a site. The Department does not have target levels for groundwater and it would be at the project managers discretion to determine whether the release(s), and pathway(s) were understood so that alternative screening criteria such as groundwater concentration data could be applied at a site. References for alternative baseline characterization methods are included in section 5.

2.3.5 VI Step Out Investigation Objectives

Data and site information collected in the baseline characterization are to be evaluated and incorporated in the CSM and will determine the need for a step out investigation. Evidence of contaminated soil gas above the soil gas target (SGT) levels , particularly within or along utilities and at the property boundary is justification for expanding the VI investigation. If a step out

---

[11] USEPA Guidance "screens in" a site for further VI evaluation when structures are located within 100 feet horizontally or vertically of subsurface media contaminated with volatile and toxic chemicals. New Jersey and Massachusetts "screen in" a site when structures are located within 30 feet of a groundwater screening level exceedance. The 30 foot distance applied to locating soil gas sample points in this Guide is considered a means to qualify the extent of the source area and to evaluate lateral COPC attenuation.

investigation is indicated, objectives may involve confirmation of baseline results, a hydrogeologic site characterization, evaluation of vapor attenuation over distance and depth, determination of routes of entry into a receptor and evaluation of additional potential receptors.

2.3.6 VI Step Out Investigation Approach:

Satisfying these criteria (volatile and toxic contaminants in the subsurface, pathway, and nearby receptors/pathways) indicates the potential for vapor intrusion and calls for a site specific sampling plan that includes soil vapor samples and near foundation or sub slab samples. Although it may appear expeditious to directly collect indoor air samples and skip the environmental sampling, direct indoor air sampling will also measure chemicals commonly found in indoor air from sources present in households and businesses, ambient air and other sources unrelated to VI. Protocol and situations for direct measurement of indoor air are discussed in Sections 1.2.2 and 2.3.1.

Build upon the results of the baseline characterization and limit sampling and analysis to the chemicals detected in the baseline characterization. Conducting an investigation that includes source soil vapor samples, near foundation vapor samples and sub slab soil vapor samples allows investigators to establish site specific chemicals of concern and helps evaluate the pathway between the source and a receptor. At least two "source entry" (sub slab or near foundation) samples should be collected to account for variability in concentration beneath or outside the building. When building entry is necessary (in the case of sub slab sampling) consider collecting indoor air samples to minimize the need of multiple building entries. If the investigation shows no evidence of a connection to receptor, do not collect indoor air samples. If vapor migration has been established the indoor air investigation can then be focused on the contaminants of concern.

2.3.7 VI Indoor Air Investigation Objectives:

Indoor air sampling may be necessary when chemical odors are detected, contaminated groundwater is detected in the basement drainage, soil gas contamination is found on the receptor property, immediately adjacent to the property, or in the sub slab of the receptor. Objectives of sampling indoor air include providing a rapid assessment of risk to the occupants, determination of a complete pathway, and sorting contributors (VI, household products and activities, ambient air) to indoor air quality.

2.3.8 VI Indoor Air Investigation Approach:

Collect indoor air samples from at least two locations within the home. Base the selection of the locations on where the contaminants are suspected to enter the home (typically through foundation floor or foundation wall) and a living space (typically a room above the foundation entry point). Avoid sampling in the building space where non VI sources may be present (kitchen, bath, craft, hobbies, shops).

Distinguishing between VI and non VI sources may be aided by simultaneously collecting outside ambient samples and source entry samples (subslab or foundation wall). The relationship between indoor air and outdoor air is extremely complex and sample/investigation objectives need to be established prior to collecting concurrent samples.

A protocol to collect indoor air samples and log details of the sample are provided in the “Draft Indoor Air Sample Protocol ” dated August 2, 2009 and the “Draft Indoor Air Sampling Field Sheet” on the Bureau’s web page.

2.4 Establish Data Quality Objectives (DQOs) for the Investigation:

2.4.1 Overview of DQO Considerations:

A critical component of the VI investigation plan is to establish DQOs. DQOs can be generally broken down into four categories which are typically related so familiarity with all aspects is necessary to satisfy DQOs in a VI investigation.

The following Table 2 provides references to documents that provide methodology, guidance and specification on deriving target levels, sample and analytical procedures, and construction methods and materials involved in conducting a VI investigation.

Table 2 References in Establishing Data Quality Objectives

DQO CATEGORY	SubCategory	Reference
1. INDOOR AIR RISK TARGET LEVELS, ANALYTICAL MRLS, OUTSIDE AMBIENT, AND TYPICAL INDOOR AIR CONTAMINANT LEVELS	Contaminants of Concern and Target Level Method Development	Appendix A
	IAT for single and multi contaminant scenario	BRWM website, Tables B1 through B8
	IAT for residential and commercial properties	
	IAT for chronic and subchronic exposures	
	MRLs, Ambient, Typical Indoor	BRWM website, Table B9
2. SOIL GAS TARGET LEVELS, SOIL GAS MRLs, AND OUTSIDE AMBIENT LEVELS		BRWM website: Table B10
3. SAMPLE POINT CONSTRUCTION, SAMPLE COLLECTION METHODS, SAMPLE QA/QC and ANALYTICAL METHODS	Soil Gas Sample SOP DR 026	BRWM website
	Draft Alternate Soil Gas Sample Collection Method with Thin Diameter SS Tubing dated 8/19/09	
	Sub Slab Sample SOP DR 027	
	Draft Indoor Air Sample Protocol dated 8/2/09	
4. LABORATORY REPORT FORMAT and DATA VALIDATION	All Vapor Samples	Requirements for DEP’s EDD v5.0 can be found at www.maine.gov/dep/rwm/egad.

2.4.2 Considerations in the Establishment of DQOs:

Establishment of DQOs is necessary to enhance the understanding of the relationships and influences of the VI pathway as well as to ensure that the selected methods are capable of providing meaningful and useful data. Considerations in establishing DQOs include the following:

- Relational properties (time, distance and concentration) between the source and receptor
- Physical properties of the VI chemicals, soil, groundwater, and building/utilities
- Indoor air contamination attributed to indoor sources such as building materials (carpet), chemical storage (gasoline powered motors, heating oil storage, cleaning chemicals) and practices (hobbies, addictions, cleaning, cooking, heating)
- Outside ambient air
- Risk based values within the realm of analytical method reporting limits (MRLs)

Table B9 compares multi contaminant, residential, chronic IATs to analytical MRLs, typical[16] indoor air contaminant levels and typical outside ambient contaminant levels. Awareness of the MRLs is important during the selection of sample container size, analytical method (standard or low level) and laboratory to ensure reporting at or below risk based target levels in indoor air. The comparison also allows the investigator to anticipate the possible interference from typical indoor and ambient sources. Review of Table B9 indicates that typical background concentrations of several compounds (1,4-dichlorobenzene, benzene, carbon tetrachloride, chloroform, ethylbenzene, tetrachloroethene and the aliphatic petroleum hydrocarbon fractions) exceed the residential chronic multi-contaminant IAT. Outside ambient concentrations of several compounds (1,1,2,2-tetrachloroethane, 1,2,4-trichlorobenzene, acrolein, benzene, carbon tetrachloride and ethylene dibromide) also exceed the residential chronic multi-contaminant IAT. Collection of sub-slab or near slab (dependent upon suspected point of entry into the foundation) and ambient outside air samples concurrent with the indoor air samples is recommended when it is necessary to quantify contributions from indoor and ambient air sources. However, the relationship between indoor air and outdoor air is extremely complex, and the investigator must have a clear idea of how the ambient samples will be used to aid in decision making before obtaining them.

A separate table (Table B10) is provided to compare multi contaminant, residential, chronic SGTs to typical outside ambient contaminant levels and MRLs for the smaller collection canisters typically associated with soil gas sampling. This comparison is to provide typical levels of contaminants in ambient Maine air that may help in evaluating integrity of sample collection and help select a sample container size, analytical method and laboratory capable of measuring at the SGT level.

2.4.3 Analytical Methods and Reporting Requirements

Sampling and analytical methodology must be capable of meeting the applicable target levels and must have established and accepted laboratory protocols. Acceptable laboratory methods for soil gas and indoor air include EPA method TO-15 and Massachusetts APH method. EPA Method TO-15 method is recommended for chlorinated hydrocarbon sites and Massachusetts APH method is recommended for petroleum hydrocarbon sites. EPA Method TO-17 may be used for measuring individual semi-volatile compounds and polycyclic aromatic hydrocarbons (PAHs).

Alternate active sample collection methods involving tedlar bags and sorbent tubes and alternate analytical methods (such as EPA method 8021 or 8260B for tedlar bags, EPA method TO-17 and NIOSH method 1501 for sorbent tubes) may be useful for screening soil gas but they may not be used as a solitary line of evidence to "screen out" a site. Passive sample collection and analytical methods may complement active sample methods. The soil gas target levels may be achieved using alternate methods but compounds such as naphthalene may adhere to the tedlar bags resulting in false negatives. Furthermore, the analytical methods, results interpretation and QA/QC methods for labs is inconsistent as the EPA methods 8021 and 8260B were developed for water and are not standardized for conducting air analysis. Proposals to use alternative sample and analytical methods must provide support that the methods and equipment are applicable and effective regarding the site specific investigation and DQO objectives.

Laboratories analyzing vapor samples for the purpose of assessing vapor intrusion are required to provide results in units of ug/m^3 in the Department's EDD v5.0 format. Requirements for EDD v5.0 can be found at www.maine.gov/dep/rwm/egad

3. EVALUATING RESULTS of a VI INVESTIGATION

3.1 Introduction

A completed VI pathway involves a source of volatile and toxic chemicals, an inhabited building, and a pathway from the source to the inhabitants.[12] Present the data, observations, and records in a conceptual site model to document and convey the current understanding of VI potential. Use lines of evidence to support conclusions pertaining to a determination of a complete or incomplete VI pathway.

3.2 Using Target Levels to Evaluate Vapor Intrusion

Comparison of the Indoor Air Target (IAT) levels to analytical data is the primary means of evaluating risk posed by contaminants in indoor air. Additional lines of evidence are required to distinguish between a subsurface source of vapors intruding into a building versus an outside air ambient source or an indoor air contaminant released within the home through household practices (interior chemical storage) and activities (wood burning, smoking, cooking, cleaning, painting, crafts, hobbies). Building lines of evidence to determine a complete VI pathway is discussed in the next section.

The IATs are intended to protect a Highly Exposed Individual, or 95% of the people that might be exposed to the contaminant from adverse health effects associated with inhalation of compounds found in petroleum or a hazardous substance. Generally the guidelines are protective of sensitive individuals including pregnant women, young children, elderly people, individuals with compromised immune systems, and individuals in the general population who may be susceptible to the toxic effects of a chemical due to their genetic make-up.

[12] ITRC Vapor Intrusion Pathway A Practical Guideline, 2007

IATs for several exposure scenarios (single and multiple contaminants for chronic and subchronic exposures at residential and commercial buildings) are provided in tables B1 through B8 of the Department's BRWM web site. The IATs are concentrations in air that, when exceeded in the living space, may require additional sampling, remedial measures, and/or evacuation of the building. The conceptual site model and soil gas sample results (when available) dictate whether the indoor air assessment involves single or multiple contaminants and whether the property under evaluation is residential or commercial.

If representative sampling of indoor air indicates that COPCs attributable to the release are:

- ≤ the chronic IAT, no further remedial action is necessary.
- > the chronic IAT but ≤ the subchronic IAT, mitigation or remediation is needed and should proceed at a measured pace.
- > the subchronic IAT and ≤ the acute[13] IAT, then mitigation or remediation is needed and should proceed as quickly as possible.
- > an acute IAT, immediate intervention is needed, such as exhausting vapors from the building or evacuation.

Factors to consider in determining the urgency and scope of the response include; the sensitivity of the occupants, non VI contributions to indoor air contaminant levels from external and internal sources, the magnitude and duration of the exceedance, the location (living space versus non living space) of the exceedance, and the schedule for implementing an effective and reliable control of the vapors.

Ideally decisions are made with several rounds of data but there are cases where evacuation decisions must be made with limited data. At least two indoor air sample rounds are recommended in decisions where timeliness is less urgent and decisions having long term implications are being made such as re-occupation, effectiveness of a mitigation, and closure of a VI assessment. At least two rounds of sampling data are necessary to capture seasonal influences on the VI pathway and at least one round should include the heating season when buildings are more likely drafting soil gas from utility corridors and the building envelope.

Re-occupation of an evacuated building may be allowed when concentrations are reduced below the subchronic IAT. The decision to allow re-occupancy is based upon confidence in the effectiveness and reliability of the vapor mitigation to quickly reduce and maintain concentrations below the chronic IAT. The goal for allowing re-occupation or closure may need to be modified in the event that it is not feasible to attribute a persistent IAT exceedance to a source due to interferences and limitations such as:

- typical indoor air contaminants (non VI sources)
- outside ambient air contaminants
- practical limitation on analytical method
- practical limitation of a mitigation

---

[13] Acute IAT of 100 ug/m^3 for perchloroethylene from "Summary of Health Effects of Tetrachloroethylene (Perchloroethylene, PERC), and Action Levels for Residential Air Concentration"MeCDC, EOHP, August 3, 2007.

Acute IATs of 29 ug/m3 for benzene from ATSDR

Acute IATs for additional "risk drivers" are under development.

Naphthalene may qualify in this regard as there is uncertainty in typical indoor air contaminant levels in Maine homes, uncertainty in outside ambient air levels, risk based IATs are within the range and below TO-15 method reporting limits, and post remedial sampling results from home heating oil spills[14] detected concentrations that exceed chronic and subchronic IATs. Modifying goals is only appropriate after demonstrating that the VI source has been assessed, removed and/or controlled, the Department is satisfied that the modification is warranted, and the occupants are advised of the modification.

Soil Gas Targets (SGTs) are used in the evaluation of representative and appropriate subslab and soil gas analytical results. Exceedance of a SGT indicates the potential for VI that necessitates further evaluation of the pathway. SGTs are derived by dividing the IAT by an attenuation factor (The Department uses an attenuation factor of 0.02 and SGTs are calculated by multiplying the applicable IAT by the inverse of 0.02 which is 50). SGTs for the chronic residential multi-contaminant scenario are provided in Table B10 of the Department's BRWM web site.

Attenuation factors are derived from empirical studies[15] which should be reviewed in order to properly apply SGTs. Observed attenuation factors range several orders of magnitude due to variations over time and space at individual sites as well as variations in hydrogeologic characteristics across sites included in the study. The particular nature of the COPC (chlorinated versus petroleum) and the distance between the soil gas sample point and the receptor and/or pathway need to be considered in the application as:

- The database used to develop the attenuation factors is primarily comprised of chlorinated solvents, therefore the SGT may be overly conservative at petroleum sites.
- The distance between the soil gas collection point paired with the indoor air measurement is not specified in the attenuation factor analysis. Review of the supporting database indicates that soil gas samples were generally collected within 50 feet of the building and the soil gas attenuation factor may be overly conservative beyond 50 feet.

Considering the above, SGTs should not be applied independent of either additional lines of evidence and/or additional rounds of data collection.

3.3 Using Lines of Evidence to Evaluate Vapor Intrusion

In addition to an exceedance of a target level, there are other lines of evidence that may contribute to a determination of a complete vapor intrusion pathway. Lines of evidence may be weighted differently from one site to the next as they are dependent upon the site specifics of the discharge, pathway and receptor. Additional lines include, but are not limited to:

- A building or a preferential pathway with contaminated media (soil, soil gas, subslab or groundwater) within the following distances:
    - 30 feet (horizontally or vertically) from petroleum VOCs
    - 100 feet (horizontally or vertically) feet for chlorinated hydrocarbons

[14] "Trial Guideline for Protecting Residents from Inhalation Exposure to Petroleum Vapors – Trial Period Findings", Menzie Cura and Associates, October, 1998
[15] USEPA's Vapor Intrusion Database: "Preliminary Analysis of Attenuation Factors", March 4, 2008

- Positive results from PID screening cracks in the foundation, slab, sumps or other preferential vapor transport pathways
- Positive results from groundwater samples collected from building drainage (sumps, perimeter drains, infiltration)
- Contaminants in indoor exceeding typical[16] residential indoor air quality (see table B9).
- Contaminants in indoor air exceeding what would be the expected contribution from ambient concentrations after site specific monitoring and modeling
- Soil gas within the building envelope or subslab vapor concentrations exceed the SGTs (see Table B10)
- Similar gas profile (same constituents) from source to near foundation/subslab to indoor air
- Ratios of contaminants in the soil gas correspond to ratios detected inside the building.
- Media concentrations fluctuate seasonally in concert with indoor air concentrations
- Spatial concentration patterns from media sample event indicate a gradient toward a receptor or along a pathway
- Soil (including surface cap) stratigraphy controlling and/or facilitating vapor migration
- Building construction and condition conducive to VI
- Presence of neat material

If lines of evidence support a complete pathway and applicable IATs are exceeded in occupied buildings, a mitigation or a remedial investigation is appropriate. If results are ambiguous, it may be cost-effective to mitigate when weighed against the cost and time associated with making an absolute determination. With inconclusive results, follow up may include one or all of the following items: mitigation, a remedial investigation, source remediation, a step out investigation, a temporal evaluation, a spatial evaluation, confirmatory sampling, or a risk assessment.

4. MITIGATION, CONCLUSIONS and REPORTING:

4.1 Mitigation

There are situations (political, economical, time sensitive) where it may be appropriate to mitigate without determination of a complete pathway. Mitigation systems are relatively low cost in comparison to a VI investigation, quick to implement and protective against other indoor air quality problems (moisture and radon). Reservations about mitigation without completing the pathway include; need to assume point of entry (subslab versus wall penetration), liability inherent with

[16] Massachusetts DEP posted a draft methodology that considers the relative concentration of laboratory MRLs, risk based target levels and typical indoor air concentrations in the establishment of threshold concentrations. An exceedance of a threshold concentration may be indicative of a complete VI pathway. See Mass DEP "Indoor Air Threshold Values for the Evaluation of a Vapor Intrusion Pathway" updated June, 2009 at: http://www.mass.gov/dep/cleanup/laws/policies.htm

assumption of a complete pathway, and, responsibility for life cycle costs and effectiveness evaluations.

However, in situations such as a home heating oil spill into a dirt floor or a cracked basement slab, it may be obvious that the pathway is complete and implementation of a vapor mitigation system may proceed without an investigation.

If point of entry mitigation is indicated, sub slab depressurization systems (SSDS) are generally considered an effective and reliable technology if the point of entry is through the basement floor. It is recommended that a Maine Registered Radon Service Provider (http://www.maine.gov/dhhs/eng/rad/Radon/hp_radon.htm) design and install the SSDS. Considering that the work atmosphere may be hazardous, the installer should be trained to evaluate and monitor hazards per OSHA 29 CFR 1910.120. http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=9765.

The ITRC VI document referenced in the following section provides a comprehensive review of mitigation options and their application.

4.2 Conclusions and Reporting upon a VI Investigation and Mitigation

When presenting results from a VI investigation , provide background on the stage of the investigation (preliminary screening, baseline characterization, step out investigation, indoor air assessment), the current site conceptual model, the risk scenario, and the particular data quality and investigative objectives of the investigation stage. Also include a description of the methodology used to construct sample points and collect samples. Tabulate current and prior results and method detection limits along side the applicable target levels.

Conclusions should review whether the investigative and data quality objectives were met, justify the IAT scenario applied to the site, and determine whether the VI pathway is complete, incomplete or inconclusive. Use data and lines of evidence to support conclusions and use conclusions to make recommendations for additional investigation, remediation or closure. Closure recommendations should identify properties that may be at a relatively high risk of VI in association with future development.

If mitigation steps were completed or are recommended, describe the mitigation, performance criteria and measurement methods, assignment of ownership of the mitigation, provisions for disclosing the remedy during property transfer, and responsibility for costs associated with operation, monitoring and maintenance of the mitigation.

If the pathway is inconclusive, provide recommendations for mitigation, monitoring or follow on investigations. The recommendations should state if there are important data gaps that need additional attention. This should include specific recommendations for collecting the data and refer to the CSM in developing a work scope.

5. REFERENCES/LINKS

Note that inclusion is not to be construed as a Department endorsement of the product or service.

VI Modeling/Risk Assessment Resources

EPA VI database
http://iavi.rti.org/index.cfm
EPA Petroleum VI Modeling
http://www.epa.gov/athens/learn2model/part-two/onsite/JnE_lite.htm
EPA Chemical Property and Risk Calculator
http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/usersguide.htm
Johnson and Ettinger (1991) Model for Subsurface Vapor Intrusion into Buildings
http://www.epa.gov/oswer/riskassessment/airmodel/johnson_ettinger.htm

VI Guidance

ITRC "Vapor Intrusion Pathway: A Practical Guideline"
Technical and Regulatory Guidance, January, 2007
http://www.itrcweb.org/Documents/VI-1.pdf
ITRC "Vapor Intrusion Pathway: Investigative Approaches for Typical Scenarios
A Supplement to *Vapor Intrusion Pathway: A Practical Guideline",* January, 2007
http://www.itrcweb.org/Documents/VI-1A.pdf
EPA "OSWER Draft Guidance for Evaluating the Vapor Intrusion to Indoor Air Pathway from Groundwater and Soils (Subsurface Vapor Intrusion Guidance)", November, 2002
http://www.epa.gov/osw/hazard/correctiveaction/eis/vapor.htm
New Hampshire DES " Vapor Intrusion Guidance", July 2006
New Jersey DEP "Vapor Intrusion Guidance", October 2005
http://www.nj.gov/dep/srp/guidance/vaporintrusion/vig.htm
ASTM E2600 - 08 "Standard Practice for Assessment of Vapor Intrusion into Structures on Property Involved in Real Estate Transactions"
http://www.astm.org/Standards/E2600.htm

API Publication 4741 November 2005 "A Practical Strategy for Assessing the Subsurface Vapor-to-Indoor Air Migration Pathway at Petroleum Hydrocarbon Sites" Prepared under contract to API by: Lesley Hay Wilson, Ph.D., Sage Risk Solutions LLC, Paul C. Johnson, Ph.D., Department of Civil and Environmental Engineering, Arizona State University, James R. Rocco, Sage Risk Solutions LLC
http://www.api.org/ehs/groundwater/lnapl/soilgas.cfm

VI Consultants

Envirogroup

http://www.envirogroup.com/index.php

H&P Mobile Geochemistry

http://www.handpmg.com/hp-mobile-geochemistry.htm

Geosyntec

http://www.geosyntec.com/UI/Default.aspx?m=ViewPractice&p=8

Air Labs

Air Toxics

http://www.airtoxics.com/

Alpha Analytical

http://www.alphalab.com/

Columbia Analytical Services

http://www.caslab.com/Simi-Valley-Laboratory/

VI Mitigation

ITRC "Vapor Intrusion Pathway: A Practical Guideline" Technical and Regulatory Guidance, January, 2007, Chapter 4 and Appendix D

http://www.itrcweb.org/Documents/VI-1.pdf

January 13, 2010

MAINE DEPARTMENT OF ENVIRONMENAL PROTECTION
BUREAU OF REMEDIATION

VAPOR INTRUSION EVALUATION GUIDANCE

APPENDIX A
Target Level Method Development

MeCDC is providing this appendix to outline the methodology used to develop indoor air targets (IATs) protective of commercial and residential buildings. IATs have been developed for both chronic (long-term) and subchronic (short-term) exposure periods for a list of volatile organic compounds (VOCs) and volatile petroleum hydrocarbon fractions identified by the Vapor Intrusion Workgroup.

Chronic IATs are intended to be used in cases of site closure. If chronic IATs are met, no action to mitigate the vapor intrusion pathway is indicated. If subchronic IATs are met, but indoor air concentrations are above chronic IATs, mitigation is indicated if the source can be attributed to vapor intrusion (i.e. the IAT exceedance is not due to products stored in the home, activities in the home, or infiltration of outside ambient air). In these instances where vapor intrusion results in an IAT exceedance, corrective actions (e.g., source removal, sub-slab depressurization) should occur as expeditiously as possible.

I. INTRODUCTION

The purpose of the IATs is to identify airborne concentrations of volatile compounds which are protective of adverse human health effects should air containing these compounds be inhaled in an indoor environment. The IATs were developed using standard methodology presented in DEP's 2009 *Guidance Manual for Human Health Risk Assessments at Hazardous Substance Sites* (the Manual). Conservative default exposure factors were selected to ensure protectiveness. Exposure to contaminants in indoor air was evaluated for both residential and commercial land use. The residential IATs are lower than the commercial IATs because residents are exposed for a greater period number of hours per day and days per year than workers.

Two sets of IATs have been developed. The first set for single-contaminant sites, represents the acceptable air concentration based on Maine's cumulative site risk levels (Hazard Quotient of 1 or Incremental Lifetime Cancer Risk of 1×10^{-5}). These IATs are appropriate for sites with only one contaminant of concern detected in indoor air. For multi-contaminant sites, a second set of IATs has been developed at lower target risk levels (Hazard Quotient of 0.2 or Incremental Lifetime cancer Risk of 1×10^{-6}) such that total site risk will not be above acceptable levels considering the detection of multiple contaminants in indoor air.

II. GENERAL METHODS

A. DOSE-RESPONSE ASSESSMENT

IAT development was based on the use of chronic and subchronic inhalation reference concentrations (RfCs) and unit risk (UR) values selected according to the hierarchy specified in the Manual. The selected RfCs and URs, as well as their sources, are the same as those used to develop the DEP Soil Remedial Action Guidelines (RAGs)[17]. A table of the toxicity values used to develop the RAGs is provided at the Bureau's web site:. For a small number of identified VOCs, compound-specific toxicity values were not available. In these instances, a structurally

[17] MERAG Basis Tables – Data used to develop the draft MERAGs
http://www.maine.gov/dep/rwm/publications/guidance/index.htm

similar chemical was selected as a surrogate and the toxicity value for the surrogate compound was used. Surrogate assignments are provided in footnotes on the IAT tables.

B. EXPOSURE ASSESSMENT

Figure 1 of the Manual lists the potential exposure pathways for the residential and commercial scenarios. In formulating the IATs, only inhalation exposures were considered.

The following text describes the methodology used to develop the IATs. For the inhalation pathway, an average daily exposure (ADE) is estimated in units of milligrams of chemical per cubic meter of air as follows:

$$ADE = \frac{EPC_{air} * ET * EF * ED * CF}{AP * HPD * DPY}$$

Where:

ADE	=	Average Daily Exposure, in these guidelines always expressed as units of mg chemical per cubic meter of air
EPC	=	Exposure Point Concentration, in these guidelines always expressed as mg chemical per cubic meter of air
ET	=	Exposure Time, hours of exposure per day
EF	=	Exposure Frequency; days per year
ED	=	Exposure Duration; years
AP	=	Averaging Period; years
HPD	=	24 hours per day
DPY	=	365 days per year

The ADE represents either a chronic or subchronic exposure period. Subchronic exposures are applicable to exposures occurring for less than 7 years in duration (i.e., an Exposure Duration of 7 years) while chronic exposures are assumed to occur for 30 years in a residential setting and 25 years in a commercial setting (i.e., Exposure Durations of 30 or 25 years, respectively). For noncarcinogenic effects, the Exposure Duration is set equal to the Averaging Period. For carcinogenic effects, the Averaging Period is set equal to the lifespan of 70 years.

The Hazard Quotient (HQ) is the ADE divided by the reference dose:

$$HQ = \frac{ADE}{RfC}$$

If a chronic Average Daily Exposure is calculated, a chronic reference concentration is used to calculate the HQ. Likewise, a subchronic reference concentration is used to calculate the HQ for subchronic Average Daily Exposures. For any given compound, a subchronic reference concentration may be identical to a chronic reference concentration (if the compound's toxicity is the same upon short-term or long-term exposure) or may be a higher value than a chronic reference concentration (if a compound's toxicity is less following a brief exposure compared to a long-term exposure). Therefore, the subchronic and chronic IATs for a given compound may be identical, or may differ by 10-fold or more.

By substitution, the HQ can also be expressed as follows:

$$HQ = \frac{EPC_{air} * ET * EF * ED}{AP * HPD * DPY * RfC}$$

The target HQ value is 1 for single contaminant sites and 0.2 of multi-contaminant sites. Therefore, by inserting the appropriate target HQ and rearranging the formula, the acceptable air EPC (i.e., the IAT for noncarcinogenic effects) can be obtained, as follows:

$$IAT_{noncancer} = \frac{RfC * AP * HPD * DPY * \text{Target HQ}}{ET * EF * ED}$$

As previously stated, to evaluate risk of exposure to carcinogens, the ADE equation is used with the Averaging Period set equal to a lifetime value of 70 years.

The Incremental Lifetime Cancer Risk (ILCR) is obtained as follows:

$$ILCR = ADE * UR$$

Where:

ILCR	=	Incremental Lifetime Cancer Risk (dimensionless, probability)
ADE	=	Average Daily Exposure (mg chemical /cubic meter of air)
UR	=	Unit Risk (mg chemical / cubic meter of air)$^{-1}$

The target ILCR for single contaminant sites is 1×10^{-5} and 1×10^{-6} for multi-contaminant sites. Therefore, by inserting the appropriate target ILCR and rearranging the formula, the acceptable air EPC (i.e., the IAT for carcinogenic effects) can be obtained, as follows:

$$IAT_{cancer} = \frac{\text{Target ILCR} * AP * HPD * DPY}{UR * ET * EF * ED}$$

Because the Exposure Duration is less for a subchronic exposure (i.e., 7 years) compared to a chronic exposure (i.e., 25 or 30 years), the IAT_{cancer} is always higher for a subchronic exposure than for a chronic exposure.

For compounds that display both carcinogenic and noncarcinogenic effects (i.e., have both a UR and a RfC), the lower of the IAT_{cancer} and $IAT_{noncancer}$ is selected as the IAT such that the IAT is protective of both types of health effects.

III. DEFAULT EXPOSURE ASSUMPTIONS

The Manual contains standard default exposure assumptions applicable to Maine. Exposure assumptions used in the development of the IATs are presented below and in the Manual Table 1.

A. RESIDENTIAL SCENARIO

The following exposure assumptions were used in the development of the residential IATs:

ET	=	Exposure Time; 24 hours per day
$ED_{chronic}$	=	Chronic Exposure Duration; 30 years
$ED_{subchronic}$	=	Subchronic Exposure Duration; 7 years
EF	=	Exposure Frequency; 350 days per year
AP_{cancer}	=	Carcinogenic Averaging Period; 70 years
$AP_{noncancer}$	=	Noncarcinogenic Averaging Period; equal to ED
DPY	=	365 days per year
HPD	=	24 hours per day

IATs for the residential scenario are located at the BRWM web page[18] and include Tables B1 through B4 as follows:

- Table B1: Chronic IATs for single-contaminant sites
- Table B2: Chronic IATs for multi-contaminant sites
- Table B3: Subchronic IATs for single-contaminant sites
- Table B4: Subchronic IATs for multi-contaminant sites

B. COMMERCIAL SCENARIO

The following exposure assumptions were used in the development of the residential IATs:

ET	=	Exposure Time; 8 hours per day
$ED_{chronic}$	=	Chronic Exposure Duration; 25 years
$ED_{subchronic}$	=	subchronic Exposure Duration; 7 years
EF	=	Exposure Frequency; 250 days per year
AP_{cancer}	=	Carcinogenic Averaging Period; 70 years
$AP_{noncancer}$	=	Noncarcinogenic Averaging Period; equal to ED
DPY	=	365 days per year
HPD	=	24 hours per day

IAGs for the commercial scenario are temporarily located at the BRWM web page and include Tables B5 through B8 as follows:

- Table B5: Chronic IATs for single-contaminant sites
- Table B6: Chronic IATs for multi-contaminant sites
- Table B7: Subchronic IATs for single-contaminant sites
- Table B8: Subchronic IATs for multi-contaminant sites

[18] http://www.maine.gov/dep/rwm/publications/guidance/index.htm

January 13, 2010

MAINE DEPARTMENT OF ENVIRONMENAL PROTECTION
BUREAU OF REMEDIATION

VAPOR INTRUSION EVALUATION GUIDANCE

APPENDIX B
Indoor Air Target Tables B1 through B8
MRL, Ambient Air, Typical Indoor Air and Soil Gas Target Comparison Tables B9 and B10

Note: Tables B1 through B10 are not included in this document. Refer to the Department's BRWM web page at:

http://www.maine.gov/dep/rwm/publications/guidance/index.htm

January 13, 2010

MAINE DEPARTMENT OF ENVIRONMENAL PROTECTION
BUREAU OF REMEDIATION

VAPOR INTRUSION EVALUATION GUIDANCE

APPENDIX C
Acronyms and Definitions

LIST OF ACRONYMS

APH	Air Phase Hydrocarbon
BRWM	Bureau of Remediation and Waste Management
COPC	Chemical or Contaminant of Potential Concern
CSM	Conceptual Site Model
DQO	Data Quality Objective
Department or DEP	Maine Department of Environmental Protection
EOHP	Environmental and Occupational Health Program
EPC	Exposure Point Concentration
HVAC	Heating Ventilation and Air Conditioning
IUR	Inhalation Unit Risk
MA	Massachusetts
MeCDC	Maine Center for Disease Control
MRL	Method Reporting Limit
MDL	Method Detection Limit
OSHA	Occupational Safety and Health Act of 1970
ORNL	Oak Ridge National Laboratory
PAH	Polycyclic Aromatic Hydrocarbons
PEL	Permissible Exposure Limit
RAG	Remedial Action Guideline
RBC	Risk-based Concentration
REL	Reference Exposure Level
RfC	Reference Concentration
RfD	Reference Dose
SF	Slope Factor
TIC	Tentatively Identified Compound
UR	Unit Risk
USEPA	United States Environmental Protection Agency
VI	Vapor Intrusion

1.2 Definition of Terms Used in this Guidance[19]

Advection:

Movement of molecules through soil, conduits, fractures due to differences in gas permeability, pressure, and temperature. The "draft" or "stack effect" is an example of molecules moving in the opposite direction of gravitational forces.

Attenuation Factor:

Attenuation is the change in concentration of a vapor between soil gas and indoor air due to vapor transport influences (boundaries, diffusion, advection, sorption, transformation reactions) coupled with dilution when the vapors mix with indoor air. An attenuation factor represents the sum of these influences and is defined as the concentration in the indoor air divided by the concentration in the subsurface.

Attenuation factors are developed from empirical observations of COPC attenuation between soil gas and indoor air. New Jersey DEP[20] uses an attenuation factor of 0.02 which results in a SGT 50 times greater than the IAT. An EPA[21] preliminary analysis of attenuation factors indicates that an attenuation factor less than 0.02 falls between the 50th and 75th percentile distribution of paired soil gas and indoor air measurements. Application of an SGT derived with an attenuation factor of 0.02 to a soil gas or sub-slab would be protective (results in an indoor air concentrations below IATs) between 50% and 75% of the time.

Building envelope:

The area around and beneath a building foundation that may interact with the interior building environment.

Contaminant:

Many terms such are used to describe the chemicals that may impact indoor air quality through VI. Aside from the term "chemical", the source of VI may be referred to as: petroleum hydrocarbons, chlorinated hydrocarbons, spills, hazardous substances, contaminants of potential concern (COPC). The Department is generically using the term "VI chemical(s)" or COPC(s) unless a product distinction is necessary. The Department's definition of hazardous substance is included in this section.

---

[19] **Implementation of Maine Remedial Action Guidelines for Soil (MERAGs) Draft for Public Comment Revision of July 20, 2009**

[20] "Vapor Intrusion Guide", October 2005, New Jersey DEP
[21] USEPA's Vapor Intrusion Database: "Preliminary Analysis of Attenuation Factors", March 4, 2008

Chemical/Contaminant(s) of Potential Concern (COPC):

Chemical(s) released to the environment that are considered toxic and due to their location in the environment or their mobility in the environment, an exposure is possible that poses an unacceptable risk to a receptor.

Diffusion:

Movement (flux) of molecules in a stagnant phase from a high concentration to a low concentration.

Direct Indoor Air Sampling:

Collection of indoor air samples at a building once a site has been screened positive for VI potential based upon the proximity of the source to utilities and/or a building. Direct Indoor Air Measurement is considered an alternative to the "connect the dots" soil gas sample approach outlined in this guidance.

Exposure pathway:

"Exposure Pathway" means the route a substance takes from its source (where it began) to its end point (where it ends), and how people can come into contact with (or get exposed to) it. An exposure pathway has five parts: a source of contamination (such as an abandoned business); an environmental media and transport mechanism (such as movement through groundwater); a point of exposure (such as a private well); a route of exposure (eating, drinking, breathing, or touching), and a receptor population (people potentially or actually exposed). When all five parts are present, the exposure pathway is termed a completed exposure pathway[22].

Exposure Point:

"Exposure Point" means a location of potential contact between an organism and a contaminant or physical agent.

Hazard Index (HI):

The sum of hazard quotients for substances that affect the same target organ or organ system. For non-carcinogenic effects, the Hazard Index is estimated as the Average Daily Dose or Average Daily Exposure for the exposure period divided by the Reference Dose or Reference Concentration, respectively. For the purpose of these guidelines, the Department requires that the Hazard Index be 1 or less for compounds that act on the same target organ.

[22] Agency for Toxic Substances and Disease Registry (ATSDR) Glossary of Terms: http://www.atsdr.cdc.gov/glossary.html#G-D-

Hazard Quotient (HQ):

For non-carcinogenic effects, the ratio of estimated site-specific exposure to a single chemical from a site over a specified period to the estimated daily exposure level, at which no adverse health effects are likely to occur.

Hazardous Substance:

Maine Uncontrolled Hazardous Substance Sites Act, 38 M.R.S.A.,§1362. 1 defines "Hazardous Substances" as:

A. Any substance identified by the Board of Environmental Protection under section 1319-O;
B. Any substance identified by the Board of Environmental Protection under section 1319;
C. Any substance designated pursuant to the United States Comprehensive Environmental Response, Compensation and Liability Act of 1980, Public Law 96-510, Sections 101 and 102 (Superfund);
D. Any toxic pollutant listed under the United States Federal Water Pollution Control Act, Section 307(a);
E. Any hazardous air pollutant listed under the United States Clean Air Act, Section 112;
F. Any imminently hazardous chemical substance or mixture with respect to which the Administrator of the United States Environmental Protection Agency has taken action pursuant to the United States Toxic Substances Control Act, Section 7; and
G. Waste oil as defined in section 1303-C.

Hazardous Substance Site :

"Hazardous Substance Site" or "site" means any Petroleum, Drycleaner, Brownfields, Federal Facilities, RCRA, Uncontrolled Hazardous Substance, VRAP, or Superfund Program site.

Incremental Lifetime Cancer Risk:

The "Incremental Lifetime Cancer Risk" or "ILCR" means the incremental probability of an individual developing cancer over a lifetime as a result of exposure to a contaminant.

Indoor Air Targets (IATs)

IATs are airborne concentrations of volatile compounds which are protective of adverse human health effects should air containing these compounds be inhaled in an indoor environment. The IATs were developed using standard methodology presented in the Department's/MeCDC July, 2009 Draft *Guidance for Human Health Risk Assessments for Hazardous Substance Sites in Maine.* Additional detail is provided in Appendix A.

Method Detection Limit

The lowest amount of an analyte in a sample that can be quantitatively determined with stated, acceptable precision and accuracy under stated analytical conditions (i.e. the lower limit of quantitation). The lowest concentration of a chemical that can reliably be distinguished from a zero concentration.

Method Reporting Limit

An adjustment to the MDL to take into account day-to-day fluctuations in instrument sensitivity, analyst performance, and other factors.

Naturally occurring substances:

"Naturally occurring substances" means contaminants present in the environment in forms that have not been influenced by human activity;

Neat material:

"Neat material" means liquid or solid hazardous substances which occur in a pure or nearly pure form and which may or may not be in a container. Neat material is distinct from dissolved contamination.

Point of Entry:

An opening in a building foundation that allows COPCs in groundwater or soil gas to infiltrate from the building exterior to the building interior. Common points of entry include basement sumps, floor drains, wall and floor penetrations for utility services, foundation crack, joints between foundation walls and floors, and bedrock intrusions.

Soil Gas Targets (SGTs)

SGTS are used in the evaluation of representative and appropriate sub slab and soil gas analytical results. Exceedance of the SGT indicates the potential for VI that necessitates further evaluation of the pathway or mitigation. SGTs are dependent upon the attenuation factor and the Department uses an attenuation factor of 0.02 which results in SGTs 50 times greater than IATs.

VI Potential:

VI potential is assigned to a site and/or a potential receptor when there is a suspected or known release of a COPC that is considered volatile and toxic in an area where residential or commercial buildings (potential receptors) are present as well as vapor pathways between the COPC and potential receptors.

VI Screening:

VI Screening is a process that is initiated upon identification of VI potential. Once VI potential is established, the site and/or receptor is "screened in" until the pathway is determined to be complete or until the pathway is determined to be unlikely (screened out).