Kansas Vapor Intrusion Guidance

August 2016

Kansas Department of Health and Environment
Division of Environment
Bureau of Environmental Remediation
Curtis State Office Building
1000 SW Jackson, Suite 410
Topeka, KS 66612-1367

Concurrence

Leo Henning, P.G. Director, Bureau of Environmental Remediation	8-5-16 **Date**
Randy Carlson, P.G. Remedial Section Chief	8/8/16 **Date**
Bob Jurgens Assessment and Restoration Section Chief	8/8/16 **Date**
Maggie Weiser Storage Tanks Section Chief	8/4/2016 **Date**
David Meyer Kansas Indoor Air Team Coordinator	8/4/2016 **Date**

Table of Contents

Acronyms and Abbreviations 4
1. Introduction and Purpose 5
2. Conceptual Site Model 5
2.1. Building Characteristics 6
2.2. Source and Environmental Conditions 8
2.3. Receptors 8
3. Site Screening 9
3.1. Threshold Screening for CVI: 9
3.2. Threshold Screening for PVI: 11
3.3. Site Screening Summary 12
4. Vapor Intrusion Assessment 13
4.1. Types of Samples 13
4.2. Building Characteristics and Surveys 15
4.3. Analytical Methods for Vapor Samples and Project Analyte Lists 15
4.4. Modeling 15
5. Vapor Intrusion Assessment Implementation 16
6. Data Interpretation 16
6.1. Screening Levels 16
6.2. Attenuation Factors 16
6.3. Background Considerations 16
7. Considering Future Use and Managing Risk 17
8. Vapor Intrusion Assessment Report 17
9. Mitigation and Source Control 18
10. References 19

Appendix A – Conceptual Site Model Development Checklist

Acronyms and Abbreviations

atm m^3 mol^{-1}	Atmosphere-meter cubed per mole
BER	Bureau of Environmental Remediation
BTEX	Benzene, Toluene, Ethylbenzene, and Xylene
CSM	Conceptual Site Model
CVI	Chlorinated Vapor Intrusion
EPA	(United States) Environmental Protection Agency
FID	Flame Ionization Detector
ITRC	Interstate Technology and Regulatory Council
LIF	Laser Induced Fluorescence
LNAPL	Light Non-Aqueous-Phase Liquid
LRH	Low-Range Hydrocarbons
KDHE	Kansas Department of Health and Environment
mg/kg	milligram per kilogram
mg/L	milligram per liter
NAPL	Non-Aqueous-Phase Liquid
OSHA	Occupational Safety and Health Administration
PID	Photoionization Detector
PVI	Petroleum Vapor Intrusion
RSL	Regional Screening Level
RSK	KDHE Risk-based Standards for Kansas RSK Manual, 5th Edition
UV	Ultraviolet Fluorescence
µg/m^3	Micrograms per cubic meter
VISL	Vapor Intrusion Screening Level (Calculator)
VOCs	Volatile Organic Compounds

1. Introduction and Purpose

The Kansas Department of Health and Environment (KDHE), Bureau of Environmental Remediation (BER) developed this guidance document to provide a framework for KDHE and Implementing Parties to evaluate the vapor intrusion pathway by outlining:

- Site screening processes for vapor intrusion (both chlorinated vapor intrusion (CVI) and petroleum vapor intrusion (PVI));
- Site investigation and decision making process; and
- Considerations for long term management of vapor intrusion risks.

Vapor intrusion assessments should proceed concurrently with other site investigation activities conducted under state cleanup programs. Collecting data to support a vapor intrusion evaluation should be considered when planning other site characterization and remediation activities. Most importantly, communication and coordination between KDHE and the Implementing Party is critical to ensure a streamlined and efficient vapor intrusion assessment.

Vapor intrusion evaluation processes can differ significantly based on the type(s) of contamination present. Petroleum hydrocarbon vapors can rapidly attenuate in the vadose zone due to aerobic biodegradation; however, these processes do not have a substantive effect on most chlorinated compounds. These substantial differences are addressed in numerous documents authored by the Environmental Protection Agency (EPA)[1,2] and the Interstate Technology and Regulatory Council (ITRC)[3], among others. For this reason, this guidance establishes two distinct screening approaches for sites undergoing PVI and CVI evaluations as presented herein. For the purposes of this guidance document, CVI includes chlorinated compounds and any non-petroleum vapor forming compounds that pose a vapor intrusion risk.

Methane and certain other vapor-forming chemicals can pose explosion hazards depending on site specific circumstances. For the purposes of this guidance, methane will be addressed on a site specific basis.

2. Conceptual Site Model

In order for the vapor intrusion exposure pathway to be complete, the following criteria must be met[4]:

- A subsurface source of vapor-forming chemicals is present (e.g., in the soil or in groundwater) underneath or near one or more buildings;

[1] https://www.epa.gov/sites/production/files/2015-09/documents/oswer-vapor-intrusion-technical-guide-final.pdf
[2] https://www.epa.gov/sites/production/files/2015-06/documents/pvi-guide-final-6-10-15.pdf
[3] http://www.itrcweb.org/PetroleumVI-Guidance/
[4] https://www.epa.gov/sites/production/files/2015-09/documents/oswer-vapor-intrusion-technical-guide-final.pdf

- Vapors form and have a route along which to migrate (be transported) toward the buildings;
- The buildings are susceptible to soil gas entry, which means openings exist for the vapors to enter the building and driving 'forces' (e.g., air pressure differences between the building and the subsurface environment) exist to draw the vapors from the subsurface through the openings into the buildings;
- One or more vapor-forming chemicals comprising the subsurface vapor sources are present in the indoor environment; and
- The buildings are occupied by one or more individuals when the vapor-forming chemicals are present indoors.

If any of these criteria are not met, the exposure pathway is not complete; however, it remains possible that the pathway could be complete under a future use scenario or if site conditions change (e.g., contaminant plume migrates, etc.). Note that the exposure pathway can be complete but may not pose a current risk if the indoor air concentrations are well within acceptable levels. Approaches for managing future risks are addressed in Section 6 of this guidance.

A Conceptual Site Model (CSM) is a summary of relevant site conditions that identifies contaminant sources, affected media, migration pathways, and potential receptors[5]. CSMs typically include text and figures to help readers visualize the concepts. CSMs are dynamic tools that evolve throughout the evaluation process as new information is gathered. New information will either confirm the CSM or indicate that the CSM may require updating. The level of detail, necessary information, and formality of the CSM varies on a site-specific basis depending on site complexity, contaminant type(s), building construction, assessment approach, and other considerations. Developing a CSM is critical for an effective, efficient, and accurate evaluation of potential vapor migration pathways. Appendix 1 provides a checklist of considerations when developing a CSM (adapted from ITRC 2014, Appendix D). Some of these elements are discussed below:

2.1. Building Characteristics

- *Construction style* – Vapor intrusion may occur in any building type. Impacts are not limited to structures with basements. The condition, size, and construction of the foundation, furnace type and location, and building ventilation appear to be more important factors than the presence of a basement.
- *Type of building* – whether the structure is residential or commercial may influence vapor migration. Ventilation systems may be designed differently for commercial buildings (e.g. positively pressured, etc.) and limit the potential for vapor intrusion.
- *Age of the structure* – Older buildings are more likely to have foundations that have developed cracks and other entry points for vapor intrusion, but are less airtight, allowing more fresh air exchanges. Newer buildings have better constructed foundations and are more airtight with less fresh air exchanges, which could lead to higher concentrations in the occupied spaces and possibly an increase of contaminant migration into the structure.

[5] http://www.itrcweb.org/PetroleumVI-Guidance/

- *Ventilation* – The type of ventilation system serving a building can affect vapor intrusion. This can vary on a seasonal basis. During winter and summer months, fresh air exchange is reduced because buildings are generally closed more tightly for climate control. For residences during the winter months, the indoor to outdoor air temperature differential and the mechanics of the heating system, may result in a stack effect that increases upward vertical migration of contaminants.
- *Dirt floors and stone foundations* – Earthen floors, concrete block, limestone, or field stone foundations are more porous and provide increased opportunity for vapor intrusion compared to poured concrete foundations. Conversely, porous floors and foundations may limit petroleum vapor intrusion due to the free movement of oxygen into the subsurface.
- *Foundation Type and Configuration*- The type of structure foundation should also be considered. Buildings with perimeter foundations will respond differently to vapor intrusion pathways and mitigation than to buildings with interior foundations that create "cells" under the floor slab. Configuration of the building foundation system should be reviewed and investigated.
- *Drain tiles / sumps* – A building with a foundation drain tile connected to a sump has a direct conduit from the subsurface to the indoor air. If the sump is active, even low Volatile Organic Compound (VOC) concentrations in groundwater can contribute to significant indoor air problems if the mass flow through the sump is relatively high. As the water flows over the ridged drain tile and into the sump, much of the VOC mass can be effectively stripped from the water (particularly for VOCs with high Henry's Law Constants), and then into the head space of the tile, sump and indoor air.
- *Interior wells* – If the building was constructed over the location of a pre-existing groundwater well, the well provides a direct conduit from the subsurface to the indoor air. If the well is screened in the contaminated aquifer significant indoor air problems may be present near the indoor well.
- *Wet basements* – If the building has chronic water intrusion problems, VOCs dissolved in water infiltrating into the basement will off-gas to indoor air. Periodic water problems can be related to improper landscaping and drainage, but may also indicate a shallow water table. Wet basements typically require an accelerated response.
- *Utility lines / preferential pathways* – Gaps or cracks around piping or other utility lines that enter through the foundation can be a preferential migration path for vapor intrusion. Permeable soil in a utility trench can also provide a conduit through which contaminants may migrate greater distances from the source area.
- *Elevators* – Buildings with elevators may have an increased likelihood of vapor intrusion due to the elevator shaft and the pumping or vacuum effect of the elevators' travel. Building codes may require drainage holes at the base of the elevator shaft that provide a conduit for vapors to enter the building.

2.2. Source and Environmental Conditions

- *Proximity of contaminant source to buildings* – Vapor intrusion is a greater concern when buildings are close either vertically or laterally to the source of VOC contamination.
- *Shallow groundwater* – The potential for vapor intrusion decreases with increasing depth to groundwater. EPA suggests that vapor intrusion cannot safely be ruled out when the groundwater table is less than 100 feet from the surface. KDHE's focus is on sites with groundwater depths of 40 feet or less. KDHE will make site specific decisions on cases with groundwater depths below 40 feet. Seasonal variations in groundwater evaluation must be considered in the CSM.
- *Soil Type* – Soil type greatly influences the transport of vapors in soil. VOCs move through the soil via the air-filled pore spaces. Pore size, permeability of the air-filled pore spaces, and water content of a soil influence the diffusion and convection of soil gases. The spatial arrangement of soil type features is as important as the presence of various soil types.
- *Fractured bedrock* – Shallow fractured bedrock can increase vapor intrusion potential by allowing faster vapor migration and movement of contaminated groundwater. Contamination migration endpoints are less predictable in this media. Additional sampling may be necessary when dealing with fractured bedrock sites.

2.3. Receptors

- The exposure scenario for the receptors of interest should be determined. For residential buildings this typically is assumed to be 24 hours/day, 7 days/week, 52 weeks/year for 30 years. For commercial and industrial buildings this typically is assumed to be 8 hours/day, 5 days/week, 50 weeks/year for 25 years.
- Buildings that are unoccupied do not pose a current VI risk.
- Buildings that are infrequently occupied, such as storage buildings at industrial sites, may warrant a different assumed exposure scenario. If screening levels are adjusted upwards, however, administrative or other controls should be in place to limit potential exposures to the assumed durations and frequency.
- Sensitive receptors generally merit an accelerated response during vapor intrusion investigations. Examples of sensitive receptors include day care centers, schools, and nursing homes as stated in Section 3.2 of the Risk-Based Standards for Kansas (RSK) Manual 5th Version (October 2010, Revised September 2015)[6].

[6] http://www.kdheks.gov/remedial/rsk_manual_page.html

3. Site Screening

Vapor intrusion site screening determines whether a more thorough vapor intrusion assessment is warranted. The vapor intrusion screening should be completed as early in the investigation process as possible to identify potential gaps in project data and the CSM. Information needed before screening a site includes: site type, contaminants present, vapor source, extent of source, site geology and hydrogeology, lateral distance between source and receptor, vertical distance between source and receptor, and the presence of preferential migration pathways (e.g., fractured bedrock geology, anthropogenic migration pathways, etc.).

The dominant risk drivers at many vapor intrusion sites are trichloroethylene (TCE), tetrachloroethylene (PCE) and/or benzene. Their presence indicates a greater concern for the vapor intrusion pathway. At the location of a release, the source may be contaminated soil and/or contaminated groundwater. For VI investigations off-site away from the historical release, the source is almost always contaminated groundwater. The processes for screening sites for vapor intrusion depends on the types of contaminants present as described below.

3.1. Threshold Screening for CVI:

The screening process for CVI sites is based on the volatility of the contaminants, presence of migration pathways, distance to the vapor source(s), and source contaminant concentrations:

Step 1 - Are the site contaminants of concern sufficiently volatile to pose a vapor intrusion threat?

KDHE considers contaminants with a Henry's Law Constant greater than 10^{-5} atmosphere-meter cubed per mole (atm m^3 mol^{-1}) to be sufficiently volatile to pose a potential vapor intrusion threat. This information is available in KDHE's Risk-based Standards for Kansas (RSK) Manual[7].

Step 2 - Are preferential migration pathways present?

Preferential migration pathways increase the potential for vapor intrusion and must be considered independent of the CVI separation distances specified below before the site can be released from further vapor intrusion evaluation.

Step 3 - Is a subsurface source of contamination near receptors?

For CVI sites, compare the vertical and lateral separation distance to the thresholds below:

CVI Separation Distances	
Vertical Separation Distance	40 feet
Lateral Separation Distance	100 feet

[7] http://www.kdheks.gov/remedial/rsk_manual_page.html

Separation distances are measured from the lowest level of the receptor building to the shallowest groundwater plume boundary as defined by KDHE's Tier 2 levels for groundwater, a calculated groundwater screening level for vapor intrusion based on EPA's Vapor Intrusion Screening Level Calculator (VISL)[8] where applicable, or equivalent. If the plume boundary is not well defined, consider using non-detect wells to tighten the VI investigation area as additional wells are installed and sampled and more information becomes available (especially for residential areas where access to install well may be difficult). Buildings with soil impacts above KDHE's Tier 2 levels for soils within these distances cannot be screened out at this stage and warrant further consideration.

The vapor intrusion pathway at CVI sites without contaminant sources within the specified separation distances and without preferential pathways is considered incomplete. No further vapor intrusion assessment activities are required. Consideration should be given to potential future vapor intrusion risks as outlined in Section 6.

[8] https://www.epa.gov/sites/production/files/2016-01/visl-calculator_v_346.xlsm

3.2. Threshold Screening for PVI:

Step 1: Are the site contaminants of concern sufficiently volatile to pose a vapor intrusion threat?

KDHE considers sites with a Henry's Law Constant greater than 10^{-5} atm m^3 mol^{-1} to be sufficiently volatile to pose a potential vapor intrusion threat. This information is available in KDHE's RSK Manual[9].

Step 2: What is the site type?

PVI Sites are generally categorized as either a storage tank facility (e.g., gas station) or industrial facility (e.g., terminal, refinery, etc.).

Step 3: Are precluding factors present?

If any of the factors identified in the box to the right are present, further characterization of the vapor intrusion pathway is warranted.

Step 4: Is a subsurface source of contamination present near receptors?

For the purposes of this section, the distances specified in the table below are based on measurements from the top of the petroleum vapor source to the lowest level of the receptor building. For groundwater sources, the distance is from the top of the capillary fringe (defined as the highest observed water level, or other value approved by KDHE) to the bottom of the enclosed space floor slab. These separation distances, which are measured from the base of the building or bottom of the enclosed floor space, were selected based on numerous peer reviewed studies and the petroleum vapor intrusion database[10] developed by EPA.

What are Precluding Factors?

Precluding factors are site characteristics that can cause the PVI screening process to underestimate potential vapor intrusion risks to receptors. If any precluding factors are present at a site, further evaluation of the PVI pathway is warranted. Precluding factors include the following (ITRC 2014):

- Preferential pathways that intercept both the vapor source and building foundations (e.g., utility corridors, karst or fractured geology, etc.)
- Ongoing releases that result in expanding or mobile contaminant plumes
- Fuel types (gasoline containing lead scavengers or greater than 10% vol/vol ethanol)
- Soils with high methane generating potential or excessively dry conditions
- The presence of sensitive receptors should be evaluated on a case-by-case basis

[9] http://www.kdheks.gov/remedial/rsk_manual_page.html
[10] https://www.epa.gov/vaporintrusion/vapor-intrusion-database

For PVI sites, compare the vertical and lateral separation distances to the thresholds below, based on site type:

PVI Separation Distances[11]		
Petroleum Storage Tank Sites	PVI Vertical Separation Distance (Dissolved Source)	5 feet
	PVI Vertical Separation Distance (LNAPL Source)	15 feet
	PVI Lateral Separation Distance	30 feet
Petroleum Industrial Sites	PVI Vertical Separation Distance (Dissolved Source)	5 feet
	PVI Vertical Separation Distance (LNAPL Source)	18 feet
	PVI Lateral Separation Distance	30 feet

The criteria specified in the table below (adapted from ITRC 2014) were used as indicators of Light Non-Aqueous Phase Liquid (LNAPL) in the various studies serving as the basis for the vertical separation distances provided herein. Please note, these LNAPL indicators apply only to PVI screening and differ from those provided in KDHE's policy on *Total Petroleum Hydrocarbons (TPH) and Light Non-Aqueous Phase Liquid (LNAPL) Characterization, Remediation, and Management*. In addition, for screening purpose only, LNAPL should be considered present in areas within 20 feet of a suspected LNAPL release.

Groundwater	Soil
• Benzene > 1mg/L • LRH >30 mg/L • BTEX > 20 mg/L • Current or historical presence of LNAPL (including sheens)	• Current or historical presence of LNAPL (including sheens, staining) • Benzene > 10 mg/kg • LRH >250 mg/kg • PID or FID readings > 500 ppm • UV or LIF fluorescence response in LNAPL Range

3.3. Site Screening Summary

The summary report to document the approach and findings of the site screening should follow the general framework for a Vapor Intrusion Assessment Report discussed in Section 8.

[11] http://www.itrcweb.org/PetroleumVI-Guidance/

4. Vapor Intrusion Assessment

Sites that do not screen out under the protocols established in Sections 3.1 or 3.2 must be further characterized to evaluate potential vapor intrusion risks. Typically, multiple lines of evidence are used to perform vapor intrusion assessments as determined on a site-specific basis. The appropriate types of data to collect will vary based on the CSM, type and number of receptors in the site vicinity, and property access or other physical constraints. The number of samples collected and their locations will be determined on a site-specific basis. Paired samples may provide directly comparable results, especially when collected at intervals that include groundwater, deep soil gas, shallow soil gas, sub-slab soil gas, and indoor air. The number of rounds of testing necessary depends on how well the site has been characterized and the available lines of evidence. At each step in the investigation process, it is important to consider whether the available information could warrant an immediate response action to mitigate adverse health risks.

4.1. Types of Samples

- *Groundwater* – Groundwater data are typically used at the screening stage and to help determine the area where more extensive vapor intrusion testing may be needed. Only groundwater samples collected across the top of the saturated zone are relevant for vapor intrusion assessment purposes. The presence of clean groundwater above contaminated groundwater (i.e., a clean water lens) can act as a barrier to volatilization of contaminants at the capillary fringe; therefore, it is important to understand the level of contamination at the top of the saturated zone and into the capillary fringe. When an attenuation factor is applied to groundwater data, they can be used to estimate a potential upper-bound indoor air concentration that may arise from vapor intrusion[12]. If contaminated groundwater (or NAPL) is in contact with the building, further assessment is warranted.
- *Near slab soil gas* – Near slab soil gas samples can help characterize subsurface vapor sources and evaluate vadose zone biodegradation processes for PVI sites. Grab samples are acceptable for collecting soil gas. Multiple samples are generally taken from various depths (below the foundation) as close to the building(s) of interest as possible to evaluate potential vapor intrusion risks. In cases where the vapor source is not directly under a building of interest, soil gas samples should be collected from the side(s) of the building closest to the vapor source. When choosing sample locations it is important to have a good understanding of the vadose zone geology and any permeable zones in the subsurface. When an appropriate attenuation factor is applied, soil gas samples can provide useful information to estimate indoor air concentrations and define the extent of potential vapor impact. Soil gas generally has less temporal variability as the depth below ground surface increases. Soil gas at 5 foot depths and below is relatively stable.
- *Soil* –Bulk soil data may not be particularly useful when quantifying potential vapor intrusion risks. The analytical detection limits for soil are relatively high, so there may be elevated soil-gas concentrations (e.g., >10,000 µg/m3) even though soil values are non-detect. However, if vadose zone soil impacts are the principal vapor source, the nature and extent of soil impacts must be determined (including the presence of NAPL).

[12] https://www.epa.gov/sites/production/files/2015-09/documents/oswer-vapor-intrusion-technical-guide-final.pdf

- *Sub-slab soil gas* – Sub-slab soil gas samples are taken from immediately below the lowest floor slab/foundation of a building. These samples are useful to characterize the levels of contaminants that can enter the building via vapor intrusion. When used in combination with an appropriate attenuation factor, sub-slab soil gas samples can provide an estimate of the upper-bound indoor air concentration for a building that may arise from vapor intrusion. Sub-slab soil-gas concentrations may be affected by environmental and building operation variables.

  Sub-slab soil gas samples can have a high degree of spatial variability. Generally, more than one sample will need to be collected beneath a building. High volume sub-slab sampling may be appropriate on a site-by-site basis with KDHE approval.

  Evaluation of the building foundation/footing system should be considered when determining the location of the sub-slab soil gas samples. Portions or areas of the subgrade may be confined due to the presence of interior footings. This is particularly important for structures where expansions or additions were constructed during different time periods.

- *Indoor air* – Indoor air samples provide an actual measurement of the contaminant concentrations in the media to which receptors are exposed. Indoor air samples are typically collected over a 24-hour period for residential buildings and over an 8-hour period for non-residential buildings. Due to seasonal variability, multiple indoor air sampling events may be necessary to accurately estimate risks posed by vapor intrusion.

  Indoor air samples are not typically collected as the first line of evidence for evaluating vapor intrusion, as the resulting data prove difficult to interpret in the absence of other lines of evidence (e.g., groundwater, external soil gas, sub-slab soil gas, building survey, etc.). Other confounding factors, such as cigarette smoke, can contribute to indoor air concentrations or interfere with indoor air result analysis and interpretation. Ambient air samples should always be collected over the same time period as indoor air samples. Sub-slab or near slab soil gas sampling should be considered when collecting indoor air in order to aid interpretation of indoor air results.

- *Ambient air* – Outdoor air samples are important to help differentiate between indoor air concentrations contributed by outdoor sources and indoor sources or subsurface vapor sources. As stated above, ambient air samples (see below) should be collected any time indoor air samples are collected.

- *Sump water* – Sumps may act as a migration pathway for contaminants to enter a building, either dissolved in water or vapors. In some cases, it is beneficial to collect water samples from these sumps to help determine if water in the sump contributes to indoor air concentrations.

4.2. Building Characteristics and Surveys

Building characteristics are critically important when performing vapor intrusion assessments. Some buildings are significantly more susceptible to vapor intrusion than others based on foundation type, ventilation systems, presence of vapor barriers, etc. KDHE's Standard Operating Procedure for Indoor Air Sampling[13] and EPA and ITRC guidance provides additional detail for performing building surveys with the goals of identifying the building's susceptibility to vapor intrusion (e.g., migration routes) and potential indoor sources of vapors from household products.

4.3. Analytical Methods for Vapor Samples and Project Analyte Lists

The majority of vapor samples collected for vapor intrusion assessments in Kansas are analyzed via EPA Method TO-15 or TO-15 SIM. TO-15 SIM provides lower reporting limits which may be necessary to facilitate comparison of indoor air data to applicable screening levels (TO-15 SIM is not appropriate nor necessary for most soil gas or sub-slab studies). Other methods (e.g., TO-17 passive or active, etc.) may also be approved by KDHE on a site-specific basis.

KDHE recommends conferring with your air laboratory to ensure the selected laboratory method is appropriate for the target analytes and satisfies project data quality objectives. Additional information on analytical methods is provided in Appendix G of ITRC 2014.

The "standard" full analyte list for most analytical methods varies by laboratory, but will often include numerous chemicals that can be sourced from common household products and are not associated with subsurface vapor sources. KDHE recommends tailoring analyte lists to site-related contaminants of concern to avoid unnecessary complication of subsequent risk communications if testing reveals the presence of chemicals not related to vapor intrusion. Problematic compounds include acetone, 2-propanol, ethanol, toluene, xylenes, 2-butanone, methyl isobutyl ketone, chloroform, methylene chloride, 1,2-dichloroethane, and 1,4-dichlorobenzene. Unless these compounds are present in groundwater or soil samples, it may be prudent to exclude them from indoor air and sub-slab soil gas target analyte lists.

4.4. Modeling

KDHE will accept vapor intrusion models as a line of evidence to support the overall vapor intrusion assessment. Models will not be accepted as the sole line of evidence to demonstrate that the vapor intrusion pathway is not complete. The EPA spreadsheets that incorporate the Johnson & Ettinger model and the BioVapor model may be useful. In general, employ the EPA default values unless there is strong justification provided. Utilization of the Johnson & Ettinger model should always include updating chemical parameters and toxicity information based on agreed upon values or the most recent EPA Regional Screening level tables, which are also incorporated into the VISL Calculator. Use the default Qsoil value of 5 L/min. Do not use site-specific soil moisture and air-filled porosity values in lieu of EPA defaults for a given soil type unless it can be shown that the site-specific values are representative of long-term conditions.

[13] BER-RS-033 - Procedures for Sampling and Analysis of Indoor Air Samples

5. Vapor Intrusion Assessment Implementation

Vapor Intrusion Assessment Work Plans must be approved by KDHE prior to implementation. The Implementing Party must complete an online "Field Activities Notification Form" at least seven days before beginning work. The form is available on KDHE's website at http://www.kdheks.gov/remedial/fieldactivities_notification.html

6. Data Interpretation

6.1. Screening Levels

Risk-based screening levels for indoor air under a residential use scenario are presented in KDHE's RSK Manual.[14] As of the date of this guidance, KDHE has not developed screening levels for non-residential scenarios. Screening levels for non-residential use scenarios are determined on a site-specific basis and may be based on EPA's regional screening levels[15] (RSL) or calculated using other means.

6.2. Attenuation Factors

Default attenuation factors for residential structures, summarized in the table below[16], can be used to evaluate the data collected as part of the vapor intrusion assessment against applicable screening levels. These attenuation factors do not consider aerobic biodegradation in the vadose zone and therefore may be overly conservative for petroleum hydrocarbon constituents. Site-specific and building-specific attenuation factors can be established with approval by KDHE.

Generic Attenuation Factors for Vapor Intrusion Evaluations	
Media	*Attenuation Factor*
Groundwater	0.001
Groundwater (fine grained soils)[17]	0.0005
Sub-Slab Soil Gas	0.03
Shallow External Soil Gas (near source)	0.03
Crawl Space Air	1

6.3. Background Considerations

It is critical to understand the potential for background contributions when performing vapor intrusion assessments. Background sources may include ambient air or other vapor sources within a building (e.g., cleaning products).

[14] http://www.kdheks.gov/remedial/download/RSK_Manual_15.pdf
[15] https://www.epa.gov/risk/regional-screening-levels-rsls-generic-tables-november-2015
[16] https://www.epa.gov/sites/production/files/2015-09/documents/oswer-vapor-intrusion-technical-guide-final.pdf
[17] Adapted from EPA 2015, laterally continuous soils in the vadose zone comprised of clay, silty clay, silty clay loam, or silt consistent with the U.S. Soil Conservation Service Classification System.

Sufficiently sensitive analytical methods can typically detect numerous VOCs in indoor air. In addition, the compounds of interest for vapor intrusion may be present in various consumer products and in the indoor space, unbeknownst to the occupants. For example, TCE may be present in gun cleaner, brake cleaner, degreasers, and pepper spray. PCE may be emitted from dry-cleaned items. Benzene may be emitted from parked vehicles, lawn mowers and other gasoline-powered equipment, fuel storage, and cigarette smoke. Consider removing or containerizing all household chemicals 48 hours prior to any indoor air sampling if allowed by residents.

One evaluation tool that shows promise to differentiate between indoor and VI sources is comparing measurements made during over-pressurization and under-pressurization of the indoor space to results made under normal conditions. Over-pressurization will "shut off" vapor intrusion and eliminate its contribution. Under-pressurization will enhance rates of vapor intrusion. The comparison among these conditions will often provide a clear signal as to whether a given VOC is present due to vapor intrusion or not. Building pressurization studies are easier to perform for residential sized buildings than for large industrial buildings.

If a given VOC is used or stored within a building, exposure to that VOC may fall under occupational exposure. For example, benzene and other hydrocarbons found in an auto maintenance facility would be considered occupational exposure and be regulated under the Occupational Safety and Health Administration (OSHA) rather than fall under a vapor intrusion program. Similarly, PCE exposures within a dry cleaning facility would be regulated under OSHA if the dry cleaner still uses PCE. In some cases, the appropriate jurisdiction may not be clear (e.g., PCE exposures at a store within a strip mall that contains a dry cleaner) and KDHE should be consulted.

7. Considering Future Use and Managing Risk

Sites that have screened out for vapor intrusion risk or where site-specific vapor investigation activities have documented no unacceptable risk under current site conditions may still present a risk in the future if site conditions or use changes (e.g., several new buildings were constructed on a previously undeveloped property overlying a contaminant plume). The vapor intrusion pathway may need to be periodically reevaluated at sites with expanding plumes to ensure that site risks are under control.

The potential for a site to pose a future vapor intrusion threat must be evaluated as part of the overall risk evaluation process performed at all sites. Site decision documents should address this potential exposure pathway on a site specific basis, either by performing periodic receptor surveys, establishing testing programs to evaluate changing vapor intrusion risks, or establishing institutional controls to require vapor resistant construction methods, further evaluation, and/or mitigation for new buildings constructed in the vicinity.

8. Vapor Intrusion Assessment Report

Vapor intrusion assessments must include a comprehensive discussion and evaluation of all relevant site data in the context of the CSM. Vapor intrusion Assessment Reports shall generally include the following components:

- Site Background – a summary of site history, including source areas, and preliminary Conceptual Site Model
- Site Screening Summary – a thorough description of the applicable screening process as described in Section 3 above.
- Vapor Intrusion Investigation Results – a summary of the data collected to support the vapor intrusion evaluation, including maps and figures.
- Recommendations and Conclusions – an update to the CSM, including an overall discussion of potential vapor intrusion risks at a site for the current and future use scenario. This section should also include recommendations for any additional testing, institutional controls, or mitigation that may be necessary to protect human health.

9. Mitigation and Source Control

Two separate but equally important approaches to preventing vapor intrusion are source control and air quality mitigation. How the two approaches are used together depends on the site conditions and whether or not the pathway is already complete. As a general rule, KDHE recommends interrupting the migration pathway as far away as possible from points of human exposure and before vapors enter occupied spaces. It is important to note that any action taken to remediate environmental contamination must be performed in coordination with KDHE.

The first and most traditional approach is to control the source of the contamination so that the contaminant migration pathway does not reach the building in question. This source control activity is usually designed to prevent groundwater contamination that would exceed drinking water standards. The same approach applies to preventing vapor intrusion originating from contaminated groundwater. Controlling soil gas migration is also an important source control activity, especially when the contaminants are migrating through soil gas directly from the source. When contaminants have reached a building, source control is still necessary and important, but mitigating indoor air impacts becomes a more immediate priority. Ultimately, source control efforts should remove the need for mitigation at the building(s).

When contaminants are entering a structure, steps should be taken to seal any gross openings that allow for direct soil vapor intrusion. These include openings in the slab, major cracks in floors and walls, gaps around utility lines, open sumps, compromised floor drains, etc. For structures with crawlspaces, installation of a vapor barrier is recommended. If odors are apparent, the basement/crawlspace air should be ventilated separately, as much as possible, from the remaining occupied portions of the building (closing cold air returns and heat vents in the impacted area). If ventilation of the crawlspace and/or basement is performed, freezing water pipes is a possibility and care must be taken with this approach.

The remaining mitigation steps involve creating a pressure differential between the indoor air and soil gas that prevents vapor migration into the structure. The most common mitigation techniques utilize the types of sub-slab depressurization systems developed to prevent radon gas migration. Sub-slab depressurization systems are designed to capture soil gases from beneath a building floor slab and vent them to the atmosphere before they can migrate into occupied spaces. These systems tend to be relatively inexpensive (compared to an indoor air investigation and other aspects of site

remediation) because they can be adapted to take advantage of existing building features. A list of radon contractors can be obtained by filling out a request form located on the KDHE Bureau of Community Health Systems website: http://www.kdheks.gov/radiation/download/Certified_Contractor_List.pdf.

A comprehensive review of mitigation strategies can be found in Chapter 4 of the ITRC Technical and Regulatory Guidance document, Vapor Intrusion Pathway: A Practical Guide[18].

10. References

Interstate Technology & Regulatory Council (ITRC). October 2014. *Petroleum Vapor Intrusion: Fundamentals of Screening, Investigation, and Management.* Interstate Technology & Regulatory Council, Vapor Intrusion Team, Washington, D.C. Available online from http://www.itrcweb.org/PetroleumVI-Guidance/

Interstate Technology & Regulatory Council (ITRC). January 2007. V*apor Intrusion Pathway: A Practical Guideline.* Interstate Technology & Regulatory Council, Vapor Intrusion Team, Washington, D.C. Available online from http://www.itrcweb.org/GuidanceDocuments/VI-1.pdf

Kansas Department of Health and Environment, Bureau of Environmental Remediation. Bureau of Environmental Remediation, Standard Operating Procedure BER-RS-033 - Procedures for Sampling and Analysis of Indoor Air Samples. Available online at BER-RS-033 - Procedures for Sampling and Analysis of Indoor Air Samples

Kansas Department of Health and Environment, Bureau of Environmental Remediation. 2010. Risk based Standards for Kansas Manual. Available online at http://www.kdheks.gov/remedial/rsk_manual_page.html

U.S. Environmental Protection Agency. June 2015. *Technical Guide for Assessing and Mitigating the Vapor Intrusion Pathway form Subsurface Vapor Sources to Indoor Air.* U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response, Washington D.C. Available online from https://www.epa.gov/sites/production/files/2015-09/documents/oswer-vapor-intrusion-technical-guide-final.pdf

U.S. Environmental Protection Agency. June 2015. *Technical Guide for Addressing Petroleum Vapor Intrusion at Leaking Underground Storage Tank Sites.* U.S. Environmental Protection Agency, Office of Underground Storage Tanks, Washington D.C. Available online from https://www.epa.gov/sites/production/files/2015-06/documents/pvi-guide-final-6-10-15.pdf

U.S. Environmental Protection Agency. 2015b. *Vapor Intrusion Screening Level (VISL) Calculator.* U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response, Washington D.C. (MS Excel Spreadsheet). Available online from https://www.epa.gov/sites/production/files/2016-01/visl-calculator_v_346.xlsm

[18] http://www.itrcweb.org/GuidanceDocuments/VI-1.pdf

U.S. Environmental Protection Agency. 2016. *Vapor Intrusion Database.* U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response, Washington D.C. Available online at https://www.epa.gov/vaporintrusion/vapor-intrusion-database

U.S. Environmental Protection Agency. 2015. *Regional Screening Levels (RSLs) – Generic Tables.* U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response, Washington D.C. Available online at https://www.epa.gov/risk/regional-screening-levels-rsls-generic-tables-november-2015

Appendix 1

Site Information

Facility/Site Name: _____

KDHE Project Code: _____

Address/Location: _____

Site Owner/Operator: _____

☐ Identify the KDHE/BER Program in which the Site is enrolled

☐ Describe historical operations at the site that impacted the property

☐ Identify Contaminant Type(s)

Solvents/degreasers	Pesticides (herbicides, insecticides, etc.)	Metals
Petroleum products	Inorganics (salt, soda ash, etc.)	PCBs
Acids/bases	Fertilizer (nitrate, ammonia)	Sludge
Paint/paint wastes		

☐ Identify affected media

Surface Soil Subsurface Soil Groundwater Surface Water Sediments Air

☐ Define magnitude and extent of affected media

☐ Describe remedial actions completed to date.

☐ Identify indicators for screening

☐ Indicators/COPCs for investigation

Source Area

☐ Identify and denote on site plan the sources and their locations contributing to vapor-phase contaminants related to the subsurface vapor intrusion pathway (NAPL, dissolved plume, contaminated soil, soil gas). Estimate mass of NAPL, dissolved plume size, affected soil volume.

☐ For petroleum sites, describe and denote on the site plan the presence, distribution, and composition (gasoline and ethanol content, diesel, and fuel oil) of LNAPL at the site.

☐ For chlorinated hydrocarbon sites, identify and denote on site plan any presence of comingled chlorinated hydrocarbon plume.

☐ Identify the vapor-phase contaminants (based on volatility and toxicity) that are to be considered for the subsurface vapor intrusion pathway (benzene).

☐ Describe the status and results for the delineation of contamination in environmental media, specifically soil and groundwater, between the source area and the potential affected buildings.

☐ Describe the environmental media (soil, groundwater, both) containing contaminants.

☐ Describe the depth to source area (LNAPL, dissolved plume, unsaturated soil, soil gas).

☐ Describe the potential migration characteristics (stable, increasing, decreasing) for the distribution of contaminants.

☐ Describe contaminant transport mechanisms (diffusion in vadose zone or through capillary zone, advective flows, movement through preferential pathways).

☐ Identify if odors have been reported or documented in buildings on site

☐ Identify any indications of an ongoing release at the site/facility.

Geology/Hydrogeology

☐ Describe regional geology (especially important in fractured rock or karst areas).

☐ Review all boring logs, monitoring well construction, and soil sampling data to understand the following: depth of vadose zone, capillary fringe and the phreatic (saturated) zone

- Note any seasonal water table fluctuations and seasonal flow direction changes (hydraulic gradient).
- Note the depth interval between the vapor source and the building foundation.
- Note the presence and thickness of a biologically active layer to support biodegradation for petroleum sites.
- Note the presence of any perched aquifers.
- Note where the water table intersects the wells screened interval or note the presence of submerged screen.

Buildings and Receptors

☐ Identify and denote on site plan existing and potential future buildings.

☐ Identify the occupancy and use of the buildings, for example residential, commercial, or industrial (may need to interview occupants to obtain this information).

☐ Describe the construction of the building including materials (such as wood frame or block), openings (windows, doors), and height (one-story, two-story, multiple-story); identify any elevator shafts present in the building (if applicable).

☐ Describe the foundation construction including:

- Type (basement, crawl space, slab on grade)
- Floor construction (such as concrete or dirt)
- Depth below grade/ground surface
- Describe foundation drainage or penetrations if they exist (French drains, sumps, cracks, or other)

☐ Describe the HVAC system in the building including:

- Furnace/air conditioning type (forced air, radiant)
- Furnace/air conditioning location (basement, crawl space, utility closet, attic, roof)
- Source of return air (inside air, outside air, combination)
- System design considerations relating to indoor air pressure (positive pressure is often the case for commercial buildings).

☐ Describe subslab ventilation systems or moisture barriers present on existing buildings, or identify building and fire code requirements for subslab ventilation systems (such as for methane) or moisture barriers below foundations.

☐ Identify occupancy and use of off-site buildings affected or potentially affect by site sources. Assess the need for public communication plan.

Engineered Preferential Pathways—Utilities, Process Piping, Sumps

☐ Locate and denote on site plan all underground utilities near the soil or groundwater impacts; note utilities that connect affected areas to occupied buildings including depths and entry points. Determine when the utility lines were originally installed and if they have ever been replaced.

☐ Locate and denote on site plan all underground process piping near the soil or groundwater impacts.

☐ Locate and denote on site plan building basement dewatering sumps.

☐ Locate and denote the presence of P-traps.

Site Characteristics and Considerations

☐ Estimate and denote on site plan the lateral extent of and the distance from edge of groundwater plume to building.

☐ Identify groundwater beneficial use (potable or non-potable).

☐ Identify nearby potential contaminant sources.

☐ Estimate vertical separation distance from vapor source to building foundation and denote on subsurface cross-sections.

☐ Describe the surface cover between the vapor source area and the potentially affected building.

☐ Identify presence of continuous pavement that may result in unimpeded migration of vapor in the subgrade layer to building foundation.

☐ Describe surface water/precipitation infiltration in unpaved areas, serving as a pathway for transport of dissolved O_2 to vadose zone for aerobic PHC degradation.

☐ Describe background contributions and concentrations of volatile contaminants to indoor air (both ambient/outdoor and indoor sources).

☐ Describe data quality for vapor intrusion assessment (sample collection methods, laboratory detection levels, sufficiency of sample numbers and events, and representative sample locations).

☐ Describe rationale for determination of vapor intrusion exposure pathways and any exclusion.

For Petroleum Sites include the following:

Biological Indicators

☐ Describe biological indicators.

- O_2 concentrations to support aerobic PHC biodegradation, note presence of large building footprint that may limit atmospheric oxygen transport beneath center area of building
- CO_2 concentrations
- Methane concentrations (generation under anaerobic biodegradation of PHC because of high concentrations at plume interior or presence of LNAPL, or because of high-ethanol gasoline), potential for concentrations in explosive range (especially in confined areas), increased O_2 demand because of aerobic biodegradation of methane
- Organic soil (such as peat) with low O_2 that limits potential for aerobic PHC degradation

☐ Describe distinct strata and characteristics (soil type, temperature, moisture content, porosity, bulk density, organic content).

☐ Identify the depth to groundwater.

☐ Describe groundwater characteristics (seasonal fluctuation, temperature, hydraulic gradient: vertical and horizontal; natural versus induced, flow directions).

Type of Petroleum Site

(Identification of indicator petroleum hydrocarbon compounds and release sources)

☐ Gasoline and/or diesel UST locations

☐ Commercial and home heating oil locations

☐ Refineries

☐ Bulk storage facilities

☐ Pipelines and transportation

☐ Oil exploration and production sites

☐ Former manufactured gas plants

☐ Creosote (wood treating) facilities

☐ Dry cleaners using petroleum solvents (such as Stoddard solvent)

☐ Other, describe:

(Required for screening evaluation)

Migration

☐ Define lateral separation distance between source and receptor.

☐ Define the thickness of unaffected ("biologically active" or "relatively clean") soil between the source(s) and the building foundation.

☐ Describe biodegradation indicators, including O_2, CO_2, methane, total organic carbon (TOC) content, moisture, temperature, and pH at depths specified.

☐ Describe vadose zone lithology.