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Overview of state approaches to vapor intrusion: 2018

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Abstract

Regulatory requirements for the evaluation of vapor intrusion vary significantly among states. For site owners and responsible parties that have sites in different regulatory jurisdictions, one challenge is to know and understand how the requirements or expectations for vapor intrusion differ from one jurisdiction to the next. Differences in requirements can make it difficult to manage sites in a consistent manner across jurisdictions. Eklund, Folkes, et al. (2007, February, *Environmental Manager*, 10–14) published an overview of state guidance for vapor intrusion in 2007 that provided a detailed summary of pathway screening values and other key vapor intrusion policies. An update by Eklund, Beckley, et al. (2012, *Remediation*, *22*, 7–20) was published in 2012, which expanded the evaluation to additional states. Since that time, numerous states have substantially revised their guidance and some states that did not have vapor intrusion-specific guidance have issued new guidance. This article provides an update to the 2012 study. For each state, the review includes tabulations of the types of screening values included (e.g., groundwater, soil, soil gas, indoor air) and the screening values for selected chemicals that commonly drive vapor intrusion investigations (i.e., trichloroethylene [TCE], tetrachloroethylene, and benzene) along with other compounds of potential interest. In addition, for each state, the article summarizes a number of key policy decisions that are important for the investigation of vapor intrusion including: distance screening criteria, default subsurface to indoor air attenuation factors, mitigation criteria, and policies for evaluation of short-term TCE exposure.

1 | INTRODUCTION

Vapor intrusion is a potential exposure pathway at contaminated sites where volatile chemicals migrate from soil or groundwater into overlying buildings. The exposure pathway has been recognized as a potential concern for decades, however, before 2000, few guidance documents provided detailed recommendations for field investigation of the pathway. The US Environmental Protection Agency (USEPA) issued draft vapor intrusion guidance in 2001 and 2002 (USEPA, 2001, 2002) and issued updated guidance in 2015 (USEPA, 2015a, 2015b). Forty-two states have issued draft or final vapor intrusion guidance since 1999 (Exhibit 1), with 22 of these states issuing new or updated guidance just since the beginning of 2016 (Exhibits 2 and 3). This rapidly evolving regulatory framework poses a challenge to site owners, particularly those entities managing sites in multiple states.

Vapor intrusion guidance can take many forms. Some states such as New Jersey have issued comprehensive guidance manuals specific to vapor intrusion that include topics ranging from standard operating procedures to policies on data interpretation. In other states, guidance on vapor intrusion is spread across multiple documents that include both traditional publication formats and web pages. Still others have not formally issued any guidance and, instead, rely primarily on USEPA guidance and/or address vapor intrusion on a case-by-case basis. Although some of these states do not have vapor intrusion guidance, per se, they may issue screening levels for indoor air exposures. The variety of formats and levels of detail provided by different states poses an additional challenge to responsible parties managing sites in different parts of the country.

This article provides a review of current state vapor intrusion guidance documents. The review focuses on the policies and procedures most commonly addressed in the guidance documents and attempts to identify areas of consensus and divergence between states. Selected key information has been tabulated to illustrate the commonalities and differences among the state approaches. Where possible, we have supplemented our compilation of the written guidance documents using knowledge gained from discussions with state regulators and our experience conducting vapor intrusion investigations in many different states. The information is believed to be current as of January 2018. This review is an update of prior similar exercises conducted by Eklund, Folkes, Kabel, and Farnum (2007) and Eklund, Beckley, Yates, and McHugh (2012).

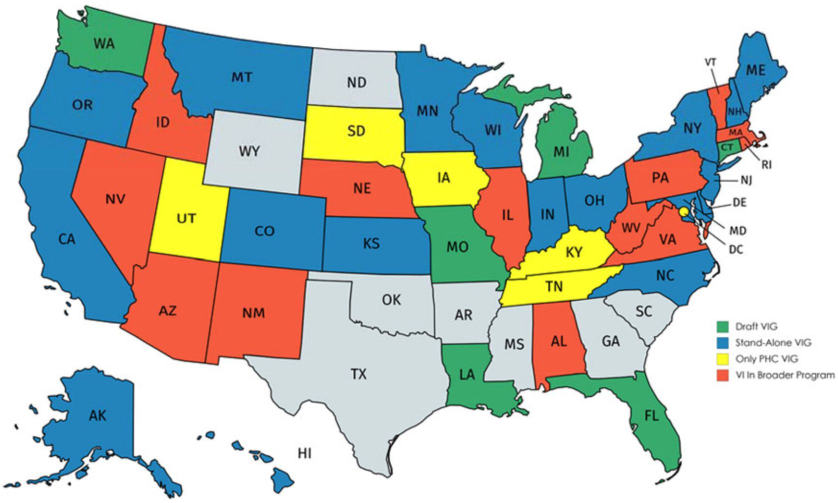

EXHIBIT 1 States with draft or final vapor intrusion guidance (as of January 2018)

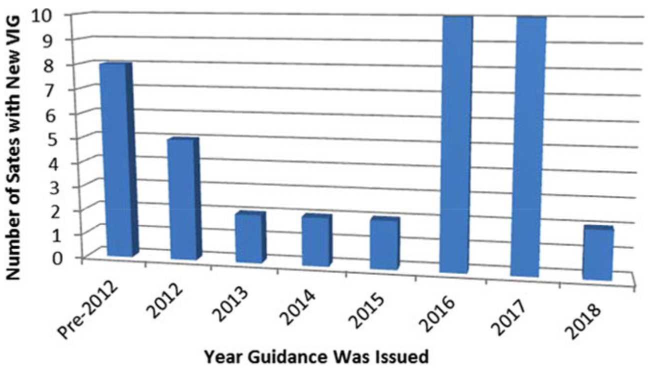

EXHIBIT 2 Twenty-eight new guides or updates issued since 2012 (as of January 2018)

2 | SUMMARY OF STATE VAPOR INTRUSION GUIDANCE

The states with current vapor intrusion guidance are listed in Exhibit 3 along with the date of the latest update. All but eight of the 42 states have issued or revised guidance since the last review published in 2012. Some states, such as New Jersey and Pennsylvania, have revised their guidance on multiple occasions in recent years. In some cases, states have issued more than one relevant document. For example, screening levels may be provided in one document and sampling and analysis or mitigation guidance in separate documents.

The eight states without guidance are generally located in the south and southwest (see Exhibit 1). Despite having no published guidance, these states may still have a robust vapor intrusion oversight program for hazardous waste sites (e.g., Oklahoma). In some states, oversight is on a case-by-case basis (e.g., Texas) and some states do not routinely address the vapor intrusion pathway within the regulatory framework for management of contaminated sites.

This review is focused on the most recently issued publicly available vapor intrusion guidance document(s) for each state, whether that document is draft or final. A complete list of the documents reviewed is provided at the end of this article.**

EXHIBIT 3 Current status of state vapor intrusion guidance

Forty-two states with vapor intrusion guidance			
State	**Last update**	**State**	**Last update**
Alabama	Feb 2017	Missouri*	Dec 2016
Alaska	Oct 2012	Montana	Apr 2011
Arizona	Apr 2017	Nebraska	Sept 2012
California	Jun 2017	Nevada	Oct 2012
Colorado^	2016	New Hampshire	Feb 2013
Connecticut*	May 2016	New Jersey	Jan 2018
Delaware	Mar 2007	New Mexico	Jul 2015
Florida*,^	Undated	New York	May 2017
Hawaii	Fall 2017	North Carolina	Apr 2014
Idaho	Aug 2012	Ohio	May 2016
Illinois	Jul 2013	Oregon	Mar 2010
Indiana	Oct 2016	Pennsylvania	Jan 2017
Iowa^	May 2017	Rhode Island	Feb 2004
Kansas	Aug 2016	South Dakota^	Mar 2003
Kentucky^	April 2011	Tennessee^	Jan 2008
Louisiana*	2014	Utah^	March 2015
Maine	Feb 2016	Vermont	Jul 2017
Maryland	Aug 2012	Virginia	2016
Massachusetts	Oct 2016	Washington*	Feb 2016
Michigan*	Aug 2017	West Virginia	Jan 2002
Minnesota	Oct 2017	Wisconsin	Jan 2018
Eight states without vapor intrusion guidance			
Region	**State**		
South	Georgia, Mississippi, South Carolina		
Southwest	Arkansas, Oklahoma, Texas		
Great Plains	North Dakota		
West	Wyoming		

Note: Exhibit 3 summarizes most recent, publicly available versions. Asterisks (*) denote drafts. Several states are in the process of revising previously issued guidance (e.g., Michigan). (^) denotes only petroleum-specific guidance for this state.

EXHIBIT 4 Criteria for exclusion distances

	Dissolved petroleum hydrocarbons		Chlorinated VOCs	
State	Lateral (ft.)	Vertical (ft.)	Lateral (ft.)	Vertical (ft.)
Alaska	30		100	
California	30	10 (LNAPL = 30)	100	100
Colorado	30	5 (LNAPL = 15)	100	
Connecticut*	30		100	
Delaware	100		100	
Florida*	50			
Hawaii	100	15 (LNAPL = 30)	100	
Idaho	50 (LNAPL = 100)		100	
Indiana	5 (LNAPL = 30)	5 (LNAPL = 30)	100	100
Iowa	500			
Kansas	30	5	100	40
Maine	30	30	100	100
Massachusetts	30	15 (LNAPL = 30)	100	15
Michigan*	30	5 (LNAPL = 15)	100	
Minnesota	100		100	
Missouri	100		100	
Montana	100		300	
Nevada			100	100
New Hampshire	30		100	
New Jersey	30	30	100	100
North Carolina	(LNAPL = 100)		100	100
Ohio	100		100	
Oregon	100		100	
Pennsylvania	30	5 (LNAPL = 15)	100	
Vermont	30		30	
Washington*	100	6 (LNAPL = 15)	100	
Wisconsin	5	5	100	

Notes: (a) Asterisks (*) denote data from draft documents. (b) Exhibit summarizes exclusion criteria for dissolved sources. States may have separate criteria for non-aqueous phase liquid (NAPL) (e.g., New Jersey). Exclusion distance defined as the distance between the building foundation and volatile organic compound (VOC) source.

Exhibits 4–8 summarize state policies with respect to vapor intrusion pathway screening. The exhibits are intended to illustrate the range of policies adopted by states and to allow the reader to evaluate similarities and differences among states. Because the exhibits present complex policies in a compact tabular format, important caveats, qualifiers, and exceptions may exist that are not presented. The simplified presentation of some policies may not reflect actual requirements for some sites. In addition, although the authors have made their best effort to accurately summarize the guidance documents reviewed, there is a possibility that we have misinterpreted some items. We encourage the readers to consult the actual documents in order to determine the specific policies applicable to any given site.

Most state guidance utilizes a stepwise evaluation procedure that allows screening out sites that do not pose likely vapor intrusion concern while requiring additional investigation for sites with higher potential for vapor intrusion.

3 | DISTANCE-BASED EXCLUSION CRITERIA

Twenty-seven of 42 states exclude sites based on the lateral or vertical distance from the source of contamination (i.e., the source of the vapors) to potentially affected buildings (Exhibit 4). Twenty-three of these 27 states use a distance criterion of 100 feet for chlorinated volatile organic compound (VOC) sources, which is consistent with general distance guidance cited by USEPA (2015a), indicating a strong consensus that this distance is appropriate.

In contrast, the exclusion distances applied to petroleum hydrocarbon sources are more variable. The USEPA has recognized that petroleum and chlorinated VOC sources differ in their potential for vapor intrusion (USEPA, 2012) and issued separate guidance for underground storage tank sites (USEPA, 2015b). Specifically, there can be a large attenuation of hydrocarbon vapors over relatively short distances when sufficient oxygen is present in the soil gas (Interstate Technology & Regulatory Council [ITRC], 2014;

Lahvis, Hers, Davis, Wright, & DeVaull, 2013). This understanding of petroleum vapor attenuation is reflected in some state guidance in the form of shorter exclusion distances for petroleum VOC sources. Only nine of the reviewed guidance documents apply a 100-foot or greater distance criterion to dissolved petroleum sources, with the remaining guidance using a shorter distance. States are moving toward adopting shorter exclusion distances for petroleum VOC sources and this trend is expected to continue. Several states (e.g., Colorado, Indiana, Pennsylvania, and Wisconsin) utilize a vertical exclusion distance of as little as 5 feet, which is generally consistent with current USEPA and ITRC guidance for petroleum vapor intrusion.

Only nine of the reviewed guidance documents apply a 100-foot or greater distance criterion to dissolved petroleum sources, with the remaining guidance using a shorter distance.

4 | SCREENING VALUES

For sites that do not meet distance-based screening criteria, VOC concentrations are typically compared to vapor intrusion pathway screening concentrations to determine whether further evaluation is required. Most states provide screening values for one or more of the following: groundwater, soil, deep soil gas, shallow soil gas, and/or indoor air. The types of vapor intrusion screening values used by each state are summarized in Exhibit 5. Of the 41 states that provide any type of screening value (39 states from Exhibit 3 plus Texas and South Carolina), 27 provide values for groundwater, 14 for deep soil gas, 29 for shallow soil gas, and 34 for indoor air. There are 11 states that provide screening values for soil, which is four more states than found in the 2012 survey. This result is surprising, given the USEPA position in recent years that it is not appropriate to use soil data to screen the vapor intrusion pathway. As seen in Exhibit 5, the number of VOCs with screening values vary significantly between states from less than 10 (i.e., Florida, Idaho, Iowa, Nevada, New York, and South Dakota) to greater than 100 (e.g., Alabama, Delaware, Indiana, etc.). Tennessee and Utah do not have look-up screening levels, but have published procedures for calculating screening levels for groundwater, soil, and soil gas for a half dozen VOCs. In addition, some states (e.g., Georgia, West Virginia) do not issue their own screening levels and instead defer to the USEPA's VISL calculator, which includes VOCs as well as many semi-VOCs.

For each state guidance document, screening values for six selected compounds (i.e., benzene, trichloroethylene [TCE], tetrachloroethylene, naphthalene, ethylbenzene, and 1,2-dichloroethane) in three media (groundwater, shallow soil gas, and indoor air) are shown in Exhibit 6. For states with different screening values for different risk scenarios (e.g., residential vs. industrial land use), the most conservative (i.e., lowest) screening values are presented in Exhibit 6. Readers are urged to read the specific state documents for further clarification, as individual states may have more than one set of screening values that apply to residential settings (e.g., New York). In the future, states are expected to continue to update their screening values to reflect updated toxicity values, consensus attenuation factors, etc.

One goal of this tabulation is to provide a summary of the range of screening values currently in use. As evident in Exhibit 6 and illustrated in Exhibit 8, there is a substantial range of screening values from state to state. Indoor air screening values vary by up to four orders of magnitude between states, groundwater screening values vary by up to five orders of magnitude, and soil gas screening values vary by up to six orders of magnitude. For indoor air, part of the variation is explained by the use of 10^{-5} versus 10^{-6} cancer risk limits and much of the remaining variation is explained by the use of different toxicity factors and exposure factors. For indoor air, the choice of target values is also complicated by consideration of background levels. For some VOCs, such as benzene, TCE, and carbon tetrachloride, the concentration in residential and nonresidential indoor air attributable to indoor or outdoor sources commonly exceeds risk-based target concentrations (Rago, Peters, & Plantz, 2017). Some states (e.g., Montana) have published background concentrations that can be utilized in lines of evidence evaluations, but most states do not have such values of “acceptable” background and default to risk-based target concentrations. As a result, the more conservative the indoor air screening level, the more difficult it may be to resolve vapor intrusion from background sources. The additional variation in subsurface screening values is attributable to different attenuation factors and other factors related to VOC fate and transport.

It was expected that, over time, screening values among states would converge due to improved understanding of VOC fate and transport along the vapor intrusion pathway. To date, this has not occurred; the variation between states is similar to that found in the 2012 review. The wide range in screening values among states suggests fundamental disagreements about what levels are appropriate. Screening values are intended to be conservative and reasonable variation will occur as the result of differences in the level of conservativeness employed. However, when screening values vary by more than 1,000 times or more between states, it is likely that either the lower screening values are overly conservative, resulting in unnecessary use of economic resources to investigate and mitigate sites, or the higher screening values may not be sufficiently protective. Given the extremely wide range of screening values for groundwater and soil gas among states, it is possible that both the lowest values are overly conservative and the highest values are not adequately protective.

EXHIBIT 5 Types of screening values used for vapor intrusion

State	Types of generic screening values					Approx. number of volatile organic compounds	Non-Residential criteria available
	Groundwater	Soil	Shallow soil gas	Deep soil gas	Indoor air		
Alabama	No	No	No	No	Yes	>100	Yes
Alaska	Yes	No	Yes	Yes	Yes	66	Yes
Arizona	No	No	No	No	No	No	No
California	Yes	No	Yes	No	Yes	61	Yes
Colorado	Yes	No	Yes	No	Yes	22	Yes
Connecticut*	Yes	No	Yes	No	Yes	47	Yes
Delaware	Yes	No	Yes	Yes	Yes	>100	No
Florida*	No	No	Yes	No	Yes	8	Yes
Hawaii	Yes	Yes	Yes	No	Yes	72	Yes
Idaho	Yes	Yes	No	Yes	No	8	No
Illinois	Yes	Yes	Yes	Yes	No	59	Yes
Indiana	Yes	No	Yes	Yes	Yes	>100	Yes
Iowa	Yes	Yes	Yes	No	Yes	4	Yes
Kansas	No	No	No	No	Yes	72	No
Louisiana	Yes	Yes	No	No	Yes	68	Yes
Maine	No	No	Yes	No	Yes	68	Yes
Maryland	No	No	Yes	No	Yes	>100	Yes
Massachusetts	Yes	No	Yes	No	Yes	40	Yes
Michigan*	Yes	Yes	Yes	No	Yes	>100	Yes
Minnesota	No	No	Yes	Yes	Yes	64	Yes
Missouri	Yes	Yes	Yes	Yes	Yes	40	Yes
Montana	No	No	No	No	Yes	>100	Yes
Nebraska	Yes	Yes	Yes	Yes	Yes	115	Yes
Nevada	Yes	No	No	No	Yes	2	No
New Hampshire	Yes	No	Yes	Yes	Yes	31	Yes
New Jersey	Yes	No	Yes	No	Yes	50	Yes
New Mexico	Yes	No	Yes	No	Yes	>100	Yes
New York	No	No	Yes	No	Yes	8	No
North Carolina	Yes	No	Yes	No	Yes	>100	Yes
Ohio	Yes	No	Yes	Yes	Yes	>100	Yes
Oregon	Yes	Yes	Yes	No	Yes	>100	Yes
Pennsylvania	Yes	Yes	Yes	Yes	Yes	>100	Yes
Rhode Island	No	No	No	No	No	NA	No
South Dakota	Yes	Yes	No	No	No	6	Yes
Texas	No	No	No	No	Yes	>100	Yes
Vermont	Yes	No	Yes	No	Yes	>300	Yes
Virginia	Yes	No	Yes	Yes	Yes	>100	Yes
Washington*	Yes	No	Yes	Yes	Yes	69	Yes
West Virginia	No	No	No	No	No	NA	No
Wisconsin	No	No	Yes	Yes	Yes	20	Yes

Note: Asterisks (*) denote data from draft documents. NA: not available.

EXHIBIT 6 Residential screening levels for selected volatile organic compounds

State	Benzene			Trichloroethylene			Tetrachloroethylene		
	Groundwater	Shallow soil gas	Indoor air	Groundwater	Shallow soil gas	Indoor air	Groundwater	Shallow soil gas	Indoor air
Alabama	–	–	3.6	–	–	2.1	–	–	42
Alaska	14	31	3.1	5.2	21	2.1	58	420	42
California	1.1	48	0.097	5.6	240	0.48	3.0	240	0.48
Colorado	15	3.60	0.36	5	4.8	0.48	5	108	10.8
Connecticut*	215	3,000	3.3	219	38,000	5	1,500	75,000	11
Delaware	5	3.1	0.31	5	0.22	0.022	5	8.1	0.81
Florida*	–	3.1	0.31	–	–	–	–	–	–
Hawaii	2,300	720	0.36	210	830	0.42	190	920	0.46
Idaho	44	–	–	3.3	–	–	–	–	–
Illinois	110	370	–	340	1,500	–	91	550	–
Indiana	28	36	3.6	9.1	21	2.1	110	420	42
Iowa	1,540	600,000	39.2	–	–	–	–	–	–
Kansas	–	–	3.1	–	–	2.1	–	–	42
Louisiana	2,900	400	12	10,000	2,000	59	15,000	3,700	110
Maine	–	10	0.31	–	70	2.1	–	1,400	42
Maryland	–	64	3.2	–	38	1.8	–	840	42
Massachusetts	1,000	160	2.3	5	28	0.4	50	98	1.4
Michigan*	1.0	110	3.3	0.073	67	2.0	1.5	1,400	41
Minnesota	–	150	4.6	–	70	2.1	–	110	3.4
Missouri	1,000	190,000	4.98	1,600	546,000	12.8	338	200,000	4.27
Montana	–	–	0.31	–	–	0.43	–	–	9.4
Nebraska	3.7	139	0.31	0.46	192	0.43	5.6	4,200	9.4
Nevada	–	–	–	5	–	2.1	50	–	32
New Hampshire	2,900	170	3.3	20	20	0.4	240	400	8
New Jersey	20	16	2	2	27	3	31	470	9
New Mexico	15.8	120	3.6	5.2	69.5	2.1	57.5	1,390	41.7
New York	–	–	–	–	6	1	–	100	10
North Carolina	16	120	0.36	1.0	14	0.42	12	280	8.3
Ohio	1.6	12	0.36	1.2	16	0.48	14.9	367	11
Oregon	190	62	0.31	160	86	0.44	2,100	1,900	9.4
Pennsylvania	23	120	3.1	9	80	2.1	110	1,600	42
South Carolina	–	–	0.22	–	–	–	–	–	–
South Dakota	1,800	–	–	–	–	–	–	–	–
Texas	–	–	11	–	–	5.9	–	–	64
Vermont	0.92	4.3	0.13	0.82	6.7	0.2	1.5	21	0.63
Virginia	–	3.1	0.31	–	4.3	0.43	–	4.1	0.41
Washington*	2.4	10.7	0.32	1.55	12.3	0.37	22.9	321	9.6
Wisconsin	16	120	3.6	5.2	70	2.1	58	1,400	42
Range of values	3,100x	193,000x	400x	137,000x	2,500,000x	2,700x	10,000x	49,000x	270x

Continued

5 | ATTENUATION FACTORS

Attenuation factors express the assumed magnitude of VOC concentration reductions from the subsurface to indoor air and are used by states to calculate subsurface screening values. For example, a shallow soil gas attenuation factor of 0.03 indicates a 33 times decrease in VOC concentration from shallow soil gas to indoor air and supports a soil gas screening level 33 times higher than the indoor air value. Twenty-four states specify one or more subsurface to indoor air attenuation factors used for the development of subsurface screening values (Exhibit 7). In addition, some states indicate that site-specific attenuation factors can be calculated. For groundwater to indoor air, most states with

EXHIBIT 6 Continued

State	Naphthalene			Ethylbenzene			1,2-Dichloroethane		
	Groundwater	Shallow soil gas	Indoor air	Groundwater	Shallow soil gas	Indoor air	Groundwater	Shallow soil gas	Indoor air
Alabama	–	–	0.83	–	–	11	–	–	1.1
Alaska	40		0.72	30	97	9.7	19	9.4	0.94
California	20		0.083	13	56	1.1	6.1	54	0.11
Colorado	–	–	–	18,000	11	1.1	5	1.1	0.11
Connecticut*	–	–	–	–	–	–	21	4,000	0.094
Delaware	150	30	3.0	700	22	2.2	5	0.94	0.094
Florida*	–	30	3.0	–	22	2.2	–	–	–
Hawaii	29,000	1,300	0.63	76,000	22,000	11	180	220	0.11
Idaho	70	–	–	50	–	–	30	–	–
Illinois	75	110	–	370	1,300	–	54	99	–
Indiana	110	8.3	0.83	–	110	11	50	11	1.1
Iowa	–	–	–	46,000	–	–	–	–	–
Kansas	–	–	0.72	–	–	9.7	–	–	0.94
Louisiana	10,000	40,000	1,200	2,300,000	330,000	10,000	3,600	130	3.9
Maine	–	24	0.72	–	323	9.7	–	31	0.94
Maryland	–	14.4	0.72	–	200	10	–	18.8	0.94
Massachusetts	700	42	0.6	5,000	520	7.4	5	6.3	0.09
Michigan*	4.2	25	–	2.8	340	10	1.4	33	–
Minnesota	–	90	9	–	140	4.1	–	13	0.39
Missouri	2,250	42,600	0.75	103,000	27,200,000	606	–	–	–
Montana	–	–	0.072	–	–	0.97	–	–	0.094
Nebraska	16.6	29.9	0.072	10.4	435	0.97	5.6	41.8	0.094
Nevada	–	–	–	–	–	–	–	–	–
New Hampshire	1,700	60	1.1	1,500	100	2	50	10	0.1
New Jersey	300	26	3	700	49	2	3	20	2
New Mexico	45.8	27.5	0.83	34.8	374	11.2	22.3	36	1.1
New York	–	–	–	–	–	–	–	–	–
North Carolina	35	21	0.083	35	370	1.1	22	360	0.11
Ohio	4.6	2.8	0.083	3.5	37	1.1	2.2	3.6	0.11
Oregon	670	14	0.072	490	190	0.97	250	19	0.094
Pennsylvania	100	28	0.72	700	370	9.7	34	36	0.94
South Carolina	–	–	–	–	–	1,100	–	–	–
South Dakota	>31,000	–	–	>170,000	–	–	–	–	–
Texas	–	–	3.1	–	–	2,000	–	–	7.2
Vermont	3.5	1	0.03	6.3	37	1.1	2.3	3.7	0.11
Virginia	4.6	2.8	0.083	3.4	37	1.1	4.2	3.2	0.096
Washington*	8.9	2.45	0.074	2,780	15,200	457	4.2	3.2	0.096
Wisconsin	46	28	0.83	34.2	370	11	22.8	37	1.1
Range of values	8,860x	42,600x	16,700x	60,700x	2,500,000x	10,300x	129x	3,640x	77x

Notes: (a) Asterisks (*) denote data from draft documents. (b) Units are μg/L for groundwater and μg/m^3 for soil gas and indoor air. (c) Exhibit shows the most conservative (i.e., lowest) screening values for each category. See individual state guidance documents for additional information, including limitations and exceptions. (d) Groundwater screening levels for Wisconsin were calculated as described in Wisconsin Statute Chapter 292; Wisconsin Administrative Code Chapter NR 700.

EXHIBIT 7 Attenuation values used in state vapor intrusion guidance

State	Attenuation coefficients (a) Groundwater	Deep soil gas	Shallow soil gas	Crawl spaces	Comments
Alaska	0.001	0.01	0.1	1	
California	–	0.002	0.05	1	Lower value for commercial buildings
Colorado*	0.001	–	0.1	1	
Connecticut*	0.0002	–	0.0013	–	
Delaware	0.001	0.01	0.1	–	
Hawaii	–	–	0.0005	1	
Idaho	–	0.01	0.1	–	
Indiana	0.0005–0.001	0.03	0.03 (sub-slab)	1	
Kansas	0.001	–	0.03	1	
Louisiana*	–	0.03–0.003	0.03		
Maine	Dependent on lateral distance	–	0.03	–	
Massachusetts	Chem specific	–	0.014	–	
Michigan*			0.03	–	
Minnesota	0.001	0.03	0.03	1	
New Hampshire	–	–	0.02	–	
New Jersey	Based on J&E modeling	–	0.02	1	
North Carolina	0.001	–	0.03 (0.01 for non-res.)	1	
Ohio	0.001	0.03	0.03	1	
Oregon	–	–	0.005 (res)/0.001 (comm.)	–	Different AF for commercial buildings
Pennsylvania	0.0009	0.005	0.026	–	
Vermont	0.001	0.03	0.03	1	
Virginia	0.001	0.01	–	–	
Washington*	0.001	0.01	0.1	1	
Wisconsin	0.001 (0.0001 comm.)	0.01 (0.001 comm.)	0.03 (0.01 comm.)	1	

Notes: Asterisks (*) denote data from draft documents. (a) AF = Attenuation factor; attenuation factor and attenuation coefficient are equivalent terms.

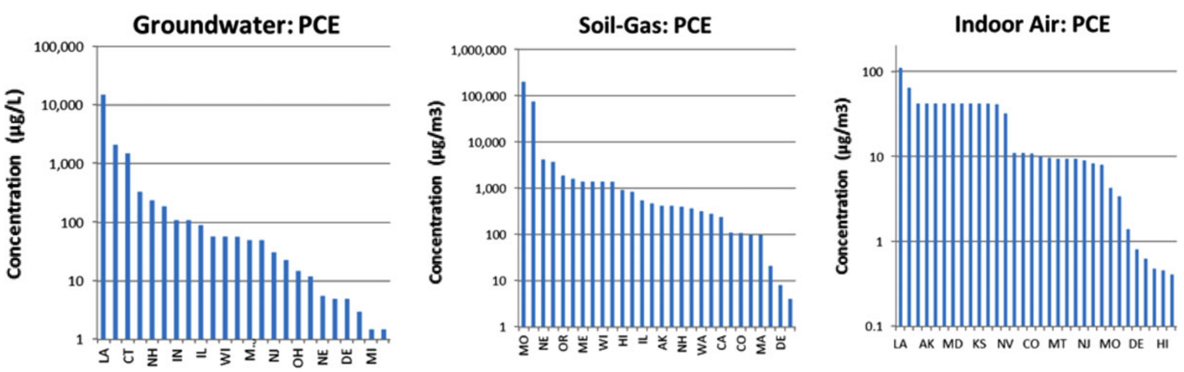

EXHIBIT 8 Distribution of lowest screening values across states

attenuation factors use the same value as the USEPA recommended value (0.001; USEPA, 2015a). For shallow soil gas to indoor air, five states use the 0.1 value long used by the USEPA and nine states use the value of 0.03 adopted by the USEPA in 2015. Seven states use smaller values (i.e., assume more VOC attenuation).

6 | INTERIM ACTION TRIGGER LEVELS

In contrast to many of the hypothetical exposure pathways evaluated at contaminated sites, vapor intrusion into an occupied building is likely to result in actual exposure to site contaminants. As a result, some state guidance documents include requirements for rapid response actions when exposure concentrations exceed long-term health-based (or odor-based) trigger levels. The trigger levels typically are based on indoor air concentrations, but also can be based on soil–gas concentrations, groundwater concentrations, or a combination of indoor air and soil gas.

Eleven states have published trigger levels to address short-term exposure to TCE (i.e., Alaska, California, Colorado, Connecticut, Massachusetts, Michigan, Minnesota, New Hampshire, New Jersey, New York, and Ohio). The short-term trigger TCE concentrations generally are 2 micrograms per cubic meter (μg/m^3) for residential buildings and 8 or 8.8 μg/m^3 for commercial or industrial buildings. States may have as many as three different trigger levels. For example, Ohio has an accelerated response level, an urgent response level, and an imminent hazard response level for TCE (2.1, 6.3, and 20 μg/m^3, respectively). Five of these states also address short-term exposure to select chemicals other than TCE.

Eleven states have published trigger levels to address short-term exposure to TCE (i.e., Alaska, California, Colorado, Connecticut, Massachusetts, Michigan, Minnesota, New Hampshire, New Jersey, New York, and Ohio).

Many states do not have trigger levels, but a tendency in some states for screening levels to become *de facto* action levels or trigger levels has been noted.

7 | OTHER REQUIREMENTS FOR VAPOR INTRUSION INVESTIGATIONS AND MITIGATION

The 2012 survey included a summary of requirements related to site characterization, such as the minimum number of soil gas or indoor air samples expected, specifications for soil gas leak checks, the minimum number of rounds of testing expected, etc. We compiled this information again, but found that the changes since 2012 were relatively minor and elected not to include a summary here. We do note, however, that the existing guidance is generally skewed toward single-family residences with little attention given to other types of buildings.

The guidance overwhelmingly specifies the use of evacuated, stainless steel canisters, as was the case in previous surveys. We did find, however, more mention of alternative sampling methods. These included 10 states that mention active sorbent sampling and 14 states that mention passive sorbent sampling. In some cases, passive sorbent data are considered to be semi-quantitative or qualitative for soil vapor (e.g., New Hampshire, Arizona). Other sampling options, such as sample bags or syringes, may be allowed in a few states. Flux chambers are discussed in the guidance of several states but, in our experience, are used regularly at vapor intrusion sites only in North Carolina.

Site characterization requirements in the majority of guidance documents are built around the traditional vapor intrusion conceptual model whereby VOC-impacted vapors migrate through the vadose zone into overlying buildings from subsurface sources. Preferential pathways are often mentioned as an additional consideration for the conceptual site model. Nineteen state guidance documents recommend sampling soil gas in utility backfill when doing detailed assessments of preferential pathways. Recently, however, utility conduits themselves, rather than the surrounding backfill material, have emerged as principal vapor migration routes for preferential pathways (Guo et al., 2015; McHugh et al., 2017). Some recent guidance documents are more explicit that preferential pathways should be considered, but still lack guidance on specifics of data evaluation. For example, the New Jersey guidance (New Jersey Department of Environmental Protection [NJDEP], 2018) states that "Due to the nature of vapor migration, the investigator shall assess the presence of preferential pathways pursuant to N.J.A.C. 7:26E-1.15(b), whether natural (e.g., shallow rock or vertically fractured soil) or anthropogenic (e.g., buried utilities)" (NJDEP, 2018, p. 19), and that "It may be necessary for the investigator to determine whether any utilities are acting as conduits for vapor migration, either along the utilities backfill or within the utility itself" (NJDEP, 2018, p. 20). Similarly, the Pennsylvania guidance states that some recognized instances of preferential pathways include "A conduit (external preferential pathway) that enters the building. This is when a utility line itself, not the backfill material, acts as a conduit for vapors." (Pennsylvania Department of Environmental Protection, 2017, p. 13). These documents do not provide guidance on how to evaluate such data. This may change in the next few years for some states (e.g., California, Indiana) are actively evaluating preferential pathway research and considering revisions to their guidance to address this issue.

Information was also collected on vapor intrusion mitigation systems, both passive and active, along with information about deed restrictions and other administrative controls. In general, the guidance was not sufficiently detailed to provide a useful summary table. Specifications for vapor barriers, the need for post-mitigation testing, operation and maintenance requirements, shutdown requirements, etc. are not set forth by most states. Minimum pressure differentials for sub-slab depressurization systems were specified by five states: 1 Pascal for New Jersey, 2 to 6 Pa for Pennsylvania, 3 to 4 Pa for Massachusetts, 3 to 5 Pa for Minnesota, and 4 to 10 Pa for California. In our experience, post-mitigation testing requirements vary greatly between states. For verification of sub-slab depressurization, some states rely primarily or exclusively on pressure differentials while others require one or more rounds of post-mitigation VOC testing for indoor air. In general, there is a need for greater guidance related to mitigation and this is expected to be a subject of future guidance updates.

8 | OBSERVATIONS

The USEPA 2015 Office of Solid Waste and Emergency Response guidance stated that one of its main purposes was to promote national consistency in assessing the vapor intrusion pathway. Despite that goal, there continues to be a great deal of variation from state to state regarding the level of detail included in the vapor intrusion guidance.

The USEPA 2015 Office of Solid Waste and Emergency Response guidance stated that one of its main purposes was to promote national consistency in assessing the vapor intrusion pathway.

Large differences among state guidance continue to exist with respect to vapor intrusion investigation and response requirements. Although different policy choices between states will always result in some differences in pathway screening values, the 10,000 to 1,000,000 times differences in indoor air, soil gas, and groundwater screening values for vapor intrusion observed between state guidance documents continue to be worrisome. Although more difficult to quantify, we have also observed large differences in the amount of testing required to support pathway evaluations or to verify mitigation effectiveness. For consultants and responsible parties who manage sites in multiple states, these large policy inconsistencies cause frustration and undermine confidence in state regulatory approaches. We encourage states to share technical resources and experience in order to narrow policy differences while maintaining policies that are protective of public health. Cooperative forums such as the ITRC have successfully facilitated this type of coordination in the past. In order to support consistency in investigation methods across jurisdictions, detailed guidance on sample collection procedures (e.g., sample point installation, leak detection, etc.) is best addressed at the interstate or international level (e.g., through ASTM International, Inc. and the International Organization for Standardization).

It is encouraging that states continue to update and refine their vapor intrusion guidance with 22 states having issued updated guidance since 2016. Many of these updates reflect recent developments in the vapor intrusion conceptual model and investigation methods. In some states, these changes include adopting updated attenuation factors, new guidance on sample leak detection, and new guidance on preferential pathways. As our understanding of vapor intrusion continues to evolve, it will be important for guidance to continue to be updated.

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