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Community Exposures to Chemicals through Vapor Intrusion: A Review of Past ATSDR Public Health Evaluations

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Introduction

Volatile contaminants in subsurface soil or groundwater can migrate up into buildings—vapor intrusion—and present a unique inhalation exposure pathway. As USEPA and ATSDR awareness of this phenomenon increases the large number of historical solvent and petroleum releases is resulting in an ever increasing number of sites with a vapor intrusion component. This column summarizes information showing which chemicals occur most frequently above screening values at sites ATSDR has reviewed, and how many of the sites with these contaminants were classified as a public health hazard. The potential for vapor intrusion and possible adverse health effects to building occupants is important information for communities to be aware of, especially during redevelopment activities and land use decision-making.

Background

Volatile organic chemicals (VOCs) are among the most common contaminants released into the environment from hazardous waste sites. In addition to contaminating groundwater and soil, these chemicals may off-gas from these two media and migrate up into the air of homes and commercial buildings. Figure 1 illustrates the potential vapor intrusion conduits into buildings. If vapors build up indoors levels may lead to the following health and safety issues: fire, explosion, and acute, intermediate and chronic health effects (ATSDR 2008).

Methods

In 2009, an ATSDR intern reviewed 135 vapor intrusion public health assessments and consultations on 121 sites published on ATSDR's website between 1994 and 2009. Here we report the following: Contaminant(s), Maximum Indoor Air Concentration, and Health Hazard Category. ATSDR assigns one of five health hazard categories to summarize the risks of particular chemical exposures at a site. The categories range from "Urgent Public Health Hazard" to "No Public Health Hazard" (ATSDR 2005). Information on the source of indoor air contamination was also collected (e.g. groundwater, soil gas, crawlspace gas, and outdoor air data).

We ranked chemicals detected in indoor air according to the frequency that they were found and the frequency in which they exceeded ATSDR comparison values (CVs). Our

Comparison Values (CVs) are chemical and media-specific concentrations used by ATSDR health assessors and others to identify environmental contaminants at hazardous waste sites that require further evaluation. Evaluating chemicals present above CVs involves analysis of site-specific exposure factors and toxicologic studies (ATDSR 2005). Lastly, we examined which chemicals resulted in sites being declared a health hazard.

Results

Of the 135 reports evaluated (121 sites), 119 (88%) were written after USEPA's 2002 draft guidance for evaluating vapor intrusion was published (USEPA 2002). Figure 2 shows the increasing number of vapor intrusion site reports published each year since 1994.

Figure 3 shows these site locations and highlights those where ATSDR determined a public health hazard existed. As with many other types of ATSDR evaluations, the locations are highly concentrated in densely populated cities and areas historically associated with heavy industry. In addition, vapor intrusion sites have historically been more focused in the colder northern regions where the stack effect is considered more pronounced. In the stack effect, heated building interiors and higher winds at rooftops draw air out near the roof creating negative pressure inside the building and drawing in subsurface vapors.

Our review identified 119 VOCs and semi-volatile organic compounds (sVOCs) in indoor air, groundwater, ambient air, and soil gas. Ninety five (80%) of the chemicals were detected in indoor air. Fifteen of these exceeded a CV or combustible hazard criteria and only five were responsible for declaring public health hazards (Table 1). The five chemicals associated with hazards were categorized in two chemical families: non-chlorinated and chlorinated VOCs. Three chemicals, benzene, PCE, and/or TCE were found in at least one medium (indoor air, groundwater, crawl space air, or soil gas) at 95% of the sites. Non-chlorinated VOCs primarily come from petroleum sources, whereas the chlorinated VOCS come from a wider variety of sources, such as dry cleaning and degreasing operations.

Additionally, Table 1 lists each contaminant's detection frequency in indoor air, the number of sites with the chemical above the CV, and the number of sites declared a health hazard due to the contaminants. Ten of the 15 contaminants found above CVs were not the basis for declaring health hazards. This could be because other more hazardous contaminants were of higher concern or because of site-specific exposure scenarios (e.g., 2 hours of exposure per week compared with 24 hours exposure per day, 7 days per week).

Chlorinated ethylenes, PCE and TCE resulted in the most health hazard conclusions (8 from indoor air measurements). Figures 4 and 5 compare maximum contaminant levels found with ATSDR CVs for non-chlorinated and chlorinated VOCs, respectively. Shaded symbols indicate contaminant concentrations exceed the CVs. Both figures display several "new" CVs. As toxicology and epidemiology science evolves new findings may result in lowering or raising a contaminant's level of health concern. This may lead to changes in health conclusions. The presence of non-chlorinated VOCs (volatile petroleum products) resulted in health hazard conclusions due to benzene carcinogenicity or danger of fire and explosion.

Benzene, a carcinogen, is the more toxic constituent of the BTEX (benzene, toluene, ethylbenzene, xylene) petroleum chemical family (ATSDR 2004). It was detected above CVs in indoor air at 28 sites and accounted for two sites with public health hazard conclusions. Confounding background sources are a concern at many benzene sites. The upper 95th percentile for benzene in indoor air, 29 μg/m^3 (EPA 2011), exceeds USEPA's risk management range of 1 in 10,000 excess cancer cases. ATSDR provides health education on reducing background exposures to benzene and other indoor air contaminants when health based levels are exceeded (EPA 2012).

Figure 4 illustrates that benzene exceeded its CV much more frequently (100%) than the remaining petroleum-related compounds (xylene =20%, toluene =14%, and ethylbenzene =6%). Methane is not particularly toxic, but does pose a fire and explosion hazard if it accumulates to flammable or explosive levels. A public health hazard from methane was declared at one site because it was detected 1,000 times above the LEL. The petroleum VOCs were measured using a nonspecific photoionizing detector and therefore are estimates. Like methane, the levels present at the petroleum VOCs site were determined to be a fire and explosion hazard and possibly high enough to cause acute health effects.

As illustrated in Figure 5, of the chlorinated VOCs, the industrial solvent methylene chloride most often exceeded its CV. Levels were above the cancer risk CV 80% of the time it was detected. Vinyl chloride, another carcinogen (ATSDR 2006), also had many measurements (70%) exceeding its CV.

Of the 121 sites reviewed, 17 (14%) posed a "Public Health Hazard," 83 (69%) posed "No Apparent Public Health Hazard", and 56 (46%) posed an "Indeterminate Public Health Hazard" (insufficient information precludes a conclusion). No sites posed an urgent public health hazard, ATSDR's highest conclusion category. Twelve of the 17 sites were classified as a public health hazard because of high indoor air measurements (Table 1). The five other sites that were deemed public health hazards exhibited relatively high soil gas, groundwater, or crawl space contamination.

Conclusions

Chlorinated ethylene pollutants and petroleum-related pollutants were the most frequently found chemicals at sites where the vapor intrusion pathway was investigated. Benzene, PCE, or TCE were found at 95% of the sites. Benzene most frequently exceeded its CV in indoor air for a chemical that resulted in health hazards. TCE, a chemical of increasing concern (Burk et al., 2009), caused the highest percentage (14%) of health hazards due to toxicity when detected, though PCE was similar (13%). Petroleum VOCs and methane each resulted in one health hazard from the potential for fire or explosion. Vapor intrusion of a combined chloroform and carbon tetrachloride mixture also resulted in one public health hazard.

We encourage state, local and federal stakeholders to increase awareness of historical sources of hazardous subsurface vapors in and near their communities. This issue is not just applicable to existing buildings—it should be considered in community revitalization and brownfields efforts and before abandoned property redevelopment decisions.

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References

Agency for Toxic Substances and Disease Registry. Interaction Profile For Benzene, Toluene, Ethylbenzene, and Xylenes (BTEX). Atlanta: U.S. Department of Health and Human Services; 2004 May. Retrieved from http://www.atsdr.cdc.gov/interactionprofiles/IP-btex/ip05.pdf.

Agency for Toxic Substances and Disease Registry. Public Health Assessment Guidance Manual (updated). Atlanta: U.S. Department of Health and Human Services; 2005 Jan. Retrieved from http://www.atsdr.cdc.gov/HAC/PHAmanual/index.html.

Agency for Toxic Substances and Disease Registry. Toxicological Profile for Vinyl Chloride. Atlanta: U.S. Department of Health and Human Services; 2006 Jul. p. 70Retrieved from http://www.atsdr.cdc.gov/toxprofiles/tp20.pdf.

Agency for Toxic Substances and Disease Registry. Evaluating Vapor Intrusion Pathways at Hazardous Waste Sites. Atlanta: U.S. Department of Health and Human Services; 2008 Feb. Retrieved from http://www.atsdr.cdc.gov/document/evaluating_vapor_intrusion.pdf.

Burk, T.; Zarus, G.; Young, R.; Fowler, D.; Joe, D.; Mann, J.; Schnell, F., et al. ATSDR Health Assessment of TCE Exposure by Vapor Intrusion at Military Faciities. Presented at the Environment, Energy & Sustainability Symposium; May 6, 2009; Denver, CO.

U.S. Environmental Protection Agency. OSWER Draft Guidance for Evaluating the Vapor Intrusion to Indoor Air Pathway from Groundwater and Soils (Subsurface Vapor Intrusion Guidance). 2002. Retrieved from http://www.epa.gov/epawaste/hazard/correctiveaction/eis/vapor.htm.

U.S. Environmental Protection Agency. Background Indoor Air Concentrations of Volatile Organic Compounds in North American Residences (1990-2005): A Compilation of Statistics for Assessing Vapor Intrusion. 2011 Jun. Retrieved from http://www.epa.gov/oswer/vaporintrusion/documents/oswer-vapor-intrusion-background-Report-062411.pdf

U.S. Environmental Protection Agency. An Introduction to Indoor Air Quality (IAQ): Volatile Organic Compounds (VOCs). 2012. Retrieved from http://www.epa.gov/iaq/voc.html.

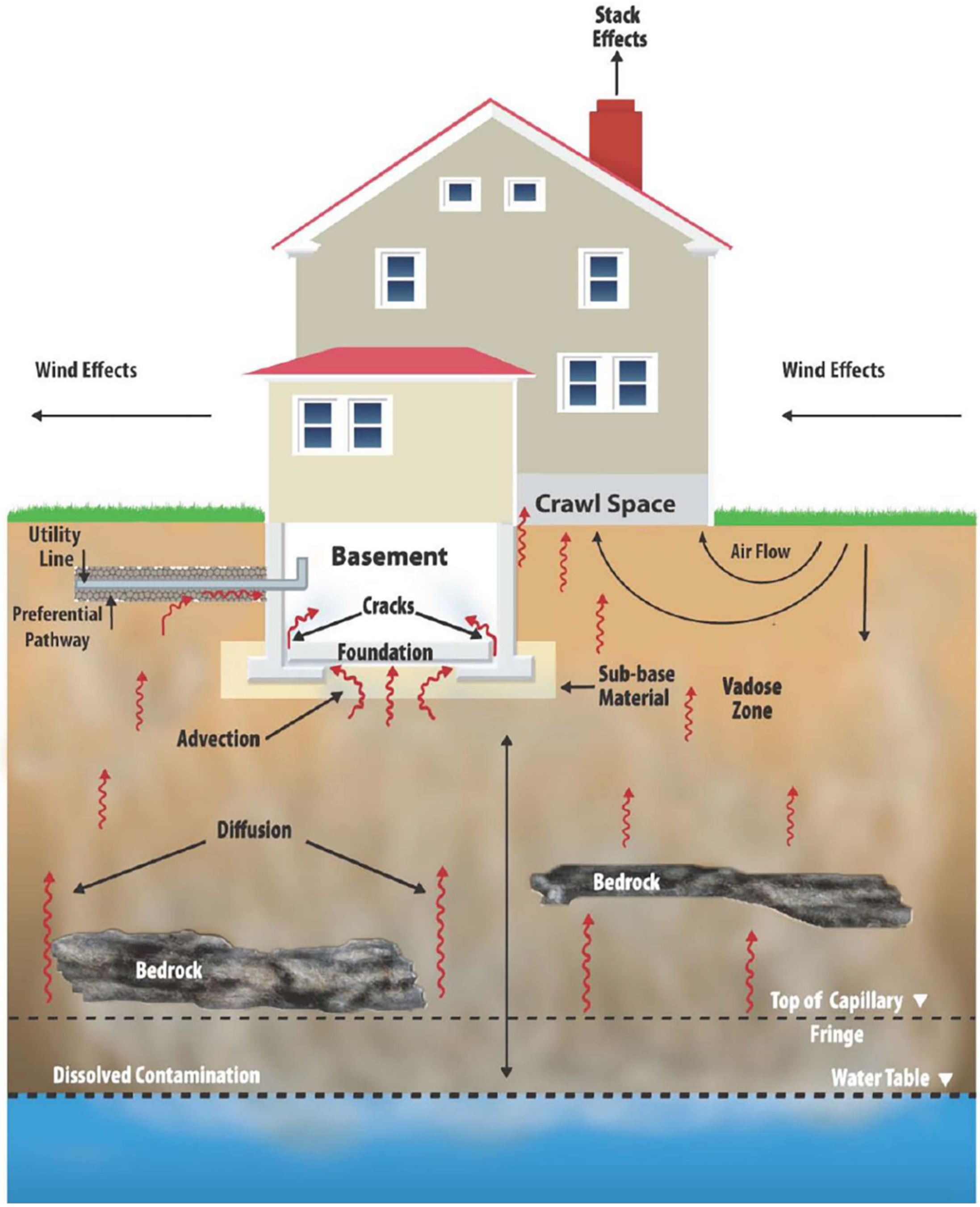

Figure 1.
Vapor Intrusion Conceptual Site Model

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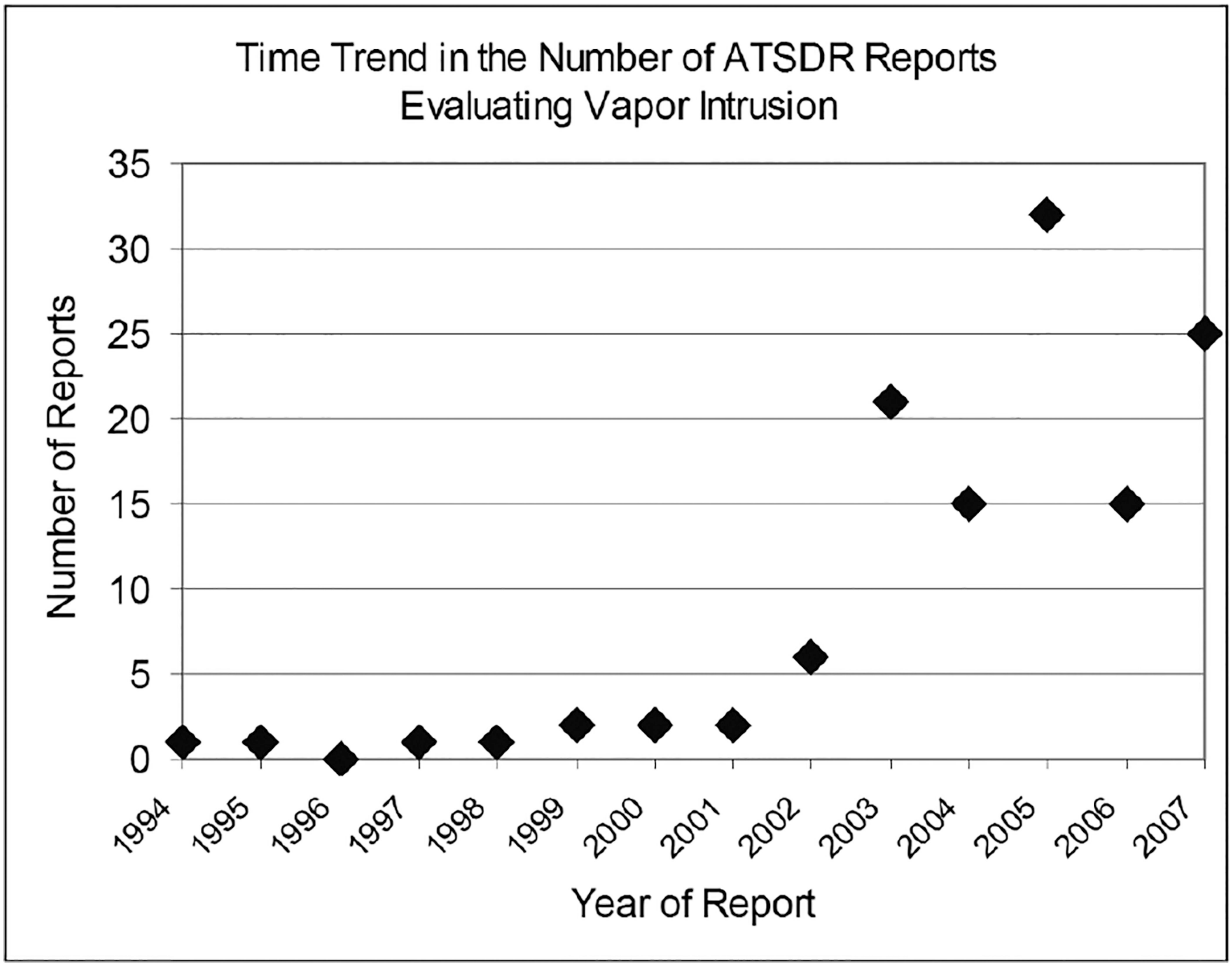

Figure 2.
ATSDR Vapor Intrusion Health Evaluations by Year

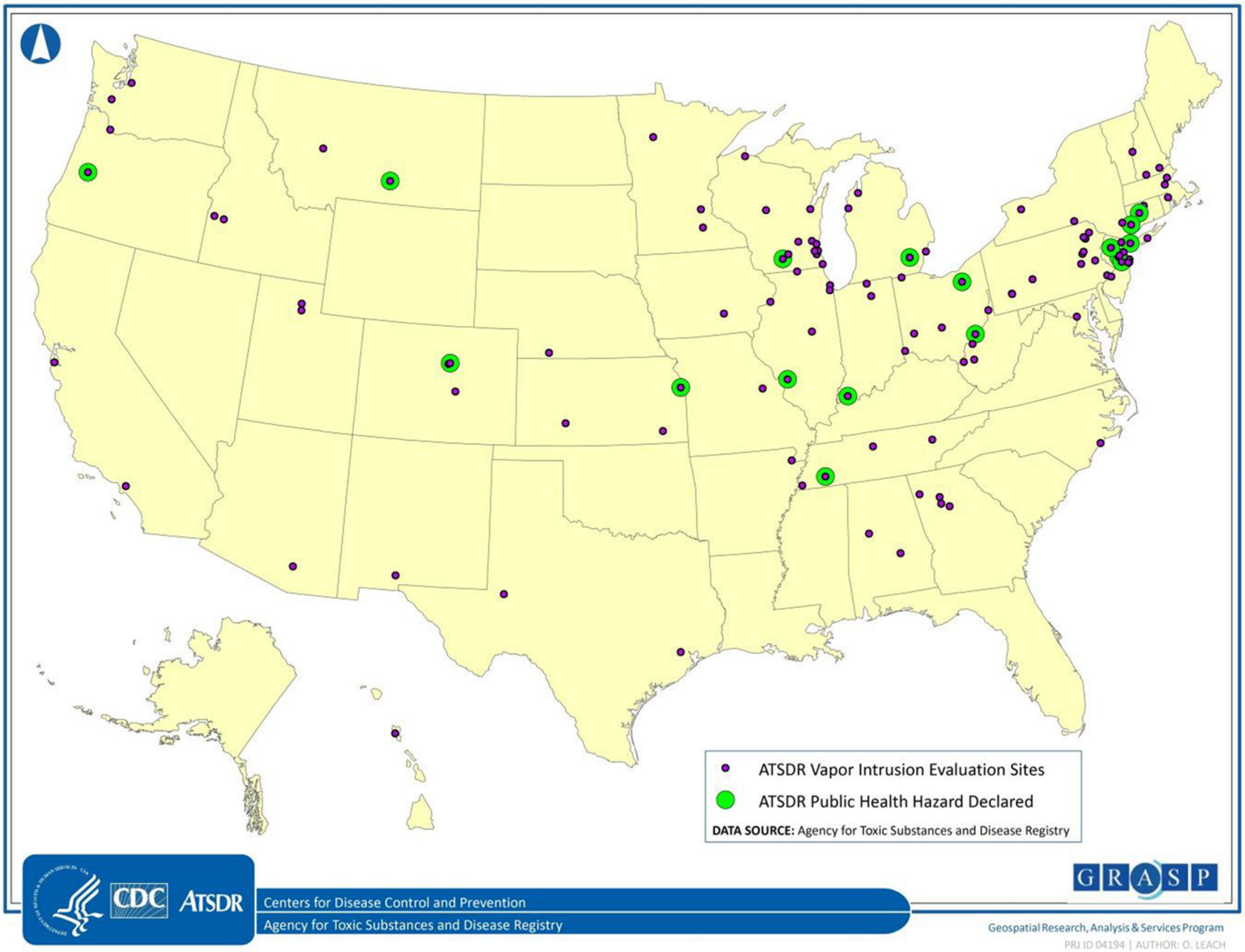

Figure 3.

Locations where ATDSR Performed Vapor Intrusion Public Health Evaluations

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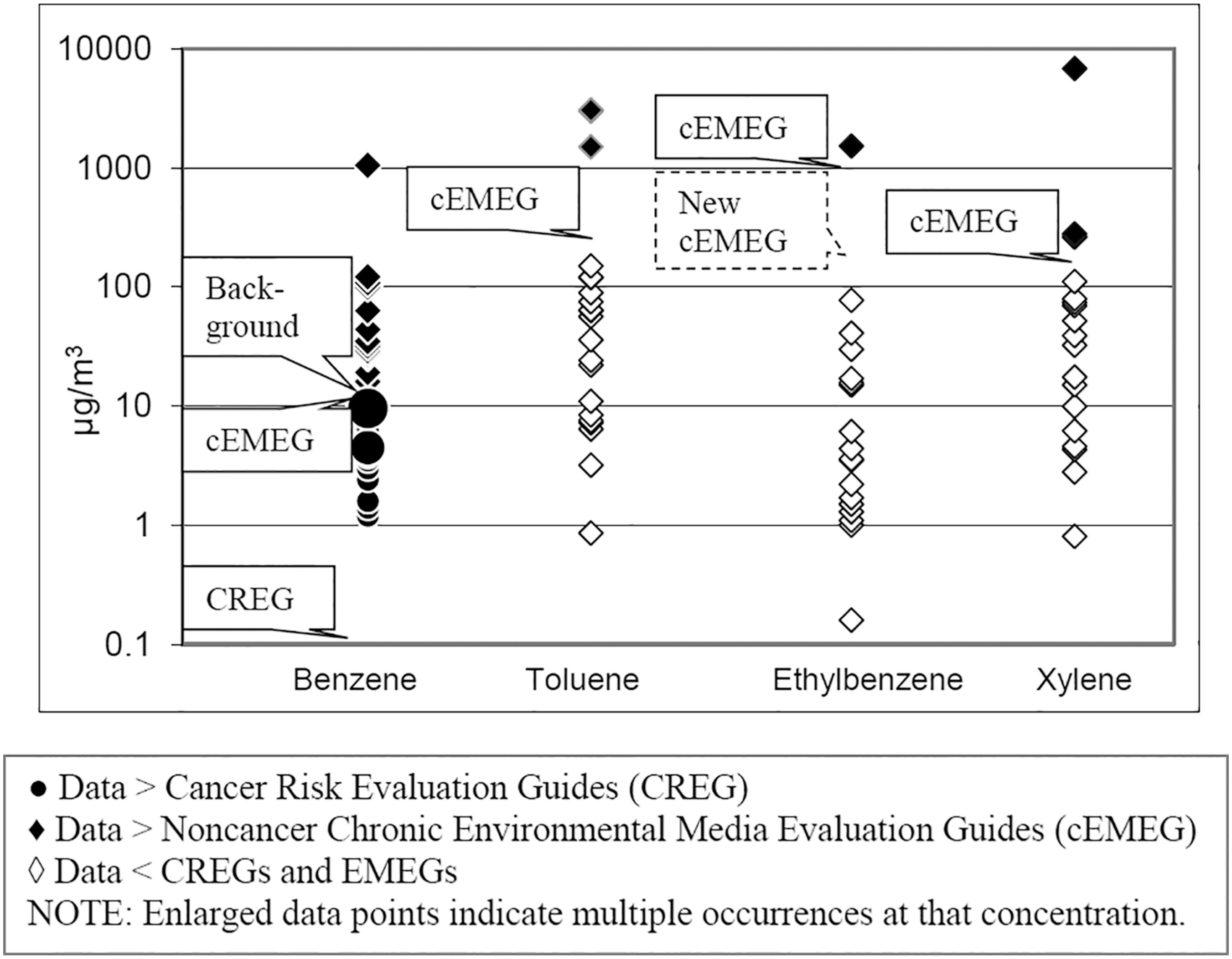

Figure 4.

Maximum Concentrations of Non-Chlorinated Volatile Organic Compounds Found in Indoor Air in Relation to ATSDR's CVs

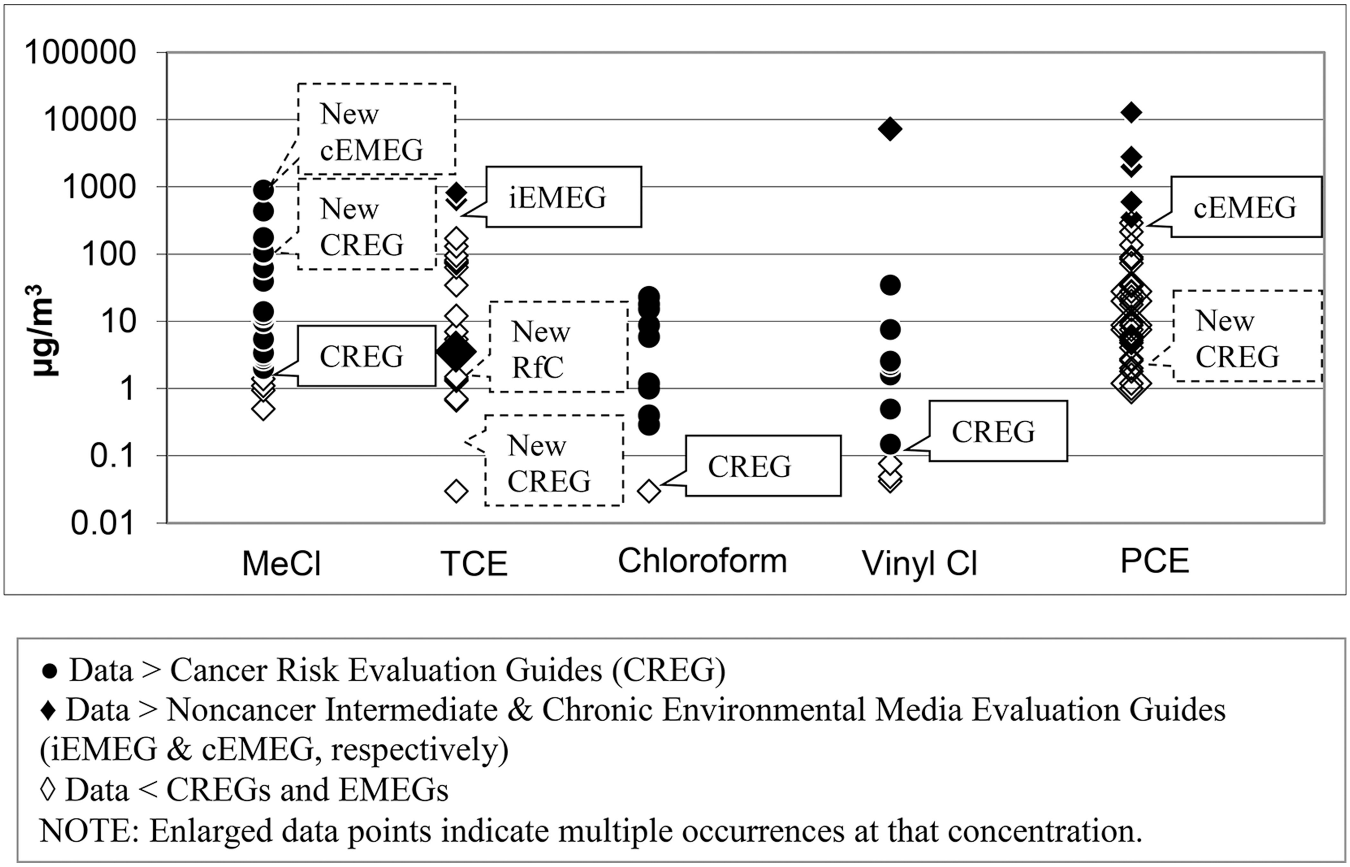

Figure 5.

Maximum Concentrations of Chlorinated Volatile Organic Compounds Found in Indoor Air in Relation to ATSDR's CVs

Table 1

Indoor Air Contaminants Found Above Comparison Values from Vapor Intrusion

Contaminants		Sites[¥] with Chemical Detected in Indoor Air	Lowest CV (Type of CV) in μg/m³	Sites[¥] with the Chemical above CV in Indoor Air	Sites Declared a Public Health Hazard due to the Chemical in Indoor Air [*]
Non-Chlorinated VOCs					
Benzene		28	0.1 (CREG)	28 (100%)	2 (7%)
Toluene		21	300 (cEMEG)	3 (14%)	0 (0%)
Ethylbenzene		17	1000 (cEMEG)[†]	1 (6%)	0 (0%)
Xylene		20	200 (cEMEG)	4 (20%)	0 (0%)
n-Hexane		9	2,100 (cEMEG)	1 (11%)	0 (0%)
1,3-butadiene		6	0.03 (CREG)	6 (100%)	0 (0%)
Combustibles:	**Methane**	2	10% LEL[‡]	1 (50%)	1 (50%)
	Petroleum VOCs	2	10% LEL[‡]	0 (0%)	1 (50%)
Chlorinated VOCs					
Tetrachloroethylene (PCE)		39	300 (cEMEG)[†]	5 (13%)	5 (13%)
Trichloroethylene (TCE)		21	500 (iEMEG)[†]	1 (5%)	3 (14%)
Vinyl Chloride		10	0.11 (CREG)	7 (70%)	0 (0%)
Methylene chloride		20	2 (CREG)[†]	16 (80%)	0 (0%)
Chloroform		10	0.04 (CREG)	9 (90%)	0 (0%)
Carbon tetrachloride		10	0.07 (CREG) [†]	9 (90%)	0 (0%)
1,4-dichlorobenzene		7	60 (cEMEG)	4 (57%)	0 (0%)

[¥] Some sites have more than one chemical of concern, i.e. the sites are not mutually exclusive.

[*] Hazard Frequency = the number of sites (and %) where the chemical was declared a situation-specific health hazard.

[†] The following updated CVs have recently been released:

Ethylbenzene: cEMEG = 260 μg/m^3

PCE: CREG = 3.8 μg/m^3

TCE: CREG = 0.24 μg/m^3, RfC = 2 μg/m^3

Methylene chloride: CREG = 100 μg/m^3, cEMEG = 1,000 μg/m^3

Carbon tetrachloride: CREG = 0.17 μg/m^3

‡No ATSDR CV available. However, the National Institution for Occupational Safety and Health has developed Immediately Dangerous to Life and Health (IDLH) values for methane and petroleum distillates that are 10% of the Lower Explosive Limit (LEL): Methane: IDLH = 5,000 parts per billion by volume (ppb); Petroleum distillates: IDLH = 1,100,000 ppb