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Background Indoor Air Concentrations of Volatile Organic Compounds in North American Residences (1990–2005): A Compilation of Statistics for Assessing Vapor Intrusion

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Acronyms and Abbreviations

BTEX	benzene, toluene, ethylbenzene, and xylenes
CDOT MTL	Colorado Department of Transportation Materials Testing Laboratory
EPA	U.S. Environmental Protection Agency
GC/MS	gas chromatography/mass spectrometry
NHEXAS	National Human Exposure Assessment Survey
OSRTI	Office of Superfund Remediation and Technology Innovation
OSWER	Office of Solid Waste and Emergency Response
PCE	tetrachloroethylene
RL	reporting limit
SIM	selected ion monitoring
TCA	1,1,1-trichlorethane
TCE	trichloroethylene
TEAM	Total Exposure Assessment Methodology
VOC	volatile organic chemical

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Executive Summary

Indoor air typically contains volatile organic chemicals (VOCs) from consumer products, building materials, and outdoor (ambient) air. Indoor air concentrations resulting from these sources are commonly referred to as "background" when assessing the potential for intrusion of subsurface contaminant vapors into the indoor air of overlying buildings. Any indoor air sample collected for site-specific assessment of subsurface vapor intrusion is likely to detect chemicals from these other sources. In many cases, the compounds detected in indoor air may be the same as those present in contaminated soil or groundwater that may enter the building through subsurface vapor intrusion. The presence of indoor and outdoor sources of VOCs can often make it challenging to assess the contribution of vapor intrusion to indoor air concentrations because it is often difficult to distinguish background from subsurface contaminant contributions.

This technical report presents a summary of indoor air studies that measured background concentrations of VOCs in the indoor air of thousands of North American residences and an evaluation and compilation of the statistical information reported in these studies. The objective of this compilation is to illustrate the ranges and variability of VOC concentrations in indoor air resulting from sources other than vapor intrusion. Similar compilations have been previously published, but these have been based on generally older data or limited statistical information.

The compilation of statistical information developed for this technical report is based on 15 indoor air studies conducted between 1990 and 2005. These were selected from a total of 18 indoor air quality studies conducted between 1981 and 2005, which reported summary statistics for distribution of indoor air concentrations measured in residences that are not expected or known to be located over contaminated soil or groundwater or that have effective vapor intrusion mitigation systems in place. The information compiled for this technical report includes percentiles (e.g., 25th, 50th, 75th, 90th, and 95th percentiles), number of samples, percent detection, and reporting limits. This report has been subject to extensive internal and external review.

This technical report is part of the U.S. Environmental Protection Agency's (EPA) efforts to update technical aspects of the *Draft Guidance for Evaluating the Vapor Intrusion to Indoor Air Pathway from Groundwater and Soils* (Draft VI Guidance), specifically, the background VOC statistics tabulated in Appendix F of that document. Those background VOCs statistics were used in the evaluation of EPA's vapor intrusion database to develop the generic groundwater and sub-slab vapor attenuation factors presented in Appendix F of the Draft VI Guidance. The information presented in this technical report was collected to provide updated information to assist in evaluating EPA's updated and expanded vapor intrusion database and to support finalization of EPA's vapor intrusion guidance, anticipated to occur by the end of 2012.

EPA also anticipates that the information presented in this report may help EPA and others evaluate indoor air quality data collected as part of site-specific vapor intrusion investigations and communicate the findings of indoor air quality studies to building occupants and other stakeholders. By comparing measured site-specific values with the background statistics provided in this report, an investigator carrying out a site-specific analysis may be able

to better understand whether the measured indoor air concentrations are within typical ranges for background indoor air.

Data Sources

To develop this compilation, EPA reviewed studies of VOCs in the indoor air of residences in North America. EPA identified a total of 18 indoor air studies that reported summary statistics, including percentiles, with sampling dates ranging between 1981 and 2005. These studies are considered to provide information on typical background indoor air concentrations because they were conducted in residences that are not expected or known to be located over contaminated soil or groundwater or have effective vapor intrusion mitigation systems in place.

The 18 studies collectively report statistics regarding the distribution of concentrations of more than 40 VOCs in thousands of indoor air samples. The sample collection dates range from 1981 to 2005. The study sample sizes vary from about 10 to 2,000 samples, although most of the studies reported 50 to 500 samples. Most of the earlier studies used adsorbent media for sample collection. Later studies favored stainless steel canisters. Sample collection periods ranged from 2 hours to over 100 hours, with most of the studies using collection periods from between 12 and 24 hours. Reporting limits vary widely from chemical to chemical and study to study. Outdoor air data also were collected in many of these studies, but those data are not compiled in this technical report. The focus of this report is indoor air, of which outdoor air is a component. All of these studies generally detected numerous VOCs in background indoor air, with wide concentration ranges.

Indoor air concentration statistics from these indoor air quality studies were compiled in a spreadsheet to facilitate analysis. The raw data were not available for most studies, so the summary statistics (e.g., percentiles) reported in the individual studies were compiled. Because of the lack of raw data, it was not possible to conduct a rigorous statistical analysis of the compiled data. Instead, qualitative analyses based on graphical and tabular summaries of the information are presented.

Data from homes identified as "smoking" homes and data based on personal air monitors worn only during the day were excluded from the compilation to avoid biasing the results with elevated levels of VOCs released from smoking or craft hobby activities that typically occur only during day-time hours. Additionally, where sample periods were separated into daytime and nighttime periods, only the nighttime statistics were evaluated as these are considered more representative of residential indoor air concentrations typically found in the home when most participants would have remained indoors at home.

Conclusions

The information and analyses presented in this technical report suggest the following conclusions:

- Time trends in concentrations reported in 18 indoor air studies evaluated for this compilation suggest that indoor air concentrations measured in North American residences starting in 1990 and later generally are lower than those measured earlier.

- Based on the observed trends in concentration over time, EPA believes the background indoor air studies with data collected starting in 1990 and later (i.e., the more recent 15 of the 18 studies) to be more representative of the current range of background indoor air concentrations than data collected earlier. **Table ES-1** presents the compilation of "typical" or background indoor air concentrations based on the post-1990 studies evaluated in this report.

- Evaluation of the indoor air concentration statistics collected for this compilation suggests that background concentrations are highly variable (range spans an order of magnitude or more). Additionally, the distributions appear log based, where most concentrations tend to be low (i.e., most of the data are skewed towards the low end of the distribution), but some very large background concentrations do occur rarely at the higher percentiles.

- Based on the percent detections reported in the evaluated studies, the VOCs most commonly detected in indoor air due to background sources include benzene, toluene, ethylbenzene, and xylenes (BTEX), along with chlorinated solvents, such as chloroform, carbon tetrachloride, tetrachloroethylene (PCE), 1,1,1-trichlorethane (TCA), and trichloroethylene (TCE). In contrast, vinyl chloride, 1,1-dichoroethylene, cis-1,2-dichloroethylene, and 1,1-dichloroethane are rarely detected in background indoor air.

EPA anticipates that the information presented in this technical report may be useful for evaluating EPA's updated and expanded vapor intrusion database. EPA also anticipates that the information presented in this report may help EPA and others determine whether indoor air quality data collected during site-specific vapor intrusion investigations are within typical background ranges.[1] The information presented in this technical document also may be useful in communicating the findings of indoor air quality studies to building occupants and other stakeholders impacted by a vapor intrusion investigation. In addition, it may help affected parties at a specific site understand which VOCs are likely to be detected in indoor air even in the absence of any contribution from subsurface vapor intrusion.

It is important to recognize that the background indoor air concentrations found in site-specific assessments or individual studies in the future may differ from those summarized in this report. Concentrations of many hazardous chemicals may continue to decrease in the future as new environmentally friendly consumer products and building materials are developed. This may be particularly true for trichloroethylene, which is an important risk driver in many vapor intrusion assessments and shows a strong decrease in concentration over time. Conversely, concentrations of some chemicals may increase in the future due to their increasing use in certain consumer products. Changes over time in building construction and ventilation codes also may result in changes in the concentrations of indoor air contaminants found in buildings.

[1] For EPA guidance on how to consider background constituent concentrations of hazardous substances, pollutants, and contaminants in the Superfund remedy selection process (e.g., risk assessments during the remedial investigation process), see *Role of Background in the CERCLA Cleanup Program*, OSWER Directive No. 9285.6-07P (April 26, 2002).

Table ES-1. Ranges of Summary Statistics[2] for Background Indoor Air Concentrations of Common VOCs Measured in North American Residences between 1990 and 2005 (all concentrations expressed in µg/m^3)

Compound	Number of Studies	Number of Samples	Range % Detect	Total % Detects	RL Range	Range of 50th%	N*	Range of 75th%	N	Range of 90th%	N	Range of 95th%	N
Benzene	14	2,615	31–100	91.1	0.05–1.6	<RL–4.7	14	1.9–7.0	9	5.2–15	11	9.9–29	5
Carbon tetrachloride	6	1248	1–100	53.5	0.15–1.3	<RL–0.68	6	<RL–0.72	3	<RL–0.94	5	<RL–1.1	2
Chloroform	11	2,278	9–100	68.5	0.02–2.4	<RL–2.4	11	<RL–3.4	7	<RL–6.2	9	4.1–7.5	5
Dichloroethane, 1,1-	2	682	1	1	0.08–0.25	<RL	2	<RL	2	<RL	2	<RL	2
Dichloroethane, 1,2-	7	1,432	1-25	13.8	0.08–2.0	<RL	7	<RL–0.08	6	<RL–0.4	7	<RL–0.2	4
Dichloroethylene, 1,1-	2	475	7-45	13	0.01–0.25	<RL	2	<RL-0.37	2	<RL-0.8	2	0.7	1
Dichloroethylene, cis 1,2-	3	875	1–9	4.9	0.25–2.0	<RL	3	<RL	3	<RL	3	<RL–1.2	3
Ethylbenzene	10	1,484	26–100	85.7	0.01–2.2	1–3.7	10	2–5.6	5	4.8–13	7	12–17	3
Methyl tert-butyl ether (MTBE)	4	502	9–70	54.5	0.05–1.8	0.025–3.5	4	0.03–11	4	0.03–41	4	71–72	2
Methylene chloride	8	1,724	29–100	79.1	0.12–3.5	0.68–61	8	1.0–8.2	6	2.0–510	8	2.9–45	4
Tetrachloroethylene	13	2,312	5–100	62.5	0.03–3.4	<RL–2.2	13	<RL–4.1	8	<RL–7	10	4.1–9.5	5
Toluene	12	2,065	86–100	96.4	0.03–1.9	4.8–24	12	12–41	7	25–77	9	79–144	4
Trichloro-1,2,2-trifluoroethane, 1,1,2- (Freon 113)	3	600	1–56	37.5	0.25–3.8	<RL–0.5	3	<RL–1.1	3	<RL–1.8	3	<RL–3.4	2
Trichloroethane, 1,1,1-	9	1,877	4–100	53.4	0.12–2.7	<RL–5.9	9	<RL–7	7	<RL–68	8	3.4–28	5
Trichloroethylene	14	2503	1–100	42.6	0.02–2.7	<RL–1.1	14	<RL–1.2	9	<RL–2.1	11	0.56–3.3	5
Vinyl chloride	4	1484	0–25	9.2	0.01–0.25	<RL	4	<RL	4	<RL–0.04	4	<RL–0.09	4
Xylene, m/p-	10	1,920	52–100	92.9	0.4–2.2	1.5–14	10	4.6–21	7	12–56	9	21–63.5	4
Xylene, o-	12	2,004	31–100	89.0	0.11–2.2	1.1–3.6	12	2.4–6.2	7	5.5–16	9	13–20	4

* N = Number of studies reporting the percentile.

[2] All summary statistics reported by an individual study for an individual chemical were included in this compilation, with the following exceptions: if all statistics, including the maximum reported value, for a chemical were below an individual study's reporting limit for that chemical, the statistics for that chemical in that study were not included in this compilation.

Background Indoor Air Concentrations of Volatile Organic Compounds in North American Residences (1990–2005): A Compilation of Statistics for Assessing Vapor Intrusion

1.0 Introduction

Indoor air typically contains detectable levels of volatile organic chemicals (VOCs) (U.S. EPA, 1998). The VOCs in indoor air may originate from ambient (outdoor) air, indoor sources (sources within the building), and, under certain conditions in areas overlying VOC-contaminated subsurface media through vapor intrusion from the subsurface (e.g., Hers et al., 2001; DiGiulio et al., 2006; McDonald and Wertz, 2007). Indoor air concentrations resulting from sources other than vapor intrusion (i.e., ambient air and indoor sources) are commonly referred to as "background." Compounds present in the ambient outdoor air generally will be present in indoor air because the air in most buildings is exchanged with outdoor air several to dozens of times each day. Indoor sources that may emit VOCs include consumer products (e.g., cleaners, solvents, strippers, polish, adhesives, water repellants, lubricants, air fresheners, aerosols, mothballs, scented candles, insect repellants, plastic products); building materials (e.g., carpet, insulation, paint, wood finishing products); combustion processes (e.g., smoking, cooking, home heating); fuels in attached garages; dry-cleaned clothing or draperies; municipal tap water; or occupant activities (e.g., craft hobbies). Some chemicals may originate from several sources simultaneously. The presence of these indoor and outdoor "background" sources of VOCs can often make it challenging to assess the contribution of vapor intrusion to indoor air concentrations because it is often difficult to distinguish background from subsurface contaminant contributions.

Several compilations of background indoor air studies have been previously published (e.g., Shah and Singh, 1988; Stolwijk, 1990; Samfield, 1992; Brown et al., 1994; Holcomb and Seabrook, 1995; U.S. EPA, 1998; Hodgson and Levin, 2003; see **Appendix A** of this document). These compilations show that many VOCs are normally found in indoor air samples in varying concentrations. However, these previous compilations generally provide only limited statistics (e.g., median, geometric mean, average, maximum values) as representative of "typical" background values, and do not include much information on the underlying frequency distributions of background concentrations. This makes review and comparison of statistical distributions impossible. In addition, a number of these studies combined background concentrations measured in commercial buildings with those measured in residences, so residential concentrations cannot be assessed independently. Furthermore, a number of these compilations include data collected from more than two decades ago, which may not be representative of current background indoor air VOC concentrations. Because of these issues, EPA is making available a new compilation of background indoor air concentrations based on more recent data and emphasizing the full statistical distribution of background indoor air concentrations in each study.

This technical report presents a summary of indoor air studies that measured background concentrations of VOCs in the indoor air of thousands of North American residences (Section 2) and an evaluation and compilation of statistical information reported in these studies. The objective of this compilation is to illustrate the ranges and variability of VOC concentrations in indoor air resulting from sources other than vapor intrusion (**Section 3**). The statistical

information compiled for this technical report includes percentiles (e.g., 25th, 50th, 75th, 90th, and 95th percentiles), number of samples, percent detection, and reporting limits. The data evaluation includes consideration of trends in indoor air concentrations over time, an analysis of the distribution of background indoor air concentrations, and an analysis of the frequency of detection of VOCs in background indoor air. A summary and conclusions are provided in Section 4.

This technical report is part of EPA's efforts to update technical aspects of the *Draft Guidance for Evaluating the Vapor Intrusion to Indoor Air Pathway from Groundwater and Soils* (U.S. EPA, 2002) (Draft VI Guidance), specifically, the background VOC statistics tabulated in Appendix F of that document. Those background VOCs statistics were used in the evaluation of EPA's vapor intrusion database to develop the generic groundwater and sub-slab vapor attenuation factors presented in Appendix F of the Draft VI Guidance. The information presented in this technical report was collected to provide updated information to assist in evaluating EPA's updated and expanded vapor intrusion database and to support finalization of EPA's vapor intrusion guidance, anticipated to occur by the end of 2012. EPA also anticipates that the information presented in this report may help EPA and others evaluate indoor air quality data collected as part of site-specific vapor intrusion investigations and communicate the findings of indoor air quality studies to building occupants and other stakeholders. Due to the potentially high variability of VOC concentrations resulting from indoor sources in individual homes, a literature review providing information based on thousands of homes, such as is done in this report, is expected to present a more reliable estimate of the range of typical background concentrations than would be possible for most site-specific background studies given typical resources available for such efforts.

1.1 Document Development and Peer Review

This document was developed by EPA's Vapor Intrusion Workgroup for the Office of Solid Waste and Emergency Response (OSWER), with Dr. Helen Dawson of EPA's Office of Superfund Remediation and Technology Innovation (OSRTI) as the primary investigator and author. This document has undergone extensive internal Agency review, including Regional review and review by other EPA programs, as well as review by members of an expert panel that provided support to OSWER. Additionally, the report has been subjected to EPA's formal external peer-review process. Details of the review process may be found in **Appendix B** of this document.

1.2 Document Organization

The remainder of this technical document is divided into the following sections:

- **Section 2:** Background Indoor Air Quality Studies
- **Section 3:** Evaluation and Compilation of Background Indoor Air Statistics
- **Section 4:** Summary and Conclusions

In addition, **Section 5** provides the references cited. **Appendix A** provides a summary of the information provided in previous compilations. **Appendix B** describes the development of this document and the peer-review process. **Appendix C** provides a detailed summary of the information reported in the indoor air studies considered in this document.

2.0 Background Indoor Air Quality Studies Considered

A total of 18 residential background indoor air quality studies were evaluated and considered for inclusion in the statistical compilation developed for this report (see Section 3). The 18 indoor air quality studies targeted specific residential populations in North America for specific purposes. Most of these studies were conducted in urban or suburban settings, although 7 of the 18 studies also included some residences in rural settings. The studies collectively report statistics regarding the distribution of concentrations of more than 40 VOCs in thousands of indoor air samples collected in residences. The collective data span more than two decades, from 1981 to 2005. The study sample sizes vary from about 10 to 2,000 samples, although most of the studies reported 50 to 500 samples. Most of the earlier studies used adsorbent media for sample collection. Later studies generally favored stainless steel canisters, though one recent study (Zhu et al., 2005) used adsorbent media to achieve very low reporting limits.[3] Sample collection periods ranged from 2 hours to over 100 hours, with most of the studies using collection periods from between 12 and 24 hours. Reporting limits vary widely from chemical to chemical and study to study. For any given chemical, reporting limits among the studies typically vary by at least an order of magnitude. Outdoor air data were also collected in many of these studies, but those data are not compiled in this technical report because the contribution of outdoor air is already reflected in the indoor air concentrations. All of these studies generally detected numerous VOCs in background indoor air, with widely varying concentration ranges.

Six of these studies (Foster et al., 2002; Kurtz and Folkes, 2002; Kurtz, 2005; Rago, 2005; Weisel, 2006; and Weisel et al., 2008) state that they present indoor air background levels unaffected by subsurface contamination. The other studies do not explicitly address this issue, but EPA believes that they are also similarly representative of indoor background levels unaffected by subsurface contamination because the studies generally were designed to provide region-specific indoor air exposure assessments in the absence of known sub-surface contaminant sources.

Basic information regarding each of the 18 background indoor air studies is provided below and summarized in **Table 1** at the end of this section, starting with the most recently published study. The percentiles, maximum values, number of samples, reporting limits, and percent detections reported for each chemical in each of the studies are presented in **Appendix C**.

Weisel (2006) and **Weisel et al. (2008).** To complement an assessment of indoor air quality by the New Jersey Department of Environmental Protection, indoor air was sampled in 2004 and 2005 in a total of 100 homes in suburban and rural areas of New Jersey that were determined to be unaffected by contaminated groundwater or soil. Samples were collected for 24 hours using a Summa canister sampler placed on the ground floor of the home in an actively used living space other than a kitchen, to minimize collection of compounds emitted during cooking. A questionnaire was administered to each participant before sampling to identify

[3] Reporting limits represent the lowest concentration that the laboratory will report for a compound without data qualifiers. In this report, the term "reporting limits" is used synonymously with the term "detection limits" because the different studies compiled used varying conventions for these two terms.

potential indoor sources of the target chemicals. Indoor air samples were analyzed using EPA Method TO-15. The study reported the number of samples, reporting limits, percent non-detects, and percentiles, including the 25th, 50th, 75th, 90th, and 95th percentiles.

New York State Department of Health (NYSDOH) (2006). This baseline indoor air quality study sampled the indoor air in basements and living spaces from 104 single-family homes heated with fuel oil. Approximately 400 samples were collected between 1997 and 2003. The residences sampled were required to have no past oil spills, no hobbies or home business that regularly use products containing VOCs, and no recent activities using products that contain VOCs (e.g., painting, staining). Building information was gathered, along with an inventory of products that might be sources of indoor VOCs. The samples were collected in 6-liter canisters over a 2-hour period during both summer and winter and were analyzed for 69 compounds by EPA's Method TO-15. The study reported the number of samples, reporting limits, percent detections, and percentiles, including the 25th, 50th, 75th, and 90th percentiles. The data for individual residences were also available, so the 95th and 98th percentiles, as well as maximum values, were calculated for this compilation to facilitate comparison with the other studies.

Rago et al. (2004) and **Rago (2005).** To obtain background indoor air quality in Massachusetts, indoor air samples were collected in 2004 and 2005 in early spring and late fall (windows closed, heat on) from the first-floor living spaces of 100 residences scattered throughout the state. The samples were collected over a 24-hour period using 6-liter Summa canisters. The participants in the study were predominantly Licensed Site Professionals in Massachusetts, and their residences were located in urban, suburban, and rural areas. The participants filled out a questionnaire that requested information on their hobbies, residence heat source, and type of building construction. VOCs were analyzed using EPA Method TO-15. The study provided reporting limits, percent detections, maximum values, and percentiles, including the 25th, 50th, 75th, and 90th percentiles.

Zhu et al. (2005). Indoor and outdoor air samples were collected at 75 randomly selected residential houses in Ottawa, Canada, as part of a baseline exposure assessment funded by Health Canada during the winter of 2002 to 2003. Researchers sampled 10 liters of air at a rate of 100 mL/min for 100 minutes using multi-sorbent sampling tubes located in the middle of the living room or family room of the house. The samples were analyzed by gas chromatography/mass spectrometry (GC/MS). The study reported the number of samples, reporting limits, percent detections, and percentiles, including the 50th, 75th, and 90th percentiles.

Kurtz (2005). As part of a program of vapor intrusion mitigation at a site (Redfield) in Denver, Colorado, a total of 375 indoor air samples were collected in 1998 from about 100 residences after installation of sub-slab depressurization systems. Because these mitigation systems are designed and installed to interrupt the vapor intrusion pathway (and on-going monitoring demonstrated their effectiveness for controlling the subsurface vapors), the author interpreted the indoor air concentrations to be representative of background indoor air with no vapor intrusion. The samples were collected on a quarterly basis from the first (lowest) occupied floor of the building over a 24-hour period and analyzed using EPA Methods TO-14 and TO-15 in full scan mode. (Note: These data include a different set of VOCs [except vinyl chloride] than the data reported in Kurtz and Folkes [2002]). The data provided (personal communication)

included the number of samples, reporting limits, percent detections, and percentiles, including the 25th, 50th, 75th, 90th, and 95th percentiles.

Sexton et al. (2004). The authors designed this study primarily to measure exposures to VOCs experienced by healthy, non-smoking adults in three Minneapolis/St. Paul metropolitan neighborhoods with different outdoor VOC profiles. They combined indoor air data from the three neighborhoods and reported statistics for the combined data set. A total of 292 indoor air samples were collected, with 48-hour charcoal-based passive air samplers placed in the 78 to 116 residences studied over three seasons. The samples were analyzed for VOCs by GC/MS. The study reported the number of samples, percent detections, and percentiles, including the 50th and 90th percentiles.

Foster et al. (2002). As part of a multiyear characterization of a vapor intrusion site (Colorado Department of Transportation Materials Testing Laboratory [CDOT MTL]) in Denver, Colorado, indoor air was sampled in residences after installation of sub-slab depressurization systems. Over 400 indoor air samples were collected from October 1998 through June 2001 from 21 single-family homes, 8 town homes, and 12 apartment buildings. Only samples with non-detectable levels (at a method detection limit of 0.011 $\mu g/m^3$) of 1,1-dichloroethylene, the primary groundwater contaminant, were compiled for this characterization of background indoor air. This data screening approach effectively excludes any contribution of vapor intrusion to the indoor air in these samples. Most of the single-family homes sampled have basements, and many have attached garages. The samples were collected quarterly over a 24-hour period from the first (lowest) occupied floor of each building and analyzed using EPA Method TO-14/TO-15 in selected ion monitoring (SIM) mode. Where possible, windows were closed for 24 to 48 hours before sampling began. The study reported the number of samples, reporting limits, percent non-detects, and percentiles, including the 25th, 50th, 75th, 90th, and 95th percentiles.

Kurtz and Folkes (2002). As part of a multiyear characterization of a vapor intrusion site (Redfield) in Denver, Colorado, indoor air was sampled in residences after installation of sub-slab depressurization systems. More than 282 indoor air samples were collected from June 1998 through December 2001 from 120 single-family homes. Most of the homes sampled have basements, and many have attached garages. Only samples with non-detectable levels (at a reporting limit of 0.04 $\mu g/m^3$) of 1,1-dichloroethylene, the primary groundwater contaminant, were compiled for this characterization of background indoor air. This data screening approach effectively excludes any contribution of vapor intrusion to the indoor air in these samples. The samples were collected quarterly over a 24-hour period from the first (lowest) potentially occupied floor of each building and analyzed for eight compounds using EPA Method TO-14/TO-15 in SIM mode. This study reported the number of samples, reporting limits, percent non-detects, and percentiles, including the 50th, 90th, and 95th percentiles.

Van Winkle and Scheff (2001). Indoor air was sampled monthly to quarterly in 10 non-smoking homes in the Chicago area as part of a Public Health Assessment for exposure to VOCs. A total of forty-eight 24-hour samples were collected using Summa canisters and analyzed using EPA Method TO-14. The study reported the number of samples, percent detections, maximum values, and percentiles, including the 50th and 90th percentiles.

Clayton et al. (1999). This paper describes the National Human Exposure Assessment Survey (NHEXAS) conducted by EPA to evaluate residential indoor air quality in residences in six states in the Great Lakes Region. A total of 396 indoor air samples from more than 200 residences were collected. The indoor air samples were collected with passive sorbent samplers (OVM 3520). The samplers were deployed in the main living area of all homes over monitoring periods of approximately 144 hours (6 days). At the end of the monitoring period, each sampler was capped and stored until it was shipped to the laboratory for analysis, where it was solvent-extracted and analyzed by GC/MS. Individual sample results were downloaded from EPA's NHEXAS Web site (http://www.epa.gov/nerl/research/nhexas/nhexas.htm), and the data were used to generate percentiles, including the 25th, 50th, 75th, 90th, and 95th percentiles.

Gordon et al. (1999). This study was part of NHEXAS, which included indoor air sampling in residences in Arizona. A total of 185 indoor air samples were collected with passive sorbent samplers (OVM 3520). The samplers were deployed in the main living area of 179 homes over monitoring periods of approximately 144 hours (6 days). At the end of the monitoring period, each sampler was capped and stored until it was shipped to the laboratory for analysis, where it was solvent-extracted and analyzed by GC/MS. The study reported the number of samples, reporting limits, percent detections, and percentiles, including the 50th, 75th, and 90th percentiles.

Mukerjee et al. (1997). This study was part of a comprehensive environmental scoping study designed to provide better estimates of total exposure of residents in the Lower Rio Grande Valley of Texas to contaminants in air, house dust, and soil. Indoor air in nine residences in and around Brownsville, Texas, was monitored over 3 weeks during the spring of 1993. Multi-sorbent active samplers were used to collect samples over a 24-hour period. The samplers were placed in high-use areas 30 cm from an interior wall and 1.5 m from the floor. The samples were analyzed using thermal desorption GC/MS. The study reported the number of samples, percent detections, and median (50th percentile) values.

Heavner et al. (1996). This study was sponsored by the Reynolds Tobacco Company and was designed to compare the indoor air quality in smoking and non-smoking homes in Mount Laurel, New Jersey. Only data from non-smoking homes are included in this compilation to avoid biasing the results from an over-selection of smoking homes.[4] A total of 61 indoor air samples from 61 non-smoking homes were obtained in Mount Laurel during November 1992. Personal VOC samplers consisted of active multi-sorbent samplers (Tenax and Carbotrap cartridges) equipped with low-flow pumps. The average sampling time was 14 nighttime hours. Air samples were analyzed by thermal desorption GC/MS. The study reported the number of samples, median (50th percentile), and maximum values.

Heavner et al. (1995). This study was sponsored by the Reynolds Tobacco Company and was designed to compare the indoor air quality in smoking and non-smoking homes in Columbus, Ohio. Only data from non-smoking homes are included in this compilation to avoid

[4] VOC concentrations, including benzene and styrene, were elevated in the smoking homes.

biasing the results from an over-selection of smoking homes.[5] A total of 24 indoor air samples from 24 non-smoking homes were obtained from February 25–29, 1991. Personal VOC samplers consisted of active multi-sorbent samplers (Tenax and Carbotrap cartridges) equipped with low-flow pumps carried by non-smoking women in non-smoking homes in Columbus, Ohio. The average sampling time was three evening hours. The samples were analyzed by thermal desorption GC/MS. The study reported the number of samples, median (50th percentile), and maximum values.

Sheldon et al. (1992). Indoor and outdoor air samples from a random probability sample of 125 homes in Woodland, California, were collected during May and June of 1990 by the California Air Resources Board for review and assessment of indoor-sourced air pollution. The samples were collected over a 24-hour period using 6-liter stainless steel Summa canisters and analyzed using GC/MS SIM, or sorbent tubes with Tenax and a low-flow pump collecting 16 liters of air analyzed by thermal desorption/high resolution GC/MS. The study reported the number of samples, reporting limits, percent detections, maximum values, and percentiles, including the 25th, 50th, 75th, and 90th percentiles.

U.S. EPA (1987a). This publication included two studies that were conducted in 1984 as part of the Total Exposure Assessment Methodology (TEAM) study conducted by EPA in the 1980s as part of a research program to develop and test statistical and chemical methods for estimating human exposure to selected toxic or hazardous substances. Indoor air samples were collected using personal air monitors (Tenax cartridges) over two 12-hour periods: 6 am to 6 pm (daytime) and 6 pm to 6 am (nighttime). A small pump was used to draw air through the sampler at approximately 30 mL/min. For this evaluation, EPA considered only the nighttime data from this study. EPA believes the nighttime data are more representative of residential indoor air concentrations typically found in the home because most participants would have remained indoors at home during the nighttime period. The air samples were analyzed by GC/MS. The portion of the TEAM study reported in U.S. EPA (1987a) included a study of residences in Los Angeles, California, from which a total of 111 samples were collected, and a study of residences in Contra Costa County, California, from which a total of 68 samples were collected. For both studies, EPA (1987a) reported the number of samples, reporting limits, maximum values, and percentiles, including the 25th, 50th, 75th, 90th, and 95th percentiles. (Note: Because time trend analysis of the background indoor air concentrations measured in the studies conducted between 1990 and 2005 are considerably lower than those measured in earlier studies, the data from U.S. EPA [1987a] were not included in the final compilation of statistics developed for this report).

U.S. EPA (1987b). This study was conducted in 1981 and was also part of the TEAM study conducted by EPA in the 1980s. Indoor air samples were collected using personal air monitors (Tenax cartridges) over two 12-hour time periods: 6 am to 6 pm (daytime) and 6 pm to 6 am (nighttime). A small pump was used to draw air through the sampler at approximately 30 mL/min. For this evaluation, EPA considered only the nighttime data from this study. EPA believes the nighttime data are more representative of residential indoor air concentrations typically found in the home, because most participants would have remained indoors at home

[5] Seven VOCs, benzene, styrene, pyridine, 2-picoline, 3-picoline, 3-ethylpyridine, and 3-ethenylpyridine, were elevated in the smoking homes.

during the nighttime period. The air samples were analyzed by GC/MS. This portion of the TEAM study included residences in an industrial/chemical manufacturing area, in Bayonne and Elizabeth, New Jersey, from which a total of 348 samples were obtained. U.S. EPA (1987b) reported the number of samples, reporting limits, percent non-detects, maximum values, and percentiles, including the 25th, 50th, 75th, 90th, and 95th percentiles. (Note: Because time trend analysis of the background indoor air concentrations measured in the studies conducted between 1990 and 2005 are considerably lower than those measured in earlier studies, the data from U.S. EPA [1987b] were not included in the final compilation of statistics developed for this report.)

Table 1. Summary of Background Indoor Air Quality Studies (1981–2005) Selected for Evaluation

Reference	Study Location	Sample Dates	Season	No. of Samples	Available Data (Statistics)	Collection Device	Collection Period	Analytical Method
Studies included in the compiled summary of statistics (15 studies)								
Weisel (2006)	NJ	2004–2005	Varies	100	Population Stats (25/50/75/90/95/Max)	Summa canister	24 hours	EPA TO-15
NYSDOH (2006)	NY	1997–2003	All	400	Population Stats (25/50/75/90/95/Max)	Summa canister	2 hours	EPA TO-15
Rago et al. (2004, 2005)	MA	2004–2005	Spring, Fall	100	Population Stats (25/50/75/90/Max)	Summa canister	24 hours	EPA TO-15
Zhu et al. (2005)	Ottawa, CA	2002–2003	Winter	75	Population Stats (50/75/90/Max)	Sorbent tube, active sampler	1.7 hours	GC/MS
Kurtz (2005)	Denver, CO	1998	All—Quarterly	375	Population Stats (25/50/75/90/95/Max)	Summa canister	24 hours	EPA TO-14/15 SCAN
Sexton et al. (2004)	Minneapolis, MN	1999	Spring, Summer, Fall	292	Population Stats (50/90)	Charcoal passive sampler	48 hours	GC/MS
Foster et al. (2002)	Denver, CO	1998–2001	All—Quarterly	427	Population Stats (25/50/75/90/95/Max)	Summa canister	24 hours	EPA TO-14/15 SIM
Kurtz and Folkes (2002)	Denver, CO	1998–2001	All—Quarterly	282	Population Stats (50/90/95/Max)	Summa canister	24 hours	EPA TO-14/15 SIM
Van Winkle and Scheff (2001)	Chicago, IL	1994–1995	All	48	Population Stats (50/90/Max)	Summa canister	24 hours	EPA TO-14
Clayton et al. (1999)	Midwest States	1995–1997	All	395	Actual Data (25/50/75/90/95/Max)	Passive sorbent sampler	6 days	GC/MS
Gordon et al. (1999)	AZ	1995–1997	All	185	Population Stats (50/75/90/Max)	Passive sorbent sampler	6 days	GC/MS
Mukerjee et al. (1997)	Brownsville, TX	1993	Spring	9	Population Stats (50)	Multi-sorbent active canister	24 hours	GC/MS
Heavner et al. (1996)	Mt. Laurel, NJ	1992	Winter	61	Population Stats (50/Max)	Active multi-sorbent sampler	14 hours	GC/MS
Heavner et al. (1995)	Columbus, OH	1991	Winter	24	Population Stats (50/Max)	Multi-sorbent sampler w/pump	3 hours	GC/MS
Sheldon et al. (1992)	Woodland, CA	1990	Summer	125	Population Stats (25/50/75/90/Max)	Canister and active sorbent sampler	24 hours	GC/MS

Reference	Study Location	Sample Dates	Season	No. of Samples	Available Data (Statistics)	Collection Device	Collection Period	Analytical Method
Pre-1990 Studies evaluated but not included in the compiled summary of statistics (3 studies)								
U.S. EPA (1987a)	Los Angeles, CA (1)	1984	Winter, Summer	111	Population Stats (25/50/75/90/95/Max)	Tenax	12 hours	GC/FID
	Contra Costa, CA (2)	1984	Summer	68	Population Stats (25/50/75/90/95/Max)	Tenax	12 hours	GC/FID
U.S. EPA (1987b)	Elizabeth and Bayonne, NJ	1981	Fall	348	Population Stats (25/50/75/90/95/Max)	Tenax	12 hours	GC/FID

GC/FID = gas chromatography/flame ionization detection; GC/MS = gas chromatography/mass spectrometry; SIM = selected ion monitoring.

3.0 Compilation and Evaluation of Background Indoor Air Statistics

The indoor air concentration statistics for VOCs commonly measured in North American residences reported in the 18 indoor air quality studies described in **Section 2** were compiled in a spreadsheet to facilitate analysis. The VOCs for which information was compiled are common groundwater contaminants and, therefore, are likely to be considered in site-specific vapor intrusion investigations and analyzed in indoor air.

In compiling the background data concentration statistics, statistical measures that were reported as lower than the laboratory reporting limit (RL), which typically had been assigned a value of one-half the analytical reporting limit by the individual study authors, were designated in this compilation as "<RL." This was done to avoid the spurious results that can arise from compiling statistical measures on data sets in which arbitrary values have been substituted for results below the reporting limits (Helsel 2005a, b; Helsel, 2006). Also as noted in the previous section, the data from homes specifically designated as smoking homes were excluded from the compilation to avoid biasing the results from an over-selection of smoking homes with elevated levels of VOCs released from smoking products. Additionally, where sample periods were separated into daytime and nighttime periods, only the nighttime statistics were evaluated as these are considered more representative of residential indoor air concentrations typically found in the home when most participants would have remained indoors at home.

Ideally, the raw data (concentrations of individual chemicals in each of the samples collected during each individual study) would have been compiled into a database and statistics generated from the consolidated data. However, the raw data were not available for most studies, so the statistics (e.g., percentiles) reported in the individual studies were compiled instead. Because of the lack of raw data, it was not possible to conduct a rigorous statistical analysis of the compiled data. Instead, analyses based on graphical and tabular summaries of the information are presented in this section.

The 50th and 90th percentile values reported by each of the 18 considered indoor air studies are shown versus the year of sample collection in **Figure 1**. The figure includes a selected group of VOCs typically encountered in site-specific vapor intrusion investigations, and the dates plotted on the time scale are the starting sample dates for each study. The time trend plots show that, for most chemicals, the 50th and 90th percentiles of indoor air concentrations measured in the individual studies conducted in North American residences after 1990 are considerably lower than those measured earlier. This is consistent with previously published compilations addressing a wider variety of building types (e.g., Hodgson and Levin, 2003). Consequently, EPA believes the background indoor air studies with data collected starting in 1990 and later (i.e., the more recent 15 of the 18 indoor air studies evaluated) to be more representative of the current range of background indoor air concentrations than data collected earlier.

Table 2 summarizes the summary statistics (e.g., 50th, 75th, 90th, and 95th percentiles), the reporting limits and percent detections for selected VOCs compiled from the 15 more recent background indoor air studies with data collection dates spanning 1990 through 2005. In compiling **Table 2**, chemicals for which all statistics were reported in a study as being less than

the reporting limit were excluded from this compilation. **Appendix C** contains the information reported by each individual study. The compiled statistics in **Table 2** collectively represent indoor air quality in urban, suburban, and rural residences, without differentiation as to setting. The population statistics from this compilation compare very well with those of existing residential buildings in Hodgson and Levin (2003) at the 50th percentile and within a factor of two at the 90th percentile. The compilation in **Table 2**, however, includes additional information that more effectively describes the variability of indoor air concentrations due to background sources that may be measured in North American residences.

In order to illustrate the variability in background indoor air VOC concentrations commonly measured in North American residences, **Figure 2** plots the individual percentiles (e.g., 50th, 75th, 90th, and 95th percentiles) reported in the more recent (1990–2005) indoor air studies versus the year sample collection started. Percentiles reported as less than the reporting limit are shown with open symbols plotted at the reporting limit. **Figure 2,** along with **Table 2,** illustrate that there is considerable variability in background indoor air concentrations. The observed variability may be the result of differences in the date of sampling and location of the studies, as well as differences in study design (e.g., sampling duration, sampling devices, and sampling strategies). In addition, the individual study statistics presented in this report were taken from studies conducted in a wide variety of geographic settings and climatic conditions, which may contribute to the overall variability in the compiled concentration statistics. Variations in house air exchange rates, consumer habits, and outdoor air concentrations also may contribute to the overall variability within and between the studies.

The concentrations in **Figures 1** and **2** are plotted on a log scale to accommodate the large ranges in concentrations reported in background indoor air. To test whether the underlying distribution of background air concentrations is log based, the concentration distribution of an example chemical commonly found in indoor air—benzene—was analyzed. The benzene concentration percentiles reported in six studies that provided a comprehensive set of percentiles (e.g., 25th, 50th, 75th, 90th & 95th percentiles; **Appendix C**) plot as roughly straight lines in a log-normal probability plot (**Figure 3**). This suggests the underlying data are log-normally distributed. The values along the x-axis in **Figure 3** are the number of standard deviations away from the mean (which has a value of zero). The characterization of the background indoor air concentrations as log-normally distributed is important because it makes clear that, although most concentrations tend to be low (i.e., the data are skewed towards zero, with most occurring in the lower part of the concentration range), some very large background concentrations do occur, though rarely, on the "long right tail" that is characteristic of the higher part of the range of a log-normal distribution. The large range of concentrations within and among the studies reviewed support the use of concentration distributions rather than a single measure of the distribution, such as a "typical" value, to characterize background concentrations in indoor air. In summary, the evidence suggests the background indoor air concentrations can be generally characterized by a log-normal (or similarly skewed) distribution, indicating that although most concentrations tend to be low, some very large background concentrations do occur.

The VOCs most commonly detected in indoor air in the 15 more recent (1990 to 2005) studies compiled in **Table 2** are presented in **Figure 4**, which ranks the chemicals on the basis of the total percent detections shown in **Table 2**. As described above, the sources that influence the concentrations of these VOCs include outdoor ambient air, as well as numerous potential indoor

sources. It is important to recognize that the studies used to develop **Figure 4** used widely varying reporting limits (shown in parentheses following each listed compound). Some compounds (e.g., trichloroethylene) commonly have been analyzed using very low reporting limits, while other compounds (e.g., cis-1,2-dichloroethylene) have been analyzed using reporting limits an order of magnitude higher. Studies with lower reporting limits nearly always have higher detection frequencies for the compounds analyzed (see **Appendix C**). For example, Foster et al. (2002) had a very low RL for TCE (0.02 $\mu g/m^3$) and a 100% detection frequency, while Weisel (2006), with the highest TCE RL of 2.7 $\mu g/m^3$, had only an 8% detection frequency for TCE. Similarly, 1,1-dichloroethylene was rarely detected in most studies except for the two using very low reporting limits. NYDOH (2006) detected 1,1-dichloroethylene in ~ 7% of their samples using a reporting limit of 0.25 $\mu g/m^3$ whereas Zhu et al. (2005) reported detecting 1,1-dichloroethylene in ~45% of their samples using a reporting limit of 0.01 $\mu g/m^3$.

Finally, it is important to note that background indoor air concentrations found in site-specific assessments or individual studies in the future may differ from those found in the individual studies shown in **Figure 2** and may even fall outside of the ranges of statistics compiled in **Table 2** of this report. Concentrations of many hazardous chemicals may continue to decrease in the future if continued efforts to replace hazardous chemicals in household products with environmentally friendly alternatives are successful. For example, since 2005, when the Energy Policy Act removed the oxygen requirement from gasoline, MTBE use in gasoline has declined considerably[6]. Thus, current MTBE levels in background indoor air are expected to be significantly lower than the concentrations reported in **Table 2**. Conversely, background indoor air concentrations of some chemicals (e.g., 1,2-dichloroethane) appear to be showing an increase over time (Kurtz et al., 2010), which has been tied to increasing use in certain consumer products (Doucette et al., 2009).

[6] http://water.usgs.gov/nawqa/vocs/oxybib/index.oxybib.html

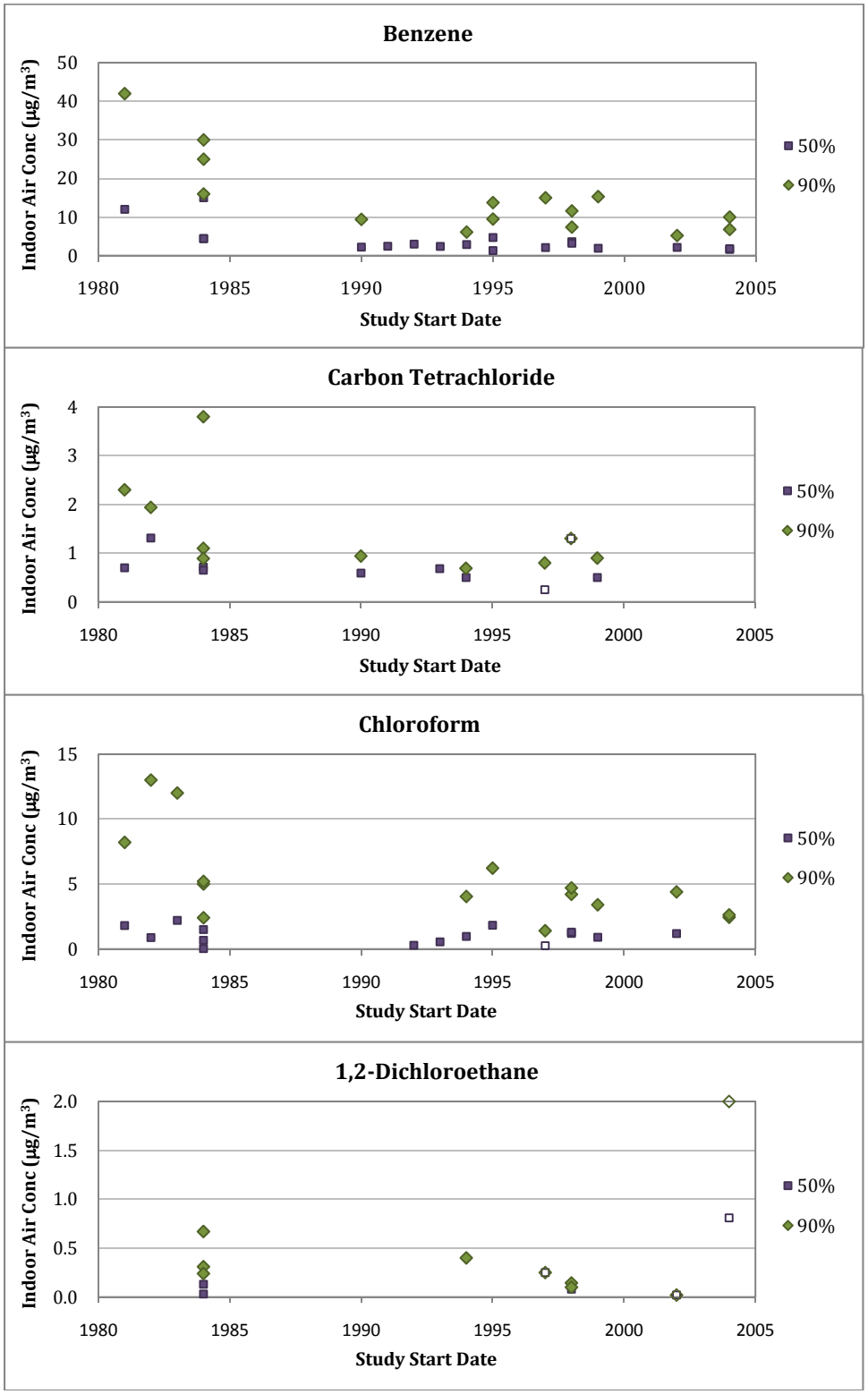

Figure 1. Background indoor air concentration (µg/m^3) percentiles (50th and 90th) versus time (1981–2005) for selected VOCs in background indoor air. The percentiles are plotted versus the starting sample date of the individual studies. Percentiles below a study's reporting limit are shown with open symbols. See Appendix C for figure data.

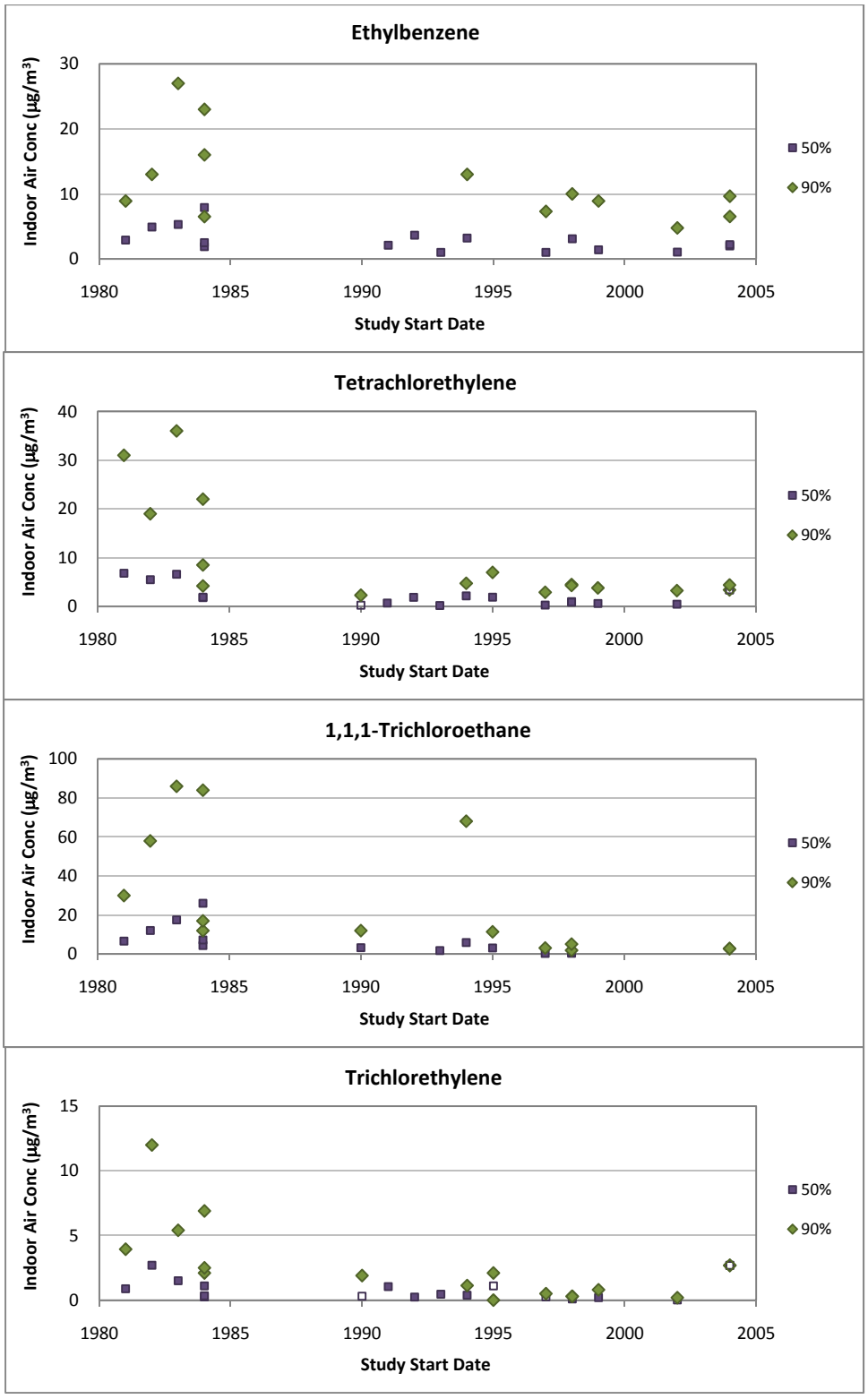

Figure 1. (cont.) Background indoor air concentration (µg/m^3) percentiles (50th and 90th) versus time (1981–2005) for selected VOCs in background indoor air. The percentiles are plotted versus the starting sample date of the individual studies. Percentiles below a study's reporting limit are shown with open symbols. See Appendix C for figure data.

Table 2. Ranges of Summary Statistics[7] for Background Indoor Air Concentrations of Common VOCs Measured in North American Residences between 1990 and 2005 (all concentrations expressed in µg/m^3)

Compound	Number of Studies	Number of Samples	Range % Detect	Total % Detects	RL Range	Range of 50th%	N*	Range of 75th%	N	Range of 90th%	N	Range of 95th%	N
Benzene	14	2,615	31–100	91.1	0.05–1.6	<RL–4.7	14	1.9–7.0	9	5.2–15	11	9.9–29	5
Carbon tetrachloride	6	1248	1–100	53.5	0.15–1.3	<RL–0.68	6	<RL–0.72	3	<RL–0.94	5	<RL–1.1	2
Chloroform	11	2,278	9–100	68.5	0.02–2.4	<RL–2.4	11	<RL–3.4	7	<RL–6.2	9	4.1–7.5	5
Dichloroethane, 1,1-	2	682	1	1	0.08–0.25	<RL	2	<RL	2	<RL	2	<RL	2
Dichloroethane, 1,2-	7	1,432	1-25	13.8	0.08–2.0	<RL	7	<RL–0.08	6	<RL–0.4	7	<RL–0.2	4
Dichloroethylene, 1,1-	2	475	7-45	13	0.01–0.25	<RL	2	<RL-0.37	2	<RL-0.8	2	0.7	1
Dichloroethylene, cis 1,2-	3	875	1–9	4.9	0.25–2.0	<RL	3	<RL	3	<RL	3	<RL–1.2	3
Ethylbenzene	10	1,484	26–100	85.7	0.01–2.2	1–3.7	10	2–5.6	5	4.8–13	7	12–17	3
Methyl tert-butyl ether (MTBE)	4	502	9–70	54.5	0.05–1.8	0.025–3.5	4	0.03–11	4	0.03–41	4	71–72	2
Methylene chloride	8	1,724	29–100	79.1	0.12–3.5	0.68–61	8	1.0–8.2	6	2.0–510	8	2.9–45	4
Tetrachloroethylene	13	2,312	5–100	62.5	0.03–3.4	<RL–2.2	13	<RL–4.1	8	<RL–7	10	4.1–9.5	5
Toluene	12	2,065	86–100	96.4	0.03–1.9	4.8–24	12	12–41	7	25–77	9	79–144	4
Trichloro-1,2,2-trifluoroethane, 1,1,2- (Freon 113)	3	600	1–56	37.5	0.25–3.8	<RL–0.5	3	<RL–1.1	3	<RL–1.8	3	<RL–3.4	2
Trichloroethane, 1,1,1-	9	1,877	4–100	53.4	0.12–2.7	<RL–5.9	9	<RL–7	7	<RL–68	8	3.4–28	5
Trichloroethylene	14	2503	1–100	42.6	0.02–2.7	<RL–1.1	14	<RL–1.2	9	<RL–2.1	11	0.56–3.3	5
Vinyl chloride	4	1484	0–25	9.2	0.01–0.25	<RL	4	<RL	4	<RL–0.04	4	<RL–0.09	4
Xylene, m/p-	10	1,920	52–100	92.9	0.4–2.2	1.5–14	10	4.6–21	7	12–56	9	21–63.5	4
Xylene, o-	12	2,004	31–100	89.0	0.11–2.2	1.1–3.6	12	2.4–6.2	7	5.5–16	9	13–20	4

* N = Number of studies reporting the percentile.

[7] All summary statistics reported by an individual study for an individual chemical were included in this compilation, with the following exceptions: if all statistics, including the maximum reported value, for a chemical were below an individual study's reporting limit for that chemical, the statistics for that chemical in that study were not included in this compilation.

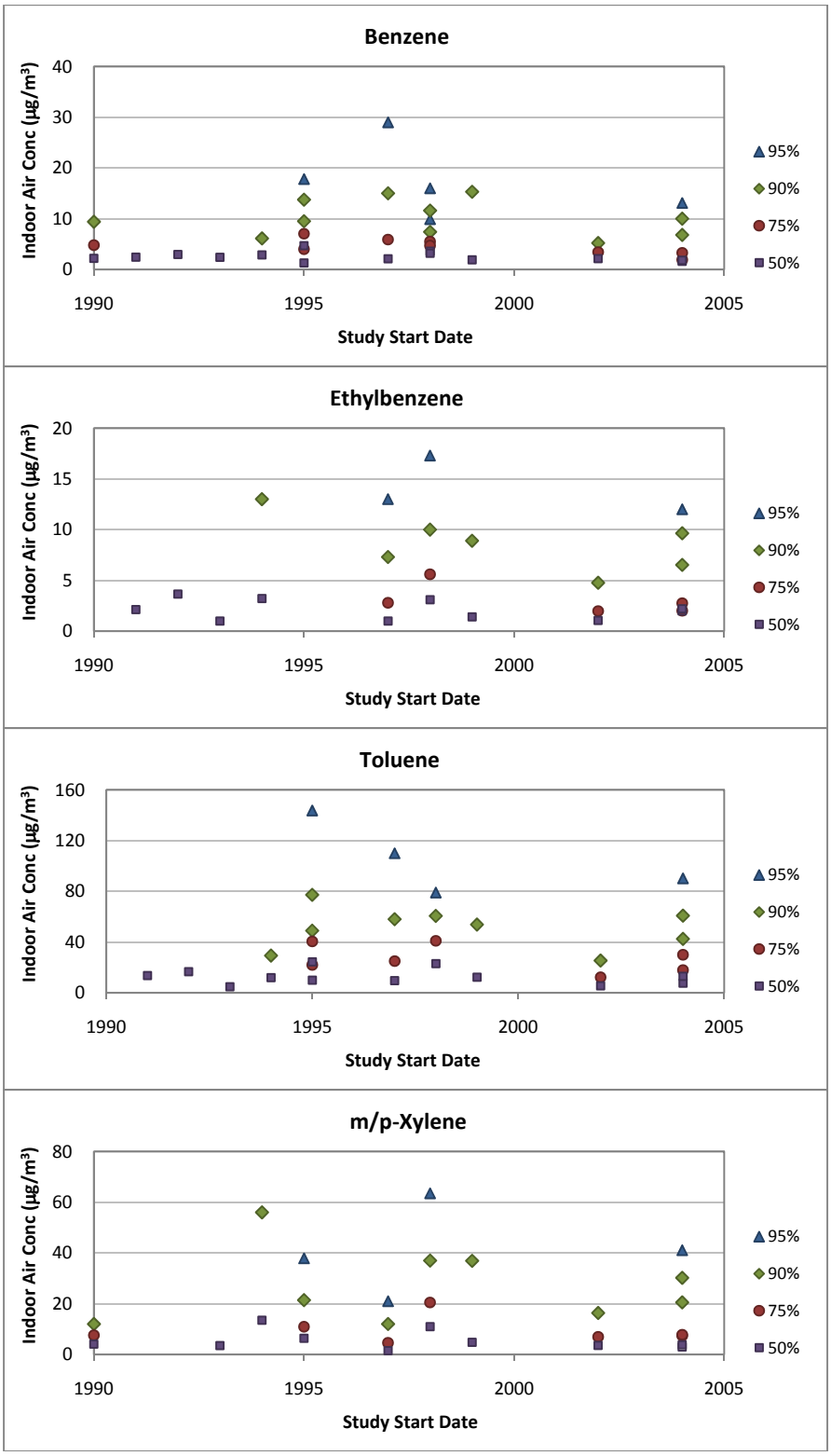

Figure 2. Summary statistics for background indoor air concentrations of selected VOCs measured in North American residences between 1990 and 2005 plotted as a function of study start date. Percentiles below a study's reporting limit are shown with open symbols. See Appendix C for figure data.

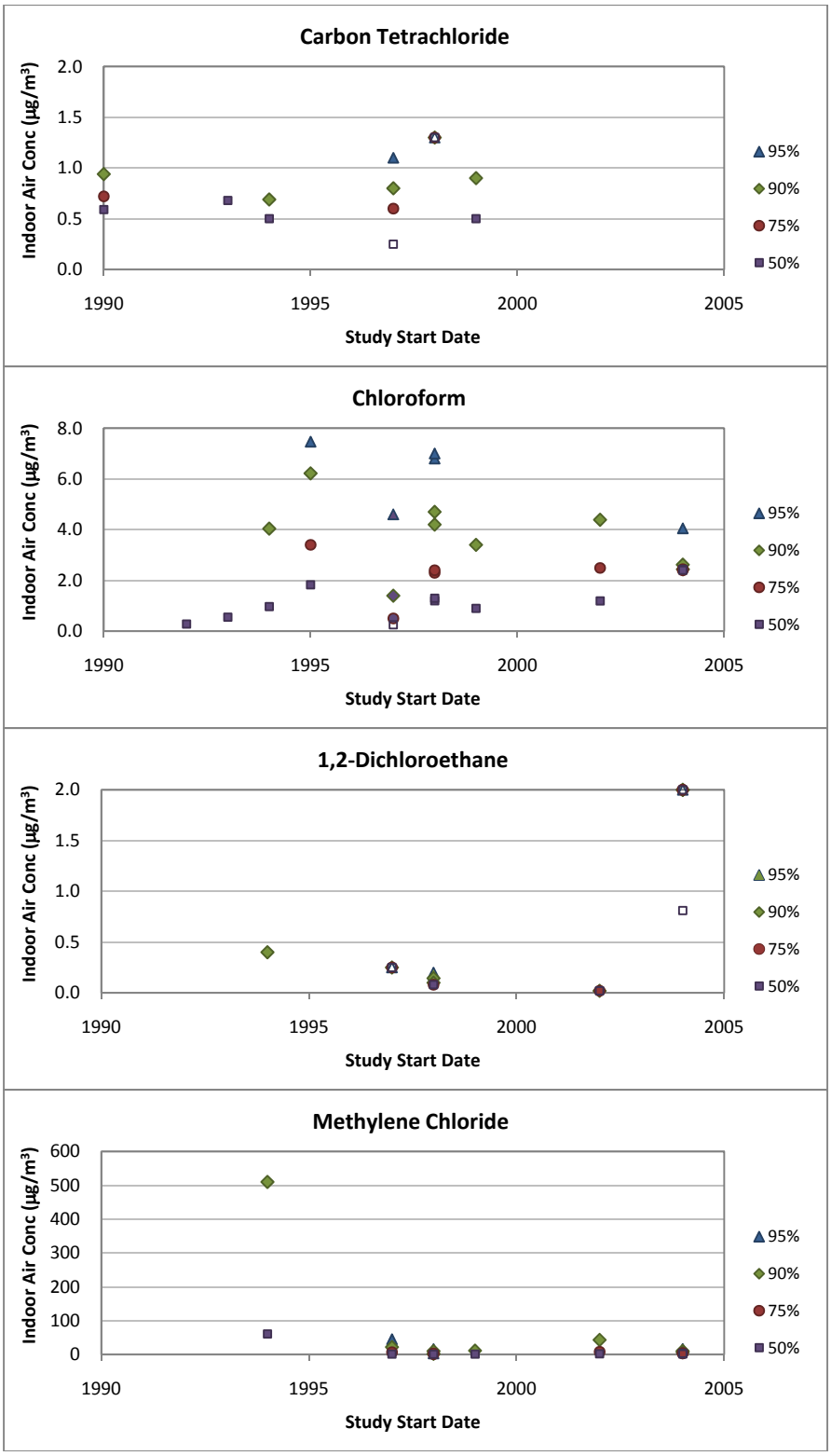

Figure 2. (cont.) Summary statistics for background indoor air concentrations of selected VOCs measured in North American residences between 1990 and 2005 plotted as a function of study start date. Percentiles below a study's reporting limit are shown with open symbols. See Appendix C for figure data

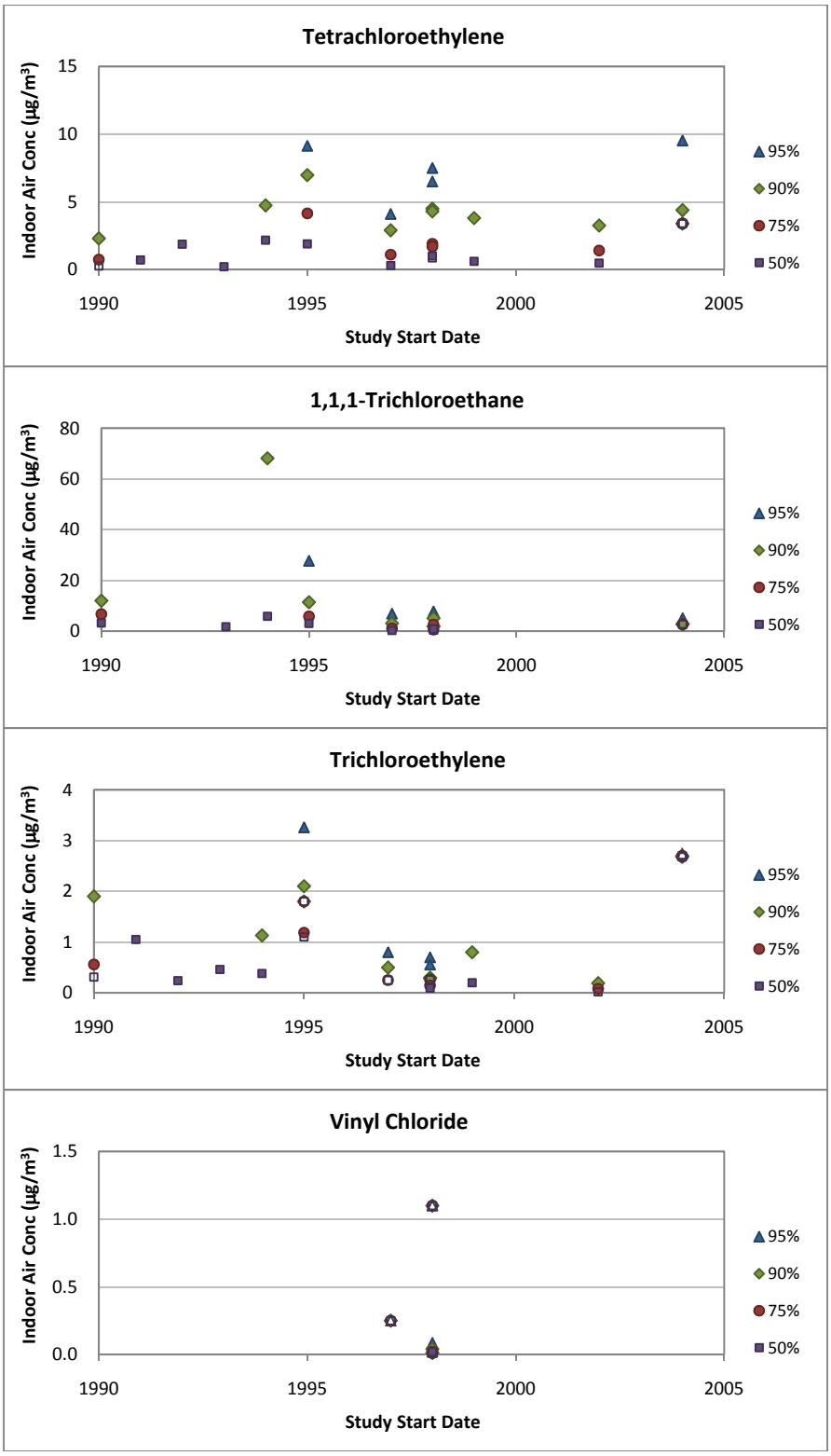

Figure 2. (cont.) Summary statistics for background indoor air concentrations of selected VOCs measured in North American residences between 1990 and 2005 plotted as a function of study start date. Percentiles below a study's reporting limit are shown with open symbols. See Appendix C for figure data.

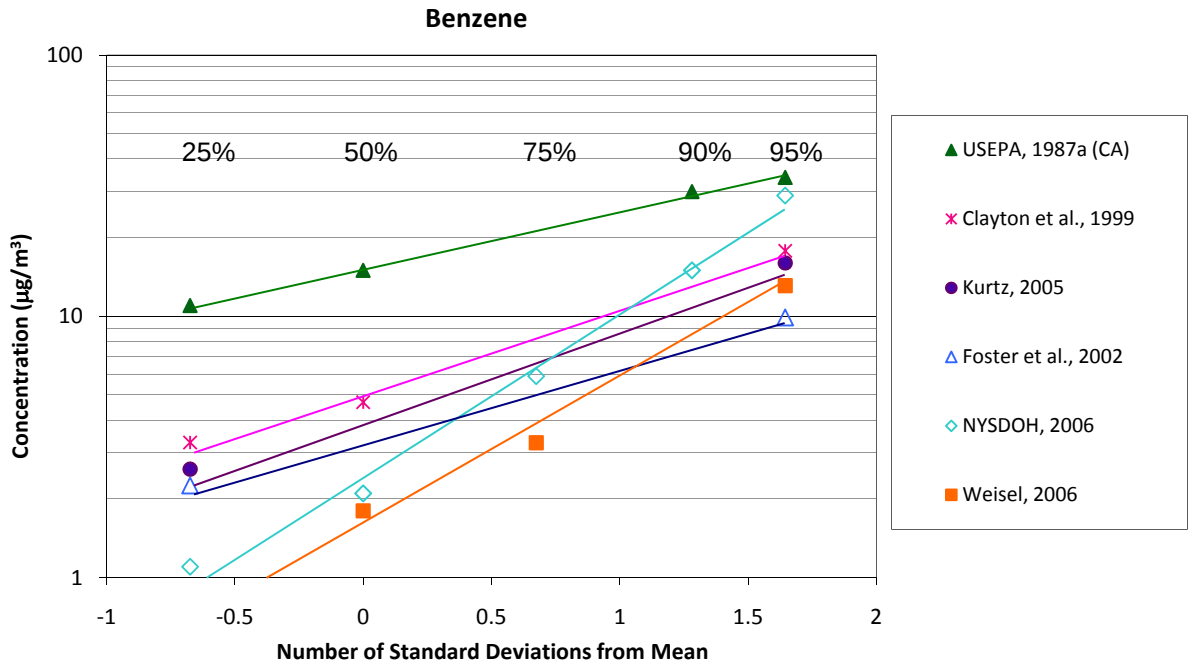

Figure 3. Log-normal probability plot for benzene in six residential indoor air quality studies. Exponential regression lines are used to represent data trends.

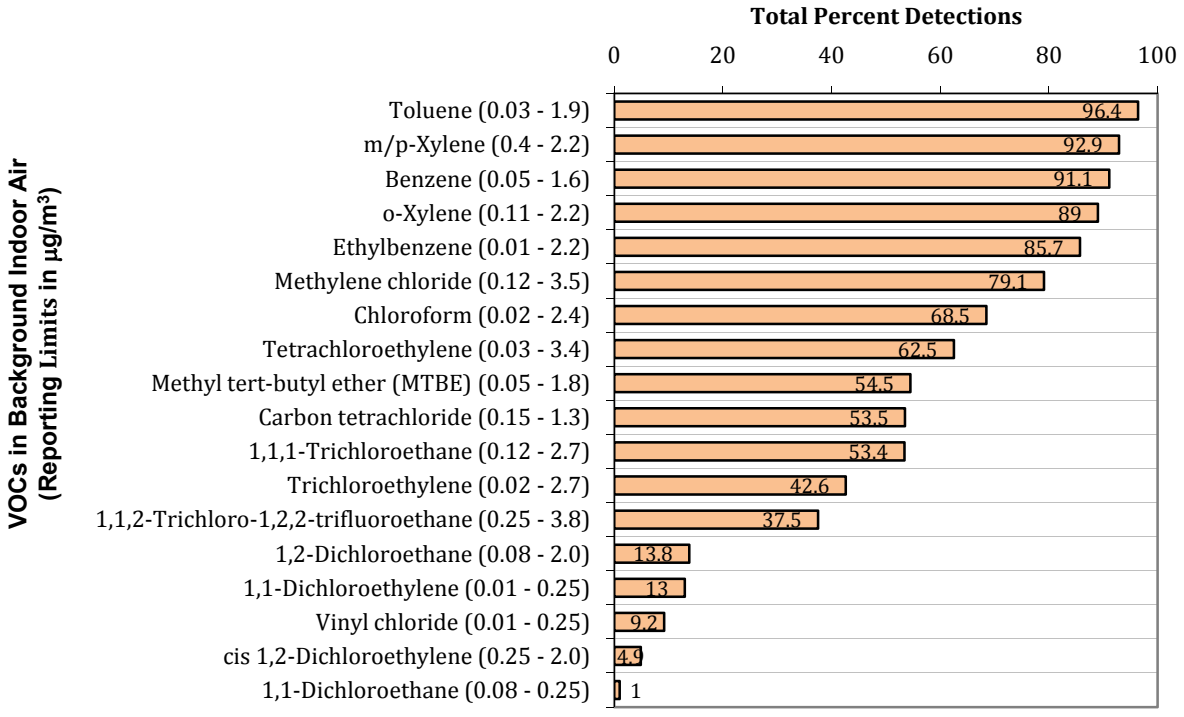

Figure 4. Total percent detections of common VOCs in background indoor air compiled from 15 studies conducted between 1990 and 2005. Range of reporting limits is shown in parentheses.

4.0 Summary and Conclusions

Indoor air typically contains chemicals from consumer products, building materials, and outdoor (ambient) air. Any indoor air sample collected for site-specific assessment of subsurface vapor intrusion is likely to detect chemicals from these other sources, and in many cases, the compounds detected in indoor air may be the same as those present in contaminated soil or groundwater that may enter the building through vapor intrusion.

This technical report presents a compilation of information on the expected ranges and variability of typical ('background') indoor air concentrations of VOCs measured in North American residences. The compilation was developed from 15 background indoor air studies targeting specific residential populations for specific purposes, conducted between 1990 and 2005. These were selected from a total of 18 indoor air quality studies conducted between 1981 and 2005, which reported summary statistics describing the distribution of indoor air concentrations measured in residences that are not expected or known to be located over contaminated soil or groundwater or that have effective vapor intrusion mitigation systems in place.

The information compiled for this technical report includes percentiles (e.g., 25th, 50th, 75th, 90th, and 95th percentiles), number of samples, percent detection, and reporting limits. Some chemicals, notably the petroleum hydrocarbons benzene, toluene, ethylbenzene and xylene, as well as the chlorinated hydrocarbons carbon tetrachloride, chloroform, tetrachloroethylene, and others, are frequently detected in background indoor air.

Evaluation of the background indoor air concentration summary statistics (i.e., percentiles) suggests that typical background VOC concentrations are log-normally distributed and vary considerably within and among the studies. This variation can be attributed to differences in the date of the study, sampling methods, geographic settings, and climatic conditions, as well as variations in house air exchange rates, consumer habits, and outdoor air concentrations. The large range of concentrations within and among the studies reviewed support the use of concentration distributions rather than a single measure of the distribution, such as a "typical" value, to characterize background concentrations in indoor air.

Time trends in the background indoor air concentration statistics reported in the studies reviewed for this technical report suggest that indoor air quality appears to have been improving over time in the United States and Canada. The indoor air concentrations measured in individual studies conducted between 1990 and 2005 and compiled here are considerably lower than those measured earlier. This is a finding that is consistent with other publications (Hodgson and Levin, 2003; Zhu et al., 2005; Weschler, 2009). It is important to note, however, that background indoor air concentrations found in site-specific assessments or individual studies in the future may differ from those summarized in this report. Concentrations of many hazardous chemicals may continue to decrease in the future as new environmentally friendly consumer products and building materials are developed. This may be particularly true for trichloroethylene, which is an important risk driver in many vapor intrusion assessments and shows a strong decrease in concentration over time. Conversely, concentrations of some chemicals may increase in the future, due to their increasing use in certain consumer products. Changes over time in building

construction and ventilation codes also may result in changes in the concentrations of indoor air contaminants found in buildings.

EPA anticipates that the information presented in this technical report may be useful for evaluating EPA's updated and expanded vapor intrusion database. EPA also anticipates that the information presented in this report may help EPA, State and tribal programs, and others determine whether indoor air quality data collected during site-specific vapor intrusion investigations are within typical background ranges. The information presented in this technical document also may be useful in communicating the findings of indoor air quality studies to building occupants and other stakeholders impacted by a vapor intrusion investigation. In addition, it may help affected parties at a specific site understand which VOCs are likely to be detected in indoor air even in the absence of any contribution from subsurface vapor intrusion.

5.0 References

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Appendix A

Summary of Previous Compilations of Background Indoor Air

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Appendix A

Summary of Previous Compilations of Background Indoor Air

- **Shah and Singh (1988)** compiled a database of 2,128 indoor air measurements, including samples from commercial buildings, for 66 VOCs representing 30 cities in 16 states (although 90% of the data are from California and New Jersey). The sampling dates for these compilations range from 1970 to 1987, with 98% collected between 1981 and 1984. Shah and Singh reported the number of samples, reporting limits, median and maximum values, percent detections, and lower and upper quartiles (i.e., the 25th and 75th percentiles).

- **Stolwijk (1990)** compiled central tendency data from four large studies of indoor air in homes collected prior to 1987 in the United States, Germany, the Netherlands, and Italy.

- **Samfield (1992)** compiled central tendency data from the literature on organic compounds measured indoors from 1975 to 1990.

- **Brown et al. (1994)** consolidated data from 50 studies that measured indoor air concentrations of VOCs in dwellings, office buildings, schools, offices, and hospitals. The samples were obtained between 1978 and 1990 in several countries. Assuming the data were log-normally distributed, the authors estimated weighted average geometric means and the 90th and 98th percentile concentrations for each VOC.

- **Holcomb and Seabrook (1995)** compiled mean VOC concentration data from studies of indoor air quality in commercial and residential buildings that were published between 1980 and 1993.

- **U.S. EPA (1998)** reviewed several field studies and compilation reports published between 1988 and 1996 to compile mean and median values of VOCs in indoor and ambient air. The samples were obtained from U.S. and foreign locations and included numerous commercial buildings, schools, and residences.

- **Hodgson and Levin (2003)** compiled central tendency data (mean and median) and maximum concentrations for a large number of VOCs, and the 90th and 95th percentiles for a limited set of VOCs, measured from 1990 to 2001 in 12 studies of indoor air quality in existing and newly constructed North American residences.

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Appendix B

Document Development and Peer Review

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Appendix B

Document Development and Peer Review

This appendix provides the history of the development and review process for EPA 530-R-10-001, *Background Indoor Air Concentrations of Volatile Organic Compounds in North American Residences: A Compilation of Statistics and Implications for Vapor Intrusion*. The document was developed by Dr. Helen Dawson of the U.S. Environmental Protection Agency (EPA), originally in response to the need to update the background data statistics that are part of the Appendix F of the *Draft Guidance for Evaluating the Vapor Intrusion to Indoor Air Pathway from Groundwater and Soils* (U.S. EPA, 2002) (Draft VI Guidance). From 2007 through the summer of 2009, Dr. Dawson worked with the Vapor Intrusion Guidance Team to develop, edit, review, and respond to comments. The Vapor Intrusion Guidance Team includes representatives from the following organizations with experience and expertise in vapor intrusion and/or indoor air:

- **U.S. EPA**. Thirteen staff from the Office of Solid Waste and Emergency Response (OSWER), Office of Superfund Remediation and Technology Innovation (OSRTI), Office of Resource Conservation and Recovery (ORCR), the Office of Brownfields and Land Revitalization, four Office of Research and Development (ORD) Laboratories, and two Regions.

- **Consultants**. Eleven subject matter experts from Arizona State University, EnviroGroup Limited, GeoSyntec Consultants, Golder Associates, and RTI International.

- **State Agencies**. Four expert practitioners/regulators from Kansas, New Jersey, and New York.

EPA's **Vapor Intrusion Forum** (VIF), a group of EPA environmental professionals involved in vapor intrusion assessment, reviewed the document from October 2008 through February 2009. For this, review the document was sent to 43 VIF members from 9 EPA Regions, 13 VIF members from EPA Headquarters, 5 VIF members from EPA ORD, and 2 members for the EPA Emergency Response Team. In addition, review was provided by staff in EPA's Office of Air and Radiation.

In 2008, Dr. Dawson and Mr. Todd McAlary (of GeoSyntec Consultants) submitted a paper based on the background data compilation to the editors of *Ground Water Monitoring and Remediation* (GWMR) journal, where it was peer reviewed and accepted for publication in a special issue on vapor intrusion (GWMR volume 29, no. 1, p. 60-69; Dawson and McAlary, 2009[8]).

[8] Dawson, H.E., and T. McAlary. 2009. A compilation of statistics for VOCs from post-1990 indoor air concentration studies in North American residences unaffected by subsurface vapor intrusion. *Ground Water Monitoring and Remediation.* 29(1):60-69.

The document was subjected to EPA's External Peer Review process from June to August 2009, where it was reviewed by four experts covering the disciplines of vapor intrusion, indoor air quality, and statistics. In response to their comments, Dr. Dawson and the Draft Vapor Intrusion Guidance Team developed responses to the external peer-review comments and made final edits to the document from September to March 2011. From March 2011 through June 2011, the document received final EPA management and legal review prior to its finalization.

Appendix C

Summary of Information Reported in Reviewed Studies for Individual VOCs

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Appendix C

Summary of Information Reported in Reviewed Studies for Individual VOCs

This appendix provides the chemical-specific information reported by the 18 indoor air studies reviewed for this report. **Table C-1** includes the number of measurements (N), percent of measurements at or above the reporting limit (% Detect), reporting limits (RL), percentiles, and the maximum values. The values in **Table C-1** are sorted by chemical and study start date. Table 1 in the main document provides information about the individual studies, including location, sample year and season, number of samples, collection device, collection period, and analytical method. The two sampling locations in U.S. EPA (1987a) are reported with numbers[1] for cross-referencing between **Table 1** of the main document and **Table C-1** in this appendix.

[1] (1) Los Angeles, CA, (2) Contra Costa, CA.

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Table C-1. Summary of Information Reported in Reviewed Studies

Start Date	Compound	N	%Detect	RL	25%	50%	75%	90%	95%	Max	Study
1992	Acetone (2-propanone)	60	NR	NR		34				390	Heavner et al., 1996
1997	Acetone (2-propanone)	227	95	0.25	10	21	52	110	140	690	NYSDOH, 2006
1998	Acetone (2-propanone)	375	99	1.9	34	49	71	110	153	2,200	Kurtz Personal Comm., 2005
2002	Acetone (2-propanone)	75	99	0.03		28	47	76		456	Zhu et al., 2005
2004	Acetone (2-propanone)	100	97	4.8	18	26	41	62		257	Rago et al., 2004, 2005
2004	Acetone (2-propanone)	100	94	12 / 12	22	35	55	91	190	2,900	Weisel, 2006
1981	Benzene[a]	348	95	0.44		12	24	42	56	200	US EPA, 1987b
1984	Benzene[a]	68	NR	0.22	2.9	4.4	7.5	16	18	32	US EPA, 1987a
1984	Benzene[a]	111	NR		11	15	21	30	34	43	US EPA, 1987a
1984	Benzene[a]	50	NR	0.21	2.2	4.45	9	25	29	35	US EPA, 1987a
1990	Benzene[b]	124	95	0.4	1.5	2.2	4.8	9.4		130	Sheldon et al., 1992
1991	Benzene[b]	24	NR	NR		2.4				19	Heavner et al., 1995
1992	Benzene[b]	61	NR	NR		3.0				33	Heavner et al., 1996
1993	Benzene[b]	9	100	NR		2.40					Mukerjee et al., 1997
1994	Benzene[b]	48	100	NR						33.9	Van Winkle and Scheff, 1995
1995	Benzene[b]	395	100	0.9	3.3	4.7	7.0	14	18	156	Clayton et al., 1999
1995	Benzene[b]	185	49	1.4	2.9	1.3	4.0	9.5	6.1	90	Gordon et al., 1999
1997	Benzene[b]	400	93	0.25	1.1	2.1	5.9	15	29	460	NYSDOH, 2006
1998	Benzene[b]	427	100	0.20	2.3	3.2	4.7	7.4	9.9	64	Foster et al., 2002; Kurtz, Pers. Comm. 2005
1998	Benzene[b]	375	100	0.64	2.6	3.6	5.5	11.6	16	39	Kurtz Personal Comm., 2005
1999	Benzene[b]	292	100	NR		1.9		15			Sexton et al., 2004
2002	Benzene[b]	75	97	0.05		2.2	3.4	5.2		21	Zhu et al., 2005
2004	Benzene[b]	100	31	1.60	<1.6	<1.6	1.9	6.8		28	Rago et al., 2004, 2005
2004	Benzene[b]	100	76	1.6 / 0.64	<1.6	1.8	3.3	10	13	42	Weisel, 2006
1998	Bromoform	375	0	2.1	<2.1	<2.1	<2.1	<2.1	<2.1	2.9	Kurtz Personal Comm., 2005
2004	Bromoform[c]	100	0	5.2 / 2.1	<2.1	<2.1	<5.2	<5.2	<5.2	<5.2	Weisel, 2006

(continued)

Table C-1. Summary of Information Reported in Reviewed Studies (continued)

Start Date	Compound	N	%Detect	RL	25%	50%	75%	90%	95%	Max	Study
1997	Bromomethane (Methyl bromide)	400	23	0.25	<0.25	<0.25	<0.25	0.6	0.9	23	NYSDOH, 2006
2004	Bromomethane (Methyl bromide)[c]	100	0	1.9 / 0.78	<0.78	<0.78	<1.9	<1.9	<1.9	<1.9	Weisel, 2006
1993	Butadiene, 1,3-	9	67	NR		0.80					Mukerjee et al., 1997
1994	Butadiene, 1,3-	48	81	NR		0.26				2.5	Van Winkle and Scheff, 1995
2002	Butadiene, 1,3-	75	32	0.32		0.2	0.47	1.6		3.7	Zhu et al., 2005
1998	Carbon Disulfide	375	10	3.1	<3.1	<3.1	<3.1	0.62	4.8	82	Kurtz Personal Comm., 2005
2002	Carbon Disulfide	75	67	0.03		0.13	0.46	0.9		3.3	Zhu et al., 2005
2004	Carbon Disulfide	100	3	1.6 / 1.6	<1.6	<1.6	<1.6	<1.6	<1.6	4.4	Weisel, 2006
1981	Carbon Tetrachloride[a]	348	30	1.7		0.7	1.1	2.3	2.7	250	US EPA, 1987b
1982	Carbon Tetrachloride[a]	157	NR	2.3		1.3	1.6	1.9	2.4	7.2	US EPA, 1987b
1984	Carbon Tetrachloride[a]	68	NR	0.26	0.6	0.71	1.6	3.8	5.5	7.6	US EPA, 1987a
1984	Carbon Tetrachloride[a]	111	NR	0.22	0.52	0.65	0.87	1.1	1.5	2.6	US EPA, 1987a
1984	Carbon Tetrachloride[a]	50	NR	0.26	0.52	0.65	0.73	0.89	0.89	3.6	US EPA, 1987a
1990	Carbon Tetrachloride[b]	124	98	0.15	0.49	0.59	0.72	0.94		2.6	Sheldon et al., 1992
1993	Carbon Tetrachloride[b]	9	100	NR		0.68					Mukerjee et al., 1997
1994	Carbon Tetrachloride[b]	48	94	NR		0.5				1.3	Van Winkle and Scheff, 1995
1997	Carbon Tetrachloride[b]	400	50	0.25	<0.25	<0.25	0.6	0.8	1.1	4.2	NYSDOH, 2006
1998	Carbon Tetrachloride[b]	375	1	1.3	<1.3	<1.3	<1.3	<1.3	<1.3	1.4	Kurtz Personal Comm., 2005
1999	Carbon Tetrachloride[b]	292	100	NR		0.5		0.9			Sexton et al., 2004
2004	Carbon Tetrachloride[c]	100	0	3.14	<3.14	<3.14	<3.14	<3.14		<3.14	Rago et al., 2004, 2005
2004	Carbon Tetrachloride[c]	100	0	3.1 / 1.3	<1.3	<1.3	<3.1	<3.1	<3.1	<3.1	Weisel, 2006
1982	Chlorobenzene[a]	157	NR	0.78		0.39	0.69	1.4	2.7	6.6	US EPA, 1987b
1997	Chlorobenzene	400	1	0.25	<0.25	<0.25	<0.25	<0.25	<0.25	0.6	NYSDOH, 2006
1998	Chlorobenzene	375	1	0.92	<0.92	<0.92	<0.92	<0.92	<0.92	9.7	Kurtz Personal Comm., 2005
2002	Chlorobenzene	75	8	0.01		<0.01	<0.01	<0.01		0.04	Zhu et al., 2005

(continued)

Table C-1. Summary of Information Reported in Reviewed Studies (continued)

Start Date	Compound	N	%Detect	RL	25%	50%	75%	90%	95%	Max	Study
2004	Chlorobenzene[c]	100	0	2.30	<2.30	<2.30	<2.30	<2.30		<2.30	Rago et al., 2004, 2005
2004	Chlorobenzene[c]	100	0	2.3 / 0.92	<0.92	<0.92	<2.3	<2.3	<2.3	<2.3	Weisel, 2006
1994	Chloroethane	48	75	NR		0.47				3.6	Van Winkle and Scheff, 1995
1997	Chloroethane	400	10	0.25	<0.25	<0.25	<0.25	<0.25	1	5	NYSDOH, 2006
2004	Chloroethane	100	0	1.3 / 0.53	<0.53	<1.3	<1.3	<1.3	<1.3	1.3	Weisel, 2006
1981	Chloroform[a]	348	59	2.1		1.8	3.7	8.2	11.5	29	US EPA, 1987b
1982	Chloroform[a]	157	NR	1.28		0.88	7.6	13	15	35	US EPA, 1987b
1983	Chloroform[a]	47	NR	0.38		2.2	6.15	12	15.5	15.5	US EPA, 1987b
1984	Chloroform[a]	68	NR	0.22	0.03	0.03	0.98	2.4	2.7	6.3	US EPA, 1987a
1984	Chloroform[a]	111	NR	0.19	0.83	1.5	2.9	5	6	9.7	US EPA, 1987a
1984	Chloroform[a]	50	NR	0.22	0.28	0.67	1.4	5.2	5.3	20	US EPA, 1987a
1992	Chloroform[b]	61	NR	NR		0.3				2.9	Heavner et al., 1996
1993	Chloroform[b]	7	78	NR		0.55					Mukerjee et al., 1997
1994	Chloroform[b]	48	98	NR		1.0				11	Van Winkle and Scheff, 1995
1995	Chloroform[b]	393	70	1.1	<1.1	1.8	3.4	6.2	7.5	34	Clayton et al., 1999
1997	Chloroform[b]	400	47	0.25	<0.25	<0.25	0.5	1.4	4.6	25	NYSDOH, 2006
1998	Chloroform[b]	427	100	0.07	0.56	1.3	2.4	4.7	7.0	21	Foster et al., 2002; Kurtz, Pers. Comm. 2005
1998	Chloroform[b]	375	66	0.97	<0.97	1.2	2.3	4.2	6.8	54	Kurtz Personal Comm., 2005
1999	Chloroform[b]	292	75	NR		0.9		3.4			Sexton et al., 2004
2002	Chloroform[b]	75	93	0.02		1.2	2.5	4.4		8.2	Zhu et al., 2005
2004	Chloroform[b]	100	9	2.44	<2.44	<2.44	<2.44	<2.44		8.3	Rago et al., 2004, 2005
2004	Chloroform[b]	100	29	2.4 / 0.98	0.98	2.4	2.4	2.6	4.1	5.9	Weisel, 2006
1994	Chloromethane (Methyl Chloride)	48	100	NR		1.69				4.3	Van Winkle and Scheff, 1995
1997	Chloromethane (Methyl Chloride)	400	54	0.25	<0.25	0.5	1.8	3.3	5	260	NYSDOH, 2006
1998	Chloromethane (Methyl Chloride)	375	98	0.82	1.1	1.3	1.5	2.0	2.5	7.5	Kurtz Personal Comm., 2005
2004	Chloromethane (Methyl Chloride)	100	79	1.0	1.1	1.2	1.4	1.8		4.2	Rago et al., 2004, 2005

(continued)

Table C-1. Summary of Information Reported in Reviewed Studies (continued)

Start Date	Compound	N	%Detect	RL	25%	50%	75%	90%	95%	Max	Study
2004	Chloromethane (Methyl Chloride)	100	81	1 / 1	1.1	1.4	1.7	2	2.1	6.2	Weisel, 2006
1993	Cyclohexane	3	33	NR		0.70					Mukerjee et al., 1997
1997	Cyclohexane	400	69	0.25	<0.25	0.80	2.6	8.1	19	88	NYSDOH, 2006
2002	Cyclohexane	75	93	0.03		4.5	7.9	15.1		54	Zhu et al., 2005
2004	Cyclohexane	100	15	1.72	<1.72	<1.72	<1.72	2.8		9.5	Rago et al., 2004, 2005
2004	Cyclohexane	100	48	1.7 / 0.69	<0.80	1.7	1.9	4.5	6.9	52	Weisel, 2006
1994	Dibromochloromethane (Chlorodibromomethane)	48	13	NR		<RL		0.09		0.26	Van Winkle and Scheff, 1995
2004	Dibromochloromethane (Chlorodibromomethane)	100	0	4.3 / 1.7	<1.7	<1.7	<4.3	<4.3	<4.3	4.3	Weisel, 2006
1981	Dichlorobenzene, 1,2- (o-Dichlorobenzene) [a]	348	82	1.3		1.3	3.5	21	44	158	US EPA, 1987b
1984	Dichlorobenzene, 1,2- (o-Dichlorobenzene) [a]	68	NR	0.2	0.02	0.03	0.08	0.4	0.7	1.6	US EPA, 1987a
1984	Dichlorobenzene, 1,2- (o-Dichlorobenzene) [a]	111	NR	0.2	0.03	0.11	0.25	0.66	1.2	3.3	US EPA, 1987a
1984	Dichlorobenzene, 1,2- (o-Dichlorobenzene) [a]	50	NR	0.2	0.02	0.03	0.13	0.3	1.3	11	US EPA, 1987a
1994	Dichlorobenzene, 1,2- (o-Dichlorobenzene)	48	29	NR		<RL				0.54	Van Winkle and Scheff, 1995
1997	Dichlorobenzene, 1,2- (o-Dichlorobenzene)	400	21	0.25	<0.25	<0.25	<0.25 0.2	0.7	1	4.9	NYSDOH, 2006
1998	Dichlorobenzene, 1,2- (o-Dichlorobenzene)	375	4	1.2	<1.2	<1.2	<1.2	<1.2	<1.2	46	Kurtz Personal Comm., 2005
2002	Dichlorobenzene, 1,2- (o-Dichlorobenzene)	75	5	0.02		<0.02	<0.02	<0.02		0.11	Zhu et al., 2005
2004	Dichlorobenzene, 1,2- (o-Dichlorobenzene)[c]	100	0	3.00	<3.00	<3.00	<3.00	<3.00		<3.00	Rago et al., 2004, 2005
2004	Dichlorobenzene, 1,2- (o-Dichlorobenzene)	100	1	3 / 1.2	<1.2	<1.2	<3.0<	<3.0	<3.0	16	Weisel, 2006
1994	Dichlorobenzene, 1,3- (m-Dichlorobenzene)	48	10	NR		<RL		0.06		0.36	Van Winkle and Scheff, 1995

(continued)

Table C-1. Summary of Information Reported in Reviewed Studies (continued)

Start Date	Compound	N	%Detect	RL	25%	50%	75%	90%	95%	Max	Study
1997	Dichlorobenzene, 1,3- (m-Dichlorobenzene)	400	21	0.25	<0.25	<0.25	<0.25	0.6	0.9	2.5	NYSDOH, 2006
1998	Dichlorobenzene, 1,3- (m-Dichlorobenzene)	375	1	1.2	<1.2	<1.2	<1.2	<1.2	<1.2	1.3	Kurtz Personal Comm., 2005
2002	Dichlorobenzene, 1,3- (m-Dichlorobenzene)	75	81	0.01		0.2	0.29	1.1		16	Zhu et al., 2005
2004	Dichlorobenzene, 1,3- (m-Dichlorobenzene)[c]	100	0	3.00	<3.00	<3.00	<3.00	<3.00		<3.00	Rago et al., 2004, 2005
2004	Dichlorobenzene, 1,3- (m-Dichlorobenzene)[c]	100	0	3 / 1.2	<1.2	<1.2	<3.0	<3.0	<3.0	<3.0	Weisel, 2006
1981	Dichlorobenzene, 1,4- (p-Dichlorobenzene)[a]	348	7								US EPA, 1987b
1982	Dichlorobenzene, 1,4- (p-Dichlorobenzene)[a]	157	NR	0.83		3.2	13	63	180	1550	US EPA, 1987b
1983	Dichlorobenzene, 1,4- (p-Dichlorobenzene)[a]	47	NR	0.35		4.2	12	140	220	570	US EPA, 1987b
1984	Dichlorobenzene, 1,4- (p-Dichlorobenzene)[a]	68	NR	0.25	0.25	0.53	3.0	8.4	46	151	US EPA, 1987a
1984	Dichlorobenzene, 1,4- (p-Dichlorobenzene)[a]	111	NR	0.2	1.25	2.6	7.3	54	100	430	US EPA, 1987a
1984	Dichlorobenzene, 1,4- (p-Dichlorobenzene)[a]	50	NR	0.25	0.42	0.84	2.7	23	110	250	US EPA, 1987a
1990	Dichlorobenzene, 1,4- (p-Dichlorobenzene)	125	74	0.26	0.26	1.1	4	28.0		300	Sheldon et al., 1992
1991	Dichlorobenzene, 1,4- (p-Dichlorobenzene)	24	NR	NR		0.3				25	Heavner et al., 1995
1992	Dichlorobenzene, 1,4- (p-Dichlorobenzene)	61	NR	NR		0.6				122	Heavner et al., 1996
1994	Dichlorobenzene, 1,4- (p-Dichlorobenzene)	48	81	NR		0.6				96	Van Winkle and Scheff, 1995
1995	Dichlorobenzene, 1,4- (p-Dichlorobenzene)	391	37	0.8	<0.8	<0.8	1.2	6.2	17	574	Clayton et al., 1999
1997	Dichlorobenzene, 1,4- (p-Dichlorobenzene)	400	34	0.25	<0.25	<0.25	0.5	1.3	2.6	770	NYSDOH, 2006

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Table C-1. Summary of Information Reported in Reviewed Studies (continued)

Start Date	Compound	N	%Detect	RL	25%	50%	75%	90%	95%	Max	Study
1998	Dichlorobenzene, 1,4- (p-Dichlorobenzene)	375	25	1.2	<1.2	<1.2	<1.2	3.3	11	5100	Kurtz Personal Comm., 2005
1999	Dichlorobenzene, 1,4- (p-Dichlorobenzene)	292	73	NR		0.2		1.5			Sexton et al., 2004
2004	Dichlorobenzene, 1,4- (p-Dichlorobenzene)[c]	100	3	3.00	<3.00	<3.00	<3.00	<3.00		34	Rago et al., 2004, 2005
2004	Dichlorobenzene, 1,4- (p-Dichlorobenzene)	100	16	3 / 1.2	1.2	3	3	3.8	17	270	Weisel, 2006
1997	Dichlorodifluoromethane	400	46	0.25	<0.25	<0.25	4.1	15.0	26	300	NYSDOH, 2006
1998	Dichlorodifluoromethane	375	100	0.99	3	3.4	4.8	15	31	210	Kurtz Personal Comm., 2005
2004	Dichlorodifluoromethane	100	10	4.94	<4.94	<4.94	<4.94	5.0		82	Rago et al., 2004, 2005
2004	Dichlorodifluoromethane	100	88	2.5 / 2.5	2.78	3.3	4.3	9.6	28	160	Weisel, 2006
1997	Dichloroethane,1,1-[b]	400	1	0.25	<0.25	<0.25	<0.25	<0.25	<0.25	4.4	NYSDOH, 2006
1998	Dichloroethane,1,1-[c]	427	0	0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	Foster et al., 2002; Kurtz, Pers. Comm. 2005
1998	Dichloroethane,1,1-[b]	282	1	0.08	<0.08	<0.08	<0.08	<0.08	<0.08	0.2	Kurtz & Folkes 2002
2004	Dichloroethane,1,1-[c]	100	0	2.02	<2.02	<2.02	<2.02	<2.02		<2.02	Rago et al., 2004, 2005
2004	Dichloroethane,1,1-[c]	100	0	2 / 0.81	<0.81	<0.81	<2.0	<2.0	<2.0	<2.0	Weisel, 2006
1984	Dichloroethane,1,2-[a]	68	NR	0.2	0.12	0.13	0.16	0.31	0.38	0.54	US EPA, 1987a
1984	Dichloroethane,1,2-[a]	111	NR	0.19	0.13	0.25	0.42	0.67	1.1	51	US EPA, 1987a
1984	Dichloroethane,1,2-[a]	50	NR	0.2	0.02	0.03	0.13	0.24	0.59	1.05	US EPA, 1987a
1994	Dichloroethane,1,2-[b]	48	19	NR		<RL				1.25	Van Winkle and Scheff, 1995
1997	Dichloroethane,1,2-[b]	400	2	0.25	<0.25	<0.25	<0.25	<0.25	<0.25	4.9	NYSDOH, 2006
1998	Dichloroethane,1,2-[b]	427	25	0.08	<0.08	<0.08	0.08	0.14	0.20	0.43	Foster et al., 2002; Kurtz, Pers. Comm. 2005
1998	Dichloroethane,1,2-[b]	282	25	0.08	<0.08	<0.08	0.08	0.10	0.18	0.72	Kurtz & Folkes 2002
2002	Dichloroethane,1,2-[b]	75	5	0.02		<0.02	<0.02	<0.02		0.71	Zhu et al., 2005
2004	Dichloroethane,1,2-[b]	100	1	2.02	<2.02	<2.02	<2.02	<2.02		2.8	Rago et al., 2004, 2005
2004	Dichloroethane,1,2-[b]	100	1	2 / 0.81	<0.81	<0.81	<2.0	<2.0	<2.0	3.5	Weisel, 2006
1997	Dichloroethene, 1,1-[b]	400	7	0.25	<0.25	<0.25	<0.25	<0.25	0.7	430	NYSDOH, 2006

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(continued)

Table C-1. Summary of Information Reported in Reviewed Studies (continued)

Start Date	Compound	N	%Detect	RL	25%	50%	75%	90%	95%	Max	Study
2002	Dichloroethene, 1,1-[b]	75	45	0.01		<0.01	0.37	0.8		4.05	Zhu et al., 2005
2004	Dichloroethene, 1,1-[c]	100	0	1.98	<1.98	<1.98	<1.98	<1.98		<1.98	Rago et al., 2004, 2005
2004	Dichloroethene, 1,1-[c]	100	0	2 / 0.79	<0.79	<0.79	<2.0	<2.0	<2.0	<2.0	Weisel, 2006
1997	Dichloroethene, cis 1,2-[b]	400	9	0.25	<0.25	<0.25	<0.25	<0.25	1.2	7.4	NYSDOH, 2006
1998	Dichloroethene, cis 1,2-[b]	375	2	0.79	<0.79	<0.79	<0.79	<0.79	<0.79	4.5	Kurtz Personal Comm., 2005
2004	Dichloroethene, cis 1,2-[c]	100	0	1.98	<1.98	<1.98	<1.98	<1.98		<1.98	Rago et al., 2004, 2005
2004	Dichloroethene, cis 1,2-[b]	100	1	2 / 0.79	<0.79	<0.79	<2.0	<2.0	<2.0	2.9	Weisel, 2006
1998	Dichloroethene, trans 1,2-[c]	375	0	0.8	<0.79	<0.79	<0.79	<0.79	<0.79	<0.79	Kurtz Personal Comm., 2005
2004	Dichloroethene, trans 1,2-[c]	100	0	1.98	<1.98	<1.98	<1.98	<1.98		<1.98	Rago et al., 2004, 2005
2004	Dichloroethene, trans 1,2-[c]	100	0	2 / 0.79	<0.79	<0.79	<2.0	<2.0	<2.0	<2.0	Weisel, 2006
1997	Dichloropropane, 1,2-	400	2	0.25	<0.25	<0.25	<0.25	<0.25	<0.25	34	NYSDOH, 2006
1998	Dichloropropane, 1,2-	375	1	0.92	<0.92	<0.92	<0.92	<0.92	<0.92	1.5	Kurtz Personal Comm., 2005
2002	Dichloropropane, 1,2-[c]	75	0	0.04		<0.04	<0.04	<0.04		<0.04	Zhu et al., 2005
2004	Dichloropropane, 1,2-[c]	100	0	2.31	<2.31	<2.31	<2.31	<2.31		<2.31	Rago et al., 2004, 2005
2004	Dichloropropane, 1,2-[c]	100	0	2.3 / 0.92	<0.92	<0.92	<2.3	<2.3	<2.3	<2.3	Weisel, 2006
1997	Dichloropropene, cis-1,3-	400	3	0.25	<0.25	<0.25	<0.25	<0.25	<0.25	4	NYSDOH, 2006
2004	Dichloropropene, cis-1,3-[c]	100	0	2.27	<2.27	<2.27	<2.27	<2.27		<2.27	Rago et al., 2004, 2005
2004	Dichloropropene, cis-1,3-[c]	100	0	2.3 / 0.91	<0.91	<0.91	<2.3	<2.3	<2.3	<2.3	Weisel, 2006
2004	Dichloropropene, trans-1,3-[c]	100	0	2.27	<2.27	<2.27	<2.27	<2.27		<2.27	Rago et al., 2004, 2005
2004	Dichloropropene, trans-1,3-[c]	100	0	2.3 / 0.91	<0.91	<0.91	<2.3	<2.3	<2.3	<2.3	Weisel, 2006
1997	Dichlorotetrafluoroethane, 1,2- (Freon 114)	400	13	0.25	<0.25	<0.25	<0.25	0.5	1.2	120	NYSDOH, 2006
2004	Dichlorotetrafluoroethane, 1,2- (Freon 114)	100	1	3.5 / 1.4	<1.4	<2.5	<3.5	<3.5	<3.5	20	Weisel, 2006
1981	Ethylbenzene[a]	348	93	0.4		2.9	5.3	8.9	12	290	US EPA, 1987b
1982	Ethylbenzene[a]	157	NR	0.68		4.9	7.9	13	18	180	US EPA, 1987b
1983	Ethylbenzene[a]	47	NR			5.3	20	27	30	32	US EPA, 1987b
1984	Ethylbenzene[a]	68	NR		1.1	1.9	3.3	6.5	9.4	28	US EPA, 1987a
1984	Ethylbenzene[a]	111	NR		4.9	7.9	11	16	19	29	US EPA, 1987a

(continued)

Table C-1. Summary of Information Reported in Reviewed Studies (continued)

Start Date	Compound	N	%Detect	RL	25%	50%	75%	90%	95%	Max	Study
1984	Ethylbenzene[a]	50	NR	0.2	1.5	2.5	4.9	23	26	35	US EPA, 1987a
1991	Ethylbenzene[b]	24	NR	NR		2.1				25	Heavner et al., 1995
1992	Ethylbenzene[b]	61	NR	NR		3.7				26	Heavner et al., 1996
1993	Ethylbenzene[b]	9	100	NR		1.00					Mukerjee et al., 1997
1994	Ethylbenzene[b]	48	100	NR		3.2				174	Van Winkle and Scheff, 1995
1997	Ethylbenzene[b]	400	86	0.25	0.4	1	2.8	7.3	13	340	NYSDOH, 2006
1998	Ethylbenzene[b]	375	98	0.87	2	3.1	5.6	10	17	170	Kurtz Personal Comm., 2005
1999	Ethylbenzene[b]	292	99	NR		1.4		8.9			Sexton et al., 2004
2002	Ethylbenzene[b]	75	83	0.01		1.1	2.0	4.8		201	Zhu et al., 2005
2004	Ethylbenzene[b]	100	26	2	<2	<2	2.0	6.5		30	Rago et al., 2004, 2005
2004	Ethylbenzene[b]	100	56	2.2 / 0.87	<1.2	2.2	2.8	9.6	12	39	Weisel, 2006
1993	Ethyltoluene, 4- (p-Ethyltoluene)	9	56	NR		0.80					Mukerjee et al., 1997
1998	Ethyltoluene, 4- (p-Ethyltoluene)	375	80	2	2.2	3.3	5.7	9.6	13.3	37	Kurtz Personal Comm., 2005
2004	Ethyltoluene, 4- (p-Ethyltoluene)	100	46	2.5 / 0.98	<1.2	<2.5	2.8	8.4	11	29	Weisel, 2006
2004	Heptane, n-	100	31	2.05	<2.05	<2.05	2.8	7.8		135	Rago et al., 2004, 2005
2004	Heptane, n-	100	68	2 / 0.82	<1.9	2	4.6	9.4	15	49	Weisel, 2006
1997	Hexachloro-1,3-butadiene	400	24	0.43	<0.43	<0.43	<0.43	4.6	11	51	NYSDOH, 2006
1998	Hexachloro-1,3-butadiene[c]	375	0	4.3	<4.3	<4.3	<4.3	<4.3	<4.3	<4.3	Kurtz Personal Comm., 2005
2004	Hexachloro-1,3-butadiene[c]	100	0	5.33	<5.33	<5.33	<5.33	<5.33		<5.33	Rago et al., 2004, 2005
2004	Hexachloro-1,3-butadiene[c]	100	0	5.3 / 2.1	<2.1	<2.1	<5.3	<5.3	<5.3	<5.3	Weisel, 2006
1993	Hexane, n-	9	100	NR		1.30					Mukerjee et al., 1997
1997	Hexane, n-	400	88	0.25	0.6	1.6	5.9	18	35	950	NYSDOH, 2006
2004	Hexane, n-	100	28	3.52	<3.52	<3.52	4.4	14		39	Rago et al., 2004, 2005
2004	Hexane, n-	100	75	1.8 / 0.7	<1.8	2.8	5.1	16	20	270	Weisel, 2006
1997	Methyl ethyl ketone (2-butanone) (MEK)	227	91	0.25	1.4	3.4	7.3	16	39	180	NYSDOH, 2006
1998	Methyl ethyl ketone (2-butanone) (MEK)	375	86	2.9	4.1	6.5	12	21	35	890	Kurtz Personal Comm., 2005

(continued)

Table C-1. Summary of Information Reported in Reviewed Studies (continued)

Start Date	Compound	N	%Detect	RL	25%	50%	75%	90%	95%	Max	Study
2004	Methyl ethyl ketone (2-butanone) (MEK)	100	79	1.5	1.8	2.7	4.0	9.6		76	Rago et al., 2004, 2005
2004	Methyl ethyl ketone (2-butanone) (MEK)	100	84	1.5 / 1.5	1.9	3.5	5.3	12	21	150	Weisel, 2006
1997	Methyl isobutyl ketone (4-methyl-2-pentanone)	227	55	0.25	<0.25	0.3	0.9	2.2	5.3	36	NYSDOH, 2006
1998	Methyl isobutyl ketone (4-methyl-2-pentanone)	375	42	1.6	<1.6	<1.6	3.4	5.7	9.0	1600	Kurtz Personal Comm., 2005
2002	Methyl isobutyl ketone (4-methyl-2-pentanone)	75	53	0.02		0.16	0.38	0.80		1.4	Zhu et al., 2005
2004	Methyl isobutyl ketone (4-methyl-2-pentanone)	100	4	2.05	<2.05	<2.05	<2.05	<2.05		11.2	Rago et al., 2004, 2005
2004	Methyl isobutyl ketone (4-methyl-2-pentanone)	100	10	2 / 2	<2.0	<2.0	<2.0	<2.0	3.1	10	Weisel, 2006
1997	Methyl tert-butyl ether (MTBE)[b]	227	70	0.25	<0.25	0.8	5.6	26	71	340	NYSDOH, 2006
2002	Methyl tert-butyl ether (MTBE)[b]	75	9	0.05		0.025	0.03	0.03		3.3	Zhu et al., 2005
2004	Methyl tert-butyl ether (MTBE)[b]	100	43	1.80	<1.80	<1.80	6.9	38		155	Rago et al., 2004, 2005
2004	Methyl tert-butyl ether (MTBE)[b]	100	66	1.8 / 1.8	<1.8	3.5	11	41	72	470	Weisel, 2006
1994	Methylene chloride[b]	48	100	NR		61		510		1190	Van Winkle and Scheff, 1995
1997	Methylene chloride[b]	400	78	0.25	0.3	1.4	6.6	22	45	2100	NYSDOH, 2006
1998	Methylene chloride[b]	427	81	0.42	0.46	0.68	1.0	2.0	2.9	12	Foster et al., 2002; Kurtz, Pers. Comm. 2005
1998	Methylene chloride[b]	282	82	0.42	0.49	0.88	3.2	10.0	16.0	180	Kurtz & Folkes 2002
1999	Methylene chloride[b]	292	98	NR		1.1		12			Sexton et al., 2004
2002	Methylene chloride[b]	75	95	0.12		1.9	8.2	43		408	Zhu et al., 2005
2004	Methylene chloride[b]	100	29	3.47	<3.47	<3.47	4.2	11		146	Rago et al., 2004, 2005
2004	Methylene chloride[b]	100	41	1.7 / 1.7	<1.7	<1.7	3.2	6.7	16	94	Weisel, 2006
1998	Methyl-tert-butyl ketone (2-hexanone)	375	1	1.6	<1.6	<1.6	<1.6	<1.6	<1.6	2.9	Kurtz Personal Comm., 2005
2004	Methyl-tert-butyl ketone (2-hexanone)[c]	100	0	2.05	<2.05	<2.05	<2.05	<2.05		<2.05	Rago et al., 2004, 2005

(continued)

Table C-1. Summary of Information Reported in Reviewed Studies (continued)

Start Date	Compound	N	%Detect	RL	25%	50%	75%	90%	95%	Max	Study
1994	Naphthalene	48	83	NR		0.47		2.15		5	Van Winkle and Scheff, 1995
2002	Naphthalene	75	83	0.02		0.4	1.1	4.8		144	Zhu et al., 2005
2004	Naphthalene	100	16	2	<2	<2	<2	2.7		42	Rago et al., 2004, 2005
1981	Styrene[a]	348	83	0.97		0.79	1.3	2.4	3	31	US EPA, 1987b
1982	Styrene[a]	157	NR	0.95		1.4	2.2	4.1	6.4	10	US EPA, 1987b
1983	Styrene[a]	47	NR	0.35		1.3	2.8	4.5	11	11	US EPA, 1987b
1984	Styrene[a]	68	NR	0.2	0.33	0.71	1.3	2	2.4	4.1	US EPA, 1987a
1984	Styrene[a]	111	NR	0.21	1.9	2.8	4.7	6.7	8.3	9.2	US EPA, 1987a
1984	Styrene[a]	50	NR	0.19	0.38	0.84	1.6	2.8	3.2	5.3	US EPA, 1987a
1990	Styrene	123	87	0.18	0.3	0.7	1.8	3.8		140.0	Sheldon et al., 1992
1991	Styrene	24	NR	NR		1.4				5.0	Heavner et al., 1995
1992	Styrene	61	NR	NR		1.0				10	Heavner et al., 1996
1993	Styrene	9	11	NR		0.70					Mukerjee et al., 1997
1994	Styrene	48	92	NR		0.9				9.5	Van Winkle and Scheff, 1995
1995	Styrene	383	85	0.8	1.1	1.8	2.6	3.8	4.4	15	Clayton et al., 1999
1997	Styrene	400	56	0.25	<0.25	0.3	0.6	1.3	2.3	50	NYSDOH, 2006
1998	Styrene	375	55	0.9	<0.9	0.9	1.6	2.8	4.1	13	Kurtz Personal Comm., 2005
1999	Styrene	292	74	NR		0.5		1.4			Sexton et al., 2004
2002	Styrene	75	88	0.05		0.5	0.87	1.5		6.5	Zhu et al., 2005
2004	Styrene	100	1	2.13	<2.13	<2.13	<2.13	<2.13		3.2	Rago et al., 2004, 2005
2004	Styrene	100	19	2.1 / 0.85	<0.85	<2.1	<2.1	<2.1	2.11	5.1	Weisel, 2006
1997	Tetrachloroethane, 1,1,2,2-	400	4	0.25	<0.25	<0.25	<0.25	<0.25	<0.25	2.7	NYSDOH, 2006
2002	Tetrachloroethane, 1,1,2,2-[c]	75	0	0.02		<0.02	<0.02	<0.02		<0.02	Zhu et al., 2005
2004	Tetrachloroethane, 1,1,2,2-[c]	100	0	3.43	<3.43	<3.43	<3.43	<3.43		<3.43	Rago et al., 2004, 2005
2004	Tetrachloroethane, 1,1,2,2-[c]	100	0	3.4 / 1.4	<1.4	<1.4	<3.4	<3.4	<3.4	<3.4	Weisel, 2006
1981	Tetrachloroethene (Tetrachloroethylene) (PCE)[a]	348	92	4.1		6.8	13	31	44	280	US EPA, 1987b

(continued)

Table C-1. Summary of Information Reported in Reviewed Studies (continued)

Start Date	Compound	N	%Detect	RL	25%	50%	75%	90%	95%	Max	Study
1982	Tetrachloroethene (Tetrachloroethylene) (PCE)[a]	157	NR	1.64		5.5	11	19	33.5	98	US EPA, 1987b
1983	Tetrachloroethene (Tetrachloroethylene) (PCE)[a]	47	NR	0.87		6.6	20	36	72	72	US EPA, 1987b
1984	Tetrachloroethene (Tetrachloroethylene) (PCE)[a]	68	NR	0.2	0.72	1.8	3.9	8.5	12	21	US EPA, 1987a
1984	Tetrachloroethene (Tetrachloroethylene) (PCE)[a]	111	NR		6	8.3	14	22	56	130	US EPA, 1987a
1984	Tetrachloroethene (Tetrachloroethylene) (PCE)[a]	50	NR	0.22	1.2	1.9	3.3	4.2	9.75	56	US EPA, 1987a
1990	Tetrachloroethene (Tetrachloroethylene) (PCE)[b]	124	52	0.26	<0.26	<0.26	0.73	2.3		30	Sheldon et al., 1992
1991	Tetrachloroethene (Tetrachloroethylene) (PCE)[b]	24	NR	NR		0.7				5	Heavner et al., 1995
1992	Tetrachloroethene (Tetrachloroethylene) (PCE)[b]	61	NR	NR		1.9				66	Heavner et al., 1996
1993	Tetrachloroethene (Tetrachloroethylene) (PCE)[b]	9	100	NR		0.21					Mukerjee et al., 1997
1994	Tetrachloroethene (Tetrachloroethylene) (PCE)[b]	48	100	NR		2.2				13.1	Van Winkle and Scheff, 1995
1995	Tetrachloroethene (Tetrachloroethylene) (PCE)[b]	370	58	1.6	<1.6	1.9	4.1 4.7	7.0	9.1	660	Clayton et al., 1999
1997	Tetrachloroethene (Tetrachloroethylene) (PCE)[b]	400	53	0.25	<0.25	0.3	1.1	2.9	4.1	51	NYSDOH, 2006
1998	Tetrachloroethene (Tetrachloroethylene) (PCE)[b]	427	63	0.68	<0.68	0.86	1.7	4.3	7.5	42	Foster et al., 2002; Kurtz, Pers. Comm. 2005
1998	Tetrachloroethene (Tetrachloroethylene) (PCE)[b]	282	70	0.68	<0.68	1.0	1.90	4.50	6.50	440	Kurtz & Folkes 2002
1999	Tetrachloroethene (Tetrachloroethylene) (PCE)[b]	292	98	NR		0.6		3.8			Sexton et al., 2004
2002	Tetrachloroethene (Tetrachloroethylene) (PCE)[b]	75	83	0.03		0.5	1.4	3.3		9.2	Zhu et al., 2005
2004	Tetrachloroethene (Tetrachloroethylene) (PCE)[b]	100	5	3.39	<3.39	<3.39	<3.39	<3.39		28	Rago et al., 2004, 2005

(continued)

Table C-1. Summary of Information Reported in Reviewed Studies (continued)

Start Date	Compound	N	%Detect	RL	25%	50%	75%	90%	95%	Max	Study
2004	Tetrachloroethene (Tetrachloroethylene) (PCE)[b]	100	23	3.4 / 1.4	<1.4	<3.4	<3.4	4.4	9.5	540	Weisel, 2006
1997	Tetrahydrofuran	400	59	0.25	<0.25	<0.25	0.4	3.3	9	180	NYSDOH, 2006
2004	Tetrahydrofuran	100	15	1.47	<1.47	<1.47	<1.47	3.2		26	Rago et al., 2004, 2005
1991	Toluene[b]	24	NR	NR		14				47	Heavner et al., 1995
1992	Toluene[b]	61	NR	NR		17				102	Heavner et al., 1996
1993	Toluene[b]	9	100	NR		4.80					Mukerjee et al., 1997
1994	Toluene[b]	48	100	NR		12				44.7	Van Winkle and Scheff, 1995
1995	Toluene[b]	396	100		17	24	41	77	144	1885	Clayton et al., 1999
1995	Toluene[b]	185	86	1.5		10	22	49		368	Gordon et al., 1999
1997	Toluene[b]	400	94	0.25	3.5	9.6	25	58	110	510	NYSDOH, 2006
1998	Toluene[b]	375	100	1.1	15	23	41	61	79	1300	Kurtz Personal Comm., 2005
1999	Toluene[b]	292	98	NR		12		54			Sexton et al., 2004
2002	Toluene[b]	75	95	0.03		5.5	12	25		113	Zhu et al., 2005
2004	Toluene[b]	100	90	1.9	4.0	7.6	18	42.5		944	Rago et al., 2004, 2005
2004	Toluene[b]	100	100	1.9 / 0.75	6.8	13	30	61	90	160	Weisel, 2006
1997	Trichloro-1,2,2-trifluoroethane, 1,1,2- (Freon 113[b])	400	56	0.25	<0.25	0.5	1.1	1.8	3.4	7	NYSDOH, 2006
2004	Trichloro-1,2,2-trifluoroethane, 1,1,2- (Freon 113)[b]	100	1	2.72	<3.83	<3.83	<3.83	<3.83		4.4	Rago et al., 2004, 2005
2004	Trichloro-1,2,2-trifluoroethane, 1,1,2- (Freon 113)[b]	100	2	3.8 / 1.5	<1.5	<1.9	<3.8	<3.8	<3.8	2.1	Weisel, 2006
1997	Trichlorobenzene, 1,2,4-	400	20	0.25	<0.25	<0.25	<0.25	3.4	6.3	37	NYSDOH, 2006
1998	Trichlorobenzene, 1,2,4-[c]	375	0	5.9	<5.9	<5.9	<5.9	<5.9	<5.9	<5.9	Kurtz Personal Comm., 2005
2004	Trichlorobenzene, 1,2,4-[c]	100	0	3.71	<3.71	<3.71	<3.71	<3.71		<3.71	Rago et al., 2004, 2005
2004	Trichlorobenzene, 1,2,4-[c]	100	0	3.7 / 3.7	<3.7	<3.7	<3.7	<3.7	<3.7	<3.7	Weisel, 2006
1981	Trichloroethane, 1,1,1-[a]	348	80	2.3		6.6	13	30	42	520	US EPA, 1987b
1982	Trichloroethane, 1,1,1-[a]	157	NR	2.32		12	24	58	68	170	US EPA, 1987b
1983	Trichloroethane, 1,1,1-[a]	47	NR	0.61		17.5	38	86	120	200	US EPA, 1987b

(continued)

Table C-1. Summary of Information Reported in Reviewed Studies (continued)

Start Date	Compound	N	%Detect	RL	25%	50%	75%	90%	95%	Max	Study
1984	Trichloroethane, 1,1,1-[a]	68	NR		2.3	4.3	8.8	12	16	40	US EPA, 1987a
1984	Trichloroethane, 1,1,1-[a]	111	NR	0.29	19	26	50	84	130	240	US EPA, 1987a
1984	Trichloroethane, 1,1,1-[a]	50	NR		6.1	7.2	11	17	24	360	US EPA, 1987a
1990	Trichloroethane, 1,1,1-[b]	115	99	0.12	1.9	3	7	12.0		94	Sheldon et al., 1992
1993	Trichloroethane, 1,1,1-[b]	9	100	NR		1.75					Mukerjee et al., 1997
1994	Trichloroethane, 1,1,1-[b]	48	100	NR		5.9				293	Van Winkle and Scheff, 1995
1995	Trichloroethane, 1,1,1-[b]	396	76	1.3	1.3	3.1	5.8	11	28	817	Clayton et al., 1999
1997	Trichloroethane, 1,1,1-[b]	400	59	0.25	<0.25	0.3	1.1	3.1	6.9	110	NYSDOH, 2006
1998	Trichloroethane, 1,1,1-[b]	427	24	0.60	<0.6	0.38	<0.6	1.9	3.4	14	Foster et al., 2002; Kurtz, Pers. Comm. 2005
1998	Trichloroethane, 1,1,1-[b]	282	61	0.60	<0.6	0.86	2.6	5.1	7.8	210	Kurtz & Folkes 2002
2004	Trichloroethane, 1,1,1-[b]	100	4	2.72	<2.72	<2.72	<2.72	<2.72		21	Rago et al., 2004, 2005
2004	Trichloroethane, 1,1,1-[b]	100	21	2.7 / 1.1	<1.1	<2.7	<2.7	2.81	5.11	9.3	Weisel, 2006
1997	Trichloroethane, 1,1,2-	400	4	0.25	<0.25	<0.25	<0.25	<0.25	<0.25	6.2	NYSDOH, 2006
1998	Trichloroethane, 1,1,2-[c]	427	0	0.10	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	Foster et al., 2002; Kurtz, Pers. Comm. 2005
1998	Trichloroethane, 1,1,2-[c]	375	0	1.1	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1	Kurtz Personal Comm., 2005
2004	Trichloroethane, 1,1,2-[c]	100	0	2.72	<2.72	<2.72	<2.72	<2.72		<2.72	Rago et al., 2004, 2005
2004	Trichloroethane, 1,1,2-[c]	100	0	2.7 / 1.1	<1.1	<2.7	<2.7	<2.7	<2.7	<2.7	Weisel, 2006
1981	Trichloroethene (Trichloroethylene) (TCE)[a]	348	52	1.5		0.88	1.8	3.94	5.9	30	US EPA, 1987b
1982	Trichloroethene (Trichloroethylene) (TCE)[a]	157	NR	2.2		2.7	7.2	12	15	59	US EPA, 1987b
1983	Trichloroethene (Trichloroethylene) (TCE)[a]	47	NR	0.68		1.5	3.2	5.4	7.1	41	US EPA, 1987b
1984	Trichloroethene (Trichloroethylene) (TCE)[a]	68	NR	0.2	0.13	0.25	0.98	2.1	2.8	6.4	US EPA, 1987a
1984	Trichloroethene (Trichloroethylene) (TCE)[a]	111	NR	0.2	0.43	1.1	3.45	6.9	14	66	US EPA, 1987a

(continued)

Table C-1. Summary of Information Reported in Reviewed Studies (continued)

Start Date	Compound	N	%Detect	RL	25%	50%	75%	90%	95%	Max	Study
1984	Trichloroethene (Trichloroethylene) (TCE)[a]	50	NR	0.2	0.08	0.34	0.88	2.5	6.4	170	US EPA, 1987a
1990	Trichloroethene (Trichloroethylene) (TCE)[b]	125	38	0.31	<0.31	<0.31	0.6	1.9		9	Sheldon et al., 1992
1991	Trichloroethene (Trichloroethylene) (TCE)[b]	24	NR	NR		1.1				9	Heavner et al., 1995
1992	Trichloroethene (Trichloroethylene) (TCE)[b]	61	NR	NR		0.2				7.4	Heavner et al., 1996
1993	Trichloroethene (Trichloroethylene) (TCE)[b]	6	67	NR		0.46					Mukerjee et al., 1997
1994	Trichloroethene (Trichloroethylene) (TCE)[b]	48	90	NR		0.4		1.1			Van Winkle and Scheff, 1995
1995	Trichloroethene (Trichloroethylene) (TCE)[b]	378	30	1.1	<1.1	<1.1	1.2	2.1	3.3	720	Clayton et al., 1999
1995	Trichloroethene (Trichloroethylene) (TCE)[b]	185	1	1.8		<1.8	<1.8	<1.8		24	Gordon et al., 1999
1997	Trichloroethene (Trichloroethylene) (TCE)[b]	400	19	0.25	<0.25	<0.25	<0.25	0.5	0.8	25	NYSDOH, 2006
1998	Trichloroethene (Trichloroethylene) (TCE)[b]	427	100	0.02	0.06	0.09	0.15	0.28	0.56	3.1	Foster et al., 2002; Kurtz, Pers. Comm. 2005
1998	Trichloroethene (Trichloroethylene) (TCE)[b]	282	14	0.26	<0.26	<0.26	<0.26	0.30	0.70	27.0	Kurtz & Folkes 2002
1999	Trichloroethene (Trichloroethylene) (TCE)[b]	292	84	NR		0.2		0.8			Sexton et al., 2004
2002	Trichloroethene (Trichloroethylene) (TCE)[b]	75	33	0.02		<0.02	0.08	0.19		0.87	Zhu et al., 2005
2004	Trichloroethene (Trichloroethylene) (TCE)[b]	100	2	2.68	<2.68	<2.68	<2.68	<2.68		110	Rago et al., 2004, 2005
2004	Trichloroethene (Trichloroethylene) (TCE)[b]	100	8	2.7 / 1.1	<1.1	<2.7	<2.7	<2.7	2.74	13	Weisel, 2006
1997	Trichlorofluoromethane (Freon 11)	400	90	0.25	1.1	2.9	5.4	17.0	30	190	NYSDOH, 2006
1998	Trichlorofluoromethane (Freon 11)	375	59	2.2	<2.2	2.6	4.3	12	19	130	Kurtz Personal Comm., 2005
2004	Trichlorofluoromethane (Freon 11)	100	17	2.81	<2.81	<2.81	<2.81	3.6		162	Rago et al., 2004, 2005

(continued)

Table C-1. Summary of Information Reported in Reviewed Studies (continued)

Start Date	Compound	N	%Detect	RL	25%	50%	75%	90%	95%	Max	Study
2004	Trichlorofluoromethane (Freon 11)	100	76	2.8 / 1.1	2.1	2.8	4.3	6.3	13.2	62	Weisel, 2006
1991	Trimethylbenzene, 1,2,4-	24	NR	NR		1.3				11	Heavner et al., 1995
1992	Trimethylbenzene, 1,2,4-	61	NR	NR		0.8				39	Heavner et al., 1996
1993	Trimethylbenzene, 1,2,4-	8	100	NR		2.90					Mukerjee et al., 1997
1997	Trimethylbenzene, 1,2,4-	400	88	0.25	0.7	1.9	4.3	9.5	18	260	NYSDOH, 2006
1998	Trimethylbenzene, 1,2,4-	375	90	2.0	2.8	4.5	8.1	13	19	65	Kurtz Personal Comm., 2005
2002	Trimethylbenzene, 1,2,4-	75	85	0.03		2.2	3.4	6.7		57	Zhu et al., 2005
2004	Trimethylbenzene, 1,2,4-	100	35	2.46	<2.46	<2.46	3.9	7.8		32	Rago et al., 2004, 2005
2004	Trimethylbenzene, 1,2,4-	100	57	2.5 / 0.98	1.68	2.5	4.2	9.8	13.1	35	Weisel, 2006
1991	Trimethylbenzene, 1,3,5-	24	NR	NR		1.1				15	Heavner et al., 1995
1992	Trimethylbenzene, 1,3,5-	61	NR	NR		0.8				67	Heavner et al., 1996
1993	Trimethylbenzene, 1,3,5-	6	67	NR		1.20					Mukerjee et al., 1997
1997	Trimethylbenzene, 1,3,5-		75	0.25	0.3	0.6	1.7	3.6	6.5	97	NYSDOH, 2006
1998	Trimethylbenzene, 1,3,5-	375	34	2	<2.0	<2.0	2.4	4.2	5.9	22	Kurtz Personal Comm., 2005
2004	Trimethylbenzene, 1,3,5-[400]	100	11	2.46	<2.46	<2.46	<2.46	2.5		8.3	Rago et al., 2004, 2005
2004	Trimethylbenzene, 1,3,5-	100	23	2.5 / 0.98	<0.98	<2.50	<2.50	2.6	4.4	11	Weisel, 2006
2004	Trimethylpentane, 2,2,4-	100	7	2.33	<2.33	<2.33	<2.33	<2.33		21	Rago et al., 2004, 2005
2004	Trimethylpentane, 2,2,4-	100	27	2.3 / 0.93	<0.93	<2.3	<2.3	7	11.1	140	Weisel, 2006
1997	Vinyl chloride[b]	400	3	0.25	<0.25	<0.25	<0.25	<0.25	<0.25	1.0	NYSDOH, 2006
1998	Vinyl chloride[b]	427	12	0.01	<.01	<.01	<.01	0.01	0.02	0.34	Foster et al., 2002; Kurtz, Pers. Comm. 2005
1998	Vinyl chloride[b]	282	25	0.02	<0.02	<0.02	0.02	0.04	0.09	0.50	Kurtz & Folkes 2002
1998	Vinyl chloride[b]	375	0	1.1	<1.1	<1.1	<1.1	<1.1	<1.1	1.6	Kurtz Personal Comm., 2005
2004	Vinyl chloride[c]	100	0	1.28	<1.28	<1.28	<1.28	<1.28		<1.28	Rago et al., 2004, 2005
2004	Vinyl chloride[c]	100	0	1.3 / 0.51	<0.51	<0.51	<1.3	<1.3	<1.3	<1.3	Weisel, 2006
1981	Xylene, m/p-[a]	348	99	0.52		6.35	11	19	21	350	US EPA, 1987b
1982	Xylene, m/p-[a]	157	NR	0.62		13	23.5	33	49	150	US EPA, 1987b
1983	Xylene, m/p-[a]	47	NR			19	57	63	67	67	US EPA, 1987b

(continued)

Table C-1. Summary of Information Reported in Reviewed Studies (continued)

Start Date	Compound	N	%Detect	RL	25%	50%	75%	90%	95%	Max	Study
1984	Xylene, m/p-[a]	68	NR		4.1	6.1	11	18	26	68	US EPA, 1987a
1984	Xylene, m/p-[a]	111	NR		16	22	31	40	42	58	US EPA, 1987a
1984	Xylene, m/p-[a]	50	NR		5.8	8.7	18	75	92	94	US EPA, 1987a
1990	Xylene, m/p-[b]	125	99	0.4	3	4	8	12.0		120	Sheldon et al., 1992
1993	Xylene, m/p-[b]	9	100	NR		3.5					Mukerjee et al., 1997
1994	Xylene, m/p-[b]	48	100	NR		14				418	Van Winkle and Scheff, 1995
1995	Xylene, m/p-[b]	396	100	0.9	4.3	6.4	11	21	38	2773	Clayton et al., 1999
1997	Xylene, m/p-[b]	400	87	0.25	0.5	1.5	4.6	12	21	550	NYSDOH, 2006
1998	Xylene, m/p-[b]	375	99	2.2	7.1	11	21	37	63.5	570	Kurtz Personal Comm., 2005
1999	Xylene, m/p-[b]	292	100	NR		4.8		37			Sexton et al., 2004
2002	Xylene, m/p-[b]	75	85	0.04		3.6	6.9	16.4		139	Zhu et al., 2005
2004	Xylene, m/p-[b]	100	52	2.17	<2.17	3.0	7.4	21		82	Rago et al., 2004, 2005
2004	Xylene, m/p-[b]	100	83	2.2 / 0.87	2.5	3.8	7.8	30	41	91	Weisel, 2006
1981	Xylene, o-[a]	348	87	1.1		2.2	3.7	6.3	9.2	220	US EPA, 1987b
1982	Xylene, o-[a]	157	NR	0.68		5.4	9.1	12	20	100	US EPA, 1987b
1983	Xylene, o-[a]	47	NR			6	16	22	23.5	27	US EPA, 1987b
1984	Xylene, o-[a]	68	NR		1.5	2.2	3.9	7.1	11	35	US EPA, 1987a
1984	Xylene, o-[a]	111	NR		7	9.7	14	19	20.5	34	US EPA, 1987a
1984	Xylene, o-[a]	50	NR	0.2	1.6	2.55	5.3	25	30	34	US EPA, 1987a
1990	Xylene, o-[b]	125	99	0.11	1.1	1.8	3.3	5.5		49.0	Sheldon et al., 1992
1991	Xylene, o-[b]	24	NR	NR		2.4				34	Heavner et al., 1995
1992	Xylene, o-[b]	61	NR	NR		2.3				35	Heavner et al., 1996
1993	Xylene, o-[b]	9	100	NR		1.30					Mukerjee et al., 1997
1994	Xylene, o-[b]	48	100	NR		3.6				186	Van Winkle and Scheff, 1995
1995	Xylene, o-[b]	395	98	0.8	2.5	3.6	6.2	11	17	937	Clayton et al., 1999
1997	Xylene, o-[b]	400	82	0.25	0.4	1.1	3.1	7.6	13	310	NYSDOH, 2006
1998	Xylene, o-[b]	375	98	0.9	2.3	3.5	6.1	12	20	130	Kurtz Personal Comm., 2005

(continued)

Table C-1. Summary of Information Reported in Reviewed Studies (continued)

Start Date	Compound	N	%Detect	RL	25%	50%	75%	90%	95%	Max	Study
1999	Xylene, o-[b]	292	100	NR		1.6		11			Sexton et al., 2004
2002	Xylene, o-[b]	75	87	0.02		1.2	3.4	6.5		205	Zhu et al., 2005
2004	Xylene, o-[b]	100	31	2	<2	<2	2.4	6.9		31.5	Rago et al., 2004, 2005
2004	Xylene, o-[b]	100	55	2.2 / 0.87	1.4	2.2	2.7	11	13	38	Weisel, 2006

Notes: All concentrations are reported in µg/m^3. Figure 1 includes those results with a subscript a or b; Figure 2 includes only those results with a subscript b.

[a] Indicates pre-1990 studies not included in the compilation of statistics

[b] Indicates the studies included in the compilation of statistics

[c] Indicates 1990 and later studies not included in compilation of statistics because all values, including the maximum value, are below detection limit