



AMCO Chemical Superfund Site

U.S. Environmental Protection Agency • Region 9 • San Francisco, CA • October 2010

AMCO 2010 Health Risk Assessment Summary

A Human Health Risk Assessment is a method of determining the probability of harm occurring to people from exposure to contaminants at a site. Both the toxic properties of hazardous substances and the ways that people may be exposed to these substances are evaluated. A risk assessment helps determine whether significant risks to people's health may exist at or near a contaminated site and also helps determine risk-based cleanup levels for contaminants at the site. The risk assessment is one factor project managers use to make decisions on how a contaminated site should be cleaned up. Other factors include state and federal regulations, costs, treatment techniques and their feasibility, and community acceptance.

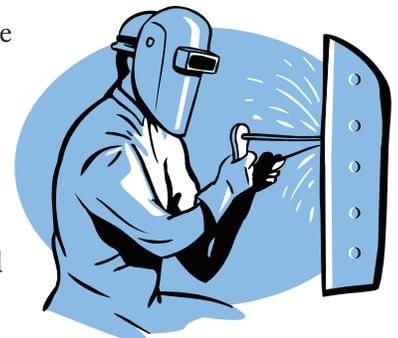
To characterize potential non-cancer effects, estimated intakes of substances and their toxicity values are examined. Potential carcinogenic effects are evaluated by calculating probabilities that an individual will develop cancer over a lifetime of exposure based on projected intakes and chemical-specific dose-response information. Non-carcinogenic health effects are expressed in terms of hazard index (HI) while carcinogenic effects are expressed in terms of an excess lifetime cancer risk (ELCR). Human health risks were compared against EPA's target risk management range of 10^{-6} to 10^{-4} for cancer risks (in other words, a cancer risk of 1 to 100 people in 1 million) and the HI benchmark of 1 for non-cancer hazards (in other words, any value over 1 is avoided). Because the neighborhood surrounding the site is a vulnerable community, EPA has elected to use the most conservative ELCR of 10^{-6} , or 1 in a million people, as the point at which action will be required at this site.

The risks calculated during the risk assessment are based on conservative assumptions so that they are not likely to be exceeded by any member of the exposed population even under reasonable maximum exposure conditions. A risk assessment cannot identify who within an exposed community may or may not become ill due to exposure to toxic agents; nor can a risk assessment be used to associate a particular illness with a particular toxic agent. A risk assessment is best used as a predictive tool to identify those circumstances under which exposure to a toxic agent may potentially lead to unacceptable health outcomes. This information can then be used to select options that will reduce or remove the community's exposure to the toxic agent.

Potential Health Risks from Exposure to Soil

For the risk assessment at the AMCO site, four areas associated with historical industrial activities were evaluated for two types of workers, industrial and construction, and potential future residential exposures. The areas include the former AMCO facility, parking lot, large vacant lot, and small vacant lot.

Industrial workers may be exposed to soil through incidental ingestion, dermal contact with soil or inhalation of dust. Estimated cancer risks are at the upper end or exceed the EPA's risk



management range for exposure to both shallow soil and deep soil at each of the four areas. Noncancer adverse health effects (HI) exceed the non-cancer threshold of 1 only at the former AMCO facility. Lead concentrations at all four soil exposure areas exceed the California Human Health Screening Level (CHHSL) for an Occupational Scenario of 320 mg/kg..

Construction workers may be exposed to soil through the same exposure pathways as the industrial worker but at higher levels (i.e., more dust in the air) for a shorter period of time. Estimated cancer risks were within EPA's risk management range for exposure to shallow soil and deep soil at each of the four exposure areas. The HIs exceed the non-cancer threshold of 1 at the former AMCO facility, parking lot, and the large vacant lot. Lead concentrations are the same as described for the industrial worker.



The four exposure areas were evaluated for a future resident in the event that any of the areas would be changed to residential. Residents are evaluated for the same exposure pathways as workers, but for a longer period of time. Children are also included in the residential evaluation because they have potential for greater risk of health effects. Estimated cancer risks exceeded EPA's risk management range for exposure to shallow soil and deep soil at all exposure areas. HIs also exceed the non-cancer threshold of 1 at all four of the exposure areas. Lead concentrations all exceed the AMCO residential CHHSL

of 80 mg/kg. See below for residents' risk from soil at their actual homes.



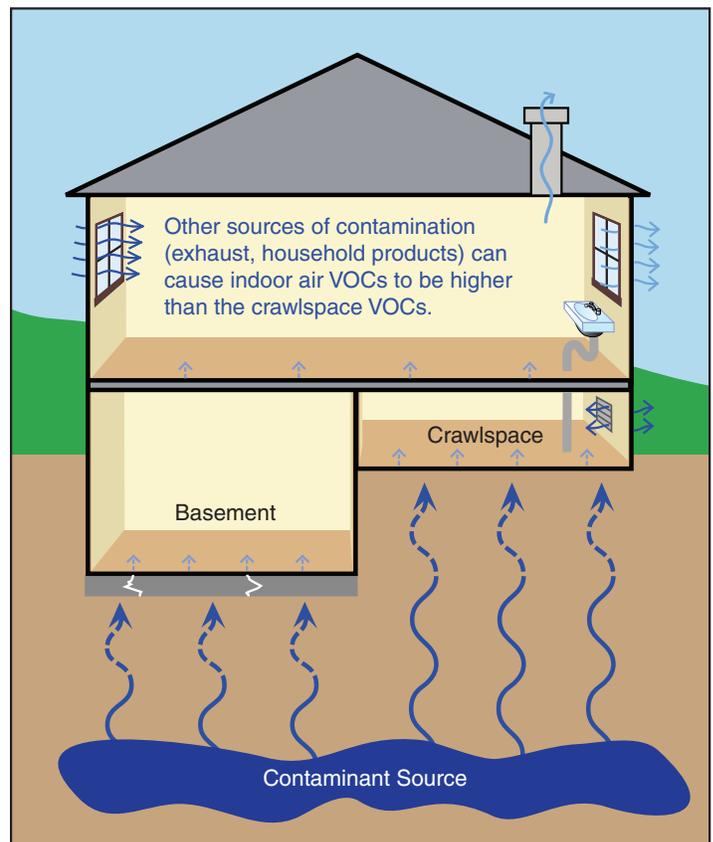
Potential Health Risks from Exposure to Groundwater

The cancer risks and non-cancer HIs are above EPA's risk management range when residential use of groundwater is considered. However, it is unlikely that groundwater will be used as a source of drinking water because the municipal water supply from EBMUD is from Sierra Nevada.

Potential Health Risks from Vapor Intrusion

Below are some of the conclusions of the vapor intrusion evaluation:

- The data from the RI sampling of crawl space and ambient air indicates that vapor intrusion was occurring in crawl spaces at the homes. As a precautionary measure, mitigation systems have been installed in selected homes nearest the site.



Vapor Intrusion Pathway

- None of the VOCs detected exceeds its acute reference concentration, indicating that there is no immediate health threat to residents. Please note that “immediate health threat” means that levels of site contaminants do not exceed short-term risk screening levels. A cumulative analysis of all of the factors that can affect a person’s health is not used by the superfund program to determine health risk.
- The source of the VOCs found inside homes is difficult to determine.
- If the level of VOCs inside homes is greater than level of VOCs found in soil gas and crawl space, it is an indication that there are other sources of than VOCs than from vapor intrusion (such as exhaust from freeway traffic, etc.).
- Risks and hazards estimated from the crawl space and outdoor air data indicates that the majority of residences sampled are similar to the risks and hazards estimated from the background samples (collected on Lewis Street located 3 blocks upwind of the site) and the outdoor air samples collected at Prescott Park. This indicates that air quality is poor in the whole area due to other sources of contamination as well.

Potential Health Risks from Residential Soil

A soil removal action was performed at residential properties adjacent to and near the former AMCO facility as a result of the high levels of lead and other compounds found during the Remedial Investigation soil sampling. As a result of the removal action, the exposure to soil and the risk and hazard has been substantially reduced.

Potential Health Risks from Homegrown Produce

The detection of TCE, PCE, and vinyl chloride in shallow groundwater and the potential migration of contaminated shallow groundwater into residential areas containing fruit trees prompted concerns that TCE, PCE, vinyl chloride, and other VOCs could be taken up and

transferred into edible fruit or vegetables. None of these chemicals were detected in the fruits and vegetables sampled from adjacent gardens.

Concentrations of metals and VOCs in sampled fruits and vegetables are below levels of concern for ingestion. Of the 47 VOCs analyzed for, only methyl acetate and styrene were detected. Some metals were found in or on the produce including arsenic, chromium, and lead, however, they were found at levels that would not be harmful.

Because produce samples were analyzed for VOCs as well as metals, none of the produce samples were rinsed or washed before analysis. As a result, the metals concentrations could reflect dust or soil deposited on the plant surfaces in addition to metals that were taken up through the root system. Community members should always wash their home grown fruits and vegetables before consuming them.



Now What?

The risk assessment shows that high risk levels from soil exposure remain for anyone who might live or work at the actual AMCO facility if the pavement is removed. It also shows high risk from possible ingestion of groundwater. Finally, there is a health risk for residents in the entire South Prescott neighborhood due to poor outdoor air quality as a result of many different sources. Improving the outdoor air quality, however, has a much larger scope than that of the Superfund cleanup. The vapor intrusion evaluation shows that the chemicals detected in the crawl space are being detected in the indoor air samples. As a precautionary measure, mitigation systems, including vapor barriers and additional ventilation, have been installed in selected homes nearest the site. The goal of the cleanup is to remove and/or clean the contaminated soil and groundwater so that all of the risk levels are brought down to the protective range. The homes will continue to be monitored until this goal has been attained.

AMCO Chemical Superfund Site

AMCO 2010 Health Risk Assessment Summary

Printed on 30% Postconsumer  Recycled/Recyclable Paper

United States Environmental Protection Agency, Region 9
75 Hawthorne Street (SFD-6-3)
San Francisco, CA 94105
Attn: Leana Rosetti (AMCO 10/10)

FIRST-CLASS MAIL
POSTAGE & FEES
PAID
U.S. EPA
Permit No. G-35

Official Business
Penalty for Private Use, \$300

Address Service Requested

TOXIC MATTERS



Toxic substances are synthetic chemicals and metals that can harm your health. Everyone can be exposed to many toxic substances every day and these exposures can affect all aspects of reproductive health. This brochure provides information on steps you can take to prevent or reduce your exposure to toxic substances and to protect your health and your family's health.

Exposure to toxic substances can harm the reproductive systems of women and men and can make it more difficult to get pregnant. Because developing fetuses and children are especially vulnerable, exposure to even small amounts of toxic substances in the womb or during infancy, childhood or puberty can lead to disease early or later in life and across generations. Some toxic substances build up in our bodies and can affect our health and future pregnancies long after exposure has occurred. Therefore, the recommendations in this brochure are designed for women, men and children. They apply to everyone, whether or not you have children, are pregnant or want to have children in the future.

**A Publication of the University of California, San Francisco
Program on Reproductive Health and the Environment
From Advancing Science to Ensuring Prevention (FASTEP)**

FASTEP is an alliance of academic, government and non-governmental partners spanning the fields of reproductive, environmental, occupational and pediatric health and toxicology. Our goal is to secure each and everyone's right to optimal reproductive health by fostering environments that prevent exposure to toxic substances and support healthy pregnancies, children, adults and future generations.

This brochure offers practical recommendations on how to avoid exposure to common substances encountered in everyday life that can be harmful to reproductive health. It is not a complete list. For more information, please check the sources provided in the **To Learn More** section of this brochure.

5 THINGS TO DO

PREVENT EXPOSURE AT HOME



PREVENT EXPOSURE AT WORK



PREVENT EXPOSURE IN YOUR COMMUNITY



BECOME A SMART CONSUMER



MAKE THE GOVERNMENT WORK FOR YOU



To view this brochure online, go to: www.prhe.ucsf.edu/prhe/toxicmatters.html

PREVENT EXPOSURE AT HOME

Do not smoke.

- Talk to your doctor if you need help quitting.
- Do not let people smoke around you and stay away from public spaces where smoking is allowed.

Use non-toxic personal care products. Personal care products may contain many ingredients, such as phthalates, that can harm reproductive health.

- Find safer products at: www.prhe.ucsf.edu/prhe/tmlinks.html#personalcare

Do not spray bugs. Do not use pesticides, which are toxic chemicals made to kill unwanted insects, rodents, weeds, bacteria and mold.

- Keep insects and rodents out of your home: clean up food crumbs and spills; store food in tightly-closed containers; seal cracks around doors, window sills and baseboards; repair drips and holes; and get rid of standing water.
- Use baits and traps instead of sprays, dusts and bombs.
- Do not use chemical tick-and-flea collars, flea baths, applications or flea dips.
- Hire only *licensed* pesticide applicators.
- Find pesticide-free alternatives at: www.prhe.ucsf.edu/prhe/tmlinks.html#pestcontrol

Get out your wet mop. Toxic substances like lead, pesticides and flame retardants are present in house dust. Sweeping or dusting surfaces with dry cloths can spread the dust into the air instead of removing it from your home.

- Use a wet mop and wet cloth to clean floors and surfaces.
- Take off your shoes. Shoes can bring pesticides and toxic chemicals inside your home.
- Wipe shoes on a sturdy doormat if you choose to keep shoes on.

Clean your home with non-toxic cleaning products.

- It is easy and inexpensive to make effective, non-toxic cleaners using common items like vinegar and baking soda. Find out how to shop for non-toxic cleaning products and get recipes to make your own at: www.prhe.ucsf.edu/prhe/tmlinks.html#cleaningproducts

Avoid dry-cleaning your clothes. Most dry-cleaning systems use a chemical called perchloroethylene (PERC), which gets released from dry-cleaned clothes and pollutes the air in your home.

- Use water instead. Most clothes labeled as “dry-clean only” can be washed with water. Hand wash these clothes or ask your dry cleaner to wet clean them for you.

Pick your plastics carefully. Some plastics release toxic chemicals such as polyvinyl chloride (PVC), phthalates and bisphenol A (BPA).

- Do not buy products made with soft PVC. For example, some shower curtains and toys are made with soft PVC.
- Do not use plastic containers for hot food or drinks. Choose glass or stainless steel.
- Use glass instead of plastics in the microwave.
- Learn more about plastics at: www.prhe.ucsf.edu/prhe/tmlinks.html#plastics

Choose safer home improvements. Many paints, glues and flooring materials can release toxic chemicals long after the project is complete.

- Ask for *VOC-free* and *water-based* materials.
- If you are pregnant, do not work on remodeling projects and stay away from recently remodeled rooms.
- Learn more about safer materials at: www.prhe.ucsf.edu/prhe/tmlinks.html#remodeling

Keep mercury out of your diet, home and garbage.

- Choose fish that are less contaminated with mercury. Find information on healthy and environmentally sustainable fish at: www.prhe.ucsf.edu/prhe/tmlinks.html#mercury
- Check local fish advisories. If you or others go fishing, never eat your catch before checking fish advisories. Learn about fish advisories at: www.prhe.ucsf.edu/prhe/tmlinks.html#mercury
- Replace your mercury thermometer with a digital one. Do not throw your mercury thermometer or any other item containing mercury (like compact fluorescent light bulbs) in the trash. Your local health department can tell you where to bring these items for safe disposal. To contact your local health department, check the government section of your phone book or call the U.S. Centers for Disease Control and Prevention at: 800-232-4636.

Avoid pesticides and other toxic substances in food and water.

- Eat local, organic food when possible to reduce your exposure to pesticides. Buying organic produce also reduces global contamination of air, water and soil with pesticides. If you can't afford to buy organic produce all the time, choose the least pesticide-contaminated fruits and vegetables and avoid the most contaminated. Learn more about reducing pesticide exposure from food at: www.prhe.ucsf.edu/prhe/tmlinks.html#foodandwater
- Join a local organic Community Supported Agriculture (CSA) system. These systems are efficient and grow food in ways that protect our health and the environment. Find a CSA system in your area at: www.prhe.ucsf.edu/prhe/tmlinks.html#foodandwater
- Limit foods high in animal fat. Toxic substances that are persistent in the environment concentrate in animal fat.
- Avoid canned foods and beverages whenever possible. Eat fresh or frozen fruits and vegetables to avoid exposure to BPA, a toxic substance used in the resin that lines the majority of canned foods and drinks.
- Request a copy of your annual water quality report from your water district. If your drinking water comes from a private well, have it tested every year. In most cases, bottled water is not a solution, but instead creates further pollution.

Avoid lead exposure. Lead may be in household paint, dust and soil. Any home built before 1978 may have lead paint.

- Call the National Lead Information Center for information about how to prevent exposure to lead hazards at: 800-424-LEAD.
- If you have lead paint in your home, make sure it is covered with a fresh coat of paint, wallpaper or tiles.
- Never sand or remove lead paint yourself. Hire a contractor who is certified in lead abatement.

Test your home for radon, a radioactive gas found in many basements and ground floors.

- Purchase an inexpensive testing kit at your local hardware store.
- Learn more about radon by calling 1-800-SOS-RADON or at: www.prhe.ucsf.edu/prhe/tmlinks.html#radon

PREVENT EXPOSURE AT WORK

Many substances used in different jobs, present in office buildings or used in workplace renovation projects are toxic to reproductive health.

By law, you have the right to a safe and healthy work environment.

- Get information and training about hazardous substances in your workplace. Your employer is required by law to provide information and training about hazards in the workplace, including access to Material Safety Data Sheets (MSDS). Follow guidelines to avoid exposure and use protective gear. Ask your employer about substitutes for toxic substances and other hazard controls.
- If you are pregnant or planning a pregnancy and are exposed at work to substances that may cause harm, request modification of your duties. Talk to your doctor or your union for guidance.
- If somebody in your household works with toxic chemicals, he or she should change and shower after work and keep work tools and clothing away from people and living areas in the home. Wash work clothes separately.
- File a complaint with your regional Occupational Safety and Health Administration (OSHA) office if you believe that your employer is violating OSHA standards or that your workplace poses serious hazards. You can find a directory of regional OSHA offices where you can get more information or file a complaint by calling 800-232-4636 or at: www.prhe.ucsf.edu/prhe/tmlinks.html#work
- If you are a farm worker, you can find information about reducing your exposure to agricultural pesticides at: www.prhe.ucsf.edu/prhe/tmlinks.html#work

PREVENT EXPOSURE IN YOUR COMMUNITY

Outside your home, on the road, in parks and in schools, you can do things that reduce pollution in your community and limit your exposure to pollution in outdoor air.

Help create a better environment for your family and everyone around you.

- Drive less. Carpool, take public transportation, ride your bike or walk.
- Never burn trash, particularly furniture, tires and plastics.
- Do not use pesticides. If you have a garden or lawn or share a community or school garden, use organic or integrated pest management techniques to fight off weeds and unwanted insects. Learn more at: www.prhe.ucsf.edu/prhe/tmlinks.html#community
- Never throw toxic substances, including oil, gasoline, pesticides, paints, solvents and medicines, down drains or toilets or in the garbage. Your local health department will give you information on how to safely dispose of these substances. To contact your local health department, check the government section of your phone book or call the U.S. Centers for Disease Control and Prevention at 800-232-4636.

Reduce your exposure to pollution in outdoor air.

- Exercise as far away as possible from sources of air pollution, such as heavy traffic or factories.
- Do not exercise outdoors on bad air quality days. Check air quality forecasts in the newspaper, on TV or radio, or online at: www.prhe.ucsf.edu/prhe/tmlinks.html#airquality

BECOME A SMART CONSUMER

Many of the products you use everyday may be made with toxic substances. When you buy and use these products, you expose yourself and your family to toxic substances and contribute to a cycle of manufacturing, use and disposal that pollutes our environment. The use of toxic substances exposes workers, consumers and the general public. Choose safer, non-toxic alternatives. This will help stop the toxic cycle and send a message to companies that make and sell consumer goods that they need to switch to healthier options.

There are many consumer guides available to help you find non-toxic products. You can find links to many of these guides at: www.prhe.ucsf.edu/prhe/tmlinks.html#consumerguide

MAKE THE GOVERNMENT WORK FOR YOU

Individual actions alone cannot prevent exposure to substances in the environment that harm our reproductive health. This is because some toxic substances remain in the environment, concentrate in the food chain, and find their way into our bodies. Some substances can travel long distances in water and air currents, contaminating the environment and affecting communities far away from the place where those substances were released. Other toxic substances do not remain in the environment for long but are constantly being released, so we are exposed to them on a regular basis. These types of exposures can only be prevented by public policies that stop chemical pollution in the first place.

You can influence public policy.

- Become informed about these issues.
- Get involved with local, state and national organizations working to prevent pollution.
- Let your representatives know what you think. You can find contact information for your state and federal representatives at: www.prhe.ucsf.edu/prhe/tmlinks.html#government

Support policies that prevent pollution.

We need policies that:

- Identify existing toxic substances, phase out their use and replace them with alternatives that are safer for human health and the environment.
- Require that new chemicals be tested for health and safety before they are allowed to be produced or sold.
- Improve worker protection by reducing permissible occupational exposure levels and giving workers access to more complete and accurate information about workplace hazards.
- Expand the nature and extent of the information given to consumers about the ingredients in the products they buy.

To Learn More

This brochure lists just some of the many ways you can prevent exposure to substances that can harm reproductive health. The prevention measures described here are based on recommendations by the leading authorities on environmental and occupational health listed below. Find links to these resources at: www.prhe.ucsf.edu/prhe/tmlinks.html#authorities

American Academy of Pediatrics Committee on Environmental Health. Etzel RA, ed. *Pediatric Environmental Health*, 2nd ed. Elk Grove Village, IL: American Academy of Pediatrics; 2003.

Physicians for Social Responsibility. *Pediatric Environmental Health Toolkit*®, endorsed by the American Academy of Pediatrics.

University of California, San Francisco and the Collaborative on Health and the Environment. *Shaping Our Legacy: Reproductive Health and the Environment*.

U.S. Environmental Protection Agency. For recommendations on how to protect the environment at home and in the garden, at work, at school, while shopping, in your community and on the road.

California Department of Public Health Hazard Evaluation System and Information Service (HESIS). For answers to questions or concerns about workplace hazards contact the HESIS helpline at: 866-282-5516.

Your local health department can also provide more information on preventing exposure to toxic substances. To contact your local health department, check the government section of your phone book or call the U.S. Centers for Disease Control and Prevention at 800-232-4636.

More Resources. Find links to many supplemental resources that provide practical tips for avoiding exposure to toxic substances at: www.prhe.ucsf.edu/prhe/tmlinks.html#tips

About Us

From Advancing Science to Ensuring Prevention is a project of the University of California, San Francisco Program on Reproductive Health and the Environment (PRHE). PRHE's mission is to create a healthier environment for human reproduction and development by advancing scientific inquiry, clinical care and health policies that prevent exposures to harmful chemicals in our environment.

Contact Us

University of California, San Francisco Program on Reproductive Health and the Environment

1330 Broadway, Suite 1100 Oakland, CA 94612 phone: (510) 986-8990 email: prhe@obgyn.ucsf.edu

www.prhe.ucsf.edu/prhe

FASTEP Advisory Council Members

Annemarie Charlesworth, MA

Program Evaluator
National Center of Excellence in Women's Health
Philip R. Lee Institute for Health Policy Studies
University of California, San Francisco

Laura Fenster, PhD

Epidemiologist, Occupational Health Branch
California Department of Public Health

Linda C. Giudice, MD, PhD

Professor and Chair, Department of Obstetrics,
Gynecology and Reproductive Sciences
The Robert B. Jaffe, MD Endowed Professor in the Reproductive
Sciences, University of California, San Francisco

Rivka Gordon, PA-C, MHS

Director of Strategic Initiatives
Association of Reproductive Health Professionals

Michelle Gottlieb, MEM

Health Care Without Harm

Katie Huffling, CNM, RN, MS

Assistant Director for Midwifery Services
Dimensions OB/GYN Associates

Sarah Janssen, MD, PhD, MPH

Staff Scientist, Natural Resources Defense Council
Assistant Clinical Professor, Occupational and
Environmental Medicine, University of California, San Francisco

Beth Jordan, MD

Medical Director
Association of Reproductive Health Professionals

Siobhan McNally, MD, MPH

Pediatrician, Caring Community Health Center
Physician Advisor, Healthy Beginnings Prenatal
Environmental Health Program, Berkshire Medical Center

Mark Miller, MD, MPH

Director, Pediatric Environmental Health Specialty Unit
Assistant Clinical Professor of Pediatrics and
Occupational & Environmental Medicine
University of California, San Francisco

Michele Ondeck, MEd

Program Director, Magee-Women's Hospital
University of Pittsburgh Medical Center

Joanne Perron, MD

Postdoctoral Fellow
Program on Reproductive Health and the Environment
University of California, San Francisco

Janice Prudhomme, DO, MPH

Public Health Medical Officer, Occupational Health Branch
California Department of Public Health

Julia Quint, PhD

Chief (Retired)
Hazard Evaluation System and Information Service
Occupational Health Branch
California Department of Public Health

Heather Sarantis, MS

Women's Health Program Manager
Commonweal

Lucia Sayre, MA

Co-Director
San Francisco Bay Area Physicians for Social Responsibility

Patrice Sutton, MPH

Research Scientist
Program on Reproductive Health and the Environment
University of California, San Francisco

Kristen Welker-Hood, PhD, RN

Director of Environment and Health Programs
Physicians for Social Responsibility

Tracey J. Woodruff, PhD, MPH

Associate Professor and Director
Program on Reproductive Health and the Environment
University of California, San Francisco

Marya G. Zlatnik, MD, MMS

Associate Professor
Department of Obstetrics, Gynecology and Reproductive
Sciences, University of California, San Francisco



University of California
San Francisco

advancing health worldwide™

Magee-Womens Hospital of UPMC



Researched and written by Julieta Pisani McCarthy, MA
Designed By Danielle Velazquez, Woman Owned, www.DanielleVelazquez.com

Copyright© 2009 The Regents of the University of California

November 2009

A Compilation of Statistics for VOCs from Post-1990 Indoor Air Concentration Studies in North American Residences Unaffected by Subsurface Vapor Intrusion

by Helen E. Dawson and Todd McAlary

Abstract

This paper provides a summary of a number of indoor air quality studies reporting concentrations of volatile organic compounds (VOCs) in indoor air samples collected from residential properties in North America and provides average values for certain statistics (percentiles, detection frequency, maximum). This compilation includes several VOCs that are commonly assessed in studies of subsurface vapor intrusion to indoor air, but may also be attributable to consumer products, building materials, or even outdoor air (ambient) sources, specifically benzene, carbon tetrachloride, chloroform, 1,1-dichloroethane, 1,1-dichloroethene, 1,2-dichloroethane, cis and trans-1,2-dichloroethene, ethylbenzene, methyl tert-butyl ether, methylene chloride, tetrachloroethene, trichloroethene, toluene, trichloro-1,2,2-trifluoroethane, 1,1,1-trichloroethane, vinyl chloride, and meta, para, and ortho-xylene. In studies spanning 1990 through 2005, eleven of these compounds were detected in more than 50% of samples collected, and for several compounds (benzene, carbon tetrachloride, chloroform, ethylbenzene, and tetrachloroethene) the lower and upper quintiles of the indoor air concentrations are within the range of typical risk-based target levels. These summary statistics may help interpret data collected during a vapor intrusion investigation and communicate the findings of indoor air quality studies to building occupants and other stakeholders. Similar studies have been published in the past, but there has been a gradual change in indoor air quality over time and a large amount of new data has been collected, so this paper provides more relevant information for current use than previous compilations.

Introduction

Because people spend a large fraction of their time in their homes, consideration of residential indoor exposures to air pollutants is a critical component of many health risk assessments. Volatile organic compounds (VOCs) are a class of pollutants that have been the subject of numerous residential indoor air studies. VOCs in indoor air may originate from several sources: ambient (outdoor) air, indoor sources (sources within a building), and—if present—subsurface sources. Any compounds present in ambient (outdoor) air will generally be present in indoor air because the air in most buildings is exchanged with outdoor air many times each day. Additional VOCs or incrementally higher concentrations of VOCs may be introduced to the indoor environment through the storage and use of consumer products (e.g., cleaners, air fresheners, aerosols, mothballs, scented candles, and insect

repellants), emissions from building materials (e.g., carpets, insulation, paint, and wood finishing products), combustion processes (e.g., smoking, cooking, and home heating), and occupant activities (e.g., craft hobbies, home improvements, automotive repairs). For example, tetrachloroethene (PCE) is a common industrial solvent that is also emitted from dry-cleaned clothes. Benzene is a component of many hydrocarbon fuel mixtures, which may be released to the ground, and is also emitted from tobacco smoke or other interior combustion sources and fuel-powered tools or vehicles stored in attached garages. Other examples include naphthalene (hydrocarbon mixtures and mothballs), 1,1,1-trichloroethane (industrial solvent and aerosol propellant), some freons (solvent and air-conditioning component), and acetone (solvent used commercially as well as in nail-polish remover).

The potential for exposure to chemicals via migration of subsurface VOCs to indoor air (vapor intrusion) has become widely recognized in response to several case studies (e.g., Hers et al. 2001; Digiulio and Paul 2006; McDonald and Wertz 2007). However, because VOCs in

indoor air also may be introduced through sources unrelated to vapor intrusion (sometimes referred to as background sources during vapor intrusion assessments), the health risks attributable to vapor intrusion from the subsurface to indoor air are often challenging to assess because of difficulties in resolving the relative contributions of the indoor, outdoor, and subsurface sources to indoor air quality. For example, the presence of indoor and outdoor sources of indoor air contaminants may confound calculation of empirical attenuation factors, analysis of compound ratios, and evaluation of the effectiveness of vapor intrusion mitigation systems. Information regarding expected ranges of indoor air VOC concentrations at properties where vapor intrusion is not occurring or is being prevented by operating mitigation systems is therefore expected to be useful during analysis and interpretation of data collected to assess the potential for subsurface vapor intrusion from contaminated soil or ground water beneath a building.

Several federal and state documents provide guidance on the characterization and evaluation of background in risk assessment (e.g., USEPA 2002a, 2002b; CDPHE 2004; MADEP 2008a). These guidance documents generally recommend including contaminant concentrations attributable to background sources in a baseline risk assessment to avoid losing important risk information for those potentially exposed. Risks attributable to background concentrations generally are considered separately only when evaluating cleanup options. For vapor intrusion assessment, this generally means that subsurface screening levels are developed by multiplying risk-based indoor air target concentrations by an empirical or modeled attenuation factor, without consideration of background concentrations. Some states (e.g., Massachusetts) have adopted a different approach when developing standards for ground water concentrations protective of inhalation exposures and set the standards at a level that are at or above background levels, even where risk-based target concentrations are lower (MADEP 2008a). In both cases, it is important to understand the background concentrations, and this paper is intended to facilitate that understanding.

Indoor air quality depends on the specific consumer products and building materials inside a building, and these vary considerably from house to house in response to consumer preferences. In addition, it is important to note that indoor air concentrations will vary spatially and temporally regardless of whether the source of a particular chemical is within or beneath the building (or both). Therefore, it may not be feasible to determine whether vapor intrusion is occurring or not simply by comparing the results of a single indoor air sample to typical or background levels of indoor air concentrations. Nevertheless, knowledge of typical concentrations is a line of evidence that will help with assessing whether vapor intrusion is occurring, simply by a qualitative comparison. Background levels may be determined on a site-specific basis, but these studies typically consist of a relatively small number of samples and, therefore, may not be as representative as the compilation of statistics from the large number of indoor air quality studies presented here.

Previous Compilations

There have been several previous compilations of indoor air studies (e.g., Shah and Singh 1988; Stolwijk 1990; Samfield 1992; Brown et al. 1994; Holcomb and Seabrook 1995; USEPA 1998; Hodgson and Levin 2003). One of the most comprehensive compilations is that of Shah and Singh (1988), who compiled a database of indoor air measurements for 66 VOCs representing 30 cities from 16 states (although most, 90%, of the data are from California and New Jersey). The sampling dates range from 1970 to 1987, with the majority, 98%, collected between 1981 and 1984. Shah and Singh reported central tendency (mean and median), maximum values, and other population statistics (lower and upper quartiles). Stolwijk (1990) also presented population statistics (arithmetic mean and 10th, 50th, 90th, and 98th percentiles) calculated from four large studies of indoor air in homes conducted prior to 1987: United States (355 homes), Germany (500 homes), Netherlands (300 homes), and Italy (15 homes). Covering a similar time period, Brown et al. (1994) consolidated data from 50 studies that measured indoor air concentrations of VOCs between 1978 and 1990 in dwellings, office buildings, schools, offices, and hospitals in several countries. Assuming the data were log-normally distributed, the authors estimated weighted average geometric means as well as the 90th and 98th percentile concentrations for each VOC. In a more recent compilation, Hodgson and Levin (2003) presented measures of central tendency (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 North American residences. By comparing the compiled mean values to the mean values reported in historical studies, the authors demonstrate that the average concentrations of a number of indoor air contaminants have decreased over time.

The other compilation studies presented only central tendency information. Samfield (1992) compiled measures of central tendency data from literature on organic compounds measured indoors using varying sampling methods and times from 1975 to 1990. Holcomb and Seabrook (1995) compiled mean VOC concentration data in commercial and residential buildings published between 1980 and 1993. USEPA (1998) reviewed several field studies and compilation reports to compile mean and median values of VOCs in indoor and ambient air.

In summary, nearly all of these compilations are more than a decade old or provided only central tendency (median, geometric mean, or average) and maximum values. The exception is the compilation by Hodgson and Levin (2003); however, in that compilation and most of the other compilations, limited information regarding the frequency distribution of indoor air concentrations was provided. Since background indoor air concentrations vary widely and indoor air quality has gradually been improving over time (Hodgson and Levin 2003; MADEP 2008b; Zhu et al. 2005), there is value in a new compilation based on more recent data, with an emphasis on the statistical distribution of background indoor air concentrations.

Background Indoor Air Quality Studies Analyzed for this Compilation

Eighteen background indoor air quality studies were reviewed and evaluated for inclusion in this compilation. Seventeen were baseline studies that targeted a specific population for a specific purpose. Most were conducted in urban or suburban settings, although seven also included residences in rural settings. The eighteenth study used in this compilation was that of Shah and Singh (2008), which was included because the study represents early data (before the 1990s) collected in residences (as well as commercial buildings, but not industrial buildings) in the United States and the study reported a range of order statistics. None of the results presented in these studies differentiated among urban, suburban, or rural settings.

Basic information regarding each of these studies is summarized in Table 1; additional information can be found in the comprehensive technical report describing the compilation (USEPA, Background Indoor Air Concentrations of Volatile Organic Compounds in North American Residences: A Compilation and Implications for Vapor Intrusion, submitted). These indoor air quality studies collectively report concentrations in indoor air for more than 40 VOCs in thousands of indoor air samples. The collective data span more than two decades, ranging from 1970 to 2005. The study sample sizes vary from about 10 to 2000, although the majority of the studies reported between 50 and 500 samples. Most of the earlier studies used adsorbent media for sample collection. Later studies favored stainless steel canisters, although one recent study (Zhu et al. 2005) used adsorbent media to achieve very low reporting limits. Sample collection periods ranged from 2 to more than 100 h, although the majority of the studies employed between 12- and 24-h sample collection periods. Reporting limits vary widely by chemical, and for any given chemical, reporting limits among the studies typically vary by at least an order of magnitude.

Data Compilation and Analysis Methods

Summary statistics of indoor air quality reported in the studies described were compiled in a spreadsheet. Ideally, the raw data (concentrations of individual chemicals in individual 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 reported statistics were compiled instead. The complete set of compiled order statistics (i.e., 25th, 50th, 75th, 90th, and 95th percentiles of the distribution of measured values), maximum values, reporting limits, and percent detections is presented in USEPA (submitted).

In compiling the order statistics, percentiles reported as lower than laboratory reporting limits, and which had been assigned a value of one-half the analytical reporting limit by the individual study authors, were replaced with “<RL”. Mean values reported by the studies were not compiled, because in most cases the mean values were calculated using nondetect data for which some fraction of the reporting limit had been substituted, which can lead to inaccurate estimates of the mean (Singh et al. 2006). Also,

statistics from homes specifically designated as “smoking” homes and statistics based on personal air monitors worn only in the daytime were excluded from the compilation.

Summary statistics calculated from the compiled indoor air quality statistics are presented in Table 2 for a subset of the VOCs included in the background indoor air studies that are also common ground water contaminants and therefore likely to be considered in vapor intrusion investigations. The approach used to develop the summary statistics is described next.

The statistical measures of indoor air concentrations reported by the individual studies vary widely, depending on the age, location, and detection limits of each study. For example, Figure 1 shows for benzene that the range of 25th to 95th percentiles measured in any individual study spans more than one order of magnitude and the value of any given order statistic reported by multiple studies also span more than one order of magnitude from lowest to highest. Figure 1 also shows that the highest concentrations at any percentile were typically reported by the earlier studies (e.g., USEPA 1987a, 1987b; Shah and Singh 1988). In general, indoor air quality has been improving over time as people have become more aware of air quality and related health concerns (e.g., cessation of smoking indoors), as manufacturers of consumer products have become more aware of environmentally friendly alternatives for household chemicals (“green” cleaners), and as emissions of VOCs to ambient air have decreased. Figure 2 shows 50th and 90th percentile concentration values vs. time for a selected group of VOCs typically encountered in vapor intrusion investigations. The dates plotted on the time scale are the starting sample dates for each individual study. The time trend plots show that the 50th and 90th percentiles of indoor air concentrations measured after about 1990 are considerably lower than those measured before that time. Thus, the summary statistics in Table 2 were calculated using post-1990 data to obtain statistics representative of the current distribution of VOC concentrations in residential indoor air. Of the 18 studies compiled, 13 have indoor air statistics for samples collected in 1990 and later (through 2005). The summary statistics collectively represent indoor air quality in urban, suburban, and rural residences, without differentiation as to setting.

Summary statistics were calculated for each chemical by computing the mean of the order statistics (percentiles) reported by the individual studies (i.e., mean of reported 25th percentiles, 50th, 75th, 90th, and 95th percentile values, respectively). This is similar to the approach used to develop consensus means for samples analyzed by different laboratories, an approach that relies on the observation that sample means (and order statistics in this compilation) are normally distributed (if the sample sizes are large enough) even if the underlying populations are not normally distributed. Weighting the statistics by sample size did not substantially influence the calculated summary statistics (there was less than 10% difference), because most studies have a relatively large number of samples.

When any statistical measure was reported as below a given reporting limit, the summary statistics were

Table 1
Summary of Reviewed Background Indoor Air Quality Studies (1970–2005)

Reference	Location	Sample Dates	Season	Sample Size	Available Data (Statistics)	Collection Device	Collection Period	Analytical Method
Weisel 2006	NJ	2004-2005	Varies	100	Population Stats (25/50/75/90/95/Max)	Summa canister	24 h	EPA TO-15
NY DOH 2006	NY	1997-2003	All	400	Population Stats (25/50/75/90/95/Max)	Summa canister	2 h	TO-15
Rago et al. 2004, 2005	MA	2004-2005	Spring, Fall	100	Population Stats (25/50/75/90/Max)	Summa canister	24 h	TO-15
Zhu et al. 2005	Ottawa, CA	2002-2003	Winter	75	Population Stats (50/75/90/Max)	Sorbent tube, active sampling	1.7 h	GC/MS
Kurtz and Folkes 2002	Denver, CO	1998	All – Quarterly	375	Population Stats (25/50/75/90/95/Max)	Summa canister	24 h	EPA TO-14/15 SCAN
Sexton et al. 2004	Mineapolis, MN	1999	Spring, Summer, Fall	292	Population Stats (50/90)	3500 OVM Charcoal passive sampler	48 h	GC/MS
Foster et al. 2002; Kurtz and Folkes 2002	Denver, CO	1998-2001	All – Qrtly	427	Population Stats (25/50/75/90/95/Max)	Summa canister	24 h	EPA TO-14/15 SIM
Van Winkle and Scheff 2001	Chicago, IL	1994-1995	All	48	Population Stats (50/90/Max)	Summa	24 h	TO-14
Clayton et al. 1999	Midwest States	1995-1997	All	395	Actual Data (25/50/75/90/95/Max)	OVM 3520 passive sorbent sampler	6 d	GC/MS
Gordon et al. 1999	AZ	1995-1997	All	185	Population Stats (50/75/90/Max)	OVM 3520 passive sorbent sampler	6 d	GC/MS
Mukerjee et al.1997	Brownsville, TX	1993	Spring	9	Population Stats (50)	Multisorbent active canister	24 h	GC/MS
Heavner et al. 1996	NJ & PA	1992	Winter	61	Population Stats (50/Max)	Active multisorbent sampler	14 h	GC/MS
Heavner et al. 1995	Columbus OH	1995	Spring	24	Population Stats (50/Max)	Multisorbent sampler w/pump	3 h	GC/MS
Sheldon et al. 1992	Woodland, CA	1989	Fall	125	Population Stats (25/50/75/90/Max)	Canister	24 h	GC/MS
Shah and Singh 1988	US	1970-1987	Varies	2128	Population Stats (25/50/75)	Varies	Varies	Mixed
USEPA 1987a	Los Angeles, CA	1984	Winter, Summer	111	Population Stats (25/50/75/90/95/Max)	Tenax	12 h	GC/FID
USEPA 1987a	Contra Costa, CA	1984	Summer	111	Population Stats (25/50/75/90/95/Max)	Tenax	12 h	GC/FID
USEPA 1987b	NJ	1981	Fall	348	Population Stats (25/50/75/90/95/Max)	Tenax	12 h	GC/FID

Table 2
Summary Statistics for Background Indoor Air Concentrations Measured in North American Residences Since 1990 (All concentrations in $\mu\text{g}/\text{m}^3$)

Compound	N Studies	N Samples	%Detect	RL Range	Percentiles											
					25% N	50% N	75% N	90% N	95% N	Max	N					
Benzene	14	2615	87	0.05 - 1.6	1.9	7	2.5	13	4.5	9	10	11	17	5	93	10
Carbon tetrachloride	5	873	88	0.15 - 0.25	0.3	2	0.5	5	0.7	2	0.8	4	1.1	1	2.7	3
Chloroform	10	2178	73	0.02 - 2.4	0.5	4	1.1	9	2.2	6	3.9	8	6.0	5	20.2	7
Dichloroethane, 1,1-	5	1309	0.3	0.08 - 2.0	<RL	5	<RL	5	<RL	5	<RL	5	<RL	4	0.9	5
Dichloroethane, 1,2-	4	950	12.6	0.02 - 0.25	<RL	2	<RL	4	<RL	3	0.15	4	0.20	2	1.8	4
Dichloroethene, 1,1-	5	957	10	0.01 - 2.0	<RL	4	<RL	5	<RL	5	<RL	5	<RL	3	86.8	5
Dichloroethene, cis 1,2-	4	975	3	0.25 - 2.0	<RL	4	<RL	4	<RL	4	<RL	4	<RL	3	3.7	4
Dichloroethene, trans 1,2-	3	575	0	0.8 - 2.0	<RL	3	<RL	3	<RL	3	<RL	3	<RL	2	<RL	3
Ethylbenzene	10	1484	81	0.01 - 2.2	0.8	4	2.0	9	3.0	5	8.6	7	14	3	126	8
Methyl tert-butyl ether (MTBE)	4	502	47	0.05 - 1.8	<RL	3	1.2	4	5.7	4	26	4	72	2	242	4
Methylene chloride	7	1,649	73	0.4 - 3.5	0.42	3	1.10	7	3.6	5	10	7	20	4	506	6
Tetrachloroethene	13	2312	64	0.03 - 3.4	<RL	7	0.9	10	1.8	6	4.0	9	7.4	5	171.2	8
Toluene	12	2065	96	0.03 - 1.9	9	5	13	12	27	7	51	9	106	4	547	9
Trichloro-1,2,2-trifluoroethane, 1,1	1	400	56	0.25	<RL	1	0.5	1	1.1	1	1.8	1	3.4	1	7	1
Trichloroethane, 1,1,1-	9	1877	60	0.12 - 2.7	0.5	7	1.9	9	2.7	7	5.5	7	10.2	5	196	8
Trichloroethene	13	2403	44	0.02 - 2.7	<RL		0.3	10	0.3	6	0.9	8	1.6	5	84	10
Vinyl chloride	6	1684	7	0.01 - 1.3	<RL	6	<RL	6	<RL	6	0.03	2	0.05	2	0.8	6
Xylene, m/p-	10	1920	90	0.4 - 2.2	2.9	6	5.5	10	9.4	7	27	9	41	4	593	8
Xylene, o-	12	2004	85	0.11 - 2.2	1.4	6	2.2	11	3.9	7	10	9	16	4	196	10

Note: "N" indicates number of studies reporting a particular statistic.

calculated using the Kaplan-Meier method, a robust non-parametric maximum likelihood estimator capable of considering censored or truncated data (i.e., data sets with nondetect values) with multiple reporting limits (Helsel, 2005a, 2005b, 2006). The Kaplan-Meier method was originally developed as a tool for medical researchers to estimate the survival probability function, i.e., the probability that a member of a given population will have a lifetime exceeding a certain age. Helsel (2005a) adapted the method to populations of data with "less than values," such as low-level concentrations. As described by Helsel (2005a), the survival function probability is the product of the $j = 1$ to k incremental probabilities to that point, going from high to low concentrations for the k detected observations. In effect, the Kaplan-Meier method assigns a percentile value to each detected observation, starting at the largest value and working down, on the basis of the number of observations above and below that observation. Percentiles are not assigned to data that are below reporting limits, but these data affect the percentiles calculated for the observations that are above reporting limits.

The summary statistics generated from the compiled indoor air statistics and presented in Table 2 provide more complete characterizations of the distributions of background indoor air concentrations typically found in residences than the single "representative" value reported in most previous compilations. This characterization allows for more robust statistical comparisons of background to measured indoor air concentrations obtained in vapor intrusion investigations.

Results and Discussion

Summary statistics were developed as described using 13 studies representing measured indoor air VOC concentrations from 1990 through 2005. Table 2 presents the summary statistics (arithmetic mean values for the 25th, 50th, 75th, 90th, and 95th percentiles, as well as the maximum values, reporting limits, and percent detected) for a subset of the VOCs reported in the compiled background studies that are also common ground water contaminants, and therefore likely to be considered in vapor intrusion investigations. Although a larger set of statistics is presented in this compilation, the population statistics in common with those in the recent compilation by Hodgson and Levin (2003) compare well: within a factor of 2 to 4.

As can be seen in Table 2, the average values for order statistics typically show more than one order of magnitude range from the 25th to the 95th percentile values and tend to be skewed toward high values in a way that is typical of log-normal distributions. This variability can be attributed to house-to-house variability in air exchange rates as well as building materials and consumer preferences and habits.

To provide a context for the assessment of health risks attributable to vapor intrusion, it is helpful to understand the health risks associated with average indoor air quality in buildings that are not affected by contaminated land. The VOCs most commonly detected in indoor air are presented in Figure 3, which ranks the compounds on the basis of the average percent detections. BTEX compounds (benzene, toluene, ethylbenzene, and xylene) are among

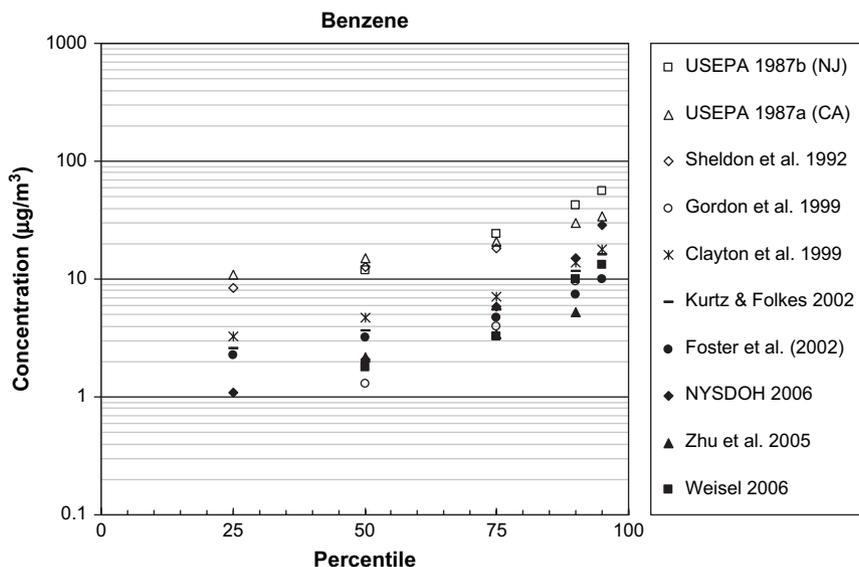


Figure 1. Indoor air concentration statistics for benzene reported by selected individual residential air quality studies.

the most commonly detected VOCs in indoor air. Several chlorinated hydrocarbons also are commonly detected, including carbon tetrachloride, chloroform, tetrachloroethene, and 1,1,1-trichloroethane. Note that the percent detections are a function of the reporting limits used in the studies. Some compounds (e.g., trichloroethene) have been analyzed using very low detection limits, while other compounds (e.g., cis-1,2-dichloroethene) have been analyzed using detection limits that are an order of magnitude higher.

Figure 4 shows that several of these commonly detected compounds have background concentrations that fall within the range of target concentrations corresponding to an incremental excess lifetime cancer risk of 10^{-4} to 10^{-6} for a typical residential exposure (based on USEPA's regional screening levels for chemical contaminants at Superfund sites; http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/Generic_Tables/index.htm). Thus, the presence of VOCs at levels of potential health concern in buildings overlying subsurface contamination may not necessarily be attributable to the vapor intrusion pathway. It is important to note that the background concentrations presented here are averages of the order statistics compiled from indoor air quality studies spanning 1990 through 2005. Background concentrations in the future may differ substantially if their uses in household or fuel products change. For example, starting in 2007, MTBE was no longer added to gasoline and, as a result, MTBE concentrations in outdoor air have decreased to very low levels. Thus, it is expected that indoor air values also will decrease as older fuel products stored in or near residences are replaced with current fuel products.

These results have several implications for evaluating indoor air data at vapor intrusion sites. Because of the wide variability in indoor air VOC concentrations, comparison of a single indoor air measurement obtained in a vapor intrusion investigation to a single value within the background concentration distribution is not likely to conclusively indicate whether subsurface vapor intrusion poses

unacceptable risks or not. Most vapor intrusion assessments are based on a small number of samples, so it is generally not feasible to perform a rigorous statistical comparison of the site data to background data using, for example, an appropriate parametric test (e.g., Student's t-test) or nonparametric test (e.g., Wilcoxon rank sum). Nevertheless, a qualitative assessment can be very instructive. If several VOCs are detected in subsurface samples, and also are present in indoor air samples at concentrations above typical indoor air concentrations, there is a high likelihood that vapor intrusion was occurring at the time and location of sample collection. Additional confidence can be derived by comparing relative concentrations of any two or more compounds in subsurface samples to the relative concentrations of the same compounds in indoor air samples (also known as compound ratio analysis; ITRC [2007]), provided that either the compounds being compared are both equally resistant to degradation or the subsurface sample is from immediately beneath the building floor where the opportunity for degradation before entry to indoor air is very limited. For example, if two compounds are the dominant compounds in soil-gas samples, and both are detected in indoor air at concentrations above typical indoor air concentrations, and the relative proportion of the two compounds is similar in indoor and subsurface samples, vapor intrusion most likely is occurring. Conversely, if compounds are detected in subsurface samples, but are not present in indoor air samples at concentrations above typical indoor air concentrations, there is a high likelihood that vapor intrusion was either not occurring at the time and location of sample collection or, if occurring, the contribution to indoor air concentrations was low relative to the contribution of indoor sources.

Summary and Conclusions

Indoor air quality typically contains chemicals from consumer products, building materials, and outdoor

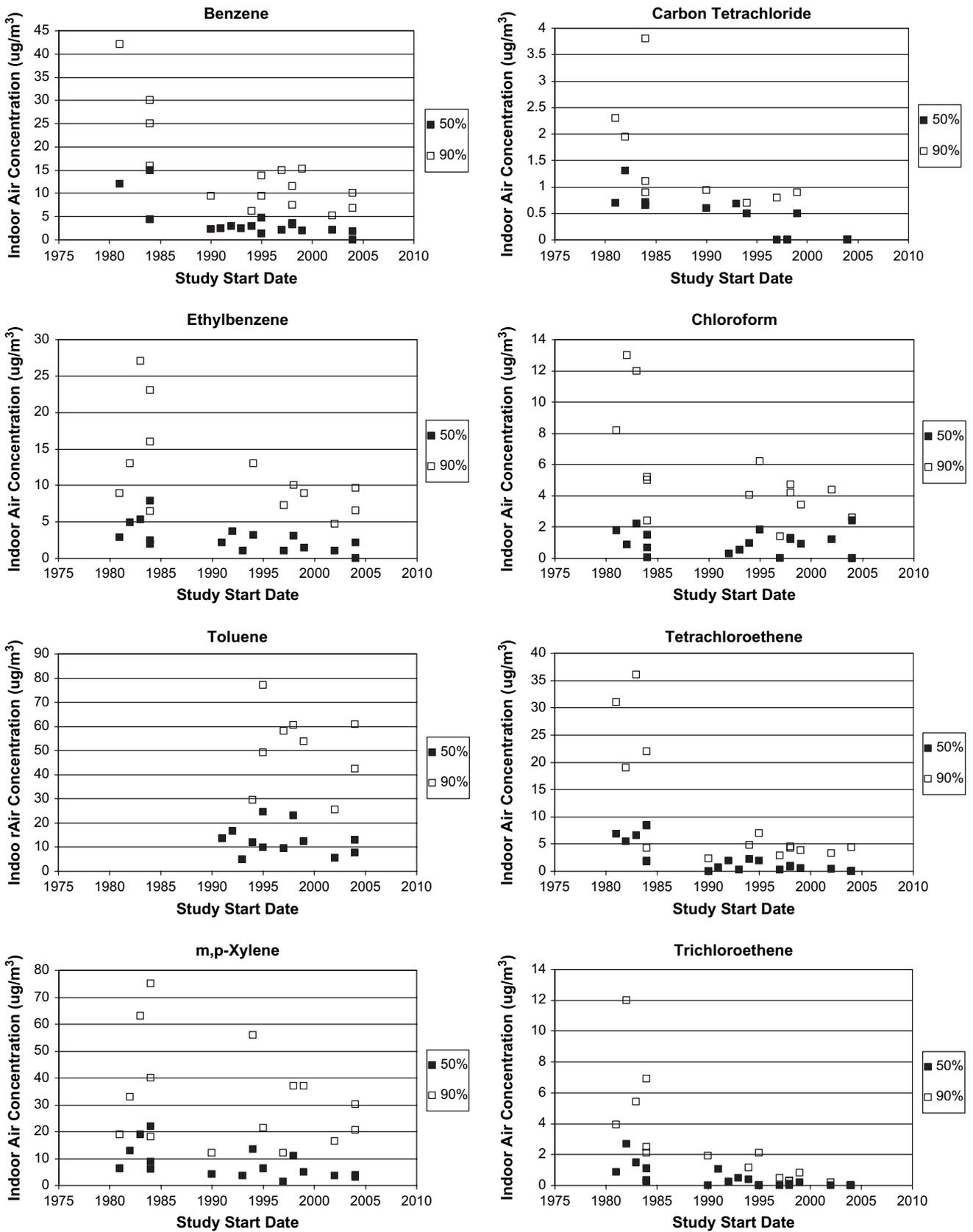


Figure 2. Concentration ($\mu\text{g}/\text{m}^3$) population statistics vs. time for selected VOCs in indoor air. The statistics are plotted vs. the starting sample date of the studies.

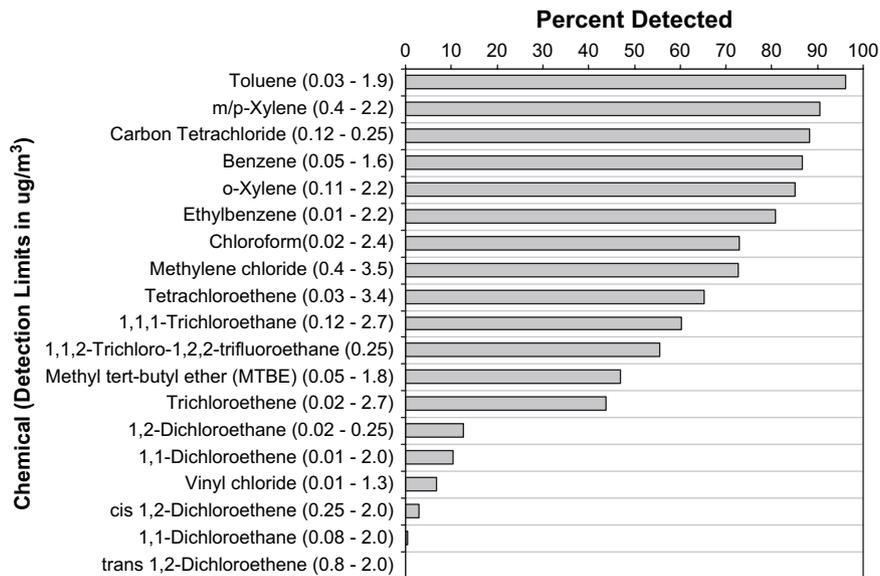


Figure 3. Average percent detection for selected VOCs in indoor air for studies listed in Table 1.

(ambient) air that may be detectable and may be present at levels that exceed health-based target concentrations. Any indoor air sample collected for assessment of subsurface vapor intrusion is likely to detect chemicals from these other sources, and in many cases, the compounds may be the same as the compounds present in soil or ground water attributable to contaminated land.

This paper provides summary statistics for typical indoor air concentrations of VOCs in North American residences for the purpose of providing a line of evidence to consider in evaluating vapor intrusion data. The summary statistics indicate that typical VOC concentrations, based on indoor air quality studies conducted from 1990 through 2005, range over one order of magnitude from the 25th to

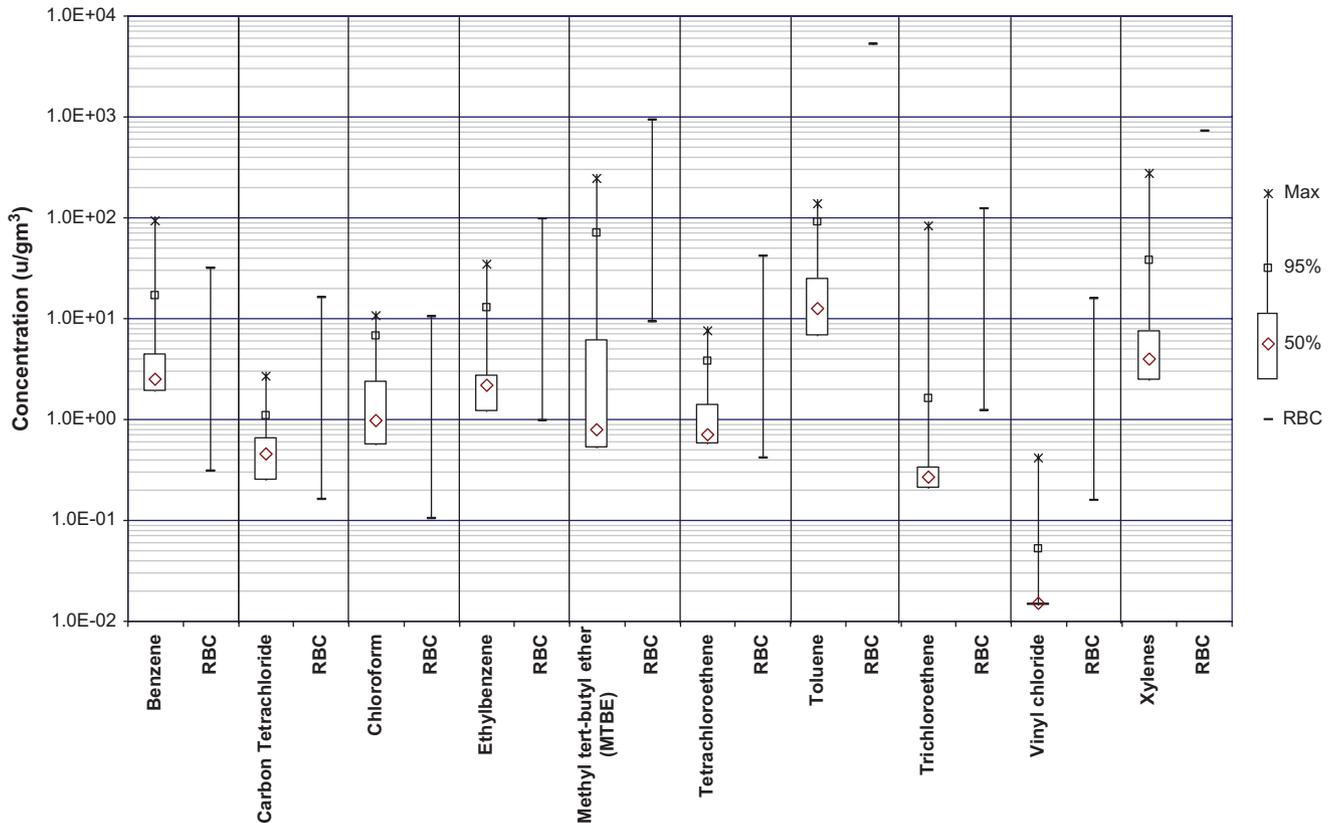


Figure 4. Residential indoor air concentration statistics listed in Table 2 compared to risk-based concentrations (RBC) for selected VOCs. The risk based concentrations shown are based on US EPA Regional Screening Levels for Chemical Contaminants at Superfund Sites assuming a cancer risk range of 1E-06 to 1E-04 or hazard quotient of 1.

the 95th percentile values. Some very common chemicals, notably benzene, carbon tetrachloride, chloroform, tetrachloroethene, and occasionally others, have background indoor air concentrations that are similar to health-based target concentrations. Therefore, it is important to resolve the relative contributions of background sources of vapors before making a final determination of whether subsurface vapor intrusion is significant. If vapor intrusion assessments are conducted with a target risk level of 10^{-6} , background concentrations will frequently pose unacceptable risks. At a target risk level of 10^{-5} , background concentrations will occasionally pose unacceptable risks. At a target risk level of 10^{-4} , background concentrations will seldom pose unacceptable risks. It is not the intent of this paper to establish or advocate for any specific target risk level, only to raise awareness of how that selection relates to the complications posed by background concentrations during vapor intrusion assessments.

Indoor air quality varies from building to building in response to occupants' habits and choice of consumer products; therefore, indoor air monitoring at a few selected control properties (properties unaffected by vapor intrusion) is less likely to provide representative information regarding background concentrations compared to large databases of statistically significant number of control properties, such as the compilation presented in this paper. The order statistics may be useful for identifying compounds that are present at concentrations consistent with typical indoor air quality, and may help identify chemicals that are present at elevated concentrations. Elevated concentrations alone are not sufficient to implicate vapor intrusion as the root cause, and concentrations within typical ranges can still have a contribution from the subsurface. Therefore, this comparison is qualitative in nature and should be viewed in context with other lines of evidence in order to assess whether vapor intrusion is occurring.

The information presented in this paper may also be helpful to communicate to occupants of buildings before the conduct of a vapor intrusion investigation, so that they will be aware that several chemicals are likely to be detected and some may be present at concentrations that pose potentially unacceptable risks, even in the absence of any contribution from subsurface vapor intrusion.

Disclosure

The findings and conclusions in this paper have not been formally disseminated by USEPA and should not be construed to represent any Agency determination or policy.

References

- Brown, S.K., M.R. Sim, M.J. Abramson, and C.N. Gray. 1994. Concentrations of volatile organic compounds in indoor air: A review. *Indoor Air* 4: 123–124.
- Clayton, C.A., E.D. Pellizzari, R.W. Whitmore, R.L. Perritt, and J.J. Quackenboss. 1999. National Human Exposure Assessment Survey (NHEXAS): Distributions and associations of lead, arsenic and volatile organic compounds in EPA Region 5. *Journal of Exposure Analysis and Environmental Epidemiology* 5, no. 9: 381–392.
- [CDPHE] Colorado Department of Public Health and Environment. 2004. *Draft Indoor Air Guidance*. <http://www.cdphe.state.co.us/HM/indoorair.pdf> (accessed February 18, 2009).
- DiGiulio, D.C., and C.J. Paul. 2006. Assessment of vapor intrusion in homes near the Raymark Superfund site using basement and sub-slab air samples. EPA/600/R-05/147. Washington, D.C.: U.S. Environmental Protection Agency.
- Foster, S.J., J.P. Kurtz, and A.K. Woodland. 2002. Background indoor air risks at selected residences in Denver Colorado. In *Indoor Air 2002, Proceedings of the Ninth International Conference on Indoor Air Quality and Climate*, June 30–July 5, Vol. 1, ed. H. Levin, 932–937. Santa Cruz, California: Indoor Air 2002.
- Gordon S.M., P.J. Callahan, M.G. Nishioka, M.C. Brinkman, M.K. O'Rourke, M.D. Lebowitz, and D.J. Moschandreas. 1999. Residential environmental measurements in the National Human Exposure Assessment Survey (NHEXAS) pilot study in Arizona: Preliminary results for pesticides and VOCs. *Journal of Exposure Analysis and Environmental Epidemiology* 9, no. 5: 456–470.
- Heavner, D.L., W.T. Morgan, and M.W. Ogden. 1996. Determination of volatile organic compounds and respirable suspended particulate matter in New Jersey and Pennsylvania homes and workplaces. *Environment International* 22, no. 2: 159–183.
- Heavner, D.L., W.T. Morgan, and M.E. Ogden. 1995. Determination of volatile organic compounds and ETS apportionment in 49 homes. *Environmental International* 21, no. 1: 3–21.
- Helsel, D.R. 2006. Fabricating data: How substituting values for non-detects can ruin results, and what can be done about it. *Chemosphere* 65: 2434–2439.
- Helsel, D.R. 2005a. *Non-detects and Data Analysis, Statistics for Censored Environmental Data*. New York: John Wiley and Sons.
- Helsel, D.R. 2005b. More than obvious: Better methods for interpreting non-detect data. *Environmental Science & Technology* 39, no. 20: 419A–423A.
- Hers, I., R. Zapf-Gilje, L. Li, and J. Atwater. 2001. The use of indoor air measurements to evaluate intrusion of subsurface VOC vapors into buildings. *Journal of the Air & Waste Management Association* 51: 174–185.
- Hodgson, A.T., and H. Levin. 2003. Volatile organic compounds in indoor air: A review of concentrations measured in North America since 1990. Lawrence Berkeley National Laboratories Report LBNL-51715. <http://eetd.lbl.gov/ie/pdf/LBNL-51715.pdf> (accessed February 18, 2009).
- Holcomb, L.C., and B.S. Seabrook. 1995. Indoor concentrations of volatile organic compounds: Implications for comfort, health and regulation. *Indoor Environment* 4: 7–26. [ITRC] Interstate Technology and Regulatory Council. 2007. Vapor intrusion pathway: A practical guideline. January. <http://www.itrcweb.org/guidancedocument.asp?TID=49> (accessed February 18, 2009).
- Kurtz, J.P., and D.J. Folkes. 2002. Background concentrations of selected chlorinated hydrocarbons in residential indoor air. In *Indoor Air 2002, Proceedings of the Ninth International Conference on Indoor Air Quality and Climate*, June 30–July 5, Vol. 1, ed. H. Levin, 920–925. Santa Cruz, California: Indoor Air 2002.
- [MADEP] Massachusetts Department of Environmental Protection. 2008a. 310 CMR 40.0000: MASSACHUSETTS CONTINGENCY PLAN, rev. February 14. Boston, Massachusetts: MADEP.
- [MADEP] Massachusetts Department of Environmental Protection. 2008b. Indoor air threshold values for the evaluation of

- a vapor intrusion pathway. Draft Policy, June 26. Boston, Massachusetts: MADEP.
- McDonald, G.J., and W.E. Wertz. 2007. PCE, TCE, and TCA vapors in subsurface soil gas and indoor air: A case study in upstate New York. *Ground Water Monitoring and Remediation* 27, no. 4: 86–92.
- Mukerjee, S., W. Ellenson, R.G. Lewis, R.K. Stevens, M.C. Somerville, D.S. Shadwick, and R.D. Willis. 1997. An environmental scoping study in the Lower Rio Grande Valley of Texas. III. Residential microenvironmental monitoring for air, house dust, and soil. *Environment International* 23, no. 5: 657–673.
- [NYSDOH] New York State Department of Health. 2006. Study of volatile organic chemicals in air of fuel oil heated homes. In: *Final NYSDOH Soil Vapor Intrusion Guidance*. Appendix C.1. http://www.health.state.ny.us/environmental/investigations/soil_gas/svi_guidance/docs/svi_appendc.pdf (accessed February 18, 2009).
- Rago, R., R. McCafferty, and A. Rezendez. 2004. Background residential indoor air quality in Massachusetts. In Proceedings of the 20th Annual International Conference on Soils, Sediments and Water, Vapor Intrusion Workshop, October 18–19. University of Massachusetts, Amherst, MA: AEHS 2004.
- Samfield, M. 1992. Indoor air quality database for organic compounds. US EPA ORD EPA/600/13. Washington, D.C.: U.S. Environmental Protection Agency.
- Sexton, K.J., L. Adgate, G. Ramachandran, G. Pratt, S.J. Mongin, T.H. Stock, and M.T. Morandi. 2004. Comparison of personal, indoor, and outdoor exposures to hazardous air pollutants in three urban communities. *Environmental and Science Technology* 38, no. 2: 423–430.
- Shah, J.J., and H.B. Singh. 1988. Distribution of volatile organic chemicals in outdoor and indoor air. *Environmental and Science Technology* 22, no. 12: 1381–1388.
- Sheldon, L., A. Clayton, B. Jones, J. Keever, R. Perritt, D. Smith, D. Whitaker, and R. Whitmore. 1992. Indoor pollutant concentrations and exposures. Final Report. California Air Resources Board Report No. A833-153. RTI Project No. 321U-4511. Research Triangle Park, North Carolina: Research Triangle Institute.
- Singh, A., R. Maicle, and S.E. Lee. 2006. On the computation of a 95% upper confidence limit of the unknown population mean based upon data sets with below detection limit observations. EPA 600/R-06/022. Washington, D.C.: U.S. Environmental Protection Agency.
- Stolwijk, J.A.J. 1990. Assessment of population exposure and carcinogenic risk posed by volatile organic chemicals in indoor air. *Risk Analysis* 10, no. 1: 49–57.
- USEPA. 2002a. Role of background in the CERCLA Cleanup Program. OSWER 9285.6-07P. Washington, D.C.: Office of Solid Waste and Emergency Response. http://www.epa.gov/oswer/riskassessment/pdf/bkgpol_jan01.pdf <http://www.epa.gov/> (accessed February 18, 2009).
- USEPA. 2002b. Draft guidance for evaluating the vapor intrusion to indoor air pathway from groundwater and soils. Washington, D.C.: Office of Solid Waste and Emergency Response. <http://www.epa.gov/osw/hazard/correctiveaction/eis/vapor.htm> (accessed February 18, 2009).
- USEPA. 1998. A comparison of indoor and outdoor concentrations of hazardous air pollutants. *Inside IAQ*. EPA/600/N-98/002 Spring/Summer Washington, D.C.: U.S. Environmental Protection Agency.
- USEPA. 1987a. The Total Exposure Assessment Methodology (TEAM) study: Elizabeth and Bayonne, New Jersey, Devils Lake, North Dakota, and Greensboro, North Carolina, vol. II, part 2. EPA/600/6-87/002c. Washington, D.C.: U.S. Environmental Protection Agency.
- USEPA. 1987b. The Total Exposure Assessment Methodology (TEAM) study: Selected communities in Northern and Southern California, vol. III. EPA/600/6-87/002b. Washington, D.C.: U.S. Environmental Protection Agency.
- Van Winkle, M.R., and P.A. Scheff. 2001. Volatile organic compounds, polycyclic aromatic hydrocarbons and elements in the air of ten urban homes. *Indoor Air* 11: 49–64.
- Weisel, C.P. 2006. Investigation of indoor air sources of VOC contamination. Final Report, Year 2. SR03-033. Trenton: New Jersey Department of Environmental Protection.
- Zhu, J., R. Newhook, L. Marro, and C. Chan. 2005. Selected volatile organic compounds in residential air in the City of Ottawa, Canada. *Environmental and Science Technology* 39, no. 11: 3964–3971.

Biographical Sketches

Helen E. Dawson, Ph.D., corresponding author, received her B.S. in geology from Stanford University, her M.S. in geochemistry from the Colorado School of Mines, and her Ph.D. in environmental engineering from Stanford University. She can be reached at US EPA Region 8, 1595 Wynkoop St., Denver, CO 80202; (303) 312-7841; fax (303) 312-7517; Dawson.Helen@epa.gov.

Todd A. McAlary is practice leader - vapor intrusion at Geosyntec Consultants, Inc. He received his B.A.Sc. in geological engineering and M.Sc. in hydrogeology from the University of Waterloo. He can be reached at Geosyntec Consultants, Inc., 130 Research Lane, Suite 2, Guelph, Ontario, N1G 5G3; (519) 822-2230, ext 239; tmcalary@geosyntec.com.