THE MASSACHUSETTS TOXICS USE REDUCTION INSTITUTE

Massachusetts Chemical Fact Sheet

Trichloroethylene (TCE)

This fact sheet is part of a series developed by TURI to help Massachusetts companies, community organizations and residents understand the chemical's health and environmental effects, as well as the availability of safer alternatives. Readers will learn how the chemicals are being used and which companies reported TCE use under the Massachusetts Toxics Use Reduction Act.

Trichloroethylene (TCE) is a common solvent, widely used in vapor degreasing, as a chemical intermediate, as part of cleaning solvent mixtures and as a solvent in adhesives. Due to the availability of economically viable, safer alternatives as well as stricter regulations, TCE use has declined steadily.

Due to its serious adverse effects on human health and the environment, TCE is subject to multiple regulations at the state, federal and international levels. TCE was designated as a higher hazard substance under the Toxics Use Reduction Act in January 2008, which reduces the associated reporting threshold to 1,000 lb/year (approximately 70 gallons).

TCE FACTS	
Other Names	1,1,2-Trichloroethylene; 1,2,2-Trichloroethylene; Acetylene trichloroethylene; 1,1-Dichloro-2-chloroethylene; Trichloroethene
Chemical Formula	C_2HCl_3
CAS Number	79-01-6
Vapor Pressure	57.8 mm Hg at 20 °C
Water Solubility	1.0 g/L of water at 25 °C (slightly)
Description	Nonflammable, colorless liquid at room temperature with a somewhat sweet odor and a sweet, burning taste

Health and Environmental Impacts

The following is a brief summary of potential exposure routes and the associated human health and environmental impacts.

Exposure Routes

Particularly large exposures, primarily via inhalation, may occur when workers clean metal parts in a vapor degreaser.

TCE is reported by the EPA to be the most prevalent solvent contaminating groundwater at superfund sites in the United States. The general public may be exposed to TCE by drinking, breathing or bathing in contaminated water. The third National Health and Nutrition Examination Survey suggested that approximately 10% of the population had detectable levels of TCE in their blood.

Human Health Effects

Acute Exposure

Acute (short-term) exposure to TCE vapors can cause central nervous system (CNS) effects (e.g., light-headedness, drowsiness, headache and giddiness) and may lead to unconsciousness or be fatal. At very high exposure levels, TCE can sensitize the heart to the effects of adrenaline and similar agents, which may lead to sudden cardiac arrest. In addition, TCE may irritate the respiratory tract at high vapor concentrations, and may be lethal at concentrations exceeding 1000 ppm.

Repeated or prolonged contact with the chemical in liquid or mist form can cause irritation of the skin and eyes. Direct exposure to liquid TCE defats the skin, causing redness, blistering and scaling.

Chronic Exposure

Frequent, prolonged exposures to organic solvents in general can have long-lasting and possibly permanent effects on the nervous system. Chronic exposure to TCE in excess of recommended occupational limits has been associated with damage to the liver and kidneys, although this is less well documented in humans than in animals

People who drink water containing TCE over many years could experience liver problems and may have an increased risk of developing liver cancer. TCE also has genotoxic and immunotoxic potential, and some studies indicate that it may be a teratogen.

Cancer Risk

Several agencies have investigated TCE's association with cancer. The US National Toxicology Program classifies TCE as "reasonably anticipated to be human carcinogen". The International Agency for Research on Cancer (IARC) lists TCE as Group 2A, probable human carcinogen.

Reproductive/Developmental Effects

Evidence from animal and epidemiologic studies suggests that several reproductive and developmental toxicity end points may be associated with TCE exposure, including infertility in males and females, impaired fetal growth, and cardiac teratogenesis. The US Agency for Toxic Substance and Disease Registry Public Health Statement for TCE, however, does not conclude that there is a direct relationship between exposure to TCE and an increased risk of reproductive effects.

Environmental Hazards

TCE most often enters the environment via fugitive emissions from metal degreasing industries and by spills or accidental releases to

air, soil and water. Because of its high vapor pressure and low rate of adsorption in soil TCE evaporates fairly rapidly when released to soil. However, where it persists it can percolate rapidly through sandy soil thereby reaching groundwater.

Chemical and biological degradation of TCE in water are expected to be very slow. TCE is not expected to accumulate in aquatic organisms or to adsorb onto sediment; however it is toxic to aquatic organisms.

When released to the atmosphere, TCE remains in the vapor phase. Once in the air about half of the TCE will break down within a week. When TCE is broken down in the air, phosgene, a significant lung irritant, can be formed. In the body, TCE may break down into dichloroacetic acid, trichloroacetic acid, chloral hydrate, and 2-chloroacetaldehyde. These byproducts have been shown to be toxic to animals and may be toxic to humans.

(For section references see endnote #1)

Use Nationally and in Massachusetts

TCE was first produced in the early twentieth century and was used as a general anesthetic until the late 1970's. TCE was also used as a solvent for extraction of palm, coconut and soy bean oils, spices, hops and the decaffeination of coffee. The United States Food and Drug Administration banned these uses as well as use in cosmetics and drug production in the 1970s.

According to the 2001 Chemical Economics Handbook, the breakdown of TCE use in the United States in 2005 is estimated as:

- 26% vapor degreasing of fabricated metal parts
- 74% chemical intermediates and miscellaneous uses

Metal Cleaning and Degreasing

TCE is used as a degreasing solvent in the metal finishing, automotive and aerospace industries. TCE is an important solvent for degreasing soft metals such as aluminum and works well cleaning steel before galvanizing. TCE has many properties that make it an excellent degreasing agent, including: high solvency; low flammability; non corrosiveness; and high stability. TCE is also relatively inexpensive and cleans thoroughly and quickly.

Chemical Intermediates

TCE in high purity grade is used as a feedstock to produce hydrofluorocarbon refrigerants and other chlorinated end products such as flame retardant chemicals. TCE is also used as a molecular-weight control agent in the manufacturer of polyvinyl chloride (PVC).

Miscellaneous uses

TCE is used as a solvent in adhesives and aerosol formulations. It is also used as a heat transfer medium as a solvent in electronics, printing, pulp and paper and in textile operations. Chlorinated solvents, such as TCE, are used in a number of operations in the textile industry. TCE is also used as a swelling agent in disperse dyeing of polyesters, for removal of basting threads, and in small quantities for scouring wool.

Since 1990 Massachusetts companies have reduced their use of TCE by more than a 77%.

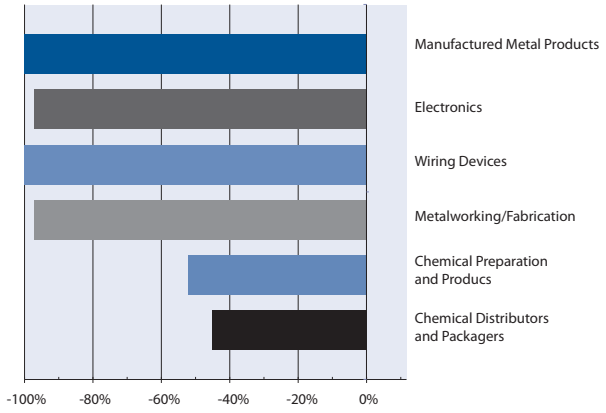
Massachusetts Uses

In 2005 almost 90% of TCE uses in Massachusetts (excluding chemical distribution) were associated with solvent use in adhesives and paints.

Table 1 shows the amount of TCE use reported in Massachusetts in the first year of reporting (1990) and in 2005. Overall, companies in Massachusetts have reduced their use of TCE by more than 77% during this period. Most companies were able to reduce their use of TCE to below the 10,000 pound reporting threshold within 5 years of the beginning of the program. With the new lower reporting threshold (1,000 pounds/year starting in reporting year 2008) more companies will likely begin reporting on their use of TCE.

Figure 1 illustrates the percent changes in use of TCE in Massachusetts by industry sector over the years 1990 to 2005.

Figure 1. Percent Change in Use by Industry Sector: 1990 – 2005



Manufactured Metal Products

The manufactured metal products sector includes companies manufacturing products such as binders, razors, lighting fixtures, motor vehicle parts, jewelry and other niche product lines. The companies in this sector used TCE to degrease or clean parts as part of their overall manufacturing processes. The companies in this sector were able to completely reduce their use of TCE below reporting thresholds, typically within seven years. At least two facilities, Lightolier and Swank, are still reporting on use of other chemicals.

Table 1. Massachusetts TCE Consumption by Industry Sector (1990-2005)					
Industry Sector	Product / Process	Facility Name	Location	Use (pounds)	
				1990	2005
Manufactured Metal Products	Blank Books and Binders	US Ring Binder Corp.	New Bedford	56,800	0
	Razors	Gillette Manufacturing (USA) Inc	Boston	212,524	0
	Residential Lighting Fixtures	Lightolier	Fall River	157,571	0
	Motor Vehicle Parts	Standard Thomson Corp	Waltham	14,520	0
	Lab Equipment	International Equipment Company	Needham	23,764	0
	Badges, Insignia, Plaques, Handbags and Jewelry	VH Blackinton & Co Inc	No. Attleboro	21,737	0
		Swank Incorporated	Plainville	21,943	0
		Robbins Co	Attleboro	21,819	0
		Whiting & Davis Inc	Attleboro	16,088	0
Electronics	Electron Tubes	Perkin Elmer Optoelectronics	Salem	15,630	0
		Raytheon Power	Waltham	24,255	0
	Environmental Controls	Texas Instruments	Attleboro	381,000	0
	Semiconductors	MA/Com Inc	Burlington	28,122	0
	Electric Capacitors	Aerovox Incorporated	New Bedford	322,800	0
		Cornell Dubilier Co	New Bedford	60,977	0
		Sprague North Adams Inc	North Adams	77,000	0
	Electronic Components	Raytheon Company	Waltham	60	0
	Electronics Connectors	Tyco Electronics	No. Attleboro	0	22,989
Wiring Devices	Current Carrying	Gould Electronics Inc	Newburyport	29,760	0
	Non Current Carrying	IBC Corp	Easton	58,829	0
		LE Mason Company	Boston	61,105	0
Metalworking / Fabrication	Non Ferrous Rolling/Drawing	Stern Leach Company	Attleboro	70,984	0
	Metal Stamping	Anderson Sons Inc	Westfield	20,250	0
		National Perforating Corp	Clinton	13,000	0
		Peter Gray Corp	Cambridge	19,073	0
		Tech Etch Inc	Fall River	15,683	0
		Valentine Tool & Stamping Co	Norton	54,856	0
	Plating and Polishing	American Electroplating	Somerville	16,555	0
		Cambridge Plating Company Inc	Belmont	97,600	0
		Duralectra Inc	Natick	19,874	0
		Federal Metal Finishing Inc	Boston	12,100	0
		Modern Electroplating Co Inc	Boston	48,000	0
		New Method Plating C	Worcester	66,700	0
	Fabricated Metal Products	JH Smith Co Inc	Greenfield	15,404	0
		Automatic Machine Products	Attleboro	28,000	0
	Machine Tool Accessories	LS Starrett Company	Athol	0	16,513
	Mechanical Rubber Goods	Precix	New Bedford	12,761	0
Chemical Preparations and Products	Polishes and Cleaners	Creative Chemicals Inc	Palmer	158,600	0
	Adhesives and Sealants	ITW TACC	Rockland	207,563	114,308
	Paints and Allied Products	Camger Coatings Systems Inc	Norfolk	0	17,639
	Laminated Textiles	Shawmut Corporation	W. Bridgewater	302,000	198,544
	Fabricated Rubber Products	New England Newspaper Supply	Millbury	16,528	0
Chemical Distributors and Packagers	Industrial Organic Chemicals	Safety Kleen	North Andover	824,547	0
	Chemical Preparations	Shield Packaging	Dudley	24,845	0
	Chemicals and Allied Products	Ashland Distribution Co	Tewksbury	0	47,110
		Astro Chemicals Inc	Springfield	0	236,015
		Callahan Company	Walpole	0	124,714
		General Chemical Corporation	Framingham	0	56,630
Total TCE Used				3,651,227	834,462

Electronics and Wiring Devices

Of the nine companies reporting use of TCE in 1990, only one company, Tyco Electronics, reported continued use of TCE as a degreaser in 2005. Tyco reported a 97% reduction in TCE use in that time. According to staff at this facility, Tyco is no longer using TCE. After merging this location with its Norwood location Tyco is now using an alternative solvent for its degreasing operations.

The three companies in the Wiring Devices sector apparently reduced all reportable uses of toxic chemicals below reporting thresholds by 2003.

Metalworking and Fabrication

Generally companies in this sector use TCE as a cleaner and degreaser for metal parts. The Metalworking and Fabrication sector reduced its use of TCE by 97% from 1990 to 2005. Several of the companies in this sector are job shop operations whose customers largely dictate the processes required for plating.

While the majority of companies in this sector reduced their use of TCE below the 10,000 lb reporting threshold, several continue to use TCE, and it is likely that many more companies in this sector will report use of TCE above the new 1,000 lb/year reporting threshold for 2008. For example, some companies that had reduced their use of TCE to just below 10,000 pounds in 2005 exhibited a slow decline in use over time and would likely continue to use TCE well in excess of the new 1,000 pound/year threshold.

Chemical Preparations and Products (including Rubber Products)

Massachusetts companies in this sector use TCE as a synthesis feedstock for such products as paints, adhesives and cleaners. This sector experienced a 52% reduction in reportable TCE use from 1990 to 2005.

ITW TACC, which processes TCE with other chemicals to create adhesives, sealants and caulks for roofing, general construction and general industrial application, reported an almost 50% reduction in TCE use over the 15 year reporting period. On the other hand, Camger began incorporating TCE into its paint formulations in 1995, and has increased the amount of TCE used by over 30% since that time.

Shawmut Corp also uses TCE as part of its adhesives used in textile lamination applications. Shawmut decreased its use of TCE by almost 35% from 1990 to 2005, using process modifications and improved chemical management techniques. New England Newspaper Supply reduced its use of TCE below reporting thresholds within one year of having to report.

Chemical Distributors and Packagers

This sector reduced the reportable amount of TCE from 1990 to 2005 by 45%.

Both Safety Kleen and Shield Packaging reduced their sales of TCE-based products to below the reporting threshold by 2005. According to a statement made by Safety Kleen, its use of TCE is wholly dependent on customer demand. Therefore, we can infer that customers have significantly altered their contract degreasing solution choices away from TCE since 1990. Shield Packaging had reported over 20,000 lb of TCE in 2004. It is possible that it may again be reporting TCE as a result of the reduced reporting threshold.

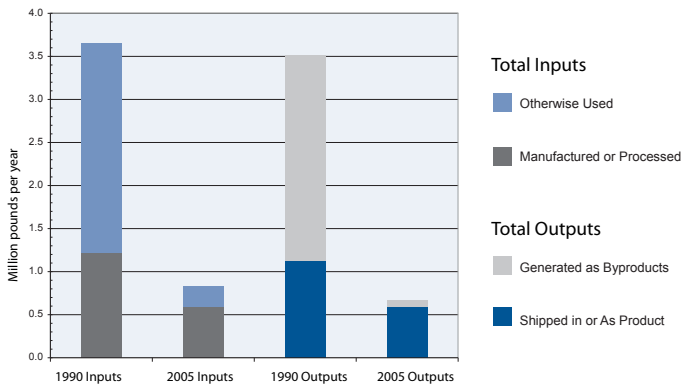
Four chemical distributors, representing over 55% of the total reported use of TCE in Massachusetts, reported processing TCE in 2005, though none reported TCE above the reporting threshold in 1990. These companies repackage TCE for bulk sales to their customers.

According to the company statement provided by one of the companies, Ashland Distribution, "customer demand dictates the amount of TURA chemicals transferred at Ashland's Tewksbury facility. Ashland has been effective in reducing waste generation by implementing process improvements at the facility. While demand for chemical products may increase, thereby increasing the volume of chemicals handled (used) and transferred on site, the company is focused on limiting waste generation and releases. It continues to evaluate potentially viable process enhancements." This statement describes the challenges facing chemical distributors and typical management of their toxic chemicals use.

Summary of Inputs and Outputs

Figure 2 illustrates the change from 1990 to 2005 in inputs and outputs of TCE in Massachusetts. Inputs include TCE that is manufactured or processed, as well as TCE that is "otherwise used" (i.e., ancillary uses that do not become incorporated into the final product). Outputs include TCE that is generated as byproduct (i.e., all non-product material created by a process line prior to release, on-site treatment, or transfer) and the amount of TCE that is shipped in or as product.

Figure 2. Inputs and Outputs of TCE in Massachusetts
1990 – 2005



Both inputs and outputs of TCE were significantly reduced overall

in the Commonwealth from 1990 to 2005. Specifically, from 1990 to 2005 the total input of TCE, including otherwise used, manufactured or processed TCE, was reduced by 77% while the total output of TCE, the amount generated as byproduct, shipped in or as product, over the same time period was reduced by 81%.

(For section references see endnote #2)

Alternatives

TCE is valued for its solvent capacity in adhesive and paint applications, as well as its ability to solubilize contaminants such as oil, grease and buffing compounds on many types and configurations of metal parts. In 2005 almost 90% of the TCE use reported in Massachusetts was as an adhesive or paint solvent. Only approximately 11% of the reported uses in 2005 were associated with degreasing applications, however occupational exposure is a particular concern in this use application.

Alternatives for Adhesive and Paint Applications

Solvent-based adhesives are used in a variety of applications, from upholstered furniture and bedding applications to flexible vinyl mounting applications to substrate lamination applications. Adhesives use a carrier to transport, often in aerosol form, the tackifying resins and polymer solids that bond substrates together.

There are hundreds of adhesive formulations available on the market, many of which use a solvent carrier such as TCE. Typical solvent-based formulations use methylene chloride, acetone, acetone/heptane blends and n-propyl bromide. Each of these solvent-based adhesive formulations has potential human health and/or environmental health impacts that make them questionable alternatives to TCE-based formulations with respect to being "safer". Other solvent adhesive formulations available use mineral spirits, petroleum solvents, petroleum distillates and VM&P naphthas.

However non-solvent based alternatives are available for many applications, including

- Aqueous-based carriers using latex or latex-synthetic blends, and
- Hot melt applications, where a solvent-free 100% solids method is used in adhesion.

TCE is a relatively common carrier used in solvent-based paints. Alternatives include lower solvent content paints containing other solvents, or switching to aqueous-based latex paints. In addition, depending on the application, 100% solids paint processes such as powder coating may be appropriate alternatives.

The TURI lab has created an extensive database of safer alternatives to TCE (and other toxic solvents and cleaners) used for degreasing purposes. This database is available on the TURI lab website at www.cleanersolutions.org.

Alternatives for Degreasing

Over the years, preferred degreasing solvents have included chlorofluorocarbons (CFCs), trichloroethane (TCA), TCE and perchloroethylene (perc). CFCs and TCA were classified as Class I ozone-depleting substances and were phased out under the Clean Air Act in 1990.

For vapor degreasing, key physical properties include: low vapor pressure, low latent heat, low boiling point, low flash point, low surface tension and high solvency powers. TCE is generally used in degreasing operations because of its high boiling point, which allows the solvent to remove soils and waxes that lower-boiling solvents may not. The stability of TCE makes it particularly useful in airless degreasing systems. TCE is also used in "cold" degreasing applications, where the liquid is applied to the contaminant directly.

There are proven alternatives for metal degreasing, including hydrocarbon solvents (e.g., terpenes, alcohols, acetone, ketones, and acetates) and aqueous and semi-aqueous processes, including ultrasonic processing. Performance evaluations conducted by the TURI lab indicate that aqueous degreasing alternatives perform comparably to or better than TCE for a wide variety of contaminants and parts configurations. Resistance to adopting aqueous cleaning continues, however, and is often attributed to the following challenges:

- Reduced efficiency at producing clean and dry parts.
- Inability of the aqueous cleaner to get into small, blind holes. Solvents in the vapor form are more successful at cleaning these hard to reach areas.
- Reluctance to write off sunken capital associated with existing vapor degreasing equipment.

Effective "drop in" solvent alternatives (i.e., solvents that can be used in existing equipment) include n-propyl bromide (nPB), hydrochlorofluorocarbons, hydrofluorocarbons, hydrofluoroethers and volatile methyl siloxanes. These drop-in solvents have purchase costs that range from 3 to 43 times that of TCE on a per gallon basis.

An important consideration in degreasing applications is the need for removal of contaminants. Companies can evaluate their manufacturing operation to identify potential process modifications that would eliminate the need for this cleaning step.

N Propyl bromide (nPB) is closest in cost and performance to TCE, and is frequently chosen as a drop-in substitute for TCE in vapor degreasing. However nPB has been shown to produce severe health effects for workers, affecting both the central nervous and

reproductive systems. California's Proposition 65 lists nPB as a reproductive toxicant.

(For section references see endnote #3)

Regulatory Context

Due to its serious adverse effects on human and environmental health, TCE is subject to many regulations at the state and federal levels.

Federal Environmental Regulations	
EPCRA	Reportable under Toxic Release Inventory Subject to Tier II reporting requirements; Reportable Quantity = 100 lb
CAA	Hazardous air pollutant Vapor degreasers must meet the national emissions standards for halogenated solvents
RCRA	Land disposal of TCE and all chlorinated solvents banned. Waste must be destroyed in incinerators or cement kilns. Characteristic Toxic Hazardous Waste: TCLP Threshold = 0.5 mg/L. Listed Hazardous Waste: U228, F001, F002, F024, F025, K018, K019, K020
CWA	Water Quality Criteria: Based on fish/shellfish and water consumption = 2.5 µg/L; based on fish/shellfish consumption only = 30 µg/L
SDWA	The maximum contaminant limit set for drinking water is 0.005 mg/L
FDA	Maximum permissible level in bottled water = 0.005 mg/L TCE may be used as a solvent in the manufacture of specified foods
Federal Occupational Exposure Limits	
OSHA	Permissible exposure limit (PEL) = 100 ppm Ceiling Concentration = 200 ppm Acceptable Peak Exposure = 300 ppm (5 minutes in any 2 hours)
ACGIH	Recommended threshold limit value - Time-Weighted Average Limit (TLV-TWA) = 10 ppm Threshold Limit Value - Short Term Exposure Limit (TLV-STEL) = 25 ppm
NIOSH	Recommended Exposure Limit (REL) = 25 ppm (as a 10-hour TWA) Immediately Dangerous to Life and Health (IDLH) = 1000 ppm Listed as a potential occupational carcinogen
State Regulations	
Massachusetts	TCE is a designated high hazard substance, with an annual reporting threshold of 1,000 lbs Threshold Effects Exposure Limit 24-hour average: 36.52 µg/m^3 (6.80 ppb) Allowable Ambient Limit annual average: 0.61 µg/m^3 (0.11 ppb)
California	PEL: 25 ppm (135 mg/m^3) Listed as a carcinogen under Proposition 65

(For section references see endnote #4)

Endnotes

Go to TURI's website to view full citations: www.turi.org

1. U.S Department of Health and Human Services, Household Products Database. *Chemical Information, Trichloroethylene*, 2008, and *Third National Health and Nutrition Examination Survey (NHANES III, 1988-1994): Multiply Imputed Data Set*, 2001; National Toxicology Program, *11th Report on Carcinogens: Trichloroethylene*; ATSDR, *Public Health Statement for Trichloroethylene*; Toxicology Data Network Hazardous Substances Data Bank, T*richloroethylene*; ATSDR, *Medical Management Guidelines for Trichloroethylene*; California Department of Health Services Hazard Evaluation System and Information Service, *Fact Sheet: Trichloroethylene;* US EPA, *Ground Water & Drinking Water Consumer Factsheet on: Trichloroethylene*; National Academy Press, *Assessing the Human Health Risks of Trichloroethylene: Key Scientific Issues*, 2006; US EPA Technology Transfer Network Air Toxics Website. *Trichloroethylene;* Toxics Use Reduction Institute, *Policy Analysis, Higher Hazard Substance Designation Recommendation: Trichloroethylene;* Ichihara, et al. *Neurological Disorders in Three Workers Exposed to 1-Bromopropane*, 2002.

2. Chemical Economics Handbook, 2002, 632.3000Y, SRI International; *IARC. Monographs on the Evaluation of the Carcinogenic Risk of Chemicals to Man, 1972;* Halogenated Solvents Industry Association, *Trichloroethylene White Paper,* 2001; Metropolitan Water District of Southern California Environmental Defense Fund, *Source Reduction of Chlorinated Solvents-Textiles Manufacture*. 1991; Toxics Use Reduction Institute TURA Data website, http://turadata.turi.org/

3. International Programme on Chemical Safety and the Commission of the European Communities; WHO; *Environ Health Criteria 50: Trichloroethylene,* 1985; Morris, et al, 2000. *Alternative Adhesive Technologies in the Foam Furniture and Bedding Industries: A Cleaner Technologies Substitutes Assessment. Volume 1: Cost and Performance Evaluation.*

4. Massachusetts Department of Environmental Protection *Revised Air Guidelines*; Mass DEP *Standards and Guidelines for Contaminants in Massachusetts Drinking Waters*, 2007; MassDEP *Maximum Concentration of Contaminants for Toxicity Characteristic;* California Department of Health Services Hazard Evaluation System and Information Service *Fact Sheet: Trichloroethylene;* NIOSH Pocket Guide http://www.cdc.gov/niosh/npg/pgintrod.html; US EPA, *Ground Water & Drinking Water Consumer Factsheet on: Trichloroethylene;* American Conference of Governmental Industrial Hygienists *Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices*, 2005.

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