Toxics Use Reduction Institute

SUMMARY OF POLICY ANALYSIS

Higher Hazard Substance Designation Recommendation:
Trichloroethylene - TCE (CAS 79-01-6)

1. State of the Science

Trichloroethylene (TCE) has both acute and chronic adverse health effects. Acute effects can include dizziness, unconsciousness, irregular heart beat, brain damage, and memory loss. IARC classifies TCE in Group 2A (probably carcinogenic to humans). TCE may also have genotoxic, immunotoxic, and teratogenic effects.

2. Number of facilities affected

The TURA program estimates that the 1,000 pound reporting threshold that would apply to a higher hazard substance would add between 30 and 80 new facilities to the 14 existing facilities that are required to report TCE use. This would include 20 to 60 new filers processing TCE (including it in products such as adhesives and paints) and 10 to 20 new filers otherwise using TCE (primarily for degreasing/cleaning applications). Many of these filers would be new to the program.

3. Opportunities for New Filers

There are many opportunities for new filers to adopt alternatives to TCE.

- For cleaning applications, popular options include aqueous and semi-aqueous systems. Additional options include non-chlorinated solvent systems; mechanical cleaning processes; and emerging technologies such as laser cleaning.

- In some cases, firms can eliminate the need for cleaning/degreasing by redesigning the production process.

- For adhesive formulations, alternatives to TCE include terpenes, water-based adhesives, and solid adhesives. Many alternatives are available for use in paints as well.

The TURA program has helped numerous companies to reduce or eliminate their use of TCE. TURI's Surface Solutions Lab (SSL) has identified viable alternatives for virtually every TCE use. In many instances, the SSL has worked individually with small TCE users that were not required to file under TURA. Based on the program's successes with these small filers, the program will be in a good position to assist new filers.

4. Regulatory context

TCE is regulated under multiple federal statutes. It is a reportable Toxics Release Inventory chemical; is regulated by the National Air Emissions Standards for Hazardous Air Pollutants (NESHAP) for halogenated solvents; and is regulated by OSHA standards in the workplace, among other provisions. California regulates TCE as a carcinogen under Proposition 65. TCE is recognized as a priority

internationally as well, and Sweden has banned TCE for professional use and for use in consumer products.

5. Implications for the TURA program

The TURA program is in a good position to offer services to new filers interested in reducing or eliminating their use of TCE. The program has extensive experience with TCE alternatives, and has a history of working successfully with users on reducing or eliminating use of this chemical.

Toxics Use Reduction Institute

POLICY ANALYSIS

Higher Hazard Substance Designation Recommendation:
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The TURA Science Advisory Board has recommended designating trichloroethylene (TCE) as a higher hazard substance under TURA. With this designation, the reporting threshold for TCE would be lowered to 1,000 lb/year for companies in TURA covered industry sectors with ten or more employees. New companies entering the program under the lower reporting threshold would be required to file annual toxics use reports, pay annual toxics use fees, and develop a toxics use reduction plan every two years. In addition, the TURA program would prioritize TCE in allocating program resources, ensuring that companies receive targeted assistance in reducing or eliminating use of this chemical.

This policy analysis begins by summarizing the scientific information considered by the Science Advisory Board. It then presents available information on companies that are likely to enter the program as a result of the lower reporting threshold; analyzes opportunities and challenges that are likely to face new filers as they enter the program; and discusses the implications of this policy measure for the TURA program. Based on this analysis, the Toxics Use Reduction Institute supports the SAB's recommendation that TCE be designated as a higher hazard substance.

1. State of the Science[1]

For a list of specific data examined by the Science Advisory Board in developing its recommendation, see Appendix A.

Acute toxicity

- The primary acute effects of TCE are on the central nervous system, kidney, and liver. Inhalation of TCE can cause dizziness, unconsciousness, an irregular heart beat, brain damage, and memory loss. At exposure levels around 1,000 ppm, TCE can be lethal.

Chronic toxicity

- The International Agency for Research on Cancer (IARC) classifies TCE in Group 2A (probably carcinogenic to humans). TCE also has genotoxic and immunotoxic potential, and some studies indicate that it may be a teratogen and may cause permanent central nervous system damage after long-term exposure.

Uncertainty

- Substantial information is available regarding both acute and chronic health effects of TCE. Uncertainty does not play a significant role in the development of our recommendations for this chemical.

2. Number of facilities affected

TCE is used as a solvent in industries including electroplating, metal products, machinery manufacturing and repair, paper, pulp, and rubber manufacture, semiconductor production, and auto maintenance. It is also used as an ingredient in some consumer products and pesticides. Historically, consumer products containing TCE have included aerosol paints, sealants, lubricating oils, automotive chemicals, laundry aids, specialty cleaning products, paint and varnish removers, synthetic resin and rubber adhesives,[2] adhesives used in hobby and craft applications,[3] and spot cleaners for dry cleaning. Use of TCE is on the decline due both to regulatory requirements and to the identification of viable alternatives.

The TURA program estimates that 30 to 80 new filers may enter the program with the lower reporting threshold. This would include 20 to 60 filers processing TCE (including it in products such as adhesives and paints) and 10 to 20 otherwise using TCE (primarily for degreasing/cleaning applications). Many of these filers would be new to the program. Below, we review the information we took into account in developing this estimate.

a. Historical data on sectors using TCE in Massachusetts

Historically, TCE has been primarily reported under TURA by the following sectors:

2261	Finishing plants, cotton
2269	Finishing plants
2782	Blankbooks and looseleaf binders
2842	Polishes and sanitation goods
2851	Paints and allied products
2869	Industrial organic chemicals
2891	Adhesives and sealants
2899	Chemical preparations
3061	Mechanical rubber goods
3069	Fabricated rubber products
3221	Glass containers
3264	Porcelain electrical supplies
3351	Copper rolling and drawing
3356	Nonferrous rolling and drawing
3421	Cutlery
3451	Screw machine products
3469	Metal stampings
3471	Plating and polishing
3479	Metal coating and allied services
3499	Fabricated metal products
3545	Machine tool accessories
3643	Current-carrying wiring devices
3644	Noncurrent-carrying wiring devices
3645	Residential lighting fixtures
3671	Electron tubes
3674	Semiconductors and related devices
3675	Electronic capacitors
3678	Electronic connectors
3679	Electronic components
3695	Magnetic and optical recording media
3714	Motor vehicle parts and accessories
3724	Aircraft engines and engine parts
3728	Aircraft parts and equipment
3822	Environmental controls
3823	Process control instruments
3829	Measuring and controlling devices
3911	Jewelry, precious metal
3961	Costume jewelry
3999	Manufacturing industries
5169	Chemicals and allied products
7389	Business services

b. Current data on TCE use in Massachusetts

As of 2004, the most recent year for which data are available, there were 14 TURA filers reporting use of TCE. Among these filers, those in sectors 28xx and 30xx use TCE as part of their formulations (i.e. these facilities "process" TCE). Those in the other SIC codes are listed as “otherwise using” TCE, indicating that they use it for cleaning/degreasing operations.

c. Estimate of new filers processing TCE

Using the information available from past and current TURA filers, the TURA program used the following additional information to estimate the number of potential new filers processing TCE.

- The sectors most likely to be processing TCE are in SIC codes 28 (chemicals and allied products) and 30 (rubber and miscellaneous plastics products).
- A trade association representative indicated that TCE use in these sectors is uncommon due to regulatory requirements and the use of other chemicals.
- EPA’s TIER II database and the MassDEP’s Hazardous Air Pollutants database show few potential new filers.
- OTA staff estimate that the sectors most likely to still be processing TCE are 2899 (Chemical Preparations), 2851 (Paints and Allied Products), 2842 (Polishes and Sanitation Goods), and 2869 (Industrial Organic Chemicals).

Based on this information, we estimate there would be between 20 and 60 potential new filers processing TCE.

d. Estimate of new filers “otherwise using” TCE for cleaning/degreasing

In principle, there is a large universe of potential filers “otherwise using” TCE, primarily for cleaning/degreasing. However, the TURA program has made extensive efforts in the past to locate facilities using TCE for cleaning/degreasing below the existing reporting threshold, and has located very few. The program took the following information into account in developing an estimate for this category of potential new filers:

- In 2004, TURI and OTA received an EPA grant to locate small users of TCE for cleaning. TURI and OTA developed a list of 273 Massachusetts firms that could possibly use TCE for cleaning, based on their industry classification. Information packets were sent to these facilities, and follow-up calls were made. From these activities, only four TCE users were identified. This experience suggests that most facilities that could potentially be using TCE for cleaning are actually using other chemicals.
- A recent project has identified several very small users of TCE in Rhode Island. There is a potential for similar use in Massachusetts. However, some may use over 1,000 lb/year but have fewer than 10 employees, while others may have more than 10 employees but use fewer than 1,000 lb/year. Few are likely to meet both requirements.
- Based on their professional experience, OTA and TURI laboratory staff estimate that the following sectors are most likely to be affected: 2396 (Automotive and Apparel Trimmings), 3471 (Plating and Polishing), 3599 (Industrial Machinery,NEC), 3911 (Jewelry, precious metal).

Based on this information, we estimate that 10 to 20 facilities may be "otherwise using" TCE for various purposes, primarily cleaning, and would be required to report TCE use under the lower reporting threshold.

e. Combined estimate

Combining the estimates above, we estimate that a total of 30 to 80 new TCE filers would enter the program under the lower reporting threshold. This includes 20 to 60 filers processing TCE, and 10 to 20 otherwise using TCE. Many of these filers would be new to the program.

3. Opportunities for New Filers

Feasible alternatives are available for most uses of TCE. In some cases, facilities have achieved financial as well as health and environmental benefits when they have made the transition from TCE to a safer alternative. In the discussion below, we briefly review trends among current TURA filers that report TCE use. We then consider the known alternatives for some of the most common industrial uses of TCE, and discuss lessons learned from the Institute's work with small TCE users in both Massachusetts and Rhode Island.

a. Trends among current TURA filers

TCE use reported under TURA has decreased dramatically since the program's inception. In 1990, 41 TURA filers reported TCE use; by 2004, only 14 reported TCE use.

In 1990, facilities reporting under TURA used 3.65 million pounds of TCE. In contrast, by 2004, the latest year for which data are available, facilities used about 1.1 million pounds. Thus, there has been a 70% reduction in TCE use from 1990 to 2004.

Massachusetts TCE Data:
Used and Released in 1990 and 2004

	Year		Change (lbs)	% Change
	1990	2004		
TCE used (lbs)	3,651,227	1,085,571	-2,565,656	-70%
TCE Released (lbs)	1,309,690	87,714	-1,221,976	-93%

The downward trend in TCE use among TURA filers is evidence that feasible options exist for reducing or eliminating use of TCE, and that many Massachusetts facilities are taking advantage of these opportunities.

b. Opportunities to reduce TCE use

TUR planning can be used to identify opportunities to reduce total use of TCE. For example, facilities using TCE as a vapor degreasing agent can shift to closed loop vapor degreasing as a way to minimize TCE losses during the cleaning process. Equipment upgrades and improved housekeeping practices can also help to reduce total TCE use. In addition, complete substitution of TCE is viable in most cases. Alternatives include both material substitutions and process changes.

i. Alternatives for cleaning

Many alternatives to TCE are available for cleaning applications. They have been evaluated extensively by TURI's Surface Solutions Laboratory (SSL). The two most popular options are aqueous and semi-aqueous systems. Advantages of these alternatives include the fact that workers are not exposed to solvents; less hazardous solid waste is produced; and the need for emission control is eliminated. Other alternatives include non-chlorinated solvent systems; mechanical cleaning processes, such as abrasive blasting; and other emerging cleaning technologies, such as laser cleaning.[4]

The SSL assists companies in finding cost effective alternatives to solvent cleaning systems while maintaining product quality. In one example, a Massachusetts precision machine shop replaced a TCE vapor degreaser by installing an aqueous ultrasonic system to remove silicon carbide lapping oil (a metal-working fluid) from parts. While the aqueous cleaning process required more time to clean the parts, this was acceptable to the company and the quality of the cleaning was equal to that of the vapor degreasing process.[5]

Another alternative is to redesign the production process to eliminate the need for cleaning/degreasing. This may be accomplished by redefining cleanliness specifications, eliminating the process step that results in a dirty part, or changing the nature of the oils and other contaminants that must be cleaned off (for example, by using vanishing machining oils). In the electronics industry, TCE is often used to remove flux (chemicals used to facilitate soldering). Fluxless, low-flux and water-soluble flux systems are available which can eliminate or alleviate the need for a solvent to remove flux.[6]

ii. Alternatives for adhesive formulations and paints

Alternatives to TCE in adhesive formulations include terpenes, water-based adhesives, and solid adhesives. The costs and benefits of making these conversions are difficult to generalize because each adhesive use is unique. Industry contacts have indicated that many alternatives exist for paints as well, and that many former users no longer use TCE.

iii. TCE alternatives: Case studies of TURA filers

The Office of Technical Assistance has documented several case studies of TURA filers that have successfully reduced their use of TCE. In some cases, the facilities achieved financial savings in the process. Examples include the following:

- Inner-Tite Corporation, a manufacturer of anti-theft devices, "replaced its existing parts degreasing equipment with two entirely enclosed Forenta® degreasing units." As a result, the company was able to reduce air emissions of TCE by 97%, and achieved significant financial savings. [7]
- V.H. Blackinton, a manufacturer of metal uniform insignia, jewelry, and other metal plated items, eliminated TCE by adopting an aqueous cleaning system. Through this and other changes, the facility was able to stop reporting under TURA, and achieved financial savings "on chemical purchases and disposal cost, regulatory reporting, permitting and monitoring, and water and sewer use charges."[8]

iv. TCE alternatives: Laboratory work with individual companies

The Toxics Use Reduction Institute has been extensively involved in analyzing TCE alternatives for surface cleaning operations. These analyses have helped companies to select the most effective TCE alternative for their specific applications. Specifically, the SSL has worked to identify alternatives for the following applications, among others:

- Abrasive cleaning for ceramics parts for a company that manufactures parts for the semi-conductor industry.
- Buffing compound removal for brass and some silver parts for a metal working shop and a light manufacturer.
- Coatings cleaning for steel surfaces for a tool manufacturing company.
- Grease removal for two industry types, a musical instrument manufacturer and a tool maker.
- Oil removal for parts made from steel, carbon steel, stainless steel, aluminum, brass and ceramics.
- Cleaning of aluminum, brass, ceramics, copper, glass and steel surfaces in the electronics and metal working sectors.
- Flux removal for a company manufacturing brass bellows.
- Paint/ink cleaning for a ceramic capacitor/electronics manufacturer and a tool making company.

In all, the Institute has worked with 42 companies on 45 projects related to TCE reduction or replacement. Of these projects, 39 involved testing TCE alternatives in the laboratory. Of those 39 projects that involved testing, 16 have made changes (41%).

Most of these companies were small, and were not TURA filers. Thus, the Institute's experience with this group is likely to be indicative of the prospects for successful identification and adoption of alternatives among new filers entering the program with the lower reporting threshold.

v. TCE alternatives: Small users in Rhode Island

In 2006, EPA Region 1 identified about 30 small firms using TCE in Rhode Island, and collaborated with TURI to provide training for these firms on safer alternatives.

Working with EPA, the SSL conducted a one-day hands-on training workshop in which staff showed companies how to use TCE alternatives appropriate for their specific needs. After the workshop, the TURI Lab continued to work with a subset of the companies that attended.

From September 2006 through April 2007, half of the identified companies in Providence area using TCE participated in the hands-on-training workshop. Half of the original attendees from the workshop have participated in pilot projects. Many of these have eliminated, or plan to eliminate, TCE in their facilities.

The Rhode Island experience offers lessons for Massachusetts. In particular, the workshops indicated that smaller TCE users can benefit significantly from on-site training and assistance in identifying and evaluating alternatives. Because there is no single substitute that will work best for each company, process-specific testing and verification is important to achieving success.

c. Implementation: opportunities and challenges

New filers entering the TURA program due to the lower reporting threshold may face some challenges in taking advantage of the opportunities outlined above.

i. Limitations due to financing or contractor specifications

Small users could face financial limitations if they wish to purchase new equipment to reduce or replace TCE use. In some instances, the cost of some alternatives can appear initially to be cost prohibitive, although they may offer financial advantages when considered over their full life cycle. Grants and loans for capital investments may be useful to assist those facilities that are interested in upgrading their equipment as part of their TUR efforts.

In some cases, military specifications may call for use of TCE as a cleaner. In these instances, facilities may have to work with the supply chain to change the specifications before shifting away from TCE use. This has been done successfully by some Massachusetts facilities.

ii. OTA barriers analysis

In 2005, the Office of Technical Assistance published the results of a survey on barriers to substituting chlorinated solvents.[9] The information presented in this report is a useful resource in assessing the opportunities and challenges associated with providing services to TCE users. Relevant findings in the report include the following:

- Of the facilities that responded to OTA's survey, the majority that had reduced their use of chlorinated solvents such as TCE had done so by "upgrading to more efficient vapor degreasing systems."
- Motivators for change included opportunities for cost savings, and improved environmental health and safety.
- Barriers to change included concerns about quality, and costs.
    - Technical barriers included ineffective cleaning that left residues either of the original soil or of the cleaning material itself; difficulty cleaning specific geometries; and increased drying time. "In addition, the wide variety of oil residues on product could not be universally cleaned using a single alternative product. Some companies reported that solvents such as TCE are still the only degreasing solvent that met all of their cleaning needs."
    - Some facilities were concerned about the cost of capital expenditures required to reduce or eliminate solvent use. On the other hand, facilities that had made those investments reported that the up-front cost " was quickly offset by reduced operating costs."
- The survey also provided indications of which types of services would be most useful to facilities still using TCE.
    - Facilities "reported needing continued assistance in evaluating alternative cleaning technologies."
    - The report suggests that companies that have successfully reduced or eliminated solvent use may be helpful in educating those companies that have not yet made the switch.
    - "Virtually all participants expressed interest in a state sponsored grant or low interest loan program to finance their investigation into chlorinated solvent alternatives."
    - The report points out that facilities using larger amounts of chlorinated solvents are subject to significant regulatory, waste management, and in some cases remediation costs, and thus have more motivation to investigate alternatives or reduction options, compared with those using smaller quantities. The report also points out that facilities may be more willing to consider TUR options

when they are undertaking a larger capital project of which new equipment for TUR forms a smaller part. This suggests that it may be particularly useful to seek and maintain contact with facilities when they are moving to a new location, upgrading equipment, or engaging in other capital investments.

iii. Users that will remain under the reporting threshold

The lower reporting threshold will help to extend the services of the TURA program to a larger number of TCE users. However, it will also be important to consider options for extending program services to small users that remain under the reporting threshold, either because their TCE use is less than 1,000 lb/year, or because they have fewer than ten employees. For example, there may be small TCE users in Massachusetts similar to those that were targeted in the successful Rhode Island program discussed above. It may be useful to collaborate with US EPA in working to identify and extend services to these very small TCE users.

4. Regulatory Context

TCE is regulated throughout its lifecycle: in the type of uses allowed, in the workplace, in its release to the environment from workplaces, and in its disposal. Because of its toxicity, many uses of TCE are forbidden in the US.[10] For a glossary of regulations referred to in this section, see Appendix B.

EPCRA	• Reportable TRI chemical[11] • Subject to US EPA Tier II reporting requirements[12]
CAA	• Hazardous air pollutant • Emissions standards under National Air Emissions Standards for Hazardous Air Pollutants: Halogenated Solvent Cleaning[13]
RCRA	• Hazardous waste[14]
Occupational exposures	• OSHA: 100 ppm TWA-PEL[15] • ACGIH recommends TWA-TLV of 10 ppm[16] • NIOSH TWA-REL is recommended set at the "lowest concentration feasible"[17]
SDWA	• MCL in drinking water is 0.005 mg/L[18]
CWA	• Hazardous substance[19]
FDA	• Regulated as an indirect food additive; subject to tolerable residue allowances in some food products[20].

Massachusetts: Occupational	• Subject to Right-to-Know requirements[21]
Massachusetts: Environmental & Public Health	• 24-hour acceptable ambient air exposure limit for TCE is 6.80 ppb; annual acceptable exposure limit is 0.11 ppb.[22] • Drinking water standard (acceptable daily intake over a lifetime exposure) is 0.005 mg/L (identical to the MCL at the federal level, under SDWA).[23]

Other state regulations of interest:

- Several states have also developed their own ambient air quality and drinking water standards and/or guidelines for TCE[24].
- TCE is regulated as a carcinogen under California's Safe Drinking Water and Toxics Enforcement Act of 1986 (Proposition 65).[25]
- "Sale of automotive repair products containing perchloroethylene, methylene chloride, or trichloroethylene are prohibited in California, effective as of June 2001; use is prohibited, effective as of December 2002."[26]

International:

- Canada: TCE is on Priority List 1 of the Domestic Substances List categorization.[27]
- Europe: TCE has been listed among First Priority Existing Chemicals (out of 4 Priority lists totalling 141 substances) under the Existing Substances Regulation.[28] These priorities are also reflected in the new European chemicals policy, REACH. TCE is also on the Consolidated Version of Annex I of Directive 76/769/EEC, as a result of being a probable human carcinogen.[29] As a result of this directive, TCE is restricted from being used in consumer available preparations, such as adhesives.
- WHO: The World Health Organization has derived a recommended drinking water guideline of 30 mg/L and a time weighted average occupational exposure limit of 135 mg/m^3 [30].
- In 1991, Sweden passed legislation banning the professional use of TCE, effective as of January 1996. Sweden also banned the use of TCE in consumer products in 1993.[31]

Replacing TCE: Case Studies from Sweden

The Swedish company **SKF** produces ball bearing components, which pose particular challenges due to their shape and size. SKF eliminated TCE use by adopting a number of changes, including "new degreasing processes that used water and (low-aromatic) oils"; changes in packaging and storage practices; and "use of lighter oils for conservation of ball bearings instead of wax, whose removal required TCE as a solvent."[32]

The Swedish company **Exact Springs,** a firm with 40 employees, manufactures metal springs for use in door locks, staplers, and electric switches. In 1996, this facility began exploring options to eliminate TCE for cleaning springs. Through simple changes in the production process, the facility was able to convert to a system in which springs no longer required cleaning. In addition to improving its environmental profile, the firm achieved financial benefits through this and other changes.[33]

5. Implications for the TURA program

The TURA program is in a good position to offer services to new filers interested in reducing or eliminating their use of TCE. As detailed in the sections above, the program has extensive experience with TCE alternatives, and has a history of working successfully with users on reducing or eliminating use of this chemical.

There would be some additional cost to companies that would begin reporting TCE based on a lower reporting threshold, including preparing annual toxics use reports and biennial toxics use reduction plans, and paying toxics use fees. The average base fee paid by TURA filers in 2006 was $3,425. However, most new filers for TCE are likely to be facilities with less than 50 employees. The base fee for this size facility

is $1,850. Some filers would not be new to the program and already pay a base fee, but would begin to pay a per chemical fee of $1,100.

Thus, the additional cost in fees to filers (and revenue to the program) could range from $88,500 (30 small companies reporting TCE only) to $362,000 (80 average sized companies reporting TCE only). If some of the facilities that begin filing for TCE under the lower reporting threshold are already TURA filers, there would be less cost to these filers since they already pay a base fee.

6. Summary

TCE is recognized as a priority toxic chemical, and is regulated heavily, at the state, national, and international levels; in Sweden, TCE is banned for both professional use and use in consumer products. TCE alternatives are well understood and widely available. Both the Office of Technical Assistance and the Toxics Use Reduction Institute have extensive experience working with individual facilities to reduce TCE use and identify viable TCE alternatives. Thus, the program is in an excellent position to extend its services to a broader range of TCE users.

Appendix A: Data the SAB considered for TCE

International Agency for Research on Cancer (IARC)	Group 2A (probable human carcinogen)
PBT Profiler:	
Half life in water	38 days
Half life in soil	75 days
Half life in sediment	340 days
Half life in air	6.7 days
Bioconcentration factor	15
ATSDR Minimum Risk Level: acute inhalation	2 ppm
ATSDR Minimum Risk Level: acute oral	0.2 mg/kg/day

Appendix B: Glossary of Regulatory Terms

ACGIH	American Conference of Governmental Industrial Hygienists
CAA	Clean Air Act
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CWA	Clean Water Act
EPCRA	Emergency Planning and Community Right to Know Act
FDA	Food and Drug Administration
MCL	Maximum Contaminant Level
NIOSH	National Institutes of Occupational Safety and Health
OSHA	Occupational Safety and Health Administration
RCRA	Resource Conservation and Recovery Act
SARA	Superfund Amendments and Reauthorization Act
SDWA	Safe Drinking Water Act
Tier II	Chemical inventory reporting requirements for facilities subject to EPCRA
TRI	Toxic Release Inventory
TWA-PEL	Time-weighted average - Permissible Exposure Limit
TWA-REL	Time-weighted average – Recommended Exposure Limit
TWA-TLV	Time-weighted average - Threshold Limit Value

[1] Massachusetts Toxics Use Reduction Institute, "Massachusetts Chemical Fact Sheet: Trichloroethylene (TCE); Hazardous Substances Data Bank (HSDB), a database of the National Library of Medicine's TOXNET system, available at http://toxnet.nlm.nih.gov/.

[2] Scorecard: The Pollution Information Site, available at http://www.scorecard.org/.

[3] National Institutes of Health and National Library of Medicine, Household Products Database, available at http://householdproducts.nlm.nih.gov/, viewed September 2007.

[4] Massachusetts Toxics Use Reduction Institute, "Massachusetts Chemical Fact Sheet: Trichloroethylene (TCE).

[5] Massachusetts Toxics Use Reduction Institute, "Massachusetts Chemical Fact Sheet: Trichloroethylene (TCE).

[6] Massachusetts Toxics Use Reduction Institute, "Massachusetts Chemical Fact Sheet: Trichloroethylene (TCE).

[7] Office of Technical Assistance (OTA) Case Study, "Inner-Tite Corporation Toxics Use Reduction Case Study: Closed-Circuit Degreaser and Other Changes Improve Environmental Health, Safety," December 2001, available at http://www.mass.gov/envir/ota/publications/cases/inner_tite_case_study.pdf.

[8] Office of Technical Assistance (OTA) Case Study, "V.H. Blackinton & Co. Toxics Use Reduction Case Study: Halogen Solvent Elimination, Chemical Reduction, and Zero Discharge," updated January 2003, available at http://www.mass.gov/envir/ota/publications/cases/vh_blackinton_case_study.pdf.

[9] SAK Environmental, *Report of Findings: Barriers to Eliminating Chlorinated Solvent Use in Cleaning Operations at Massachusetts Manufacturers*. Report prepared for Massachusetts Office of Technical Assistance, December 2005, available at http://www.mass.gov/envir/ota/publications/pdf/barriers_to_tce_reductions_final_2006.pdf.

[10] Massachusetts Toxics Use Reduction Institute, "Massachusetts Chemical Fact Sheet: Trichloroethylene (TCE).

[11] United States Environmental Protection Agency, Toxics Release Inventory, www.epa.gov/tri/chemical/RY2005ChemicalLists

[12] Massachusetts Department of Public Safety, State Emergency Response Commission (SERC), Policy Position, Policy #1, http://tinyurl.com/283vdh

[13] *Federal Register* 40 CFR Part 63 (Subpart T): National Air Emissions Standards for Hazardous Air Pollutants: Halogenated Solvent Cleaning. Available at http://www.epa.gov/ttn/atw/degrea/fr03my07.pdf.

[14] Hazardous Substances Data Bank (HSDB), a database of the National Library of Medicine's TOXNET system, http://toxnet.nlm.nih.gov, click on HSDB and enter CAS number Environmental Standards & Regulations, "RCRA Requirements"

[15] Agency for Toxics Substances and Disease Registry (U.S. Centers for Disease Control and Prevention), Toxicological Profiles: Trichloroethylene, www.atsdr.cdc.gov/toxprofiles/tp19-c7.pdf
[16] Agency for Toxics Substances and Disease Registry (U.S. Centers for Disease Control and Prevention), Toxicological Profiles: Trichloroethylene, www.atsdr.cdc.gov/toxprofiles/tp19-c7.pdf
[17] Agency for Toxics Substances and Disease Registry (U.S. Centers for Disease Control and Prevention), Toxicological Profiles: Trichloroethylene, www.atsdr.cdc.gov/toxprofiles/tp19-c7.pdf
[18] Agency for Toxics Substances and Disease Registry (U.S. Centers for Disease Control and Prevention), Toxicological Profiles: Trichloroethylene, www.atsdr.cdc.gov/toxprofiles/tp19-c7.pdf
[19] Agency for Toxics Substances and Disease Registry (U.S. Centers for Disease Control and Prevention), Toxicological Profiles: Trichloroethylene, www.atsdr.cdc.gov/toxprofiles/tp19-c7.pdf
[20] Agency for Toxics Substances and Disease Registry (U.S. Centers for Disease Control and Prevention), Toxicological Profiles: Trichloroethylene, www.atsdr.cdc.gov/toxprofiles/tp19-c7.pdf
[21] Massachusetts Division of Occupational Safety, Massachusetts "Right-to-Know" Law (MGL 111F), Workplace Regulation (454 CMR 21.00), www.mass.gov/dos/rtk/index.htm
[22] Massachusetts Department of Environmental Protection, Revised Air Guidelines, www.mass.gov/dep/air/aallist.pdf
[23] Massachusetts Department of Environmental Protection, "Standards and Guidelines for Contaminants in Massachusetts Drinking Waters" (Spring 2007), available at http://www.mass.gov/dep/water/dwstand.pdf
[24] Agency for Toxics Substances and Disease Registry (U.S. Centers for Disease Control and Prevention), Toxicological Profiles: Trichloroethylene, www.atsdr.cdc.gov/toxprofiles/tp19-c7.pdf
[25] California Office of Environmental Health Hazard Assessment, Proposition 65 The Safe Drinking Water and Toxic Enforcement Act of 1986, www.oehha.ca.gov/prop65/prop65_list/files/060107LST.pdf
[26] See http://www.arb.ca.gov/regact/amr/finreg.pdf.
[27] The Canadian Environmental Network, Canadian Environmental Protection Act (CEPA) Priority Substances, Priority List 1, www.ec.gc.ca/CEPARegistry/subs_list/PSL1.cfm.
[28] European Chemicals Bureau, European chemical Substances Information System (ESIS), http://ecb.jrc.it/esis/index.php?PGM=ora, select "1st Priority List"
[29] Council Directive on the Approximation of the Laws, Regulations and Administrative Provisions of the Member States Relating to Restrictions on the Marketing and Use of Certain Dangerous Substances and Preparations (76/769/EEC). Available at http://ec.europa.eu/enterprise/chemicals/legislation/markrestr/01976L0769_2006_1230_consolidated.pdf.
[30] Agency for Toxics Substances and Disease Registry (U.S. Centers for Disease Control and Prevention), Toxicological Profiles: Trichloroethylene, www.atsdr.cdc.gov/toxprofiles/tp19-c7.pdf
[31] Daniel Slunge and Thomas Sterner, "Implementation of Policy Instruments for Chlorinated Solvents: A Comparison of Design Standards, Bans, and Taxes to Phase Out Trichloroethylene." Report by Resources for the Future, Washington, D.C., September 2001 (Discussion Paper 01-32), p. 6. Available at http://www.rff.org/documents/RFF-DP-01-32.pdf.
[32] Slunge and Sterner 2001.
[33] Rachel Massey, *Building a Healthy Economy: Chemicals Risk Management as a Driver of Development*, Swedish Chemicals Inspectorate (KemI) Report No. 2/05, September 2005), available at http://www.ase.tufts.edu/gdae/Pubs/rp/KemiReport_05.pdf.