Massachusetts Toxics Use Reduction Institute
TUR and Disease Prevention Fact Sheet

ASTHMA

This fact sheet is part of a series developed by the Toxics Use Reduction Institute (TURI) to help Massachusetts companies and communities better understand the opportunities to prevent disease through toxics use reduction. TURI supports disease prevention efforts by helping companies and communities reduce their use of toxic chemicals and by promoting the development and adoption of safer alternatives.

Asthma: What Is It?

Asthma is a chronic lung disease that results from a complex interplay between environmental and genetic factors. Common symptoms of asthma include recurrent periods of:

- wheezing
- coughing
- chest pain or tightness
- difficulty breathing
- breathlessness

Once asthma develops, the airways of the lungs become more responsive to a variety of stimuli. If asthma is left untreated, the resulting inflammation may lead to irreversible changes in the structure of the lungs.

The Prevalence and Costs of Asthma

Asthma is a pressing public health problem. In 2009, over 24 million people in U.S. reported currently having asthma.[1] In 2007, the annual economic cost of asthma in the U.S. was $56 billion. Direct health care costs such as prescriptions; physician services; and inpatient, outpatient, and emergency room visits amounted to $50.1 billion while indirect costs (lost productivity from workers or their children being sick with asthma as well as productivity losses from mortality due to asthma) contributed an additional $5.9 billion.[2]

Asthma in Massachusetts

Asthma rates in Massachusetts communities are among the highest in the nation, causing a substantial societal burden of human suffering, lost capacity and productivity as well as direct fiscal costs. In 2010, 10.4% of adults reported that they “currently have” asthma.[3] During the 2007/2008 school year, 10.9% of children grades K-8 had asthma.[4] Total hospitalization costs due to asthma in Massachusetts increased 78%, from $50 million in 2000 to $89 million in 2006.[5]

Initial Onset Versus Exacerbation

According to the Association of Environmental and Occupational Clinics, as well as prominent reviews of the scientific literature, hundreds of chemicals can contribute to the initial development of asthma.[6,7] Much of this evidence comes from peer-reviewed literature about workers exposed in the workplace. However, exposure to chemicals may contribute to the asthma burden in communities as well.[8,9]

Preventing exposure to chemicals associated with asthma is a form of **primary prevention**: preventing healthy people from developing the disease in the first place. In order to identify primary prevention opportunities, it is important to distinguish between what can cause the *initial onset* of asthma and what can *exacerbate* existing asthma. Once a person has asthma, reducing or eliminating exposure to agents that can trigger asthma attacks is crucial to preserving lung function and improving overall health.

Initial onset. Asthma initially develops through a complex process with multiple contributing factors, including:

- dose, duration of exposure and the physiochemical characteristics of a causal agent
- physiologic status at the time of exposure
- previous exposure to other risk factors for the disease
- genetic factors

Chemicals are among the exposures that can contribute to the initial onset of asthma.

Exacerbation. Chemicals can also cause exacerbations of asthma symptoms (asthma attacks or episodes) in people who already have the disease. Asthma exacerbations can be triggered by exposure to the same agent(s) that originally caused the initial symptoms of the disease, or by exposure to a range of additional agents. Frequent asthma exacerbations result in worsening lung function.

Two Types of Asthma Onset: Allergic and Irritant

There are two common classifications for the initial onset of asthma, which reflect differing exposures and pathologic mechanisms: (1) allergic asthma and (2) non-allergic (irritant) asthma.

1. **Allergic asthma** is characterized by exposure to a **respiratory sensitizer**, though the initial exposure does not produce symptoms. The resulting asthma may develop within a few hours or days, weeks or even years after the initial exposure. Frequently, people with allergic asthma also have a family history of asthma, rhinitis (runny

nose), eczema and urticaria (hives). Sensitizers that cause allergic asthma include chemicals found in the workplace, such as diisocyanates, as well as some environmental allergens such as cockroaches and dust mites. These substances and other common environmental allergens such as animal dander, pollen, and mold can trigger subsequent asthma attacks, even with very low levels of exposure. Inhalation exposure is the principal route of respiratory sensitization, but evidence suggests that dermal exposure to some sensitizers, including some diisocyanates, can also result in respiratory sensitization and associated asthma.[10]

2. **Non-allergic (irritant) asthma** is a subset of new-onset asthma that does not result from an allergic sensitization response. Non-allergic asthma presents the same symptoms as allergic asthma, but unlike allergic asthma, the symptoms are caused by exposures to an irritant. **Reactive Airways Dysfunction Syndrome (RADS)** is a subset of non-allergic asthma generally caused by a one-time, high-level exposure to an irritant.[11]

For both allergic and non-allergic asthma, individual responses to specific substances are highly variable. A given exposure may trigger asthma in one person and not in another. Some individuals may respond to a few agents and others may respond to many agents. The response of some individuals may be mild, while the response of others may be life-threatening. Asthma symptoms may occur immediately, hours or even days after the exposure depending on the substance and how an individual responds.

Work-related asthma—asthma caused or exacerbated by exposures at work—is common. In a recent survey of Massachusetts residents, 40% of adults with current asthma reported their disease was caused or made worse by exposures at either a current or previous job.[12] Further, over 5% reported changing or quitting jobs because of their work-related asthma.[13] Given the proportion of workers who identify problems associated with work, and the risk of job loss, it is crucial to identify the exposures.

Common work-related exposures associated with asthma in Massachusetts are noted in Table 1. Cleaning products were the most frequently reported exposure associated with work-related asthma (13.2% of cases reported). Of the confirmed work-related asthma cases reported from 1995-2008, 23.2% were among those working in the manufacturing industries. The majority of cases (52%) worked within service industries, such as healthcare and education.[14]

Table 1. Most Frequently Reported Exposures Among Confirmed Cases of Work-related Asthma in Massachusetts, 1995-2008(1,184 Cases Reported)[15]

EXPOSURE	% New-Onset Asthma	% RADS	% Work-Aggravated Asthma	% TOTAL
Cleaning Products	11.0	22.3	14.7	13.2
Indoor Air Quality	13.7	7.4	14.1	13.0
Dust, Fibers & Talcs	12.3	8.8	14.7	12.2
Chemicals, unspecified	7.6	13.5	9.2	8.9
Mold	7.7	1.4	9.2	7.0
Solvents	5.4	9.5	4.9	5.8
Products of Combustion	4.1	5.4	6.0	4.6
Isocyanates	4.0	2.0	0.0	3.0
Latex	3.6	0.7	2.2	3.0
Formaldehyde & Glutaraldehyde	3.0	0.0	1.1	2.3
Metals	3.0	1.4	1.1	2.4
Paints & Lacquers	2.2	0.7	2.7	2.2
Acids & Bases	1.8	6.1	0.5	2.1
Plastics & Other Polymers	1.8	2.0	1.6	1.8
Other	18.6	18.9	17.9	18.5
Total	100.0	100.0	100.0	100.0

Asthma-Related Chemicals

A wide variety of chemicals are associated with asthma. Table 2 shows TURI's master list of asthma-related chemicals that are reportable under the Massachusetts Toxics Use Reduction Act (TURA). TURI has worked with researchers to compile this list from a number of authoritative sources. (Note that the Material Safety Data Sheet (MSDS) for a given product may not list asthma in its hazard identification sections, especially for chemicals associated with non-allergic asthma).

TURA Data: Revealing Asthma Prevention Opportunities

TURA data are useful for revealing trends regarding general industry uses and releases of asthma-related chemicals. Facilities are subject to TURA reporting and planning requirements if they use more than a specified amount of a toxic or hazardous substance per year (25,000 lbs for manufacturing or processing; 10,000 lbs for "otherwise using;" 1,000 lbs for substances designated as Higher Hazard Substances under TURA; or lower amounts for persistent bioaccumulative toxics [PBTs]); are within specified industry sectors; and have ten or more full-time employee equivalents.

TURA data can help identify specific opportunities for toxics use reduction activities and their associated asthma prevention opportunities among those facilities reporting to the TURA program. However, additional data are needed to better understand asthma prevention needs and opportunities among small companies, low-quantity industrial users of asthma-related chemicals, and sectors not required to report to TURA, such as the health care and construction industries.

Table 2. Asthma-Related Chemicals Reportable under the Toxics Use Reduction Act

CHEMICAL NAME	SYNONYM	CAS NUMBER	TURA Reportable Category (If Applicable)	STRENGTH OF EVIDENCE (SOURCE*)
1,1-dichloroethane		75-34-3		Good (CHE)
Acephate	Orthene	30560-19-1		Yes (AOEC)
Acetaldehyde		75-07-0		Good (CHE)
Aluminum Oxide		1344-28-1		Yes (AOEC)
Acetic Acid	Glacial Acetic Acid	64-19-7		Yes (AOEC), Strong [acids] (CHE)
Acrolein		107-02-8		Good (CHE)
Acrylates				Strong (CHE)
Aluminum		7429-90-5		Yes (AOEC), Strong (CHE), Associated (Malo J-L, Chan-Yeung M)
Ammonia		7664-41-7		Strong (CHE)
Ammonium Bichromate		7789-09-5	Chromium compounds	Yes (AOEC)
Aziridine‡		151-56-4		Limited (CHE)
Benzene‡		71-43-32		Limited (CHE)
Butylphthalate‡	Dibutyl phthalate	84-74-2		Limited [phthalates] (CHE)
Caprolactam ‡		105-60-2		Limited (CHE)
Chlorine^$^{\Phi}$		7782-50-5		Yes (AOEC), Strong (CHE)
Chloroform‡		67-66-3		Limited (CHE)
Chlorothalonil	Tetrachloro-Isophthalonitrile	1897-45-6		Yes (AOEC), Strong (CHE), Associated (Malo J-L, Chan-Yeung M)
Chromic Acid^		1333-82-0	Hexavalent chromium compounds	Yes (AOEC)
Chromium^	Includes chromium metal and trivalent and hexavalent chromium	[multiple numbers]	Chromium compounds and hexavalent chromium compounds	Yes (AOEC), Strong (CHE), Associated (Malo J-L, Chan-Yeung M)
Diazinon		333-41-5		Yes (AOEC)
Dibromochloropropane^‡	DBCP	96-12-8		Limited (CHE)
Dicyclohexylmethane 4,4-diisocyanate	methylene bis (4)-cyclohexylisocyanate	5124-30-1	Diisocyanates	Strong [isocyanates] (CHE), Associated (Malo J-L, Chan-Yeung M)
Diethanolamine	DEA	111-42-2		Yes (AOEC)
Diethylhexyl-phthalate	Dioctylphthalate, DEHP	117-81-7		Limited [phthalates] (CHE), Associated (Malo J-L, Chan-Yeung M)
Dimethoate		60-51-5		Yes (AOEC)
Ethyl methacrylate		97-63-2		Associated (Malo J-L, Chan-Yeung M)
Ethylene Oxide^	ETO	75-21-8		Yes (AOEC), Good (CHE), Associated (Malo J-L, Chan-Yeung M)
Ethylenediamine		107-15-3		Yes (AOEC), Good (CHE), Associated (Malo J-L, Chan-Yeung M)
Fenthion		55-38-9		Yes (AOEC)
Fluorine		7782-41-5		Yes (AOEC)
Formaldehyde^	Formalin	50-00-0		Yes (AOEC), Good (CHE), Limited evidence of association for exacerbation (IOM), inadequate evidence of association for development (IOM), Associated (Malo J-L, Chan-Yeung M)
Freon, Heated	Welding Freon, Freon 23	75-46-7		Yes (AOEC)
Hexamethylene Diisocyante	Hexamethylene-1,6-diisocyanate, HDI, 1,6-Diisocyanato-hexane	822-06-0	Diisocycanates	Yes (AOEC), Strong [isocyanates] (CHE), Associated (Malo J-L, Chan-Yeung M)
Hexachlorophene	Hexachlorophene	70-30-4		Yes (AOEC), Good (CHE), Associated (Malo J-L, Chan-Yeung M)
Hexamethylene tetramine		100-97-0		Associated (Malo J-L, Chan-Yeung M)
Hydrazine^		302-01-2		Good (CHE)
Hydrogen Sulfide		7783-06-4		Strong (CHE)
Diisocyanates, NOS	Isocyanates, NOS, Diisocyanates, NOS		Diisocyanates	Yes (AOEC), Strong (CHE)
Isofenphos		25311-71-1		Yes (AOEC)
Isophorone Diisocyanate	Isophorone Diisocyanate, IPDI	4098-71-9	Diisocyanates	Yes (AOEC), Strong [isocyantes] (CHE), Associated (Malo J-L, Chan-Yeung M)
Malathion	Malathion	121-75-5		Yes (AOEC)
Maleic Anhydride	Maleic Anhydride	108-31-6		Yes (AOEC), Associated (Malo J-L, Chan-Yeung M)

Table 2. Asthma-Related Chemicals Reportable under the Toxics Use Reduction Act				
CHEMICAL NAME	**SYNONYM**	**CAS NUMBER**	**TURA Reportable Category (If Applicable)**	**STRENGTH OF EVIDENCE (SOURCE*)**
Methyl methacrylate	Methacrylate monomer, Methyl Methacrylate	80-62-6		Yes (AOEC), Strong (CHE)
Methylene Diisocyanate^	MDI, Methylene Bisphenyl Isocyanate, Diphenylmethane Diisocyanate	101-68-8	Diisocyanates	Yes (AOEC), Strong [isocyanates] (CHE), Associated (Malo J-L, Chan-Yeung M)
Naphthalene Diisocyanate	Diisocyanates, 1,5-Naphthalene Diisocyanate, 1,5-Naphthylene Ester Isocyanic Acid, NDI	3173-72-6	Diisocyanates	Yes (AOEC), Associated (Malo J-L, Chan-Yeung M)
Nickel^ and nickel compounds	Includes nickel and nickel compounds	[multiple numbers]	Nickel compounds	Yes (AOEC), Strong (CHE), Associated (Malo J-L, Chan-Yeung M)
Nitrogen dioxide	NOX	10102-43-9, 10024-97-2		Strong (CHE); Sufficient evidence of association for exacerbation (IOM), inadequate evidence of association for development (IOM)
Orthophenylphenol		90-43-7		Yes (AOEC)
Osmium Tetraoxide		20816-12-0		Good (CHE)
Ozone		10028-15-6		Good (CHE)
Peroxyacetic Acid		79-21-0		Yes (AOEC)
Paraformaldehyde		30525-89-4		Yes (AOEC)
Phenols^		No specific CAS§		Good (CHE)
Phosgene^		75-44-5		Good (CHE)
Phthalic Anhydride	Phthalic Acid Anhydride	85-44-9		Yes (AOEC), Associated (Malo J-L, Chan-Yeung M)
Polymethylene Polyphenylisocyanate	Polymeric diphenylmethane diisocyanate , PPI	9016-87-9	Diisocyanates	Yes (AOEC), Strong [isocyanates] CHE, Associated (Malo J-L, Chan-Yeung M)
Propionaldehyde		123-38-6		Good (CHE)
Pyrfon	Isofenphos	25311-71-1		Yes (AOEC)
Pyromellitic dianhydride		89-32-7		Associated (Malo J-L, Chan-Yeung M)
Safrotin	Propetamphos	31218-83-4		Yes (AOEC)
P-Phenylenediamine		106-50-3		Strong (CHE)
Styrene	Cinnamene, Styrene monomer, Vinylbenzene	100-42-5		Yes (AOEC), Limited (CHE), Associated (Malo J-L, Chan-Yeung M)
Sulfuric Acid^	Hydrogen Sulfate	7664-93-9		Yes (AOEC)
Tetramethrin		7696-12-0		Associated (Malo J-L, Chan-Yeung M)
Tributyl Tin Oxide		56-35-9		Yes (AOEC), Associated (Malo J-L, Chan-Yeung M)
Toluene		108-88-3		Limited (CHE)
Toluene Diisocyanate^	TDI, Toluene-2,4-Diisocyanate	584-84-9; 91-08-7; 26471-62-5		Yes (AOEC), Strong [isocyanates] CHE, Associated (Malo J-L, Chan-Yeung M)
Vanadium	Vanadium, vanadium oxide or pentaoxide dust/fume,	1314-62-1; 7440-62-2		Strong (CHE)
Zinc Oxide	(delisted from TURA 1997)	1314-13-2		Yes (AOEC)

Chemicals in **bold** type have been reported to the TURA program by Massachusetts facilities.

‡ Chemicals that were classified as only limited evidence by CHE (see below) as limited ("Limited (CHE)") were excluded from the trend analysis in this fact sheet.

^ Included on TURA's Science Advisory Board's More Hazardous Chemicals list. For chromium, only hexavalent chromium compounds are on the SAB More Hazardous list.

Φ Only chlorine gas has been associated with asthma onset. Several other chlorine-based substances (e.g. sodium hypochlorite and chlorinated disinfection byproducts) are linked with asthma exacerbation.

§ No specific phenolic compound has been identified as associated with asthma onset or exacerbation.

* Evidence Sources:

1. The Collaborative for Health and the Environment's (CHE) Toxicant Disease Database: http://database.healthandenvironment.org/.
2. The Association of Occupational and Environmental Clinic's (AOEC) Exposure Database: http://www.aoecdata.org/ExpCodeLookup.aspx
3. The Institute of Medicine's (IOM) 2000 report, Clearing the Air: http://books.nap.edu/books/0309064961/html.
4. A comprehensive review of the peer-reviewed literature by Malo and Chan-Yeung (Lit Review; Malo J-L, Chan-Yeung M): Malo J-L, Chan-Yeung M. Appendix: Agents Causing Occupational Asthma with Key References. In: Bernstein LI, Chan-Yeung M, Malo J-L, Bernstein DI (eds). Asthma in the Workplace. 3rd Ed. New York: Taylor & Francis, 2006.

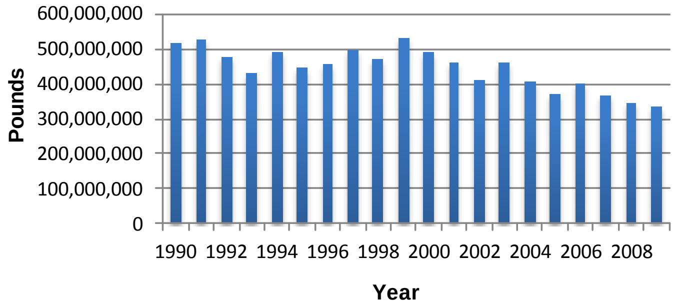
NOTE: There are dozens of additional chemicals, as well as biological agents, that are associated with asthma and are not currently reportable under TURA. To view a list of these agents, go to: www.turi.org/asthma_chemicals_list.

TURA Data Trends: Use of Asthma-Related Chemicals

Of the over 70 asthma-related chemicals that are reportable under TURA, approximately 42 have been reported at some point during the 20 years of the TURA program. Among facilities reporting from 1990 to 2009, there was a 35% decline in total use of these asthma-related chemicals (Figure 1). The five chemicals used in the greatest amount (see Table 3) are:

- **Styrene.** In Massachusetts, the primary use of styrene is for the production of polystyrene. Styrene is also used to produce styrene-based emulsions and resins. Multiple case reports link styrene with asthma.[16,17]
- **Sulfuric acid**. In Massachusetts, sulfuric acid is used across many industry sectors, including electricity generators, metal industries (during electroplating and anodizing processes), and chemical distributors. Case reports reveal that high exposure to sulfuric acid, often as a result of accidents, has caused irritant-induced asthma among workers. In addition, exposures to much lower doses of aerosols of sulfuric acid can exacerbate asthma in workers and the public.[18,19,20]
- **Ammonia.** In Massachusetts, the primary users of ammonia are wholesale chemical distributers and NOx pollution control at power plants. Several studies have documented increased asthma symptoms among exposed workers in a number of industries.[21,22,23] Because of its properties as a lung irritant, ammonia inhalation puts both adults and children with asthma at risk of exacerbations.[24]
- **Diisocyanates**. The principal sectors reporting diisocyanate use in Massachusetts are the chemical distribution industry and the rubber and plastic industries. Diisocyanates are used to make a wide variety of products, including foams, adhesives, binders, surface coatings, elastomers, resins, and sealers. Toluene diisocyanate (TDI) and methylene diphenyl isocyanate (MDI) are the most commonly reported diisocyanates under TURA and two of the most widely studied chemicals in the workplace that can induce the onset of asthma. Studies continue to document cases of diisocyanate-induced asthma where airborne levels are very low or non-detectable, but where there is opportunity for skin exposure.[25] Dermal exposure to diisocyanates may also result in respiratory sensitization.[26,27]

Figure 1. Total Use of Asthma-Related Chemicals, TURA Program 1990-2009



- **Nickel and nickel compounds**. In Massachusetts, the principal users of nickel and nickel compounds include primary metals, metal fabricating and metal finishing industries. Evidence linking nickel compounds with asthma is primarily from several workplace studies which have demonstrated that exposure to nickel aerosols (for example, during plating operations) can cause asthma.[28]

Despite overall reductions, the use of some asthma-related chemicals in Massachusetts is increasing. As shown in Table 3, the total use of ammonia increased by 66% from 1990 to 2009. While use of diisocyanates overall has decreased by 38%, TDI use gradually increased by 70% from 1990 to 2007, and declined 34% from 2007 to 2009. Use of other chemicals in the diisocyanate category increased 63% between 1995 and 2009.

Trends such as the use of ammonia, as well as the volumes of asthma-related chemicals that continue to be used, demonstrate continued opportunities for toxics use reduction in Massachusetts, including research on safer alternatives. TURI and the Office of Technical Assistance and Technology (OTA) can provide technical assistance to industries to identify safer chemical alternatives or process changes to minimize use.

Table 3. Use: Top-Five Asthma-Related Chemicals, TURA Program 1990-2009

Rank 1990-2009	Chemical Name	% Change since first reporting year*	Total Use in 2009	Primary Industry Sectors	# of Facilities Reporting (2009)
1	Styrene Monomer	-8%	262,932,518	Chemical and resin manufacturing	12
2	Sulfuric Acid	-45%	23,784,147	Electricity generation, fabricated metal, chemical distributors	95
3	Ammonia	+66%	14,063,675	Electricity generation, electronic equipment, fabricated metal	38
4	Diisocyanates	-38%*	11,860,966	Chemical and resin manufacturing, rubber and plastic products	23
5	Nickel and Nickel Compounds	-92%**	1,114,737	Primary metals, fabricated metals	10

* With the exception of diisocyanates, the percent change for all chemicals listed here covers the period 1990-2009. Reductions for diisocyanates are for the period 1995 to 2009, as several diisocyanates were not reportable until 1995. ** Note that nickel as part of an alloy was delisted in 1995.

TURA Data Trends: Air Releases of Asthma-Related Chemicals

Because inhalation is the primary route of respiratory sensitization and subsequent asthma attacks, air releases of asthma-related chemicals can put both workers and communities at risk. Trends associated with fugitive and point source air releases among facilities reporting to the TURA program are reviewed below.

Fugitive Air Releases

Fugitive air releases of asthma-related chemicals show dramatic declines over the history of the TURA program. As illustrated in Figure 2, for the 42 asthma-related chemicals reported to the TURA program, a 95% reduction in total fugitive releases from 1990 to 2009 was achieved.

Table 4 shows the top five asthma-related chemicals that contributed the most to total fugitive emissions from 1990 to 2009. Each of these five chemicals declined substantially—reductions ranged from 94% to 100% during that period.

Figure 2. Total Fugitive Air Releases of Asthma-Related Chemicals, TURA Program 1990-2009

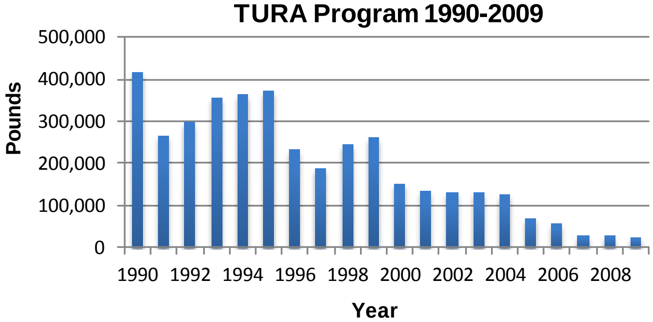


Table 4. Fugitive Air Releases: Top-Five Asthma-Related Chemicals, TURA Program 1990-2009			
Rank 1990-2009	**Chemical Name**	**% Change Total Fugitive Air Releases***	**Fugitive Air Releases in 2009**
1	Ammonia	-94%	16,470
2	Sulfuric Acid	-97%	1,577
3	Acetic Acid	-98%	614
4	Styrene Monomer	-96%	1,198
5	Nitrogen Dioxide	-100%	0
*Reductions for nitrogen dioxide are for the period 1993-2009, as the first reportable year was 1993. Reductions for acetic acid are for the period 1991-2009 as the first reportable year was 1991. For other chemicals, reductions are for the period 1990-2009.			

Point Source Air Releases

Point source air releases of the same 42 asthma-related chemicals show a decreasing trend from 1990 to 2009 (Figure 3). During this time period, there was a 22% reduction in total point source air releases. (The large spike shown in 1991 corresponds to the first year that utilities were required to report under TURA.)

Figure 3. Total Point Air Releases of Asthma-Related Chemicals, TURA Program 1990-2009

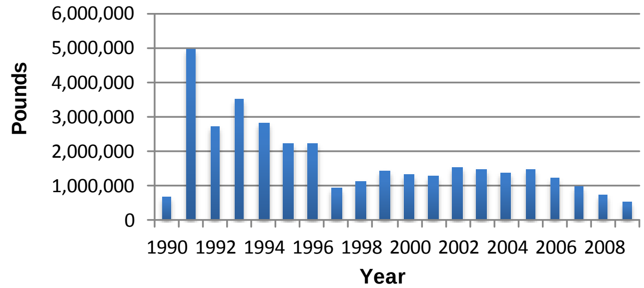


Table 5 displays the predominant point source air emissions of asthma-related chemicals. Among the five highest volume chemicals, only releases of ammonia increased over the period 1990-2009. However, since 2002, releases of ammonia have declined. Electricity generators are the primary source of ammonia emissions.

Table 5. Point Source Air Releases: Top-Five Asthma-Related Chemicals, TURA Program 1990-2009			
Rank 1990-2009	**Chemical Name**	**% Change Point Air Releases**	**Total Point Source Air Releases in 2009**
1	Sulfuric Acid	-35%	73,535
2	Ammonia	+73%	369,893
3	Formaldehyde	-94%	10,442
4	Acetic Acid	-96%*	3,069
5	Styrene Monomer	-54%	27,229
* Reduction shown 1991-2009 as acetic acid was first reportable in 1991.			

Alternatives to Major Asthma-Related Chemicals of Concern

Below is a brief review of alternatives to three asthma-related chemicals—styrene, formaldehyde, and diisocyanates—that are of priority concern based on the above trends. Formaldehyde and diisocyanates are also a focus of a Massachusetts interagency working group (comprised of the Department of Public Health, OTA and TURI) working to address the chemical risks associated with asthma. For many processes, safer alternatives are available. However, in other cases, the alternatives also pose health concerns, and research on safer chemicals and processes is needed. For additional information about these chemicals, including information about alternatives, see TURI's chemical fact sheets: http://www.turi.org/Our_Work/Toxic_Chemicals.

Styrene

The primary use of styrene among Massachusetts TURA filers in 2009 was for the production of polystyrene. Styrene was also used as a resin in the fabrication of fiberglass products and in the manufacture of other resins such as polyester resins.

Polystyrene production

There are no alternatives to styrene when used in the production of polystyrene. However, there are suitable alternatives to polystyrene products, including polyethylene terephthalate (PET) as well as bioplastics such as polylactic acid (PLA).

Fiberglass product fabrication

Alternative methods to reduce or replace the use of styrene in the fabrication of fiberglass products are available. Reductions in styrene monomer use and associated emissions can be achieved when changing from an open molding process to a closed molding process.[29] Other process changes that can reduce the use and emissions of styrene include using resin with a lower styrene content as well as using heat to reduce viscosity.[30] Where open mold processes are required, using nonatomized application equipment reduces emissions.[31] Vinyl toluene resin can be used as a substitute for styrene monomer, yet its detailed toxicology remains understudied.[32] *It is important to note that there are health concerns with the use of fiberglass, such as respiratory irritation that may include exacerbation of asthma symptoms with high exposure levels.*[33]

Manufacture of polyester resins

Chemical alternatives to the use of styrene in the production of polyester resins include aromatics such as vinyl toluene, p-methylstyrene, divinyl benzene, and tert-butylstyrene as well as methacrylates such as 2-hydroxyethyl methacrylate.[34] However, health concerns are present with these alternatives and more research on safer alternatives is needed.

Formaldehyde[35]

Formaldehyde use among Massachusetts TURA filers in 2009 was dominated by resin manufacturers and chemical distributors. Formaldehyde is used to manufacture many products, including plastic resins and adhesives, resin coated paper and fabric, printed wiring boards, embalming chemicals and building materials. Alternatives include:

Manufacture of Phenolic Resins: Alternative methods to replace formaldehyde for manufacturing a variety of phenolic resins include enzymatic water-based polymerization processes and pyrolysis of biomass. Soy peroxidase enzyme can result in decreased processing time and increased yield. Pyrolysis of agricultural and forestry wastes to produce phenolic resins is predicted to cost half as much as the current formaldehyde-based process.

Printed Wiring Boards: Formaldehyde is used in electroless copper processes in the manufacture of printed wiring boards. Alternative reducing agents for this process include carbon, graphite, organic-palladium, tin-palladium, or electroless copper using sodium hypophosphite as the reducing agent. Conductive polymer technologies are also viable alternatives in some instances.

Sanitary Storage in Barbering/Cosmetology: Use of formaldehyde-based sanitizer in barbering and cosmetology goes against nationally accepted best practices. The National Interstate Council of State Boards of Cosmetology (NIC) recommends an alternate procedure of proper cleaning, wet disinfection with EPA-registered disinfectants, drying and storage of tools in covered containers to ensure isolation from contaminants. Suitable alternatives have also been developed for formaldehyde in hair straightening products.

Embalming and Tissue Preservation: The use of video dissection is a safer alternative to preserving tissue for educational purposes. Alternatives to formaldehyde for the preservation of biological specimens also include propylene glycol-based formulations, diazolidinyl urea-based formulations and glutaraldehyde. Alternatives to formaldehyde in embalming products include methanol (also typically used in formaldehyde-based fluids), glutaraldehyde, phenoxyethanol, polyethylene glycol, isopropyl alcohol, and iodine.[36,37] While none of these chemical alternatives (for both tissue preservation and embalming) are classified as a carcinogen as is formaldehyde, they can irritate the skin, eyes and respiratory system. In addition, glutaraldehyde is a sensitizer and can both cause the initial onset of asthma and trigger asthma attacks.[38]

Building Materials: Alternatives to formaldehyde-containing fiberglass insulation include plastic foams, rock wool, cellulose, cotton, and fiberglass using acrylic or other non-formaldehyde binders. Plastic foams can contain asthma-related chemicals such as MDI. Rock wool is also a respiratory irritant capable of exacerbating asthma symptoms among those experiencing high exposures.[39] Cellulose insulation—made from 75%-85% post-consumer recycled newsprint and treated with borate compounds to provide fire retardancy and pest and mold resistance—is an effective and safer replacement for formaldehyde-bearing fiberglass insulation. However, wet cellulose material is conducive for the growth of some molds, which could inadvertently introduce other asthma triggers into the building. Alternatives to pressed wood products containing formaldehyde include those labeled "formaldehyde-free." Products labeled "low-emitting" or those made from phenol-formaldehyde (such as oriented strand board, softwood plywood or exterior grade plywood) generally emit lower levels of formaldehyde than typical pressed wood products. Hardwood and softwood plywood or oriented strand board can be manufactured using alternative adhesives, such as soy-based resins.[40]

Diisocyanates

The primary uses of diisocyanates reported by TURA filers in 2009 were in foams, surface coatings, adhesives, binders, elastomers, resins, and sealers.

Polyurethane Foams and Adhesives: According to a 2011 EPA review, a new class of non-isocyanate polyurethanes is emerging.[41,42,43] Though some have suggested that these polymers pose minimal health and environmental risks, adequate toxicity testing data are lacking. Other emerging alternatives include soy-based adhesives and a hybrid silane terminated polymer for expanding foam.[44]

Reducing Exposure to Asthma-Related Chemicals

The most effective approach for preventing exacerbations and additional new cases of asthma is product and/or process substitution. Where asthma-related chemicals continue to be used—at home, in community settings, and at work—it is important to minimize exposure.

Exposure limits set by the Occupational Safety and Health Administration (OSHA) or recommended by the American Conference of Governmental Industrial Hygienists (ACGIH) or the National Institute for Occupational Safety and Health (NIOSH) are one approach to protecting workers. However, many current exposure limits do not offer adequate protection from chemicals capable of causing exacerbations at very low levels.[45]

Need more information?

- **TURA regulatory compliance:** Massachusetts Department of Environmental Protection, 617-292-5500 or www.mass.gov/dep/toxics/toxicsus.htm.
- **Confidential toxics use reduction technical assistance:**, MA Office of Technical Assistance and Technology, 617-626-1078 or www.mass.gov/eea/ota.
- **Technical assistance regarding safer cleaning alternatives:** TURI Surface Solutions Laboratory, 978-934-3050 or www.cleanersolutions.org.
- **General toxics use reduction policy and technical questions:** TURI, 978-934-3275 or www.turi.org.
- **Work-related asthma:** Massachusetts Department of Public Health, Occupational Health Surveillance Program, 617-624-5632 or www.mass.gov/dph/ohsp.
- **General asthma prevention and control:** Massachusetts Department of Public Health, Asthma Prevention and Control Program, 617-994-9807 or www.mass.gov/dph/asthma.
- **Safe working practices:** Massachusetts Department of Labor Standards, Onsite Consultation Program, 508-616-0461.

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