Asthma-Related Chemicals in Massachusetts: an Analysis of Toxics Use Reduction Act Data

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The Lowell Center for Sustainable Production at the University of Massachusetts Lowell

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This report was produced by the Lowell Center for Sustainable Production's Environmental Health Initiative (EHI). The Lowell Center established EHI in 2004 to help people better understand links between environmental conditions and human health, and to find sustainable solutions in policy and practice that improve health. EHI is grounded in the evidence that environmental and social conditions – driven by political choices – are primary determinants of health. EHI provides tools to government and non-governmental organizations seeking effective action on these conditions, conducts research and analysis, and provides leadership and vision.

The Massachusetts Toxics Use Reduction Institute

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The recommendations that the researchers present in this document are based on the research funded through the project, and represent their judgment on appropriate and innovative policy actions. These recommendations do not necessarily reflect the policies and perspectives of TURI or the Toxic Use Reduction Program as a whole.

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EXECUTIVE SUMMARY

Massachusetts has one of the highest rates of asthma in the nation, causing a substantial societal burden of human suffering, lost capacity and productivity as well as fiscal costs. Nearly 150,000 children and 500,000 adults currently have asthma in Massachusetts. Increasingly, health payers, providers, and government programs emphasize the use of effective chronic disease management programs that can substantially improve the quality of life for people living with asthma. Despite these efforts, asthma in many people remains out of control, requiring frequent use of rescue medications and often—particularly for low income people living in challenging social circumstances and substandard home and community environments—trips to the emergency room, hospitalizations, and infrequently, death. Only a small percentage of health care expenditures is devoted to disease prevention—particularly primary prevention, or preventing disease processes before they start in the first place—despite the potential to lower rates of disease and reduce costs.

The scientific literature clearly distinguishes between causes of the initial onset of asthma in people previously free of the disease, and causes of asthma attacks in people who already have a diagnosis of asthma. As is true of most diseases, both genetic and environmental factors contribute to asthma onset. Evidence suggests that hundreds of chemicals are among those environmental factors contributing to the initial development of asthma. These chemicals along with others can also trigger exacerbations in people who already have the disease. Much of this evidence comes from workers exposed in the workplace. Yet individuals may also be at risk from chemical exposures at home, from consumer products, building materials, and outdoor air pollution. With the exception of occupational health professionals, clinicians and decision-makers in government and the private sector tend to overlook strategies for minimizing exposure to asthma-related chemicals as they work to reduce the burden of asthma. Moreover, efforts to promote research and the adoption of safer substitutes for chemicals associated with asthma are often not a component of comprehensive asthma prevention and control agendas.

The purpose of this project was to understand the extent to which chemicals that can cause the initial onset of asthma or trigger subsequent asthma attacks are being used by Massachusetts industries who report under the Toxics Use Reduction Act (TURA) program. TURA is a Massachusetts law passed in 1989 to encourage the reduction in amounts of toxics and toxic byproduct used or generated by Massachusetts industries. Examining TURA data can help identify opportunities for reducing exposure to asthma-related chemicals in the workplace and in the community, which may, in turn, help prevent new cases of asthma and/or exacerbations in people who already have the disease. The project involved: (a) assembling a master list of agents that cause the initial onset of asthma or exacerbate existing asthma; (b) researching trends in the use of asthma-related chemicals in Massachusetts using TURA data; and (c) exploring the associations between the TURA data and asthma surveillance data gathered by the Massachusetts Department of Public Health (MDPH) to help generate hypotheses to explain such trends and point to opportunities for interventions. This report first provides background on asthma to highlight why this disease is a public health priority in Massachusetts. We then detail the methods and findings of our data analyses.

This project yielded the following results and policy/research recommendations:

I. TURA Reportable Chemicals that Cause or Exacerbate Asthma

- Findings:
  1. Approximately 335 substances are known or suspected of causing or exacerbating asthma based on evidence from a variety of sources.* These substances include chemicals, as well as biological agents, such as molds, animal proteins, insect proteins and plant proteins. Of these 335 substances:
     - 68 chemicals are reportable under TURA and 41 have been reported to TURA at some point in the program's history.
     - Of the 41 chemicals that have been reported to TURA, 15 have been characterized as "more hazardous" (based on endpoints other than asthma) by the TURA program's Science Advisory Board.
     - TURA does not mandate reporting for approximately 100 chemicals known to be capable of causing and/or exacerbating asthma.
- Recommendations:
  1. TURA decision-makers should consider adding to the "list of reportable chemicals" those chemicals known or suspected of causing or exacerbating asthma that are not currently on the list.
  2. The Science Advisory Board should also include asthma as an endpoint as it evaluates chemicals for its "more hazardous" list. Although over a dozen asthma-related chemicals reported to TURA are on the TURA program's Science Advisory Board's "more hazardous" list because of other health concerns, asthma is not a health outcome considered in the development of this list.
  3. The Science Advisory Board should consider including "capacity to cause and/or exacerbate asthma" among the criteria for recommending that a chemical from the "more hazardous" list be reviewed for a "higher hazard" designation, which carries with it a lower reporting threshold.

II. Trends in Asthma-Related Chemicals Reported to TURA

- Findings:
  1. Between 1990 and 2005, the total cumulative use of asthma-related chemicals in Massachusetts declined by 27%, but uses of some individual asthma-related chemicals increased.
     - The chemicals driving the total cumulative use of asthma-related chemicals in Massachusetts from 1990-2005 include: styrene monomer, sulfuric acid, zinc and zinc compounds, diisocyanates (when all reported diisocyanates are combined), and chromium and chromium compounds. Of these chemicals, ammonia, zinc and zinc compounds, and diisocyanates showed an increase in total cumulative use from 1990-2005. Toluene diisocyanate was the main diisocyanate driving the increased use for diisocyanates.

* Sources include (1) the Association of Occupational and Environmental Clinics, (2) the Collaborative on Health and Environment, (3) a 2006 comprehensive review of the literature by Malo and Chan-Yeung, and (4) the Institute of Medicine's 2000 report, "Clearing the Air."

2. Total cumulative fugitive and point source air emissions† of asthma-related chemicals from 1990-2005 also declined, 82% and 71% respectively.
    - Specific asthma-related chemicals that were the primary contributors of the total cumulative fugitive releases include: ammonia, sulfuric acid, acetic acid, styrene monomer, and nitrogen dioxide. Fugitive emissions for all five chemicals showed dramatic declines from 1990-2005
    - Specific asthma-related chemicals contributing the most to the total cumulative point source air emissions from 1990-2005 include: sulfuric acid, ammonia, formaldehyde, acetic acid, and styrene monomer. Of the five chemicals, ammonia and sulfuric acid showed overall increases in point source air emissions over this fifteen year period (since 1991, sulfuric acid emissions have been declining).

- Recommendations:
    1. The Commonwealth should increase support for the Office of Technical Assistance (OTA) and the Toxic Use Reduction Institute (TURI) to provide technical assistance and to support innovation among Massachusetts industries thus enabling them to further reduce their use and release of asthma-related chemicals.
        - Among industries reporting to TURA, millions of pounds of chemicals associated with asthma continue to be used and released as (1) fugitive emissions, which may impact workers, and (2) point-source air emissions which may impact communities. The results of toxics use reduction planning and technical support to businesses—provided by the state Office of Technology Assistance and the Toxic Use Reduction Institute are impressive: 40% reduction in use, 71% reduction in waste, and 91% reduction of on-site releases since the program's inception in 1989. With sufficient resources, further reductions in uses and releases of chemicals known to cause and/or exacerbate asthma could be expected.
    2. The Massachusetts Department of Pubic Health should increase asthma surveillance activities among individuals and workers at risk from exposure to toluene diisocyanate (TDI). In addition, the TURA program should also support research and technical assistance to identify safer alternative to TDI.
        - Given the increasing use of TDI in Massachusetts and emerging evidence about the role of isocyanate skin exposure in the development of asthma, occupational asthma prevention efforts should be strengthened, and resources should be allocated for research and technical support to identify safer alternatives.

III: Exploring Associations between TURA Chemicals Data and Massachusetts Asthma Surveillance Data

- Findings:
    - Work-related asthma surveillance data: The Massachusetts Department of Public Health's (MDPH) sentinel work-related asthma surveillance system documents that asthma-related chemicals, including those reported under TURA, have

† Fugitive air emissions are releases not captured by emission control technologies, such as leaks through pipe fittings, loading/unloading operations, or evaporative losses. Point source air emissions are those releases that occur through confined air streams such as stacks, vents, ducts, or pipes.

caused or aggravated existing asthma among Massachusetts workers. These surveillance data also show that the highest numbers of work-related asthma cases are in industries not required to report to TURA, including the health care industry. Workers in these sectors are exposed to asthma-related chemicals on TURA's list of reportable chemicals, some of which are also on the TURA program Science Advisory Board's "more hazardous" list (e.g. formaldehyde and ethylene oxide).

- School-based asthma surveillance data: According to MDPH's school-based surveillance data, the prevalence of asthma among schoolchildren is higher in some communities where high amounts of asthma-related chemicals are used and released by industries that report under TURA. Preliminary analysis was insufficient to document or to rule out an association between the higher rates of the disease and higher use or point air releases of asthma-related chemicals.

- Recommendations:
  - Work-related asthma surveillance data: Based on substantial numbers of work-related asthma cases reported from industries other than those that report under TURA, consideration should be given to require additional industries—in particular health care—to report .
  - School-based asthma surveillance data: Given the high prevalence of asthma among Massachusetts children, the TURA data are an important data source to further explore constituents of both indoor and outdoor air pollution and their connection with pediatric asthma. Priority analyses for future work include examining the association between prevalence rates in particular schools, as reported to MDPH, and the use and release of specific asthma-related chemicals, such as nitrogen dioxide, sulfuric acid and formaldehyde, in those locations. These more refined ecological analyses could help generate hypotheses for further testing using more rigorous study designs.

Though the development of asthma is complex and varies individual to individual, exposure to chemicals is a risk factor for many people. Researching and promoting safer alternatives has the potential to make an important contribution to reducing exposure to asthma-related chemicals and thereby reducing the burden of the disease. Toxic Use Reduction programs in the public and private sectors are an important prevention strategy and should be included in any comprehensive asthma prevention and control agenda. The declines in use and air releases of asthma-related chemicals observed in this analysis are good news, yet there remains ample opportunity for further reductions via technical and planning support provided through TURA as well as including asthma in the Science Advisory Board's evaluation process for chemicals listing and classification. The increase in use of isocyanates is of particular concern, and deserves attention by public health officials and the TURA program.

A. INTRODUCTION

Today, Massachusetts has among the highest asthma rates in the country. Nearly 150,000 children[c] and 500,000 adults[d] currently have asthma and the numbers are even higher of people who report having asthma at some point during their life. Effective chronic disease management—emphasized increasingly by health payers, providers and government programs—can improve the quality of life for people living with asthma. Better compliance with drug treatments, behavior modifications and environmental interventions that reduce a person's exposure to allergens and irritants are essential secondary prevention strategies that can reduce asthma attacks and keep people out of the doctor's office, emergency room or hospital. Moreover, though these chronic disease management initiatives are important for both improving quality of life and health care costs, they do not reduce incident cases of asthma. To control costs and reduce the burden of asthma over time, there is great need to pursue opportunities not only for secondary and tertiary prevention but also for reducing rates of new cases of asthma, in both children and adults.

Chemicals play a potentially important role in asthma. Reducing people's exposure to chemicals that trigger asthma attacks—including, for example, fluids used for cleaning and disinfecting in the home, or chemicals used in the workplace setting—is an important element of secondary prevention strategies. Though asthma is a complex disease that varies individual to individual, and there remains much to learn about its etiology, we do know that chemicals can cause the initial onset of asthma in people previously free of the disease. The availability of information about chemical uses and releases in Massachusetts, and the state's track record in reducing uses of hazardous substances, provide an opportunity to target exposures of concern and seek safer alternatives.

The purpose of this project was to understand the extent to which chemicals that can cause or exacerbate asthma are being used by Massachusetts industries in order to identify potential prevention opportunities. The project first assembled a master list of 335[e] agents that cause the initial onset of or exacerbate existing asthma. Then, using data reported to the Toxics Use Reduction Act (TURA) program, we researched trends in the use and release of asthma-related chemicals, and explored associations between those trend data and data gathered by Massachusetts Department of Public Health's (MDPH) asthma surveillance programs. This report details the methods and findings of this project, but first provides essential background on asthma to provide greater context for why the disease is a public health priority. The report ends by providing recommendations to help guide future policies and programs and to make the connection between asthma prevention and sustainable production policies and practices.

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[c] Based on a current asthma prevalence of 10% (Behavioral Risk Factor Surveillance Survey, 2007) and population estimates for children under 18 years from the U.S. Census Bureau (see: http://quickfacts.census.gov/qfd/states/25000.html).

[d] Based on a current asthma prevalence of 9.9% (Behavioral Risk Factor Surveillance Survey, 2007) and population estimates for MA adults 18 years and over (U.S. Census Bureau (see: http://quickfacts.census.gov/qfd/states/25000.html).

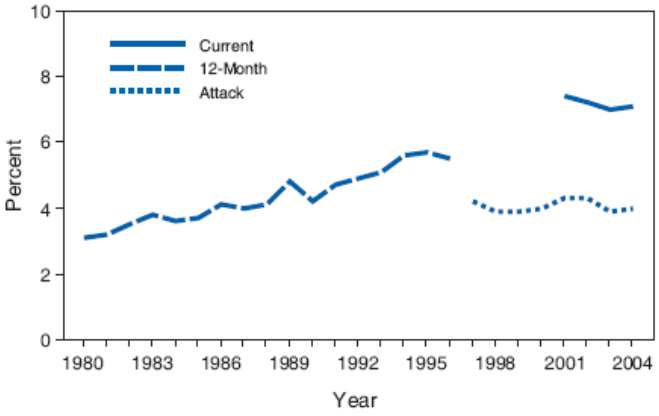
[e] It is difficult to obtain an exact number, as lists of agents that can cause or exacerbate asthma reflect a mixture of individual and classes of compounds.

B: BACKGROUND ON ASTHMA

Asthma is a chronic inflammatory disease that results from a complex interplay between environmental and genetic factors. The disease causes inflammation with recurrent episodes of wheezing, dyspnea (difficult or labored breathing), breathlessness, chest pain or tightness and/or cough. Once asthma develops, the airways of the lungs become more responsive to a variety of stimuli. If left untreated, the resulting inflammation may lead to irreversible changes in the structure of the lungs.

Asthma is a pressing public health problem. In 2006, over 22.9 million people reported currently having asthma. Of these, 6.8 million were children and 16 million were adults.[1,2] Prevalence rates of asthma markedly increased beginning in 1980. The estimated number of persons with self-reported asthma during the previous 12 months increased from 6.8 million in 1980 (3.1%) to 14.9 million (5.6%) in 1995. Current national rates appear somewhat stable at historically high levels over the last few years. However, as a result of changes in the way in which asthma data are collected by our national surveillance systems, recent data cannot be connected to historical trends (See Figure 1).[3]

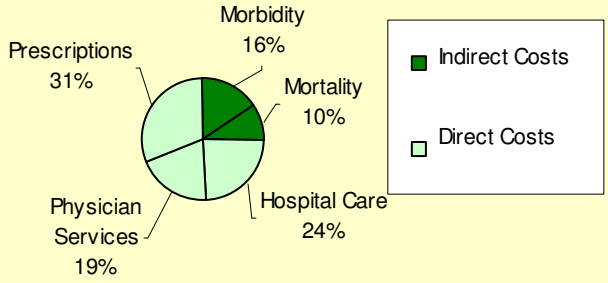
FIGURE 1. Estimated prevalence of asthma, by persons who reported an asthma attack during the preceding 12 months, persons who reported having asthma during the preceding 12 months, and persons who reported current asthma — United States, 1980–2004 [3]



Source: National Health Interview Survey; National Center for Health Statistics.

As of 2007, estimated direct and indirect costs associated with asthma in the U.S. totaled $19.7 billion dollars annually (Figure 2).[4] Direct costs such as prescriptions, physician services, inpatient, outpatient and ER visits accounted for nearly $15 billion. Employees or their children who were sick with asthma accounted for over $3.1 billion in lost productivity.[4] Substantial costs can be reduced by (1) preventing new cases of the disease and (2) effectively managing symptoms of people with asthma in order to avoid costly hospitalizations, emergency room visits, sick visits to the doctor, and missed days at work and school.

Figure 2: Economic Cost of Asthma, United States (2007): $19.7 Billion[4]



I. Asthma in Massachusetts

Massachusetts communities have among the highest rates of asthma in the nation, causing a substantial societal burden of human suffering, lost capacity and productivity as well as direct fiscal costs.[5] According to the most recent health statistics (2007), 10.3% of Massachusetts children and 9.9% of our adults currently have asthma.[6] Although similar data are not available for children, data from 2000 through 2007 show that adults in Massachusetts with current asthma increased 16.5%.[6]

Among Massachusetts children who reported currently having asthma in 2006-2007:[6]

- 40.5% had asthma symptoms in the past 30 days
- 44.2% had an asthma attack within the last year
- 13.3% had one or more visit to the emergency room, other urgent care, or hospital admission for asthma in the last year
- 14% had a moderate amount or a lot of limitations to their usual activities due to asthma
- 37.8% missed one or more days of school or daycare due to their asthma in the last year.

Among Massachusetts adults who reported currently having asthma:[6]

- 67.5% had asthma symptoms in the past 30 days
- 52.9% had an asthma attack within the last year
- 14.3% had one or more visit to the emergency room or other urgent care visit for asthma in the last year
- 4.4% had one or more hospital admission for asthma in the last year
- 22.1% had a moderate amount or a lot of limitations to their usual activities due to asthma
- 8.9% were unable to work or carry out usual activities 11 or more days in the last year
- 40.2% reported that their asthma was either caused or made worse by exposures at either their current or previous job. Yet among these adults, only 26.8% reported discussing their work environment in relation to their asthma symptoms with their health care provider.

A recent analysis examining hospitalizations show that total hospitalization costs due to asthma in Massachusetts increased 77.7% from $50 million in 2000 to $89 million in 2006.[6] Total indirect and direct cost asthma in Massachusetts have not been updated since 2002. Yet, even at that time, asthma costs in the state totaled over $35 million annually.[7]

II. Cause vs. Exacerbation

As with most diseases, asthma develops through a complex process with multiple contributing factors. Contributing risk factors involved in the initial onset of asthma include a person's sensitivity to particular substances, dose and duration of exposure to a causal agent, genetic makeup, physiologic status at the time of exposure, and previous exposure to/occurrence of other risk factors for the disease. The scientific literature clearly

distinguishes between causes of initial asthma onset on the one hand and exposures that result in subsequent asthma attacks or exacerbations of the disease on the other. Current evidence suggests that not all agents capable of triggering an asthma attack can cause the initial onset of the disease. For example, the 2000 Institute of Medicine's (IOM) report, "Clearing the Air" concluded there is insufficient evidence in the scientific literature that mold or dander from cats or dogs can cause the initial onset of asthma, yet there is sufficient evidence that these agents can exacerbate existing asthma[8]. For dust-mites, in contrast, the IOM declared that there is sufficient evidence that they can both cause the initial onset of asthma as well as exacerbation of the disease.[8] In people who have asthma, subsequent exacerbations of their disease—also known as asthma attacks—can be triggered by exposure to the same agent(s) that originally caused the disease, or by exposure to a range of other agents. Exacerbations cause continued disease symptoms such as increased airway inflammation and progressively increased non-allergic airway responsiveness. Frequent asthma exacerbations—which constitute "uncontrolled asthma"—result in worsening lung function, referred to as airway remodeling.

Distinguishing between what can cause the initial onset of asthma and what can exacerbate existing asthma is necessary for characterizing primary prevention opportunities to stop people previously free of the disease from developing asthma in the first place. However, once a person has asthma, strategies for secondary prevention that reduce or eliminate exposure to agents that can trigger asthma attacks are crucial to preserving lung function and improving overall morbidity.

III. Two Types of Asthma Onset: Allergic and Irritant

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

1. Allergic asthma is the most common form of asthma in which an immune-mediated allergic response that produces symptoms such as wheezing, coughing and shortness of breath may be triggered by both causal and exacerbating agents.[9] Allergic asthma is characterized by a causal exposure to a sensitizing agent that starts the immune-mediated response, though it initially does not produce symptoms. Sensitizers act as complete antigens. They bind to specific types of antibodies to produce a cascade of events that activate inflammatory cells and the synthesis and release of several mediators that control the inflammatory reaction in the airways.[9] Frequently, people who have allergic asthma also have a family history of asthma, rhinitis, eczema and urticaria (hives). Agents that cause allergic asthma include high molecular weight substances found in the workplace, such as diisocyanates, and some environmental allergens such as cockroaches and dust-mites. All of these substances and more common environmental allergens such as animal dander, pollen, and mold can trigger subsequent asthma attacks.

2. Non-allergic (irritant) asthma does not involve the immune system, and allergic sensitization does not occur. Non-allergic asthma causes the same symptoms as allergic asthma, but the symptoms are the result of a physical irritant response rather than due to an allergic/immunologic response.[9] Irritant asthma may be

caused by a single exposure to factors such as cold, exercise, chemicals, tobacco smoke, gases or fumes.

We know more about the characteristics of exposures that lead to allergic asthma than we do about those that produce irritant asthma. Research in both occupational[10] and non-occupational[11] settings clearly demonstrates that for allergic asthma, the higher the degree of exposure to an agent, the higher the risk of asthma. Although levels of exposure required to sensitize an individual vary across individuals and substances, once this event occurs, extremely low levels of either respiratory irritants or allergens can trigger an asthma attack. It is not clear from the research literature whether irritant-induced asthma is caused by intermittent high level exposures, chronic low level exposures, or both.[12] Yet for both irritant and allergic asthma, it is evident that reducing an individual's exposure to agents that trigger their asthma not only decreases asthma symptoms and the need for medication, but also improves lung function. Response to agents is highly variable. One agent may trigger asthma in one person and not in another. Some individuals may be responsive to a few agents and others may be responsive to many agents. The response of some individuals to these exposures may be mild, but the response of others may be life-threatening. Asthma symptoms may occur immediately or hours after the exposure.

IV. Occupational and Work-Related Asthma

Occupational asthma is defined in the literature as new cases of asthma caused by work exposure. Work-related asthma includes both individuals whose work exposures caused their asthma, and individuals whose existing asthma has been exacerbated by exposures in their work environment (work-aggravated asthma). Diisocyanates are a leading cause of occupational asthma worldwide and the majority of cases seem to occur via an immune-mediated allergic response.[13] Other common occupational agents that initiate allergic asthma include wood dusts, natural rubber latex, acrylates, and glutaraldehyde.[13] Exposure to chlorine, sulfur dioxide, combustion products, and ammonia are the most common occupational agents that can cause irritant-induced asthma.[13] Once asthma is initiated, subsequent asthma attacks can be triggered by a broad range of substances. For workers with asthma, understanding what triggers their symptoms and avoiding these exposures is an essential component of managing their disease.

C. PROJECT METHODS

Our project focused on analyzing data reported to the Toxics Use Reduction Act (TURA) program. TURA is a Massachusetts law passed in 1989 to encourage the reduction in amounts of toxics and toxic byproduct used or generated by Massachusetts industries. TURA requires that Massachusetts companies that use or manufacture large quantities[f] of any one of approximately 1,500 listed chemicals[g]: (1) report their use and release of these chemicals every year; (2) prepare a Toxics Use Reduction Plan every two years describing how they can reduce their use of toxics; and (3) pay an annual fee based on the size of the company and the number of chemicals reported. We utilized data reported by industry filers to identify trends in Massachusetts in the use and release of chemicals known to cause or exacerbate asthma.

I. Developing the Master List of Substances Capable of Causing or Exacerbating Asthma

In order to analyze the TURA data, we first developed a Master List of chemicals or other substances capable of causing the initial onset of asthma and/or exacerbating existing asthma. This Master List was based on four sources:

1. The Collaborative for Health and the Environment's (CHE) Toxicant Disease database.[14] This database outlines the strength of evidence linking chemical and biological agents in the home, work and intrauterine environments with asthma. This database does not distinguish agents capable of causing the initial onset of asthma from those that can exacerbate the disease.
2. The Association of Occupational and Environmental Clinic's (AOEC) Exposure Database. This database lists occupational agents capable of causing the initial onset of asthma.[15] This list includes chemical, biological and physical hazards in workplaces.
3. The Institute of Medicine's (IOM) 2000 report, *Clearing the Air.*[8] This report reviews the state of the evidence associated with both the initial asthma onset and asthma exacerbation associated with exposures in non-occupational indoor environments.
4. A comprehensive review of the peer-reviewed literature by Malo and Chan-Yeung published in Bernstein's 2006 edition of *Asthma in the Workplace*.[16] The appendix of this book provides an extensive list of agents which can cause asthma in the workplace and serves as an update to the first three sources above, which were published 5-10 years ago.

We compiled the four lists and eliminated duplication where necessary. Each agent on the Master List notes the original source that identified it as asthma-related and the strength of the evidence supporting the association with asthma onset or asthma exacerbation.

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[f] The 1989 statute defines large quantity as 25,000 pounds per year if a firm manufactures or processes a substance, or 10,000 pounds per year if a firm "otherwise uses a substance." Amendments to TURA adopted in 2006 provide for the designation of higher and lower hazard chemicals. The reporting and planning threshold for higher hazard chemicals is lowered to 1,000 pounds per year.

[g] Identified through: Massachusetts Department of Environmental Protection. Toxic Use Reporting Appendices (appendix b), 2006.

II. Developing the TURA Asthma Toxicant List

Having compiled the Master List of substances capable of initiating or exacerbating asthma, we then cross referenced it with two TURA lists: (1) those chemicals that are "reportable" under the TURA legislation and (2) those chemicals that have actually been reported at some point during the program. A number of related chemicals reported separately to TURA were combined for this analysis given that the asthma literature does not differentiate between such agents in terms of their health effects. These agents include:

1. Chromium (CAS# 7440-47-3), chromium and compounds (reference # 1012) and chromic acid (CAS# 7738945)
2. Nickel (CAS# 7440-02-0) and nickel and compounds (reference # 1029)
3. Para-phenylenediamine (CAS#106-50-3) and meta-phenylenediamine (CAS# 108-45-2)
4. Toluene diisocyanate A (CAS# 91-08-7), toluene diisocyanate B (CAS# 584-84-9), and toluene diisocyanate C (CAS# 26471-62-5)
5. Zinc (CAS# 7440-66-6) and zinc and zinc compounds (reference # 1039)

The final TURA list of chemicals capable of causing or exacerbating asthma provides: (1) the CAS number for each chemical if known (2) the evidence source, (3) the strength of the evidence (4) whether the chemical is reportable under TURA and (5) whether TURA ranks the chemical as a "more hazardous chemical." Under the 2006 TURA amendments, the TURA Science Advisory Board reviews the scientific evidence as to whether any one of these "more hazardous chemicals" should be categorized as "higher hazard" and as a consequence, subject to lower reporting thresholds. Subsets of the Master List are included in Appendix A-C (A: Chemical Agents Reported under TURA; B: Chemical Agents Reportable under TURA but Not Reported; and C: Chemical Agents Not Reportable under TURA). The entire Master List, including biologicals associated with asthma can be found online at the Lowell Center for Sustainable Production's website: www.sustainableproduction.org.

III. TURA Trend Analysis

Our analysis of trends in the TURA data focused on chemicals that have been reported to the program at some point during the period 1990-2005. The analysis examined total cumulative quantities of asthma-related chemicals used and released both as fugitive air emissions (emissions not captured by emission control technologies, such as leaks through pipe fittings, tanks and loading/unloading operations, evaporative losses, etc.) and air releases or from point sources (through confined air streams such as stacks, vents, ducts or pipes) throughout the 15 years of the program. In addition, we examined annual use, fugitive air emissions and point source air release trends by chemical, by city/town, and by industry type. The trend analysis focused on air releases because the primary route of respiratory sensitization and subsequent asthma attacks for most asthma-related chemicals is via inhalation.[h]

[h] Evidence is emerging for isocyanates that dermal exposure may also be an exposure report that produces respiratory sensitization.[17]

For all trend analyses we excluded those chemicals where there was only "limited evidence" of an association with asthma based on the CHE review of the evidence (see data source #1 on page 7). In addition, we did not analyze "phenols" because it represents a class of compounds rather than a specific chemical identifiable through a CAS number. Finally, for the top 5 asthma-related chemicals that drive the use, fugitive and point source air release trends, we reviewed the scientific literature using PubMed to better illuminate the evidence base regarding the association between asthma and the specific chemical.

IV. Exploring Associations between TURA Chemicals Data and Massachusetts Asthma Surveillance Data

In the final stage of the project, we examined potential associations between asthma surveillance data and TURA data to begin to explore potential links between chemical use and release and the burden of asthma in the Commonwealth. For this analysis, we used data on cases of work-related asthma and pediatric asthma data collected by the Massachusetts Department of Public Health (MDPH). Our review of work-related asthma data did not include specific analyses, but rather reported on data as published in MDPH's Sentinel Event Notification System for Occupational Risk (SENSOR), Occupational Lung Disease Bulletin, July 2007.[18] For our review of pediatric asthma data, we used city/town data as published in MDPH's report on Pediatric Asthma in Massachusetts 2005-2006.[19] These data were collected as part of MDPH's K-8 school-based asthma surveillance program. We matched asthma prevalence data for all reporting cities/towns with 1990-2005 TURA city/town asthma toxicant use and point air emission data, and conducted a correlation analysis using Microsoft Excel.

D. PROJECT RESULTS

I. TURA Reportable Chemicals that Cause or Exacerbate Asthma

Based on the four evidence sources described in the methods section, there are approximately 335[i] substances that can cause or exacerbate asthma. These substances include both chemicals as well as biologicals (e.g. plant, animal and insect proteins) and also include agents where the evidence is considered "limited" according to the CHE review. Of the 335 agents, 68 (20%) are reportable under TURA, 41 (12%) of which have been reported to TURA at some point during the program's history (see Appendix A & B).

Figure 3: Asthma-Related Chemicals Included on TURA Program's Science Advisory Board's "More Hazardous" List

- Benzene*
- Chlorine
- Chloroform*
- Chromic Acid
- Chromium and compounds
- Dibromochloropropane*
- Ethylene oxide
- Formaldehyde
- Hydrazine
- Methylene Diisocyanate
- Nickel and compounds
- Phenols (NOS)
- Phosgene
- Sulfuric Acid (and sulfuric acid fuming)
- Toluene diisocyanate

**evidence limited*

Of those reported, 15 chemicals have been characterized as "more hazardous" by the TURA program's Science Advisory Board. It is important to note that these 15 chemicals are on this list not because of their potential to cause or exacerbate asthma, but rather because of evidence that they are associated with other public health or environmental endpoints such as cancer, toxicity (neurotoxicity, developmental/reproductive toxicity, aquatic toxicity) or the potential for the chemical to persist in environmental media and/or bioconcentrate.

While Figure 3 lists those chemicals with only limited evidence of an association with asthma, we excluded these agents from our analyses and associated results. In total, 6 chemicals with limited evidence of an association were excluded from our trend analyses, including benzene, chloroform, dibromochloropropane (DBCP), dibutyl phthalate, caprolactam, and toluene.

Of the agents not reportable under TURA, the majority includes drugs, animal antigens, plant antigens, and other compounds not covered by the TURA mandate, which focuses on industrial chemicals. However, approximately 100 of the agents not reportable under TURA are chemicals, including non-specific classes of compounds (e.g. anhydrides), non-specific compounds (e.g. epoxy resins, cutting oils) as well as non-specific environmental contaminants (e.g. environmental tobacco smoke, air pollutants). These chemicals are identified in Appendix C.

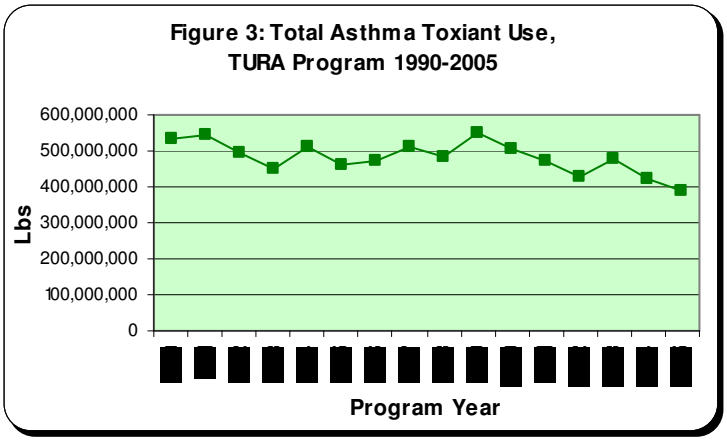
II. Total Use and Release Trends of Asthma-Related Chemicals

The following sections describe the data on use and air releases of asthma-related chemicals reported under TURA. The total use numbers give a sense of the scale of potential exposure to chemicals known to cause or exacerbate asthma.

[i] It is difficult to obtain an exact number, as lists of agents that can cause or exacerbate asthma reflect a mixture of individual and classes of compounds.

Total Use

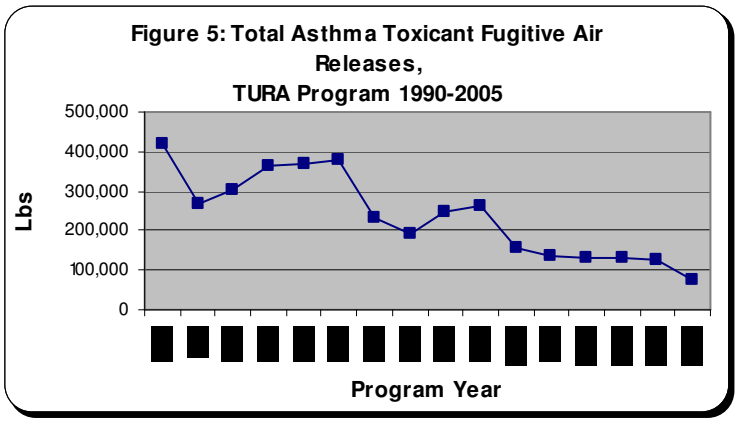
The total cumulative use of all asthma-related chemicals by TURA filers from 1990 to 2005 was 7.7 billion pounds. "Use" in this analysis is the amount of chemical a company manufactured, incorporated into a product or processed or otherwise used.



As shown in Figure 4, total use of asthma-related chemicals declined 27% from 532 million pounds in 1990 to a total of 387 million pounds by 2005. Of the 41 agents analyzed, the vast majority showed overall use reductions. Sixty-nine percent of the total asthma toxicant use was from styrene monomer, which decreased by 31% from 1990-2005. Excluding styrene from the calculation of total pounds of asthma-related chemicals, the decline in use of asthma-related chemicals is 18% over the period 1990-2005. However, total use of some chemicals increased from 1990 to 2005, notably ammonia (103% increase), chlorine (1013% increase), ethylene oxide (2200% increase), hydrazine (732% increase), maleic anhydride (3029% increase), and toluene diisocyanate (62% increase). Between 1995, when it was first reported to TURA, and 2005, the use of chlorothalonil increased 295%.

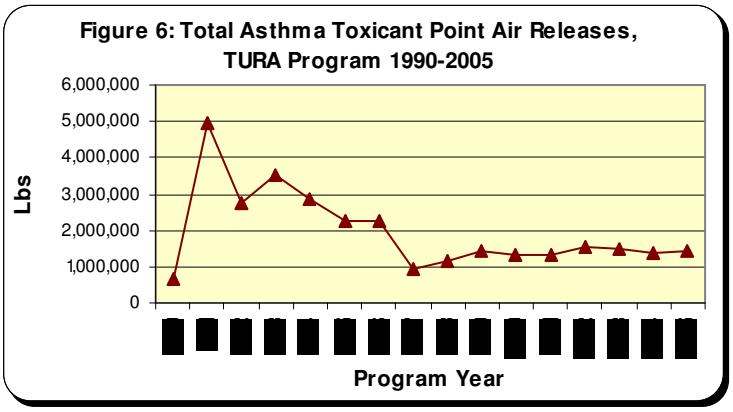
Total Fugitive Air Releases

Fugitive air releases are those not captured by emission control technologies, such as leaks through pipe fittings, tanks and loading/unloading operations, losses through evaporation, etc. These uncontrolled releases can be of particular concern for worker health and safety. Total cumulative fugitive releases of asthma-related chemicals over the period 1990-2005 were 3.8 million pounds. As shown in Figure 5, fugitive air releases of asthma-related chemicals have dramatically declined since the beginning of the TURA program. Although total fugitive air releases remained relatively high until 1995, the data indicate significant improvements in fugitive air releases, with an overall decline of 82%, from 1990-2005. In general, fugitive air releases of asthma-related chemicals have decreased since 1990, with the exception of a few chemicals that experienced increases in the initial years of the program followed by subsequent declines (e.g. acetic acid, formaldehyde and phenol).



Total Point Source Air Releases

Cumulative point source air releases of asthma-related chemicals from 1990-2005 totaled 31.3 million pounds. These air releases occur through confined air streams such as stacks, vents, ducts or pipes and may pose a threat to surrounding ecosystems and the health of local residents.



As shown in Figure 6, point source air emissions dramatically increased in 1991. This reflects the phase-in of additional industry sectors reporting to TURA at that time, rather than a rise in actual releases. Point source air releases steadily declined until 1997, at which point there was a gradual minor increase until 2005, with 1.5 million pounds released in 2005. From 1991 to 2005, there was a 71% decrease in point source air emissions. Although point source air releases of nearly all asthma-related chemicals have declined since the earliest years of the TURA program, a few chemicals showed increases, including ammonia (224% increase), nickel (305% increase), and sulfuric acid (422% increase).

III. Asthma-related chemicals Driving the Trends

The top 10 agents that drive total use, fugitive air release and point source air release patterns are noted in Table 1, Table 2, and Table 3 respectively. Although we calculate percent change from 1990-2005, these calculations do not always reveal a complete understanding of trends as few chemicals show steady increases or declines. Thus, we further describe specific trends in our review of the top five asthma-related chemicals most frequently used and released to air. Tables 4-6 outline the top 10 Massachusetts cities/towns with the highest asthma toxicant uses, and air releases. Within these tables, the top-5 chemicals contributing to the totals within each town are noted.

TABLE 1. TOTAL CUMULATIVE USE (1990-2005): TOP 10 ASTHMA-RELATED CHEMICALS*

#	CAS#	Chemical	Total (lbs) Used**	% Change 1990-2005
1	100425	STYRENE MONOMER	5,300,543,547	-31%
2	7664939	SULFURIC ACID	739,947,593	-27%
3	7440666, 1039	ZINC & ZINC COMPOUNDS	277,513,308	+2%
4	7664417	AMMONIA	243,941,991	103%
5	91087, 584849, 26471625, 101688, 1050	DIISOCYANATES (TDI, MDI, IDI & Diisocyanates)	232,592,411	+24%
6	7440473, 1012	CHROMIUM & CHROMIUM COMPOUNDS	149,695,676	-84%
7	85449	PHTHALIC ANHYDRIDE	139,378,492	-91%
8	64197	ACETIC ACID	120,423,731	-65%
9	50000	FORMALDE-HYDE	105,505,823	-63%
10	7782505	CHLORINE	84,818,846	+1013%

TABLE 2. TOTAL CUMULATIVE FUGITIVE AIR EMISSIONS (1990-2005): TOP 10 ASTHMA-RELATED CHEMICALS*

#	CAS#	Chemical	Total (lbs) Fugitive Emissions	% Change 1990-2005
1	7664417	AMMONIA	1,841,681	-85%
2	7664939	SULFURIC ACID	664,227	-86%
3	64197	ACETIC ACID	565,321	-85%
4	100425	STYRENE MONOMER	327,407	-51%
5	10102440	NITROGEN DIOXIDE	102,527	-100%
6	50000	FORM-ALDEHYDE	86,126	-94%
7	7440666, 1039	ZINC & ZINC COMPOUNDS	52,266	-72%
8	7440473, 1012	CHROMIUM & CHROMIUM COMPOUNDS	40,392	-95%
9	7440020 & 1029	NICKEL & NICKEL COMPOUNDS	30,678	-90%
10	117817	DIETHYL-HEXYL-PHTALATE	23,836	-57%

TABLE 3. CUMULATIVE POINT AIR EMISSIONS (1990-2005): TOP 10 ASTHMA-RELATED CHEMICALS*

#	CAS#	Chemical	Total (lbs) Air Point Emissions	% Change 1990-2005
1	7664939	SULFURIC ACID	17,873,773	+422% (-86% since 1991)
2	7664417	AMMONIA	9,034,730	+224%
3	50000	FORM-ALDEHYDE	1,439,539	-66%
4	64197	ACETIC ACID	1,085,437	-92%
5	100425	STYRENE MONOMER	567,740	-48%
6	10102440	NITROGEN DIOXIDE	527,060	-89% (since 1993)
7	7440666, 1039	ZINC & ZINC COMPOUNDS	107,106	-60%
8	75070	ACETALDEHYDE	102,300	-62%
9	7782505	CHLORINE	88,389	-99%
10	117817	DIETHYL-HEXYL-PHTALATE	61,299	-100%

*Agents with only limited evidence excluded from analysis; **Total Cumulative Amount Manufactured, Processed & Otherwise Used: 1990-2005

Table 4: Top 10- Massachusetts Towns with the Highest Total Cumulative Use (1990-2005) of Asthma-related chemicals*

#	Town	Top 5 Responsible Chemicals (descending order of use)	Total Cumulative (lbs) Use**
1	SPRINGFIELD	Styrene, Sulfuric acid, MDI, Diisocyanates, Acetic acid	3,585,072,957
2	OXFORD	Styrene, Zinc & compounds	1,022,148,682
3	HOLYOKE	Styrene, Sulfuric acid, Zinc & compounds, Acetic acid, Chromium & compounds	527,152,623
4	FALL RIVER	Sulfuric Acid, Ammonia, Acetic acid, Sulfuric acid (fuming), Chlorine	323,824,055
5	LEOMINSTER	Styrene, Zinc & compounds, Acetic Acid, DEHP, Chromium & compounds	275,943,682
6	ATTLEBORO	Phthalic anhydride, Nickel & compounds, Ammonia, Sulfuric acid, Chromium & compounds	269,587,876
7	NEW BEDFORD	Chromium & compounds, Zinc & compounds, Nickel & compounds, Sulfuric acid, DEHP	130,949,817
8	NEWBURYPORT	TDI, Diisocyanates, MDI, Ammonia, Sulfuric Acid	110,260,010
9	CHICOPEE	Zinc & compounds, Sulfuric acid, Nickel & compounds, Formaldehyde, MDI	102,572,591
10	PEABODY	Sulfuric Acid, Ammonia, Diisocyanates, Chromium & compounds, TDI	70,296,586

Table 5: Top 10- Massachusetts Towns with the Highest Total Cumulative Fugitive Air Releases (1990-2005) of Asthma-related chemicals*

#	Town	Top 5 Responsible Chemicals (descending or of use)	Total Cumulative (lbs) Fugitive Releases
1	FALL RIVER	Ammonia, Acetic acid, Formaldehyde, Sulfuric acid, Styrene	816,458
2	NEW BEDFORD	Sulfuric acid, Zinc & compounds, DEHP, Ammonia, Nickel & compounds	272,036
3	PEABODY	Ammonia, Acetic acid, Sulfuric acid, Zinc & compounds, TDI	254,759
4	WORCESTER	Sulfuric acid, Ammonia, Formaldehyde, Chromium & compounds, Nickel & compounds	236,540
5	LOWELL	Ammonia, Styrene, Sulfuric acid, DEHP	213,128
6	SALEM	Ammonia, Chromium & compounds, Nickel & compounds, Zinc & compounds, Sulfuric acid	212,093
7	HAVERHILL	Acetic acid, Sulfuric Acid, Ammonia	151,257
8	CANTON	Ammonia, Aluminum, Phenylenediamine, Zinc & compounds, Styrene	112,901
9	GRAFTON	Nitrogen dioxide, Chromium & compounds, Aluminum, Nickel & compounds, Cobalt	108,819
10	LUDLOW	Styrene	104,277

Table 6: Top 10- Massachusetts Towns with the Highest Total Cumulative Air Point Emissions (1990-2005) of Asthma-related chemicals*

#	Town	Top 5 Responsible Chemicals (descending or of use)	Total Cumulative (lbs) Air Point-Emissions
1	EVERETT	Sulfuric acid, Ammonia, Formaldehyde, Nickel & compounds, Vanadium	4,775,619
2	SANDWICH	Sulfuric acid, Nickel & compounds, Vanadium, Ammonia, Formaldehyde	4,242,314
3	SOMERSET	Sulfuric acid, Ammonia, Nickel & compounds, Chromium & compounds, Vanadium	4,149,233
4	SALEM	Ammonia, Sulfuric acid, Nickel & compounds, Vanadium, Zinc & compounds	3,670,557
5	BOSTON	Sulfuric acid, Ammonia, Chromium & compounds, Nickel & compounds, Formaldehyde	2,914,876
6	SPRINGFIELD	Ammonia, Nitrogen dioxide, Styrene, Sulfuric acid, Acetylaldehyde	1,432,045
7	WEST GROTON	Ammonia, Sulfuric acid, Formaldehyde, Acetic acid	864,600
8	PITTSFIELD	Ammonia, Zinc & compounds, Sulfuric acid, Nickel & compounds	774,964
9	FALL RIVER	Acetic acid, Ammonia, Sulfuric acid, Ethylenediamine, Styrene	549,974
10	FITCHBURG	Formaldehyde, Sulfuric acid, Chromium & compounds, Acetic acid, Ammonia	484,562

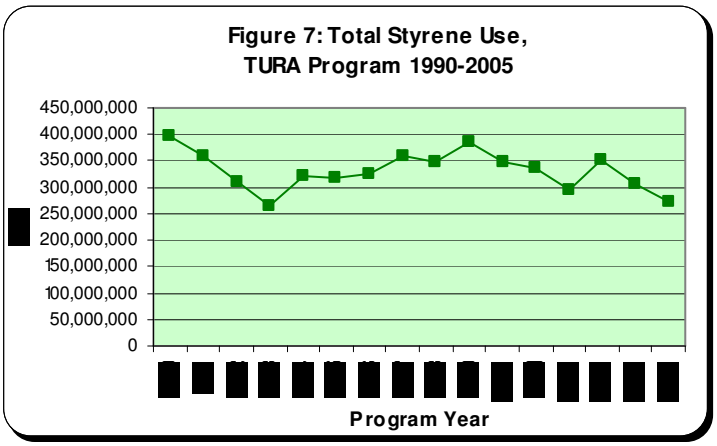
*Agents with only limited evidence excluded from analysis; **Total Cumulative Amount Manufactured, Processed & Otherwised Used: 1990-2005

The following subsections describe the five major chemicals used, released via fugitive emissions, or released via point source air emissions.

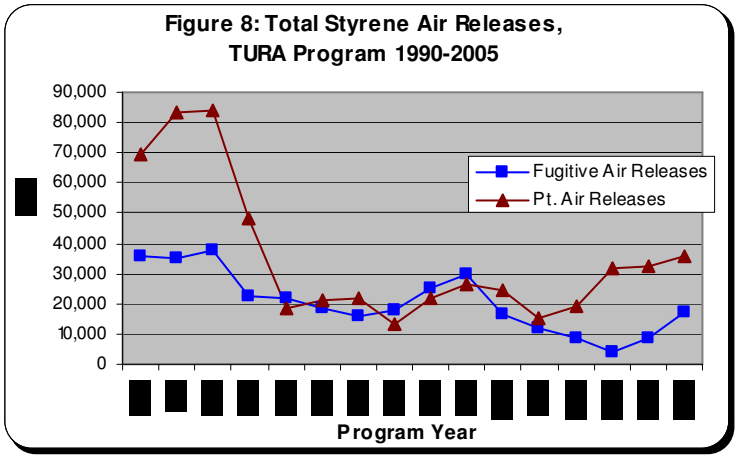
Styrene Monomer

Styrene monomer is used extensively in the production of polymers, co-polymers, resins and reinforced plastics and is used as a reactant. In Massachusetts, the primary use of styrene is for the production of polystyrene, a transparent, solid, and very light weight plastic produced by the polymerization of styrene monomer. Although the total number of Massachusetts employees working with styrene is unknown, OSHA estimates that more than 90,000 workers are potentially exposed to styrene nationally.

Styrene is the predominant chemical driving the use trends of asthma-related chemicals in Massachusetts. Over 5.3 billion pounds were used from 1990-2005. The majority of total cumulative use of styrene during 1990-2005 occurred among facilities in Springfield (3.4 billion pounds), Oxford (1.0 billion pounds) and Holyoke (516.2 million pounds) (Appendix D). Styrene was the highest used chemical among four of the top 10 cities/towns with the highest total cumulative use of asthma-related chemicals (Table 4). Use of styrene has declined by 31% from 1990-2005 (Figure 7).



Styrene is also on the top-5 total cumulative fugitive air releases and point source air emissions. While facilities in the towns of Ludlow (104,227 pounds), Holyoke (59,602 pounds) and Norton (42,597 pounds) released the highest total cumulative fugitive air emissions of styrene, facilities in Springfield (214,276 pounds), Rockland (176,771 pounds) and Oxford (43,829 pounds) represented the primary drivers of total cumulative point source air releases. Styrene fugitive air emissions and point source air releases have declined over the past 15 years by 51% and 48% respectively (Figure 8).



Although CHE described the evidence as "limited" regarding styrene monomer's ability to cause or exacerbate asthma, AOEC lists it as an agent capable of causing asthma among those previously free of the disease and Malo and Chan-Yeung list it as an occupational

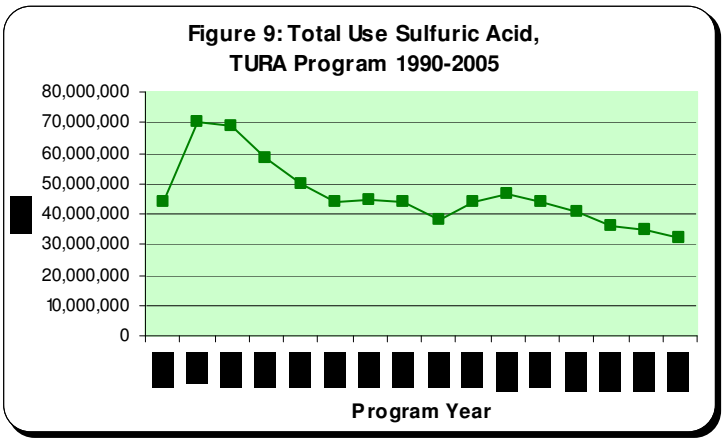
asthmagen. Evidence linking styrene with asthma comes from a number of case reports published in the scientific literature.[20, 21] Although the underlying mechanism associated with styrene-induced asthma is unknown, current evidence suggests that styrene is a sensitizing agent and that asthma develops via an allergic, hypersensitivity response to exposure.[22]

In addition to asthma, styrene is identified by International Agency for Research on Cancer (IARC) as a Group 2B possible carcinogen. Other health effects associated with exposure to styrene monomer include first degree burns as a result of short term skin exposure, contact dermatitis, liver toxicity, and encephalopathy from exposure to high concentrations over an extended period of time.

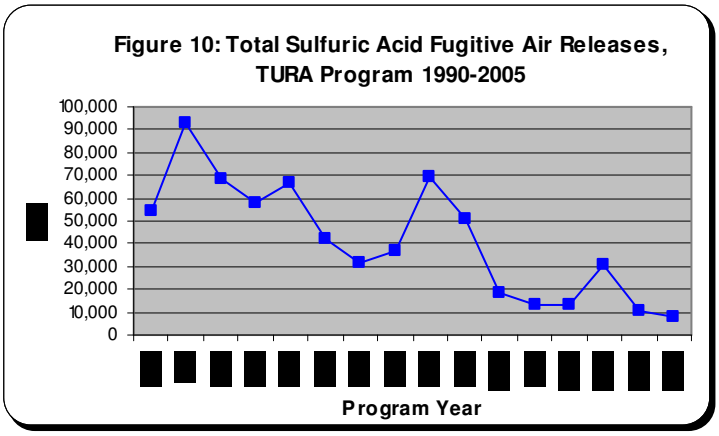
Sulfuric Acid

Sulfuric acid is used in several industries such as textiles, food and beverage processing, electronics, metals, and pulp and paper mills, and among electricity generators in processes including chemical production, electroplating and anodizing processes and is otherwise used in water and wastewater treatment processes.[23] Sulfuric acid is on the TURA program's Science Advisory Board's "more hazardous" list.

Sulfuric acid was the second highest asthma toxicant used in Massachusetts from 1990-2005, totaling 740 million pounds (Figure 9). The majority reported using sulfuric acid for the manufacture of chemicals (Appendix D). Facilities with the highest total cumulative use of sulfuric acid were located in Fall River (85.6 million pounds), Springfield (84.3 million pounds), and Peabody (40.6 million pounds) (Appendix D). Total use of sulfuric acid rose between 1990 and 1991 as additional industries, such as electric utilities and chemical distributors, began reporting to the TURA program. From 1990 to 2005, total cumulative use of sulfuric acid declined by over 27%.

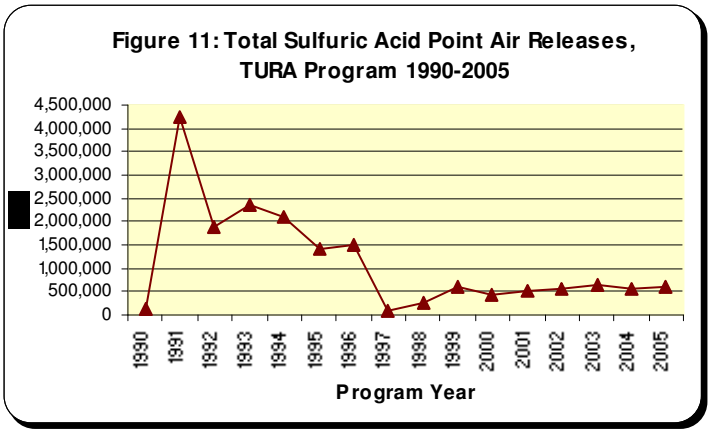


Among asthma toxicant air releases, sulfuric acid had the second highest total cumulative fugitive emissions (664,227 pounds) and the highest total cumulative point source air emissions (17.9 million pounds). Both fugitive and point source air emissions increased sharply from 1990-1991 as electric generating industries first began reporting to TURA (Figures 10 and 11). Total



fugitive emissions were 54,346 pounds in 1990 with a dramatic rise in the second year of reporting and then a fairly consistent decline to 7,546 pounds in 2005, representing a total reduction of 86%. Facilities in New Bedford (262,574 pounds) and Worcester (102,452 pounds) were primary drivers of total cumulative sulfuric fugitive air emissions (Table 5 and Appendix D).

Point source air release trends for sulfuric acid were similar to use trends with releases rising from 113,925 pounds in 1990 to over 4.2 million pounds in 1991 as electric utility industries began reporting to TURA. Point source air releases have dramatically dropped after 1991 and have leveled out over the last seven years to a total of 594,699 pounds in 2005, representing an 86% decrease from 1991. Electric generating facilities in Everett (4.2 million pounds), Sandwich (4.0 million pounds), Somerset (3.8 million pounds), Boston (2.6 million pounds) and Salem (1.1 million pounds) were the primary drivers of total cumulative sulfuric acid point air source emissions (Table 6).



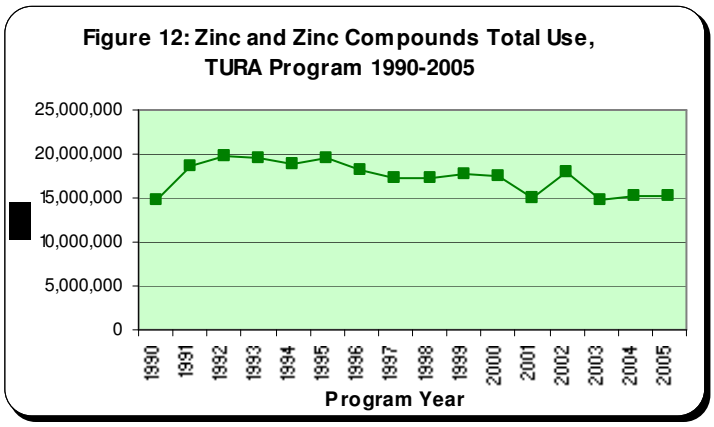
Both AOEC and Malo and Chan-Yeung list sulfuric acid as an occupational asthmagen. Neither CHE nor IOM evaluated this compound, although CHE does rank the evidence for "acids" as strongly associated with irritant asthma. High dose exposure to sulfuric acid, often as a result of accidents, spills or equipment failure has caused irritant-induced asthma among workers. Evidence also suggests that aerosols of sulfuric acid at much lower doses can exacerbate asthma among workers and the public, including children. Much of this evidence is from studies demonstrating an increase in asthma symptoms associated with exposure to acid aerosols in air pollutant mixtures.[24-26]

In addition to asthma, inhalation of sulfuric acid produces other respiratory hazards including bronchitis, emphysema and respiratory symptoms such as shortness of breath. IARC classifies exposure to sulfuric acid mists as a known (Group 1) lung carcinogen. Sulfuric acid can also severely irritate and burn the skin, eyes and potentially cause blindness.

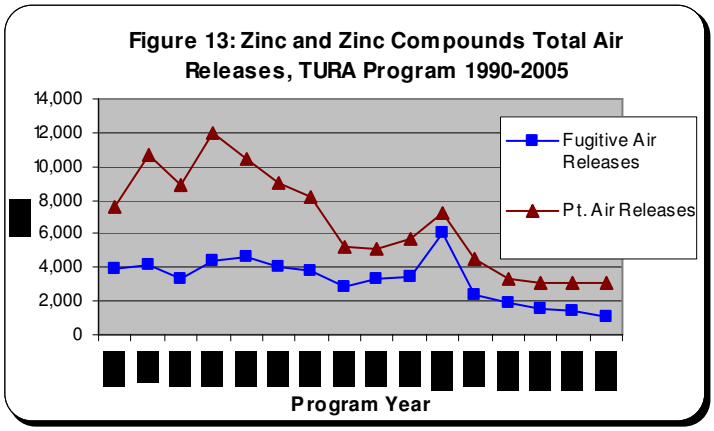
Zinc and Zinc Compounds

Zinc has many commercial uses, as coatings to prevent rust, in dry cell batteries, and mixed with other metals to make alloys like brass, and bronze. Zinc compounds include zinc chloride, zinc oxide, zinc sulfate, and zinc sulfide. Zinc compounds are widely used in industry to make paint, rubber, dyes, wood preservatives, and ointments.[27]

Zinc and associated compounds were the 3rd highest used asthma-related chemicals in Massachusetts from 1990-2005, totaling 277.5 million pounds. Use of zinc and zinc compounds was relatively stable from 1990-2005, with only a 2% increase in use over that time period (Figure 12). In 1995 use of zinc and zinc compounds reached a high of over 19.5 million pounds. Thus zinc and zinc compounds use was reduced by 22% over the last 10 years. Industries using the greatest amount of zinc and zinc compounds include miscellaneous manufacturing industries and rubber and miscellaneous plastic product industries (Appendix D). Facilities in Chicopee (86.2 million pounds), Dartmouth (55.2 million pounds) and New Bedford (29.5 million pounds) had the highest total cumulative use of these chemicals (Appendix D).



Zinc and zinc compounds were not among the top-5 highest asthma-related chemicals in terms of total cumulative fugitive and point source air emissions; they were ranked 7th for both. From 1990-2005, fugitive air releases totaled 53,266 pounds and declined by 72% (Figure 13). Cumulative air point releases over this same time period totaled 107,106 pounds and declined 60% (Figure 13). Facilities in Everett contributed the most to total cumulative fugitive zinc and zinc compounds air emissions (17,930 pounds) while facilities in Pittsfield (24,100 pounds), Worcester (18,921 pounds) and New Bedford (17,899 pounds) were the primary drivers of total cumulative point source air releases. Industry types contributing to the greatest burden of fugitive air releases were metal fabrication companies, whereas electronic and other electrical equipment and component industries (excluding computers) contributed to the greatest burden of zinc and zinc compounds point air releases (Appendix D).



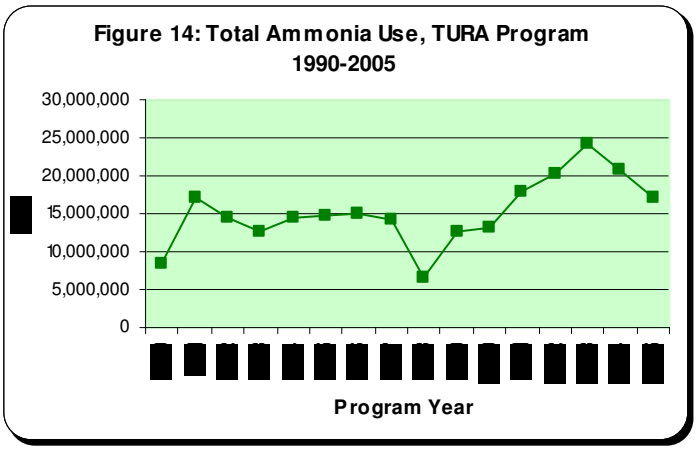
Both AOEC and Malo and Chan-Yeung list zinc and zinc compounds as occupational asthmagens. Neither IOM nor CHE evaluated the evidence for zinc. Case reports in the literature document workers developing asthma after exposure to heated zinc.[28] A more recent study also suggests that higher levels of zinc in fine air pollutant particulate matter (PM2.5) are associated with an increased risk of severe pediatric asthma exacerbations resulting in an increase of emergency room visits and hospitalizations.[29]

Animal studies suggest that exposure to large doses of zinc may affect fertility and skin exposure to zinc acetate and zinc chloride likely causes skin irritation. Exposure to high concentrations of zinc also has been linked to a specific short-term disease called metal fume fever.[27]

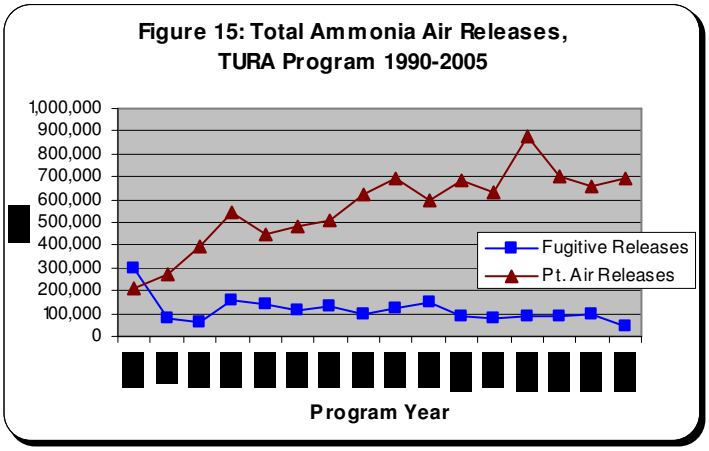
Ammonia

Nationally, approximately 80-90% of ammonia and ammonium compounds are used for agricultural fertilizers, with the remainder used in the commercial production of plastics, synthetic fibers and resins, explosives, and other uses.[30] In Massachusetts, wholesale trade industries and electric, gas and sanitary service industries are the primary users of ammonia comprising 34% and 25% of the total use from 1990-2005, respectively (Appendix D).

Ammonia was the 4th highest used asthma toxicant in Massachusetts from 1990-2005, totaling 243.9 million pounds. Total cumulative use of ammonia was highest among facilities in Fall River (76.3 million pounds), Attleboro (28.1 million pounds), and Boston (23.4 million pounds) during this time period (Appendix D). Although use has declined since 2003, overall use since 1990 has increased 103% (Figure 14).



Total fugitive air releases of ammonia from 1990-2005 were the highest of all asthma-related chemicals, totaling 1.8 million pounds. Facilities in Fall River (410,524 pounds), Peabody (254,472 pounds), Lowell (211,822 pounds), and Salem (210,366 pounds) had the highest total cumulative fugitive air emissions (Appendix D). The primary industries emitting ammonia as fugitive air releases were textile mill products (29%), chemical and allied products (17%), and electric, gas and sanitary services (15%). (Appendix D). Fugitive air emissions have been somewhat stable since 1991 and moreover dropped to the lowest level of 42,590 pounds in 2005 (Figure 15). Overall, fugitive releases for ammonia from 1990-2005 declined by 85%.



On the other hand, point source air releases of ammonia increased 224% during this same time period (Figure 15). Cumulative point source air emissions from 1990-2005 totaled 9.0 million pounds and were driven primary by

releases by facilities in Salem (2.5 million pounds), Pittsfield (745,530 pounds), Springfield (643,015 pounds), and West Groton (528,000). These point source air releases were the second highest of all asthma-related chemicals and dominated by the electric, gas and sanitary service industry. More recently, air point source emissions show a 21% decline from 2002 to 2005.

Neither AOEC nor Chan-Yeung list ammonia as an occupational asthmagen. Similarly, IOM did not evaluate ammonia. However, CHE ranks the evidence as strong with regard to an association with irritant asthma. CHE's evaluation is based on epidemiologic studies documenting an association between ammonia and asthma. Evidence suggests ammonia exposure is associated with non-atopic asthma (atopic asthma is connected with a broader syndrome of conditions all characterized by allergic sensitivity) among farmers.[31] Workers in concentrated animal feeding operations are also at an increased risk of asthma due to exposure to indoor ammonia levels from animal urine and feces and other contributing factors such as grain dust and endotoxins.[32] In a study of fertilizer workers, exposure to ammonia gas resulted in an increase of respiratory symptoms, including bronchial asthma.[33] Other occupations also showed an increased risk of asthma symptoms associated with ammonia exposure, particularly among janitorial and cleaning personnel. In one study of domestic cleaning personnel, there was over a three-fold elevation in asthma and chronic bronchitis symptoms associated with the use of undiluted ammonia.[34] Due to its lung irritant properties, both adults and children with asthma are more susceptible to an exacerbation of their symptoms from ammonia inhalation[30] and thus most environmental management guidelines for asthma strongly recommend avoiding exposure.

Due to its irritating and corrosive nature, inhalation of ammonia can cause coughing and nose and throat irritation. At higher concentrations it can cause bronchiolar and alveolar edema, and airway destruction resulting in respiratory distress or failure. Ingestion can damage the mouth, throat and stomach, while skin or eye contact can produce rapid irritation, burns, permanent eye damage or blindness.[35]

Diisocyanates

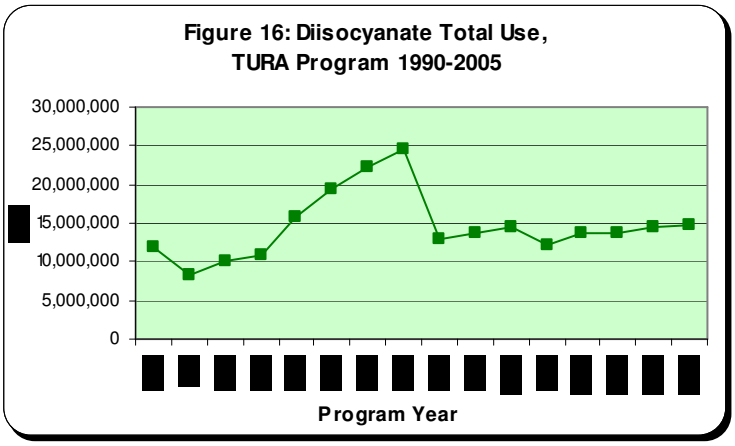
Diisocyanates are used in a wide variety of applications, such as in adhesives, binders, foams, elastomers, resins, sealers, and surface coatings.[36] There are several types of diisocyanates in use by industry. Toluene diisocyanate (TDI) and methylene diphenyl isocyanate (MDI) are the most commonly reported diisocyanates under TURA. Other diisocyanates, including polymethylene polyphenylisocyanate, dicyclohexylmethane 4,4-diisocyanate (HMDI), and isophorone isocyanate are reportable under TURA along with 20 others that are reported under the group "diisocyanates" rather than as individual chemicals. In Massachusetts, rubber and miscellaneous plastic product industries are the primary users of diisocyanates comprising 67% of the total use from 1990-2005 (Appendix D).

Table 11: Cumulative Total Use of Specific Diisocyantes Reported under TURA, 1990-2005

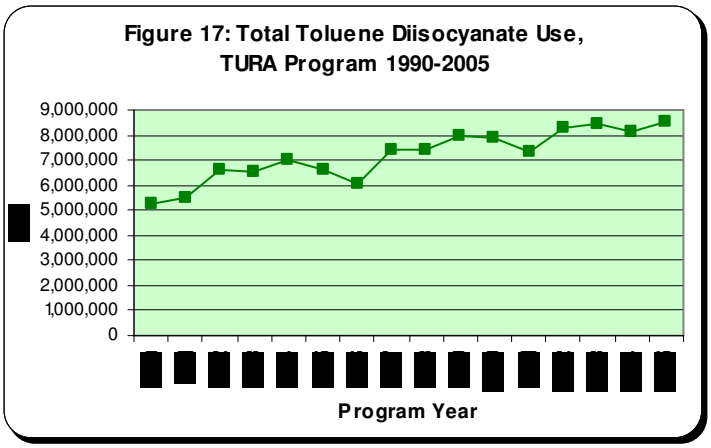
Chemical/ Reporting Group	Lbs Used
Dicyclohexylmethane 4,4-diisocyanate	193,904
Diisocyanates group (20 chemicals)	70,404,759
4,4' methylene diisocyanate	46,906,353
Isophorone diisocyanate	73,464
Polymethylene polyphenylisocyanate	46,331
Toluene diisocyanate (all isomers)	114,967,600
TOTAL	*232,592,411*

When the diisocyanates are considered individually, none are among the top-5 highest used asthma-related chemicals. However, when examining at this category of chemicals as

a whole, diisocyanates are ranked as the 5th highest used asthma-related chemicals in Massachusetts from 1990-2005. Total cumulative use of diisocyanates over that time period was 232.5 million pounds. As shown in Figure 16, the sharp decline in diisocyanate use in 1998 was primarily due to a drop in use of MDI. Despite this decline, overall, diisocyanate use has increased 24% from 1990-2005.



The overall increase in total cumulative use of diisocyanates is driven by the use of TDI. As Table 11 reveals, TDI was the most heavily used diisocyanate comprising 49% of the total cumulative diisocyanate use from 1990-2005. TDI use has gradually increased from 1990-2005 (Figure 17). Over this time period, total cumulative use of TDI has increased 62%.



Facilities that reported the highest total cumulative use of TDI were located in Newburyport (94.6 million pounds), Fall River (7.4 million pounds) and Wilmington (4.4 million pounds) (Appendix D). Facilities with the highest total cumulative use of MDI were located in Springfield (36.1 million pounds), Fall River (1.7 million pounds) and Newburyport (1.4 million pounds) (Appendix D). Total cumulative use of other diisocyanates was driven by facilities in Wilmington (15.3 million), Springfield (10.5 million pounds) and Newburyport (8.7 million pounds) (Appendix D).

It is important to note that including the broad "diisocyanate" reporting group may overestimate the total use of asthma-related chemicals by Massachusetts industries, since the literature reports asthma links with only a few of the 20 chemicals in this category. However, evidence suggests that chemicals with an isocyanate functional group are likely respiratory irritants.[37] Since TURA requires industries to report their use or release of these 20 chemicals for the group "diisocyanates" rather than as the individual chemical, it is impossible to discern which diisocyanates contributed to the use patterns.

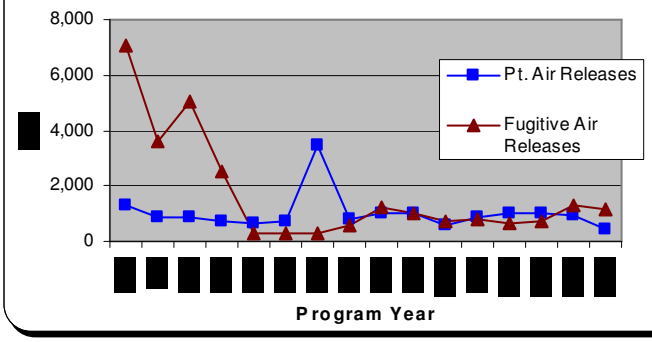
Cumulative total fugitive and point source air emissions from 1990-2005 for diisocyanates were not among the top five asthma-related chemicals, but rather ranked 13th and 19th respectively. From 1990-2005, fugitive air emissions totaled 16,235 pounds and the greatest percent of these releases (50%) were driven by releases of diisocyanates reported

to TURA as the diisocyanates group (Table 12). Over this same program period, point air emissions totaled 27,214, of which TDI releases contributed the most (63%) to this cumulative total (Table 12). In 1996, point source air releases rose dramatically (Figure 18). This spike was driven by diisocyanate emissions as reported through the "diisocyanate" group. Overall, point source air releases as well fugitive air emissions have declined from 1990-2005 by 83% and 66% respectively.

Table 12: Cumulative Total Air Releases of Specific Diisocyantes Reported Under TURA, 1990-2005

Chemical/ Reporting Group	Fugitive Release (lbs)	Pt. Releases (lbs)
Dicyclohexylmethane 4,4-diisocyanate	10	10
Diisocyanates group (20 chemicals)	8,074	7,574
4,4' methylene diisocyanate	2,310	2,057
Isophorone diisocyanate	38	0
Polymethylene polyphenylisocyanate	0	0
Toluene diisocyanate (all isomers)	5,803	17,573
TOTAL	*16.235*	*27.214*

Figure 18: Diisocyanate Total Air Releases, TURA Program 1990-2005



Both AOEC and Malo and Chan-Yeung list TDI, MDI, 1,5 naphthylene diisocyanate, isophorone diisocyanate, HDI prepolymers, TDI prepolymers, and polymethylene polyphenylisocyanate as occupational asthmagens. HMDI is not specifically included on AOEC, Malo and Chan-Yeung or by CHE, yet is included as both the AOEC and CHE lists "non-specific" isocyanates and studies are emerging supporting the link between exposure to HMDI and asthma onset.[38] CHE does not review individual diisocyanates, but ranks the evidence as "strong" for the link between "isocyanates" and allergic asthma. IOM did not review this agent.

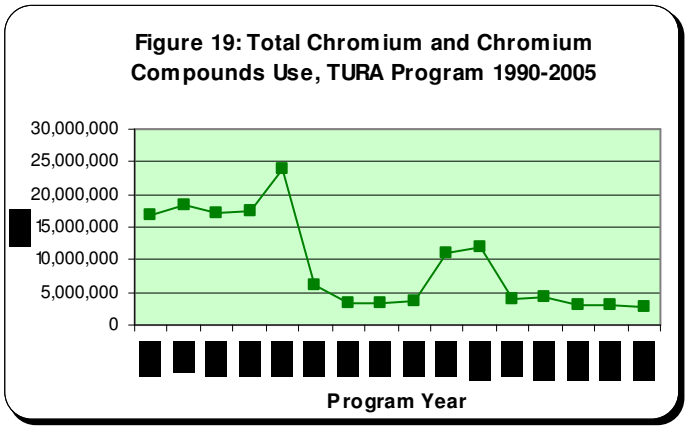
TDI and MDI are two of the most widely studied agents in the workplace that can induce the onset of asthma. Although improved industrial hygiene practices have dramatically reduced respiratory exposure levels of isocyanate in most work environments, studies continue to document cases of isocyanate-induced asthma where levels are very low or non-detectable, but where there is opportunity for skin exposure.[17] Inhalation exposure is the principal route of respiratory sensitization. However, evidence is emerging that dermal exposure to diisocyanates may also result in respiratory sensitization.[17,37] In addition to asthma, diisocyanates are also a cause of contact dermatitis and IARC lists TDI as a possible carcinogen (Group 2b).

Chromium and Chromium Compounds (including chromic acid)

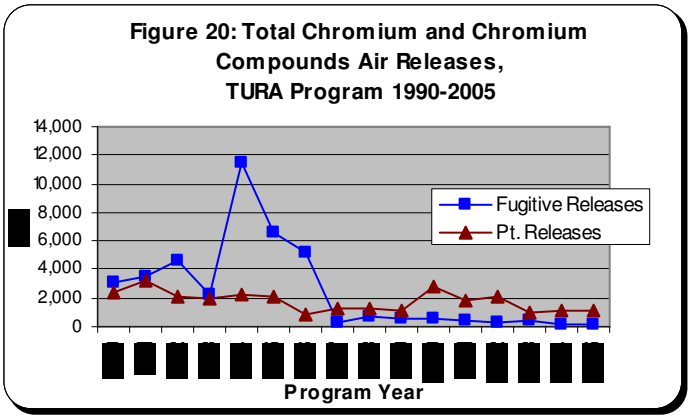
Chromium is a naturally occurring element and is present in the environment in several different forms. The most common forms (oxidative states) are elemental chromium (or chromium (0)), trivalent (or chromium (III)), and hexavalent (or chromium (VI)). Elemental chromium is used mainly for making steel and other alloys. Chromium compounds, mostly in chromium (III) or chromium (VI) forms produced by the chemical industry are used for chrome plating, the manufacture of dyes and pigments, leather tanning, and wood preserving. Smaller amounts are used in drilling muds, rust and corrosion inhibitors, textiles,

and toner for copying machines.[39] While Chromium VI is much more toxic than other forms of chromium, the TURA reporting does not distinguish among specific forms of chromium. Chromic acid is also used in chromium plating, ceramic glazes, colored glass, and in musical instrument repair to "brighten" brass. Use of chromium and chromium compounds in Massachusetts from 1990-2005 was largely dominated by primary metal industries, which comprised 40% of the total use (Appendix D). Chromium and chromium compounds (including chromic acid) are on the TURA program's Science Advisory Board's "more hazardous" list.

Chromium and chromium compounds were the 6th highest used asthma-related chemicals from 1990-2005 (ranked 5th if diisocyanates are not combined and considered separately). Total cumulative use over that time period was 149.7 million pounds. Use spiked in 1994 at 23.4 million pounds, and was at its lowest in 2005, totaling 2.8 million pounds (Figure 19). A dramatic reduction in reported uses of chromium and its compounds is shown between 1994 and 1995, which is associated with the delisting of metals, including chromium, from TURA reporting when used in metal alloys. Overall, from 1990-2005 there was an 84% reduction in the use of chromium and chromium compounds. Facilities that had the highest total cumulative use of chromium and chromium compounds were located in New Bedford (37.3 million pounds), Attleboro (18.6 million pounds), and Belchertown (10.4 million pounds) (Appendix D).



Fugitive air emissions for chromium and chromium compounds were not among the top five but were ranked 8th among all asthma-related chemicals, totaling 40,392 pounds from 1990-2005. Fugitive air releases dramatically increased in 1994 corresponding to the increase in use during that same year (Figures 19 and 20). Fugitive air releases declined in the subsequent years. From 1990-2005, overall fugitive air emissions of chromium and chromium compounds declined 95%. Facilities that had the highest total cumulative releases of these compounds were located in Grafton (15,351 pounds), South Walpole (7,873 pounds), and Winchester (2,199 pounds). Releases from 1990-2005 were highest among stone, clay, glass and concrete product industries as well as industrial and commercial machinery and computer equipment industries.



Cumulative point source air emissions of chromium and chromium

compounds totaled 28,438 pounds from 1990-2005 and were ranked 11th among asthma-related chemicals. Facilities driving these releases were located in Attleboro (7,431 pounds), Somerset (4006 pounds), and Wilmington (2775 pounds) and were highest among fabricated metal and electrical, gas and sanitary service industries.

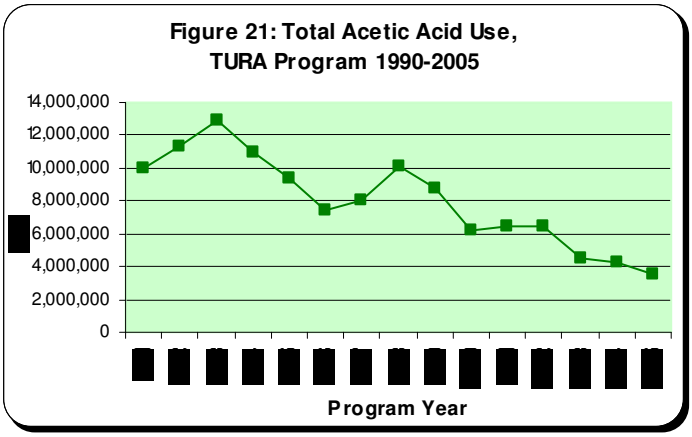
Both AOEC and Malo and Chan-Yeung list chromium as an occupational asthmagen. Only AOEC lists chromic acid as an occupational asthmagen. In addition, CHE ranks as "strong" the evidence associating chromium exposure with allergic asthma. The evidence linking chromium and asthma is primarily from case reports. Multiple case reports have described the initial onset of asthma caused by exposure to chromium and chromium salts in a number of occupations and industries.[40-43] IOM did not review this agent as chromium is not routinely found in indoor residential settings. In addition to asthma, chromium(VI) is a Group 1 known lung carcinogen as classified by IARC.

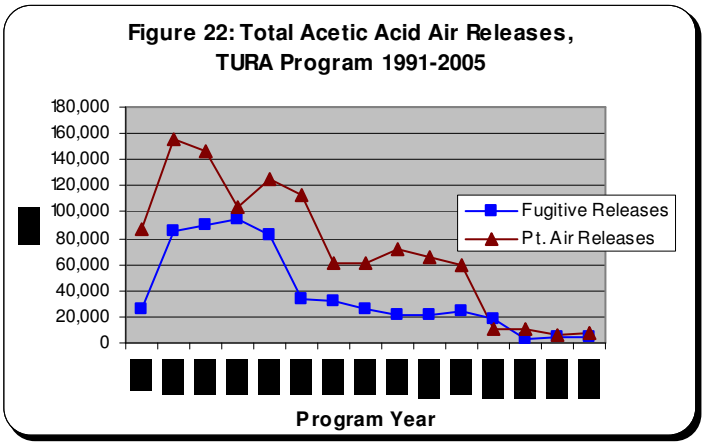
Acetic Acid

Acetic acid is the organic chemical compound which gives vinegar its sour taste and pungent smell. Acetic acid is used in many forms: as a chemical reagent to make soft drink bottles, in producing photographic film, wood glue, synthetic fibers and fabrics and, when diluted, as a household descaling agent. Acetic acid is used to manufacture acetic anhydride and other organic chemicals used in the plastic, pharmaceutical, dye, insecticide, textile, rubber, and photographic industries. It is also used as a food additive in the food industry.[44] In Massachusetts, wholesale trade and chemical and allied product industries were the primary users of acetic acid (29% each) (Appendix D).

Acetic Acid is not ranked among the top-5 asthma-related chemicals for total cumulative use, but is ranked 8th with 120.4 million pounds reported to TURA from 1991 through 2005 (Table 1). Acetic Acid was first listed as a reportable chemical in 1991. Use peaked in 1993 and then made a fairly consistent decline through 1996 with an upturn in 1997 and 1998 and then a consistent decline through 2005 to an all-time low of 3.5 million pounds (Figure 21). Use declined by 65% from 1991 to 2005. Facilities with the highest total cumulative use of acetic acid were located in Fall River (66.0 million pounds), Springfield (9.6 million pounds) and Marlborough (6.4 million pounds).

Acetic acid ranked #3 for asthma toxicant fugitive air emissions from





1991-2005 with cumulative emissions totaling 565,321 pounds. Although fugitive emissions rose dramatically during the first years of the TURA program, emissions have declined overall from 1991 to 2005 by 85% (Figure 22). Total cumulative fugitive emissions were driven by facility releases in Fall River (326,603 pounds), Haverhill (138,349 pounds) and Webster (47,561 pounds) and most prominently within the chemical and allied products, textile mill products and paper and allied products industries.

Acetic acid ranked #4 for asthma toxicant point source air emissions with cumulative releases of 1.1 million pounds from 1991-2005. Emissions peaked in 1992 at 155,750 pounds (Figure 22). Overall point source air emissions declined by 92% from 1991-2005. The highest total cumulative point source air emissions were among facilities located in West Springfield (455,265 pounds) and Fall River (448,941). Releases were most prominent within the paper and allied product and chemicals and allied product industries.

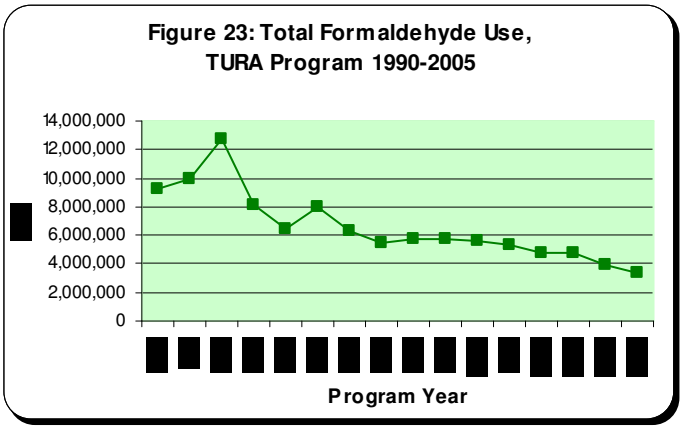
Acetic acid is listed as an occupational asthmagen by AOEC. CHE lists "acids" as strongly linked to irritant asthma, but does not specifically identify acetic acid. Malo and Chan-Yeung did not list acetic acid in their review of occupational asthmagens and IOM did not review the evidence for this specific chemical. Evidence from the research literature supporting the link between acetic acid and asthma includes a case report documenting glacial acetic acid (water free acetic acid) as a sensitizing agent capable of causing allergic asthma,[45] as well as findings of occupational asthma based on an evaluation of hospital workers exposed at medium and high levels to acetic asthma and subsequently developed reactive airway disease syndrome (RADS), a form of irritant asthma.[46]

Acetic acid is corrosive and as a vapor it causes irritation to the eyes, burning in the nose, sore throat and congestion in the lungs. Acetic acid liquid can cause second degree burns after a few minutes of contact with the skin, as well as contact urticaria (hives). Respiratory exposure to high concentrations can result in pulmonary edema.[44]

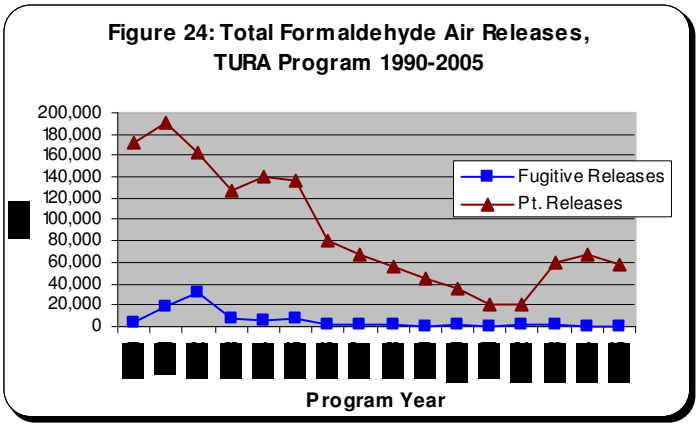
Formaldehyde

Formaldehyde is used to manufacture many products, including resins and adhesives, permanent press fabric treatments, tissue preservatives, lawn fertilizers, cosmetics and disinfectants. Formaldehyde is found consistently at low levels in both indoor and outdoor air as a result of off-gassing from building materials and release by manufacturing facilities and combustion sources.[47] Formaldehyde is on the TURA program's Science Advisory Board's "more hazardous" list.

In Massachusetts, total cumulative use of formaldehyde was not among the top-5 asthma-related chemicals, yet it was ranked 9th. Cumulative use from 1990 through 2005 totaled 105.5 million pounds, primarily among chemicals and allied product industries as well as wholesale trade industries (Appendix D). Facilities located in Fall River (16.1 million



pounds), Marlborough (12.1 million pounds) and Cambridge (11.5 million pounds) had the highest cumulative use of formaldehyde during 1990-2005 (Appendix D). Use rose after 1990 and peaked at 12.8 million pounds in 1992. Use was at its lowest level in 2005 at 3.4 million pounds (Figure 23). This represents a 63% decline in use from 1990 to 2005 and a decrease of 73% if compared against the 1992 maximum.



Formaldehyde fugitive air emission levels were ranked #6 among asthma-related chemicals in Massachusetts. Facilities that contributed most to the 86,126 pounds of total fugitive formaldehyde air releases from 1990-2005, were located in Fall River (41,681 pounds), Fitchburg (10,590 pounds) and Chicopee (7,729 pounds) and primarily came from wholesale trade, chemicals and allied products, and paper and allied products (Appendix D). Emissions initially rose from 3,805 pounds in 1990 to a peak of 31,270 pounds in 1992 (Figure 243). Releases subsequently declined and leveled off through 2005 when the levels reached a low of 238 pounds. There was a decline of 94% from 1990-2005 and a 99% decline from 1992 (peak levels) to 2005.

Point source air releases for formaldehyde were ranked the 3rd highest among all asthma-related chemicals. Cumulative point source air releases of formaldehyde totaled 1.4 million pounds from 1990-2005 and were driven primarily by paper and allied products and electric, gas, and sanitary service industries in Fitchburg (475,235 pounds), West Groton (126,900 pounds), and Everett (105,239). There was a fairly consistent decline in formaldehyde point source emissions from 1991-2002, but releases have subsequently risen in more recent years (Figure 24). This increase in point source air emissions associated with two new TURA filers reporting formaldehyde releases starting in 2003: Boston Generating Mystic I LLC and Hopkinton LNG Facility. The overall decline in point emissions from 1990 to 2005 is 66%.

Both AOEC and Malo and Chan-Yeung list formaldehyde as an occupational asthmagen. CHE lists as "good" the strength of evidence for an association between formaldehyde and the onset of allergic asthma. The IOM states there is limited evidence of association for exacerbation and inadequate evidence of association for development of asthma. This conclusion is primarily based on evaluation of population-based studies of formaldehyde in the indoor, non-occupational environment, in which most studies have been unable to isolate formaldehyde as the causative agent. Other reviews of the literature have also found that formaldehyde causes asthma and indicate that approximately 30% of exposed individuals may be affected.[48] Since IOM's 2000 report, additional studies have been published regarding the risk of asthma from formaldehyde in indoor air. One study with detailed exposure assessment of formaldehyde found increased childhood asthma associated with increased exposure.[49] A second study found that increasing formaldehyde exposure was associated with severe allergic sensitization, and that among children

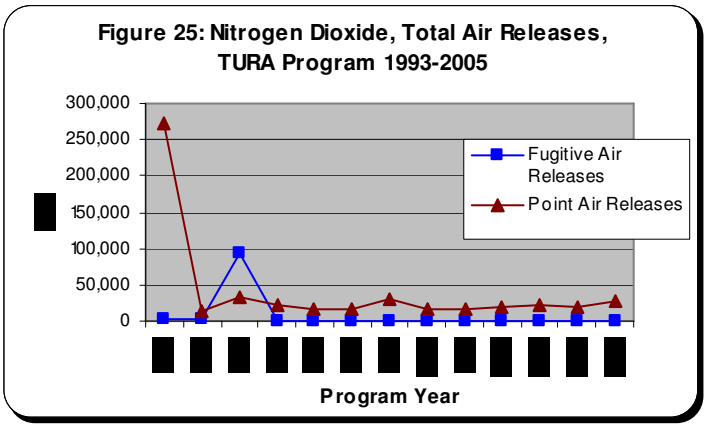
suffering from respiratory symptoms, more frequent symptoms were noted in those exposed to higher levels of formaldehyde.[50]

Formaldehyde is often targeted as a cause of health complaints associated with "sick building syndrome," such as respiratory irritation and headaches. The primary source of exposure is through inhalation, but in liquid form it may also be absorbed through the skin. Repeated prolonged exposure may lead to sensitization and a higher likelihood of experiencing not only asthma, but also contact dermatitis. Formaldehyde was categorized by IARC as a known human carcinogen (Group 1) in 2004.[51]

Nitrogen Dioxide

Nitrogen dioxide is a highly reactive compound formed in most combustion processes. Internal combustion engines, thermal power station and pulp and paper mills are primary industrial sources of nitrogen dioxide emissions. The EPA estimates that nationally approximately 56% of nitrogen dioxide emissions are from vehicular emissions whereas industrial sources, including the burning of oil and natural gas for power generation, comprise about 42% of nitrogen dioxide emissions.[52] Although nitrogen dioxide was not among the top-5 asthma-related chemicals in terms of use (ranked 24th), nearly 1.1 million pounds of nitrogen dioxide was used by Massachusetts industries in specific manufacturing processes. Total cumulative point emissions for nitrogen dioxide were the 5th highest, and total fugitive emissions ranked 6th.

Reporting for nitrogen dioxide began in 1993. During that year, point source air emissions were at their highest at 272,600 pounds. Of the total cumulative nitrogen dioxide released as point source air emissions from 1990-2005 (527,060 pounds), the primary contributing industries were metal fabricators and electric, gas and sanitary services within Grafton (192,420 pounds) and Springfield (258,000 pounds) respectively (Appendix D). Emissions were dramatically reduced in the following year and have remained somewhat stable, averaging 21,000 pounds from 1994-2005 (an 89% reduction from 1993-2005) (Figure 25).



Total cumulative fugitive air emissions are ranked #6 among the asthma-related chemicals due to the large releases recorded in 1995 of 94,000 pounds. For all subsequent years, with the exception of 1999 (1200 pounds reported), zero fugitive emissions have been reported. Of the 102,527 pounds of nitrogen dioxide released from 1993-2005, the majority was released by metal fabricating industries in Grafton (92,000 pounds) and North Adams (9,300 pounds) (Appendix D).

Neither AOEC nor Malo and Chan-Yeung include nitrogen dioxide as an occupational asthmagen. Yet CHE found strong evidence for an association between nitrogen dioxide and

asthma. IOM's review of indoor air pollutants documents sufficient evidence of association for asthma exacerbations, but inadequate evidence of association for asthma development. The difference between the findings of AOEC/Malo and Chang-Yeung and CHE/IOM is likely because the latter focused on community health studies, whereas the former focused on worker health. There is considerable evidence of an increased risk of asthma exacerbations associated with nitrogen dioxide levels in outdoor air pollution caused by industrial as well as vehicular emissions.[53] Dozens of studies examining the indoor environment and reviewed by IOM comprise "sufficient evidence" that nitrogen dioxide levels in the indoor setting can increase the risk of asthma exacerbations. The literature also suggests that exposure to nitrogen dioxide increases the severity of asthma symptoms and other respiratory symptoms associated with respiratory virus infection among children.[54] Important sources of nitrogen dioxide in the indoor setting include gas stoves, furnaces, wood stoves and unvented space heaters (kerosene or gas). Nitrogen dioxide fugitive emissions from industries reporting to TURA over the last six years have been zero.

In addition to asthma, nitrogen dioxide can severely irritate the eyes, nose, skin, throat and lungs. Inhalation of high levels can produce pulmonary edema and can be fatal. Chronic exposure to nitrogen dioxide at lower levels can predispose individuals to lung infections and chronic obstructive pulmonary diseases.[55]

IV. Potential Associations between Uses and Releases of Chemicals and Asthma Events

The enormous volume of use and release of chemicals capable of causing and exacerbating asthma is likely contributing to the burden of the disease in Massachusetts. It is impossible to characterize precisely the role of chemicals in new cases of the disease and in triggering asthma attacks, but surveillance data from workplace and community settings can highlight opportunities for further research and/or intervention.

For this review, we took only the most initial steps to explore associations between the TURA data and Massachusetts Department of Public Health surveillance data. We did not link TURA data on asthma-related chemicals with individual-level surveillance data, but rather reviewed possible links at a broader ecological/descriptive level. As anticipated, the analysis revealed nothing conclusive, but does suggest directions for future work.

Massachusetts Work-Related Asthma Surveillance Data

For our evaluation of work-related asthma data, we abstracted information from MDPH's Sentinel Event Notification System for Occupational Risk (SENSOR) Occupational Lung Disease Bulletin, July 2007.[19] Since 1993, Massachusetts physicians have been required to report both confirmed and suspected cases of work-related asthma to MDPH as part of this program. More recently, case reporting and ascertainment activities by the program have expanded and require that physicians and all other health care providers report to the program. In addition, program staff now query a state-wide database of emergency department visits to identify cases of asthma associated with worker compensation claims. Cases of suspected asthma are confirmed via telephone interviews with each individual case. This surveillance system does not comprehensively capture the total number of work-

related cases of asthma, so statistics should not be interpreted as describing the burden of work-related asthma in the Commonwealth. The data do identify "sentinel events" that can point to specific occupations and locations where workers are at risk and where prevention activities are needed.

From 1993-2006, 633 cases of work-related asthma were reported and confirmed in Massachusetts. The majority of these cases were the result of exposures in the workplace that caused new-onset asthma (84%), while exposures that aggravated existing asthma or caused a type of irritant asthma (reactive airways dysfunction syndrome (RADS)) were less frequent (11% and 14%, respectively). Interestingly, the majority of cases were from the service sector (53%), with the manufacturing sector accounting for 24% of cases. Within the service sector, cases occurred primarily from the healthcare and educational service sectors (29% and 13% respectively). Nurses and administrative/office workers were the most frequent occupations reported. Since the TURA program does not cover either the health care or the education sector, it is impossible to compare data from these sectors to trends in the TURA data.

Table 13 documents the frequency of work-related asthma events in settings where workers likely used chemicals reported to TURA. "Other" operators/repair/laborers was the most frequent occupation listed (11.3% of total cases) followed by construction/painters (3.3%) and mechanics/repairers (3.2%).

Table 13: Frequency of Occupations with Work-Related Asthma Likely Working with Chemicals Covered by TURA

Occupation	No.	% N=631*
Engineers/scientists	10	1.6%
Construction/painters	21	3.3%
Mechanics/repairers	20	3.2%
Assemblers	13	2.1%
Spray painting	12	1.9%
Plastic/metal machine operators	12	1.9%
Welders	12	1.9%
Textile/apparel	10	1.6%
All Other operators/repair/laborers	71	11.3%
TOTAL	181	43.2%

*Occupation codes missing for two 2 cases.

SOURCE: Massachusetts Department of Public Health, SENSOR Bulletin, July 2007

Table 14 lists the 15 most frequent asthma-related occupational exposures as identified by the Massachusetts SENSOR program. Non-specific indoor air pollutants were the most frequent exposure reported (156 cases, 8.2%). Thirteen of the 15 most frequent chemicals associated with asthma events are likely reportable under the TURA program and responsible for 598 of the asthma cases reported to the SENSOR program. However, some of these 13 chemicals are nonspecific (e.g. solvents, products of combustion, metals, etc.). Exposures implicated in work-related asthma in the Commonwealth that are not reportable under TURA include latex (a primary cause of asthma among health care professionals), and mold (an important asthma exacerbator in indoor-settings).

Table 14: Fifteen most frequently reported exposures for cases of WRA by case classification: New Onset Asthma (NOA), Reactive Airways Dysfunction Syndrome (RADS), and Work Aggravated Asthma (WAA), Massachusetts SENSOR, 1993-2006 N=1899 agents[a]

AGENT	NOA [b]	RADS	WAA	WRA unclass.	No.	%
Indoor Air Pollutants[c]	119	10	24	3	156	8.2
Cleaning Products[d]	87	32	22	4	145	7.6
Minerals and Inorganic Dusts	102	14	22	4	142	7.5
Chemicals, NOS*	75	18	13	2	108	5.7
Mold	64	2	12	0	78	4.1
Solvents	46	15	11	1	73	3.8
Products of Combustion[e]	35	7	9	0	51	2.7
Latex	41	1	4	0	46	2.4
Isocyanates [f]	35	3	1	0	39	2.1
Paints and Lacquers	18	1	6	2	27	1.4
Acids and Bases	15	9	1	0	25	1.3
Metals	19	2	2	0	23	1.2
Formaldehyde	19	0	2	0	21	1.1
Polymers	14	3	3	0	20	1.1
Welding Fumes	14	4	1	0	19	1.0

*NOS = Not otherwise specified
[a] At least one agent was reported for each case; a maximum of three agents could be reported
[b] Excludes RADS cases
[c] Includes cases who report "bad air", "indoor air pollutants", poor ventilation" or "sick building syndrome". Specific agents coded separately.
[d] Includes specific cleaning products such as bleach and ammonia.
[e] Includes smoke and exhaust
[f] Includes MDI, TDI, and HDI, etc.

SOURCE: Massachusetts Department of Public Health, SENSOR Bulletin, July 2007

Many of the chemicals in Table 14 were also among those that contribute the most to total cumulative use and fugitive air emissions of asthma-related chemicals in Massachusetts from 1990-2005 as reported to TURA. These include ammonia (included within "cleaning agents" and "acids and bases"), sulfuric acid and acetic acid (included within "acids and bases"), chromium and chromium compounds, zinc and zinc compounds (both included within "metals") and isocyanates.

Isocyanates are widely used and of crucial importance with regard to asthma since they are potent respiratory sensitizers. As reported earlier, diisocyanate fugitive air emissions decreased from 1990-2005 by 68% for TDI, 84% for MDI and 84% for the diisocyanates group reporting category. Yet the TURA data also show that total cumulative use of TDI increased 62% from 1990-2005, though use of other diisocyanates declined over the same time period. Reductions in fugitive air emissions are a testament to successful efforts to reduce respiratory exposure to diisocyanates through improved controls. However, it important to note that the scientific literature continues to report cases of isocyanate-induced asthma in work environments where measured diisocyanate respiratory exposures are very low or non-detectable, but where there is opportunity for skin exposure.[17] Dermal exposure of isocyanates has been shown to induce asthma in animal studies.[17] Given the increasing use of TDI in Massachusetts and emerging evidence about the role of isocyanate skin exposure in the development of asthma, heightened occupational asthma prevention efforts are warranted to prevent isocyanate-induced asthma.

Although the Massachusetts SENSOR data likely capture only a small fraction of work-related asthma cases in Massachusetts, the data show that asthma-related chemicals—including those captured by the TURA program—are related to cases of occupational asthma in the Commonwealth.

Massachusetts School-Based Asthma Surveillance Data

Although evidence linking chemical exposures and asthma has emerged primarily from occupational studies, a growing literature is exploring the role of outdoor air exposures in both the initial onset and exacerbation of asthma. Strong evidence supports the role of ambient air pollution in exacerbating asthma. These studies have focused primarily on the criteria air pollutants regulated by the Environmental Protection Agency under the Clean Air Act and have shown that ground-level ozone, particulate matter, nitrogen oxides, and sulfur dioxide can contribute to asthma exacerbations.[56] Consistent findings from multiple studies suggest that residential proximity to traffic sources increases the risk of asthma onset and asthma exacerbations in both children and adults.[57] More recently, studies are beginning to examine a broader set of air toxics. For example, a small study of school children in Los Angeles found that a number of air toxics were associated with asthma symptoms, including: benzene, styrene, toluene, acetaldehyde, and formaldehyde.[58] These studies demonstrate the plausibility of hypotheses that emissions of chemicals known to be capable of causing and/or exacerbating asthma from manufacturing facilities are contributing to the asthma burden in a given community. The purpose of our examination of Massachusetts school-based asthma prevalence data was to explore whether or these data can be useful in generating hypotheses and/or guiding interventions to reduce exposure to asthma-related chemicals in communities.

The initial step we took in this review was to assess the correlation between TURA data on total amounts of point-source air emissions of asthma-related chemicals and data on asthma prevalence in schools located in the same communities as the point sources. The asthma prevalence data are reported on children K-8 to MDPH by every public, charter or private school in Massachusetts.[19] Our analysis using MDPH's 2005-2006 school-based asthma surveillance data was not intended to draw causal links between releases of asthma-related chemicals reported to TURA and asthma rates, but rather to identify trends and better understand strengths and limitations of the data that can inform the design and conduct of future studies.

Asthma Toxicant Point Source Air Releases and Pediatric Asthma Prevalence

Four of the 10 top cities/towns for asthma toxicant point source air releases had an elevated pediatric asthma prevalence compared to the state: (Boston (13.5%), Fall River (11.8%), Fitchburg (12.8%), Springfield (17.7%). However, our analysis did not reveal a correlation between school-based asthma prevalence across all Massachusetts cities and towns and the amounts of chemicals released from facilities located in those cities and towns (correlation coefficient=0.07). The lack of correlation does not rule out a role for point source emissions in elevated asthma rates. More likely, it reflects the limitations of an ecological analysis in explaining complex phenomena. As noted earlier, asthma is influenced by many factors, including genetic susceptibility, social and environmental exposures—both indoor and outdoor. Low-income urban children—of which there are a

disproportionate number in the cities listed above—live in conditions rife with social stress and indoor as well as outdoor environmental exposures associated with asthma onset and exacerbation.

Undoubtedly industrial emissions of sulfuric acid, nitrogen dioxide and ammonia are important air pollutants as shown by the TURA data (Table 3), and it is well-established that air pollutants can exacerbate asthma symptoms. The elevated asthma rates and potential for point source emissions to be contributing to the burden of asthma argue for more refined data analyses in the future. For example, future data analyses could map the air-shed of the emissions from particular facilities and examine data from schools in that air-shed. Moreover, they could focus their analysis on specific air pollutants that have previously demonstrated an association with childhood asthma in a community setting, such as sulfuric acid, nitrogen dioxide, and formaldehyde. Given the interest in the burden of childhood asthma in Massachusetts and possible links with chemical exposures, more refined data linkage analyses using TURA data and the MDPH school-based asthma surveillance system should be considered in future studies.

E. SUMMARY & RECOMMENDATIONS

This analysis is the first to use TURA data to identify the extent to which chemicals capable of initiating or exacerbating are being used and released by Massachusetts industries. Our analysis revealed that of the 335 substances capable of causing or exacerbating asthma as identified by AOEC, CHE, Malo and Chan-Yeung and IOM (which both chemicals as well as biological substances such as plant, insect, and animal proteins), 68 are reportable under TURA and 41 have been reported to TURA at some point in the program's history. However, approximately 100 chemicals that can cause and/or exacerbate asthma are not currently reportable under TURA. Little is known about the use of these chemicals Massachusetts: in what amounts, by which industries, in what locations. Although beyond the scope of this preliminary analysis, future work should explore the legal and health basis for requiring that these chemicals be added to TURA's Reportable Chemical List.

Over a dozen asthma-related chemicals reported to TURA are on the TURA program's Science Advisory Board's "more hazardous" list. This does not mean that other chemicals used in the state are of less concern with regard to asthma, since the TURA program does not consider a chemical's association with asthma in the development of this list. Given that thousands of individuals are currently affected by asthma in Massachusetts and that there is solid evidence implicating several hundred chemicals in causing or exacerbating asthma, we recommend that the Science Advisory Board add asthma as an endpoint in its evaluation of "more hazardous" chemicals. Similarly, asthma should also be one of the criterion considered when chemicals from the "more hazardous" list are evaluated and recommended for a "higher hazard" designation.[j]

From 1990 to 2005, the total cumulative use of asthma-related chemicals in Massachusetts declined by 27%, but uses of some individual asthma-related chemicals increased. Specific chemicals that showed an increase in total cumulative use over this time period include ammonia, zinc and zinc compounds, and diisocyanates. Toluene diisocyanate was the main diisocyanate driving the increased use for diisocyanates. Although evidence to date does not suggest that ammonia can cause asthma, it can exacerbate symptoms in both children and adults who already have the disease. Given the increasing use of TDI in Massachusetts and emerging evidence about the role of isocyanate skin exposure in the development of asthma,[17] we recommend heightened occupational asthma prevention efforts to prevent isocyanate-induced asthma. We also recommend additional research and technical support to investigate safer alternatives to isocyanates as well as to ammonia.

From 1990-2005, total cumulative fugitive and point source air emissions of asthma-related chemicals also declined, 82% and 71% respectively. Specific asthma-related chemicals contributing the most to the total cumulative fugitive releases include: ammonia, sulfuric acid, acetic acid, styrene monomer, and nitrogen dioxide. Fugitive emissions for these five chemicals all showed dramatic declines from 1990-2005. Specific asthma-related

[j] Recent amendments to the TURA legislation now require a lower reporting threshold (1,000 pounds) for chemicals classified as "higher hazard."

chemicals driving the total cumulative point source air emissions over this same 15-year period include: sulfuric acid, ammonia, formaldehyde, acetic acid, and styrene monomer. Of the five chemicals, only ammonia and sulfuric acid showed overall increases in point source air emissions over this fifteen year period (since 1991, sulfuric acid emissions have been declining).

The overall reduction in use and air releases of asthma-related chemicals in Massachusetts is a significant achievement by Massachusetts industries. Our analysis did not adjust for changes in production to determine whether these reductions were simply a result of change in the volume of business, or whether they were the result of process changes. However, previous reports by the TURA program have demonstrated that even after adjusting for changes in production, the use of chemicals reported to TURA has declined.

Data from MDPH's sentinel work-related asthma surveillance system demonstrate that asthma-related chemicals, including those reported to the TURA program as currently used and released in Massachusetts, have impacted people in the Commonwealth by causing asthma, aggravating existing asthma, or causing reactive airway disease syndrome, a form of irritant-induced asthma. The data also show that the health care industry—not required to provide information about chemical use to TURA—reports the highest number of events of work-related asthma. Previous reports suggest that a range of asthma-related chemicals reportable under TURA, including ethylene oxide and formaldehyde, are widely used not only in sectors reporting to TURA but also in health care. Moreover, studies have linked these particular chemicals with asthma events in health care workers.[59] We know from the literature that a number of other chemical disinfectants, such as chlorohexidine and benzalkonium chloride, as well as sterilants such as gluteraldehyde, which are not reportable to TURA, pose risks for the development and exacerbation of asthma in the health care setting and potentially in other industries as well.[59] These findings lead to two recommendations to TURA program decision-makers: (1) they should consider requiring reporting of asthma-related chemicals not currently reportable under TURA; (2) they should consider whether additional industries such as health care should be required to report their chemical use and release data to TURA as a means of encouraging pollution prevention and disease prevention activities among all sectors.

Our evaluation of school-based asthma surveillance data did not shed any light on the role of point-source emissions of asthma-related chemicals in high rates of asthma among children attending school nearby. The hypothesis that some asthma-related chemicals used and released by Massachusetts industries are adding to the burden of asthma in children in the Commonwealth remains plausible, however, given studies elsewhere of associations between exposures to air toxicants in a community setting and the development and exacerbation of asthma. More refined analyses exploring associations between TURA data and school-based asthma surveillance data should be pursued to generate more specific hypotheses and help prioritize chemicals for toxics use reduction.

Of the 41 asthma-related chemicals reported to TURA from 1990-2005, approximately two-thirds can cause asthma in a previously healthy individual (Appendix A). Although not everyone exposed to asthma-related chemicals will develop asthma, one strategy to prevent future cases of the disease is to eliminate potential exposure to those chemicals through

substitution with safer alternatives. Paired with use and release data, reports published by the Toxics Use Reduction Institute on safer alternatives for a range of asthma-related chemicals can point to opportunities for reducing exposure to hazardous chemicals. With regard to consumer products, organizations such as Green Seal are developing "eco-labeling" standards for products such as cleaners that will help consumers avoid products that contain asthma-related chemicals.

When substitution with a safer chemical alternative is not possible, other prevention strategies for asthma should concentrate on reducing exposure through: (1) emission controls that are sufficient to protect communities in addition to workers, (2) safe practices in the workplace and at home (personal protective equipment, spill containment, good housekeeping), and (3) ongoing worker training and education. More extensive high quality worker and employer education about asthma caused by chemical exposures is needed to ensure that appropriate environmental controls and safe working practices are in place. Worker and employer education are also crucial strategies for secondary prevention to raise awareness about the early signs and symptoms of asthma.

In summary, the Toxics Use Reduction Act Program has a role to play in preventing asthma. Though the etiology of asthma is complex and varies individual to individual, exposure to chemicals is a risk factor for many people in the development and exacerbation of the disease. Researching and promoting safer alternatives has the potential to make an important contribution to reducing exposure to asthma-related chemicals and thereby reducing the burden of the disease. Toxic Use Reduction is an important asthma prevention strategy and should be included in any comprehensive asthma prevention and control agenda. The declines in use and air releases of asthma-related chemicals observed in this analysis are good news, yet there remains ample opportunity for further reductions via technical and planning support provided through TURA as well as via policy decisions to include asthma in the Science Advisory Board's evaluation process for listing and classifying chemicals. The Increase in use of isocyanates is of particular concern, and deserves attention by public health officials and the TURA program.

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APPENDIX A: CHEMICAL AGENTS REPORTED UNDER TURA (1990-2005) THAT CAUSE OR EXACERBATE ASTHMA

CHEMICAL NAME	CAS NUMBER	STRENGTH OF EVIDENCE (SOURCE)	TURA MORE HAZARDOUS RANK?
Acetaldehyde	75-07-0	Good (CHE)	No
Acetic Acid	64-19-7	Yes (AOEC), Strong [acids] CHE	No
Aluminum	7429-90-5	Yes (AOEC), Strong (CHE), Associated (Malo J-L, Chan-Yeung M)	No
Ammonia	7664-41-7	Strong (CHE)	No
Benzene	71-43-32	Limited (CHE)	Yes
Butylphthalate	84-74-2	Limited [phthalates] (CHE)	No
Caprolactum	105-60-2	Limited (CHE)	No
Chlorine	7782-50-5	Yes (AOEC), Strong (CHE)	Yes
Chloroform	67-66-3	Limited (CHE)	Yes
Chlorothalonil	1897-45-6	Yes (AOEC), Strong (CHE), Associated (Malo J-L, Chan-Yeung M)	No
Chromic Acid	1333-82-0	Yes (AOEC)	Yes
Chromium	7440-47-3	Yes (AOEC), Strong (CHE), Associated (Malo J-L, Chan-Yeung M)	Yes
Cobalt	7440-48-4	Strong (CHE), Associated (Malo J-L, Chan-Yeung M)	No
Dibromochloropropane	96-12-8	Limited (CHE)	Yes
Dicyclohexylmethane 4,4-diisocyanate (methylene bis(4-cyclohexylisocyanate)	5124-30-1	Strong [isocyanates] (CHE), Associated (Malo J-L, Chan-Yeung M)	No
Diethanolamine	111-42-2	Yes (AOEC)	No
Dioctyl-phthalate (diethylhexylphthalate)	117-81-7	Limited [phthalates] (CHE), Associated (Malo J-L, Chan-Yeung M)	No
Ethylene Oxide	75-21-8	Yes (AOEC), Good (CHE), Associated (Malo J-L, Chan-Yeung M)	Yes
Ethylenediamine	107-15-3	Yes (AOEC), Good (CHE), Associated (Malo J-L, Chan-Yeung M)	No
Formaldehyde	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)	Yes
HDI Prepolymers	822-06-0	Yes (AOEC), Strong [isocyanates] (CHE), Associated (Malo J-L, Chan-Yeung M)	No
Hydrazine	302-01-2	Good (CHE)	Yes
Isophorone Diisocyanate	4098-71-9	Yes (AOEC), Strong [isocyanates] (CHE), Associated (Malo J-L, Chan-Yeung M)	No
Maleic Anhydride	108-31-6	Yes (AOEC), Associated (Malo J-L, Chan-Yeung M)	No

APPENDIX A: CHEMICAL AGENTS REPORTED UNDER TURA (1990-2005) THAT CAUSE OR EXACERBATE ASTHMA (cont.)

CHEMICAL NAME	CAS NUMBER	STRENGTH OF EVIDENCE (SOURCE)	TURA MORE HAZARDOUS RANK?
Methacrylates	80-62-6	Yes (AOEC), Strong (CHE)	No
Methylene Diisocyante [4,4' methylene diphenyl isocyanate]	101-68-8	Yes (AOEC), Strong [isocyanates] (CHE), Associated (Malo J-L, Chan-Yeung M)	Yes
Nickel	7440-02-0	Yes (AOEC), Strong (CHE), Associated (Malo J-L, Chan-Yeung M)	No
NO2, NOX	10102-43-9, 10024-97-2	Strong (CHE); Sufficient evidence of association for exacerbation (IOM), inadequate evidence of association for development (IOM)	No
Phenols (NOS)	NOS, No CAS	Good (CHE)	Yes
Phenylene Diamine	25265-76-3	Yes (AOEC), Associated (Malo J-L, Chan-Yeung M)	No
Phosgene	75-44-5	Good (CHE)	Yes
Phthalic Anhydride	85-44-9	Yes (AOEC), Associated (Malo J-L, Chan-Yeung M)	No
Polymethylene Polyphenylisocyanate	9016-87-9	Yes (AOEC), Strong [isocyanates] (CHE), Associated (Malo J-L, Chan-Yeung M)	No
P-Phenylenediamine	106-50-3	Strong (CHE), Associated (Malo J-L, Chan-Yeung M)	No
Styrene	100-42-5	Yes (AOEC), Limited (CHE), Associated (Malo J-L, Chan-Yeung M)	No
Sulfuric Acid	7664-93-9	Yes (AOEC), Associated (Malo J-L, Chan-Yeung M)	Yes
TDI Prepolymers*	NOS, No CAS	Yes (AOEC), Strong [isocyanates] (CHE), Associated (Malo J-L, Chan-Yeung M)	No
Toluene	108-88-3	Limted (CHE)	No
Toluene Diisocyanate	584-84-9	Yes (AOEC), Strong [isocyanates] (CHE), Associated (Malo J-L, Chan-Yeung M)	Yes
Vanadium	1314-62-1	Strong (CHE)	No
Zinc	1314-13-2	Yes (AOEC), Associated (Malo J-L, Chan-Yeung M)	No

APPENDIX B: CHEMICAL AGENTS THAT CAUSE OR EXACERBATE ASTHMA AND REPORTABLE UNDER TURA, BUT NOT REPORTED DURING 1990-2005

CHEMICAL NAME	CAS NUMBER	STRENGTH OF EVIDENCE	TURA MORE HAZARDOUS RANK?
1,1-dichloroethane	75-34-3	Good (CHE)	No
Acephate	30560-19-1	Yes (AOEC)	No
Acrolein	107-02-8	Good (CHE)	No
Ammonium Bichromate	7789-09-5	Yes (AOEC)	No
Aziridine	151-56-4	Limited (CHE)	No
Diazinon	333-41-5	Yes (AOEC)	No
Dichlorvos	62-73-7	Yes (AOEC)	Yes
Dimethoate	60-51-5	Yes (AOEC)	No
Ethyl methacrylate	97-63-2	Associated (Malo J-L, Chan-Yeung M)	No
Fluorine	77-82-41-8	Yes (AOEC)	No
Freon Heated, Welding Freon	75-46-7	Yes (AOEC)	No
Hexachlorophene	70-30-4	Yes (AOEC), Good (CHE), Associated (Malo J-L, Chan-Yeung M)	No
Hexamethylene tetramine	100-97-0	Associated (Malo J-L, Chan-Yeung M)	No
Hydrogen Sulfide	7783-06-4	Strong (CHE)	No
Malathion	121-75-5	Yes (AOEC)	No
Naphthalene Diisocyanate*	3173-72-6	Yes (AOEC), Associated (Malo J-L, Chan-Yeung M)	No
Nitrogen chloride	10025-85-1	Associated (Malo J-L, Chan-Yeung M)	No
Osmium Tetraoxide	20816-12-0	Good (CHE)	No
Ozone	10028-15-6	Good (CHE)	No
Parathion	56-38-2	Yes (AOEC)	No
Peroxyacetic Acid	79-21-0	Yes (AOEC)	No
Propionaldehyde	123-38-6	Good (CHE)	No
Pyrfon	25311-71-1	Yes (AOEC)	No
Pyromellitic dianhydride	89-32-7	Associated (Malo J-L, Chan-Yeung M)	No
Safrotin	31218-83-4	Yes (AOEC)	No
Tetramethrin	7696-12-0	Associated (Malo J-L, Chan-Yeung M)	No
Tin, Organic	56-35-9	Yes (AOEC), Associated (Malo J-L, Chan-Yeung M)	No

*compound may have been reported as "diisocyanates" using the diisocyanate group category

APPENDIX C: CHEMICAL AGENTS THAT CAUSE OR EXACERBATE ASTHMA AND NOT REPORTABLE UNDER TURA

CHEMICAL (AND SYNONYMS)	CAS	EVIDENCE
1,2-Benzisothiazolin-3-one	2634-33-5	Associated (Malo J-L, Chan-Yeung M)
3-DMAPA, 3-Dimethylamino Propylamine	109-55-7	Yes (AOEC), Associated (Malo J-L, Chan-Yeung M)
4-Methylmorpholine, 4-Methyl-1-oxa-4-azacyclohexane	109-02-4	Yes (AOEC), Associated (Malo J-L, Chan-Yeung M)
Alkyl Aryl Polyether Alcohol, Polypropylene Glycol	25322-69-4	Yes (AOEC)
Aminoethylethanolamine	111-41-1	Yes (AOEC), Associated (Malo J-L, Chan-Yeung M)
Ammonium Hexachloroplatinate (IV)	16919-58-7	Yes (AOEC)
Ammonium persulphate	7727-54-0	Associated (Malo J-L, Chan-Yeung M)
Amprolium	137-88-2	Yes (AOEC)
Anesthetic Gases, Halogenated	13838-16-9	Yes (AOEC)
Azodicarbamide, Azobisformamide, 1,1-Azobisformamide, Azodicarbonamide	123-77-3	Yes (AOEC), Limited (CHE), Associated (Malo J-L, Chan-Yeung M)
Benzalkonium Chloride, Quaternary Ammonium Compounds, NOS	8001-54-5	Yes (AOEC), Associated (Malo J-L, Chan-Yeung M)
Captafol	2425-06-1	Strong (CHE), Associated (Malo J-L, Chan-Yeung M)
Chloramine T	127-65-1	Yes (AOEC), Good (CHE), Associated (Malo J-L, Chan-Yeung M)
Chlorendic anhydride, Chloran 542, HET anhydride, dicarboxylic acid anhydride	115-27-5	Associated (Malo J-L, Chan-Yeung M)
Chlorhexidine	55-56-1	Yes (AOEC), Associated (Malo J-L, Chan-Yeung M)
Coal Dust	Chemical NOS, No CAS	Good (CHE)
Colophony	8050-09-7	Yes (AOEC), Strong (CHE), Associated (Malo J-L, Chan-Yeung M)
Cutting Oils, Metal Working Fluids, Oil Mist	Chemical NOS, No CAS	Yes (AOEC), Associated (Malo J-L, Chan-Yeung M)
Diazonium Salt	Chemical NOS, No CAS	Yes (AOEC), Good (CHE), Associated (Malo J-L, Chan-Yeung M)
Diesel Exhaust	Chemical NOS, No CAS	Good/Strong (CHE)
Dimethylethanolamine, Dimethylaminoethanol	108-01-0	Yes (AOEC), Associated (Malo J-L, Chan-Yeung M)
Environmental Tobacco Smoke	Chemical NOS, No CAS	Sufficient evidence of causal relationship for exacerbation and sufficient evidence of association for development (preschool aged children) (IOM), limited evidence of association for exacerbation and inadequate evidence of association for development (school aged children older children and adults) (IOM), Strong (CHE)
EPO 60, Polyamine EPO 60	142443-98-9	Yes (AOEC), Associated (Malo J-L, Chan-Yeung M)
Ethyl cyanoacrylate, Alkylcyanoacrylates	7085-85-0	Yes (AOEC), Associated (Malo J-L, Chan-Yeung M)
Fiber Dust	Chemical NOS, No CAS	Strong (CHE)
Fragrances	Chemical NOS, No CAS	Limted (CHE), Limited evidence of association for exacerbation (IOM)
Furfuryl Alcohol, 2- Furylmethanol; 2 Hydroxymethylfuran	98-00-0	Yes (AOEC), Associated (Malo J-L, Chan-Yeung M)

APPENDIX C: CHEMICAL AGENTS THAT CAUSE OR EXACERBATE ASTHMA AND NOT REPORTABLE UNDER TURA (cont.)

CHEMICAL (AND SYNONYMS)	CAS	EVIDENCE
Gas Metal Arc Welding on Uncoated Mild Steel	Chemical NOS, No CAS	Yes (AOEC)
Glutaraldehyde	111-30-8	Yes (AOEC), Strong (CHE), Associated (Malo J-L, Chan-Yeung M)
Hexahydrophthalic Anhydride	85-42-7	Yes (AOEC), Associated (Malo J-L, Chan-Yeung M)
Hexamethylenetetramine	100-97-0	Yes (AOEC)
Himic Anhydride	2746-19-2	Yes (AOEC), Associated (Malo J-L, Chan-Yeung M)
Hydralazine	86-54-4	Yes (AOEC)
Lauryl dimethyl benzyl ammonium chloride	139-07-1	Associated (Malo J-L, Chan-Yeung M)
Methyl 2-cyanoacrylate	137-05-3	Associated (Malo J-L, Chan-Yeung M)
Methyl Blue	28983-56-4	Yes (AOEC)
Methyl Tetrahydrophthalic Anhydride, 1,3-Isobenzofurandione	26590-20-5	Yes (AOEC), Associated (Malo J-L, Chan-Yeung M)
Methylchloro-isothiazolinone, Chloromethylisothiazolinone, Chloromethylisothiazolone	26172-55-4	Associated (Malo J-L, Chan-Yeung M)
Monoethanolamine, 2-Aminoethanol, Ethanolamines	141-43-5	Yes (AOEC), Strong (CHE), Associated (Malo J-L, Chan-Yeung M)
Nemacur	22224-92-6	Yes (AOEC)
Ninhydrin	485-47-2	Associated (Malo J-L, Chan-Yeung M)
Oil fly ash	Chemical NOS, No CAS	Good (CHE)
Palladium	7440-05-3	Associated (Malo J-L, Chan-Yeung M)
Particulate Air Pollution, Soot	Chemical NOS, No CAS	Strong (CHE)
Persulfate Salts	Chemical NOS, No CAS	Yes (AOEC), Good (CHE)
Phenylglycine Acid Chloride	NA	Yes (AOEC)
Piperazine Hydrochloride, Diethylenediamine dihydrchloride	142-64-3	Yes (AOEC), Associated (Malo J-L, Chan-Yeung M)
Plastic Dusts	Chemical NOS, No CAS	Strong (CHE)
Plastic Fumes	Chemical NOS, No CAS	Strong (CHE)
Platinum, Platinum Black, Platinum Metal, Platinum Sponge	7440-06-4	Strong (CHE), Associated (Malo J-L, Chan-Yeung M)
Plexiglass Dust	87210-32-0	Yes (AOEC), Associated (Malo J-L, Chan-Yeung M)
Polyethylene Terephthalate/Polybutylene Terephthal	Chemical NOS, No CAS	Yes (AOEC)
Polyethylene, Heated	9002-88-4	Yes (AOEC), Associated (Malo J-L, Chan-Yeung M)
Polypropylene Heated, Atactic PP, Propylene Resin	9003-07-0	Yes (AOEC), Strong (CHE), Associated (Malo J-L, Chan-Yeung M)
Polyvinyl Chloride, Heated & Dust	9002-86-2	Yes (AOEC), Strong (CHE), Associated (Malo J-L, Chan-Yeung M)
Pyromellitic Dianhydride, Pyromellitic Acid Dianhydride	89-32-7	Yes (AOEC)
Radiographic Fixative	Chemical NOS, No CAS	Yes (AOEC)
Rosin, Tall Oil	8052-47-9	Yes (AOEC), Associated (Malo J-L, Chan-Yeung M)
Sodium Metabisulfite	7681-57-4	Yes (AOEC)
Soldering Flux, Zinc Chloride/Ammonium Chloride	Chemical NOS	Yes (AOEC), Associated (Malo J-L, Chan-Yeung M)

APPENDIX C: CHEMICAL AGENTS THAT CAUSE OR EXACERBATE ASTHMA AND NOT REPORTABLE UNDER TURA (CONT.)

CHEMICAL (AND SYNONYMS)	CAS	EVIDENCE
Soluble Halogenated Platinum Compounds, (NOS)	7440-06-4	Yes (AOEC), Associated (Malo J-L, Chan-Yeung M)
Sulfites	Chemical NOS	Associated (Malo J-L, Chan-Yeung M)
Sulfonates, (NOS)	Chemical NOS, No CAS	Yes (AOEC), Associated (Malo J-L, Chan-Yeung M)
Sulfur Dioxide	7446-09-5	Strong (CHE)
Tannic Acid	1401-55-4	Good (CHE)
Terpene	9003-74-1	Yes (AOEC)
Tetrachlorophthalic Anhydride	117-08-8	Yes (AOEC), Associated (Malo J-L, Chan-Yeung M)
Tetrazene	14097-21-3	Yes (AOEC), Associated (Malo J-L, Chan-Yeung M)
Tobacco smoke	Chemical NOS, No CAS	Strong (CHE)
Triethanolamine, TEA	102-71-6	Yes (AOEC), Associated (Malo J-L, Chan-Yeung M)
Triethylene Tetramine	112-24-3	Yes (AOEC), Associated (Malo J-L, Chan-Yeung M)
Triglycidyl isocyanurate, TGIC,Teroxirone,Tris(epoxypropyl) isocyanurate	2451-62-9	Associated (Malo J-L, Chan-Yeung M)
Trimellitic Anhydride, 1,2,4-Benzenetricarboxylic Acid 1,2-Anhydride, TMA	552-30-7	Yes (AOEC), Associated (Malo J-L, Chan-Yeung M)
Trimethylhexanediamine/Isophorondiamine Mixture	Chemical NOS, No CAS	Yes (AOEC), Associated (Malo J-L, Chan-Yeung M)
Trimethylolpropane Triacrylate/2-Hydroxypropyl Acrylate	15625-89-5	Yes (AOEC)
Tungsten Carbide	12070-12-1	Yes (AOEC), Strong (CHE), Associated (Malo J-L, Chan-Yeung M)
Urea Formaldehyde	9011-05-6	Yes (AOEC), Associated (Malo J-L, Chan-Yeung M)
Welding Fume, Stainless Steel (NOS)	Chemical NOS, No CAS	Yes (AOEC)

APPENDIX D: TOP-5 ASTHMA-RELATED CHEMICALS- USE & RELEASES BY CITY & INDUSTRIES, 1990-2005

ACETIC ACID

City/Town	Industry Type (SIC Code)	Use (lbs)	Fugitive Air Releases (lbs)	Pt. Air Releases (lbs)
AGAWAM	Food & Kindred Products	15,745	0	0
ANDOVER	Chemicals & Allied Products	225,480	1,140	0
ASHLAND	Chemicals & Allied Products	117,110	30	1,544
ASSONET	Chemicals & Allied Products	69,281	67	1,239
	Measuring, Analyzing & Controlling Instruments; Photographic, Medical & Optical Goods; Watches & Clocks	330,869	697	2,235
ATTLEBORO	Fabricated Metal Products, Except Machinery & Transportation Equipment	60,009	5	539
BEVERLY	Primary Metal Industries	24,806	6	0
BILLERICA	Electronic & Other Electrical Equipment & Components, Except Computer Equipment	36,419	0	583
CHARLESTOWN	Chemicals & Allied Products	430,848	1,664	6,084
COLRAIN	Textile Mill Products	1,344,711	60	7,948
DEERFIELD	Food & Kindred Products	3,021,921	0	0
DIGHTON	Chemicals & Allied Products	254,200	628	37
EASTHAMPTON	Textile Mill Products	12,869	0	0
FALL RIVER	Chemicals & Allied Products	30,452,111	113,924	223,049
	Rubber & Miscellaneous Plastics Products	15,981,838	119,106	188,665
	Textile Mill Products	1,998,552	84,129	37,211
	Wholesale Trade-non-durable Goods	17,528,837	9,444	16
FITCHBURG	Chemicals & Allied Products	2,258,056	8,894	781
FRAMINGHAM	Paper & Allied Products	23,000	0	0
FRANKLIN	Paper & Allied Products	388,408	0	0
HAVERHILL	Paper & Allied Products	138,349	138,349	0
HOLLISTON	Wholesale Trade-non-durable Goods	3,639,197	0	10
HOLYOKE	Textile Mill Products	409,652	0	0
LAWRENCE	Paper & Allied Products	17,618	0	0
	Textile Mill Products	1,877,727	1,755	750
LEOMINSTER	Textile Mill Products	1,004,537	23,307	13,579
	Wholesale Trade-non-durable Goods	4,142,901	25	305
LOWELL	Textile Mill Products	489,479	0	0
LYNN	Food & Kindred Products	14,455	0	0
MARLBOROUGH	Chemicals & Allied Products	168,962	34	40
	Food & Kindred Products	6,090,919	1,220	0
	Wholesale Trade-non-durable Goods	126,751	0	0
MILFORD	Chemicals & Allied Products	92,858	0	1,198
NEW BEDFORD	Fabricated Metal Products, Except Machinery & Transportation Equipment	199,260	0	0
	Measuring, Analyzing & Controlling Instruments; Photographic, Medical & Optical Goods; Watches & Clocks	94,138	0	0
	Textile Mill Products	2,103,841	0	2,480
NEWBURYPORT	Chemicals & Allied Products	114,995	1,773	188
NORWOOD	Measuring, Analyzing & Controlling Instruments; Photographic, Medical & Optical Goods; Watches & Clocks	248,160	61	0
PEABODY	Transportation Equipment	12,940	144	466
SALEM	Chemicals & Allied Products	181,720	20	0
	Wholesale Trade-non-durable Goods	1,399,437	9	267
SAUGUS	Chemicals & Allied Products	13,895	255	255
SOUTH DEERFIELD	Food & Kindred Products	1,371,116	0	0
SPRINGFIELD	Chemicals & Allied Products	1,024,995	1,021	1,021

ACETIC ACID (cont.)

City/Town	Industry Type (SIC Code)	Use (lbs)	Fugitive Air Releases (lbs)	Pt. Air Releases (lbs)
Springfield	Wholesale Trade-non-durable Goods	8,612,953	1,278	0
TAUNTON	Textile Mill Products	14,443	0	0
TEMPLETON	Paper & Allied Products	38,998	0	0
THORNDIKE	Paper & Allied Products	83,260	0	0
WALPOLE	Paper & Allied Products	528,671	1,606	78,200
WALTHAM	Measuring, Analyzing & Controlling Instruments; Photographic, Medical & Optical Goods; Watches & Clocks	4,720,036	4,489	42,339
WARREN	Textile Mill Products	447,161	3,025	4,550
WATERTOWN	Electronic & Other Electrical Equipment & Components, Except Computer Equipment	27,343	0	800
WEBSTER	Textile Mill Products	5,944,808	47,561	7,621
WEST GROTON	Paper & Allied Products	32,000	5	4,700
WEST SPRINGFIELD	Paper & Allied Products	659,195	0	455,265
WOBURN	Food & Kindred Products	195,370	0	0

AMMONIA

City/Town	Industry Type (SIC Code)	Use (lbs)	Fugitive Air Releases (lbs)	Pt. Air Releases (lbs)
ACTON	Measuring, Analyzing & Controlling Instruments; Photographic, Medical & Optical Goods; Watches & Clocks	614,024	0	0
ADAMS	Chemicals & Allied Products	1,636,778	5	1,342
AGAWAM	Electric, Gas & Sanitary Services	902,056	0	57,112
AMESBURY	Electronic & Other Electrical Equipment & Components, Except Computer Equipment	1,568,826	569	1,845
ANDOVER	Electronic & Other Electrical Equipment & Components, Except Computer Equipment	1,207,884	2,153	6,749
ASSONET	Chemicals & Allied Products	14,410	0	0
ATHOL	Industrial & Commercial Machinery & Computer Equipment	117,368	763	20
ATTLEBORO	Electronic & Other Electrical Equipment & Components, Except Computer Equipment	1,362,975	255	5
	Fabricated Metal Products, Except Machinery & Transportation Equipment	1,438,674	36	214
	Measuring, Analyzing & Controlling Instruments; Photographic, Medical & Optical Goods; Watches & Clocks	14,958,892	4,220	18,930
	Miscellaneous Manufacturing Industries	524,065	3,091	51
	Primary Metal Industries	9,832,744	1,599	1,339
BELLINGHAM	Electric, Gas & Sanitary Services	654,389	43,709	337,728
BEVERLY	Electronic & Other Electrical Equipment & Components, Except Computer Equipment	367,853	0	0
	Measuring, Analyzing & Controlling Instruments; Photographic, Medical & Optical Goods; Watches & Clocks	177,365	0	0
BLACKSTONE	Electric, Gas & Sanitary Services	424,779	258	18,232
BOSTON	Electric, Gas & Sanitary Services	21,819,706	529	218,214
	Electronic & Other Electrical Equipment & Components, Except Computer Equipment	765,232	0	17,293
	Fabricated Metal Products, Except Machinery & Transportation Equipment	736,533	21,100	0
	Food & Kindred Products	10,466	10,466	0
	Stone, Clay, Glass & Concrete Products	59,694	0	15,294
BURLINGTON	Electronic & Other Electrical Equipment & Components, Except Computer Equipment	461,130	1,652	0

AMMONIA (cont.)

City/Town	Industry Type (SIC Code)	Use (lbs)	Fugitive Air Releases (lbs)	Pt. Air Releases (lbs)
CAMBRIDGE	Electric, Gas & Sanitary Services	14,942	0	1,631
	Food & Kindred Products	24,090	22,590	1,500
CANTON	Chemicals & Allied Products	78,838	260	1,500
	Food & Kindred Products	120,426	111,286	0
CHARLESTOWN	Chemicals & Allied Products	804,178	23,286	14,344
CHARLTON	Electric, Gas & Sanitary Services	2,135,325	4,446	263,638
CHICOPEE	Chemicals & Allied Products	192,153	214	1,623
CLINTON	Electronic & Other Electrical Equipment & Components, Except Computer Equipment	133,051	2,102	7,836
DARTMOUTH	Electric, Gas & Sanitary Services	2,169,664	25	157,831
DIGHTON	Chemicals & Allied Products	152,650	1,972	27
	Electric, Gas & Sanitary Services	563,537	0	64,736
EAST BRIDGEWATER	Measuring, Analyzing & Controlling Instruments; Photographic, Medical & Optical Goods; Watches & Clocks	58,776	5	5
EASTHAMPTON	Textile Mill Products	28,087	510	510
EVERETT	Electric, Gas & Sanitary Services	972,427	487	484,321
FALL RIVER	Fabricated Metal Products, Except Machinery & Transportation Equipment	1,444,645	5	0
	Rubber & Miscellaneous Plastics Products	78,650	78,361	0
	Textile Mill Products	471,219	313,168	35,714
	Wholesale Trade-non-durable Goods	74,337,951	18,990	3,128
FITCHBURG	Chemicals & Allied Products	476,585	1,395	559
	Paper & Allied Products	98,274	1,199	5
FOXBORO	Measuring, Analyzing & Controlling Instruments; Photographic, Medical & Optical Goods; Watches & Clocks	226,508	10	10
FRAMINGHAM	Food & Kindred Products	18,160	4,491	0
FRANKLIN	Food & Kindred Products	57,625	0	0
GARDNER	Paper & Allied Products	70,475	19,545	13,557
	Printing, Publishing & Allied Industries	93,094	80,236	10,471
HAVERHILL	Electric, Gas & Sanitary Services	464,228	0	17,003
	Electronic & Other Electrical Equipment & Components, Except Computer Equipment	631,240	4,625	83,460
HINGHAM	Chemicals & Allied Products	193,949	13,057	176,928
	Fabricated Metal Products, Except Machinery & Transportation Equipment	588,003	30	5
HOLDEN	Electronic & Other Electrical Equipment & Components, Except Computer Equipment	14,575	0	14,575
HOLLISTON	Wholesale Trade-non-durable Goods	8,486,290	0	3,708
HUDSON	Electronic & Other Electrical Equipment & Components, Except Computer Equipment	94,907	162	32,138
LAWRENCE	Chemicals & Allied Products	338,713	2,316	255
	Rubber & Miscellaneous Plastics Products	228,553	2	0
	Textile Mill Products	590,316	1,275	123,827
LEOMINSTER	Rubber & Miscellaneous Plastics Products	268,314	23,942	215,759
LOWELL	Electric, Gas & Sanitary Services	2,249,606	0	3,262
	Electronic & Other Electrical Equipment & Components, Except Computer Equipment	692,034	10,507	9,212
	Textile Mill Products	56,119	201,375	30,801
	Transportation Equipment	23,366	0	1,218
LYNN	Leather & Leather Products	163,951	4,857	0
	Transportation Equipment	293,680	540	44,032
MARLBOROUGH	Chemicals & Allied Products	406,725	882	717
	Electronic & Other Electrical Equipment & Components, Except Computer Equipment	10,718	0	11
	Fabricated Metal Products, Except Machinery & Transportation Equipment	73,162	7,138	7,259
	Food & Kindred Products	13,599	510	0

AMMONIA (cont.)

City/Town	Industry Type (SIC Code)	Use (lbs)	Fugitive Air Releases (lbs)	Pt. Air Releases (lbs)
METHUEN	Electronic & Other Electrical Equipment & Components, Except Computer Equipment	1,206,199	6,870	2,724
MILFORD	Chemicals & Allied Products	123,983	10	60
	Electric, Gas & Sanitary Services	906,267	267	224,746
	Stone, Clay, Glass & Concrete Products	166,846	523	5
MILLBURY	Primary Metal Industries	344,236	29,830	54,595
NEW BEDFORD	Electronic & Other Electrical Equipment & Components, Except Computer Equipment	466,456	55	73,656
	Fabricated Metal Products, Except Machinery & Transportation Equipment	216,485	0	0
	Stone, Clay, Glass & Concrete Products	428,189	1,790	0
NEWBURYPORT	Electronic & Other Electrical Equipment & Components, Except Computer Equipment	783,120	0	168
NORTH ANDOVER	Electronic & Other Electrical Equipment & Components, Except Computer Equipment	124,600	1,020	4,350
NORTH ATTLEBORO	Miscellaneous Manufacturing Industries	1,767,124	4,771	22,062
	Primary Metal Industries	2,877,104	1,020	96,874
NORTHAMPTON	Fabricated Metal Products, Except Machinery & Transportation Equipment	954,988	2,250	0
	Primary Metal Industries	2,867,222	3,573	0
NORWOOD	Electronic & Other Electrical Equipment & Components, Except Computer Equipment	64,620	0	0
	Primary Metal Industries	34,070	255	0
PALMER	Primary Metal Industries	25,297	0	0
PEABODY	Chemicals & Allied Products	14,710,603	253,797	25,641
	Leather & Leather Products	350,433	675	0
PEPPERELL	Paper & Allied Products	799,838	28,000	38,703
PITTSFIELD	Electric, Gas & Sanitary Services	7,898,040	3,354	745,530
PLYMOUTH	Leather & Leather Products	23,327	1,166	0
RANDOLPH	Electronic & Other Electrical Equipment & Components, Except Computer Equipment	227,369	15	785
RUSSELL	Paper & Allied Products	36,634	0	36,634
SAGAMORE	Electric, Gas & Sanitary Services	32,175	0	0
SALEM	Electric, Gas & Sanitary Services	7,472,793	209,085	2,537,686
	Electronic & Other Electrical Equipment & Components, Except Computer Equipment	1,348,482	1,281	1,285
	Leather & Leather Products	165,203	0	3,328
SANDWICH	Electric, Gas & Sanitary Services	551,458	0	31,981
SOMERSET	Electric, Gas & Sanitary Services	3,084,491	172	288,246
SOUTH DEERFIELD	Fabricated Metal Products, Except Machinery & Transportation Equipment	1,263,347	0	0
SOUTHBRIDGE	Fabricated Metal Products, Except Machinery & Transportation Equipment	211,025	0	0
SPRINGFIELD	Chemicals & Allied Products	391,144	66	29
	Electric, Gas & Sanitary Services	7,028,432	6,630	642,986
	Fabricated Metal Products, Except Machinery & Transportation Equipment	883,739	20,430	0
	Primary Metal Industries	706,131	0	0
TAUNTON	Electronic & Other Electrical Equipment & Components, Except Computer Equipment	91,762	1,185	1,288
	Miscellaneous Manufacturing Industries	961,630	0	869
	Primary Metal Industries	59,970	0	0
TEMPLETON	Paper & Allied Products	12,007	255	0
WAKEFIELD	Fabricated Metal Products, Except Machinery & Transportation Equipment	1,225,992	0	0
WALPOLE	Chemicals & Allied Products	153,109	2,860	1,925

AMMONIA (cont.)

City/Town	Industry Type (SIC Code)	Use (lbs)	Fugitive Air Releases (lbs)	Pt. Air Releases (lbs)
WALTHAM	Electronic & Other Electrical Equipment & Components, Except Computer Equipment	877,963	1,525	4,927
	Measuring, Analyzing & Controlling Instruments; Photographic, Medical & Optical Goods; Watches & Clocks	28,823	231	258
WARD HILL	Electronic & Other Electrical Equipment & Components, Except Computer Equipment	137,046	0	0
WEST BROOKFIELD	Primary Metal Industries	534,060	0	0
WEST GROTON	Paper & Allied Products	836,400	4,070	528,000
WESTFIELD	Fabricated Metal Products, Except Machinery & Transportation Equipment	20,670	1,543	0
WEYMOUTH	Electric, Gas & Sanitary Services	184,700	104	104,418
WILBRAHAM	Food & Kindred Products	83,139	6	0
WILMINGTON	Chemicals & Allied Products	103,539	220	812
	Electronic & Other Electrical Equipment & Components, Except Computer Equipment	2,955,200	3,482	30,304
	Transportation Equipment	1,776,988	3,397	3,929
WOBURN	Electronic & Other Electrical Equipment & Components, Except Computer Equipment	1,524,522	36,804	271,030
	Food & Kindred Products	3,064,906	2,856	6,070
WORCESTER	Chemicals & Allied Products	74,715	0	0
	Fabricated Metal Products, Except Machinery & Transportation Equipment	2,475,424	33,180	19,833
	Primary Metal Industries	2,541,199	17,294	123,703
	Stone, Clay, Glass & Concrete Products	509,303	73,523	83,123
WRENTHAM	Fabricated Metal Products, Except Machinery & Transportation Equipment	1,687,441	25	7,305

CHROMIUM AND CHROMIUM COMPOUNDS

City/Town	Industry Type (SIC Code)	Use (lbs)	Fugitive Air Releases (lbs)	Pt. Air Releases (lbs)
ACTON	Textile Mill Products	127,298	0	0
ASSONET	Chemicals & Allied Products	67,421	0	5
	Measuring, Analyzing & Controlling Instruments; Photographic, Medical & Optical Goods; Watches & Clocks	138,951	0	0
ATHOL	Industrial & Commercial Machinery & Computer Equipment	287,761	0	0
ATTLEBORO	Chemicals & Allied Products	3,681,045	0	51
	Industrial & Commercial Machinery & Computer Equipment	263,309	0	0
	Measuring, Analyzing & Controlling Instruments; Photographic, Medical & Optical Goods; Watches & Clocks	6,987,762	1,300	3,640
	Primary Metal Industries	736,000	0	0
	Transportation Equipment	6,969,651	30	3,740
AUBURN	Industrial & Commercial Machinery & Computer Equipment	216,395	10	10
AVON	Fabricated Metal Products, Except Machinery & Transportation Equipment	206,751	1,490	745
BEDFORD	Electronic & Other Electrical Equipment & Components, Except Computer Equipment	1,482,963	1,260	10

CHROMIUM AND CHROMIUM COMPOUNDS (cont.)

City/Town	Industry Type (SIC Code)	Use (lbs)	Fugitive Air Releases (lbs)	Pt. Air Releases (lbs)
BELCHERTOWN	Lumber & Wood Products, Except Furniture	10,443,405	0	0
BOSTON	Fabricated Metal Products, Except Machinery & Transportation Equipment	5,197,603	550	25
BRAINTREE	Primary Metal Industries	8,439,659	0	1,668
BRIDGEWATER	Primary Metal Industries	112,720	0	0
CAMBRIDGE	Fabricated Metal Products, Except Machinery & Transportation Equipment	46,300	5	0
CHICOPEE	Chemicals & Allied Products	24,563	0	0
CHICOPEE	Fabricated Metal Products, Except Machinery & Transportation Equipment	236,750	0	0
CLINTON	Chemicals & Allied Products	22,605	0	0
	Fabricated Metal Products, Except Machinery & Transportation Equipment	513,000	0	0
	Rubber & Miscellaneous Plastics Products	165,000	255	0
DALTON	Industrial & Commercial Machinery & Computer Equipment	1,515,931	248	0
DANVERS	Transportation Equipment	76,441	260	15
DEERFIELD	Rubber & Miscellaneous Plastics Products	92,858	0	0
DIGHTON	Chemicals & Allied Products	143,000	30	43
EAST BRIDGEWATER	Measuring, Analyzing & Controlling Instruments; Photographic, Medical & Optical Goods; Watches & Clocks	273,328	0	0
EAST LONGMEADOW	Fabricated Metal Products, Except Machinery & Transportation Equipment	496,992	0	95
EVERETT	Fabricated Metal Products, Except Machinery & Transportation Equipment	223,495	277	344
FALL RIVER	Textile Mill Products	723,701	0	0
FITCHBURG	Fabricated Metal Products, Except Machinery & Transportation Equipment	184,376	0	0
	Industrial & Commercial Machinery & Computer Equipment	90,163	78	0
	Measuring, Analyzing & Controlling Instruments; Photographic, Medical & Optical Goods; Watches & Clocks	479,673	149	823
	Paper & Allied Products	19,650	0	0
FOXBORO	Measuring, Analyzing & Controlling Instruments; Photographic, Medical & Optical Goods; Watches & Clocks	130,716	0	0
FRANKLIN	Chemicals & Allied Products	1,528,464	2,274	69
FREETOWN	Fabricated Metal Products, Except Machinery & Transportation Equipment	1,010,780	0	0
GARDNER	Construction Special Trade Contractors	1,649,744	20	15
	Electronic & Other Electrical Equipment & Components, Except Computer Equipment	142,219	5	0
GRAFTON	Fabricated Metal Products, Except Machinery & Transportation Equipment	3,608,574	351	623
	Stone, Clay, Glass & Concrete Products	6,564,057	15,010	0
GREENFIELD	Fabricated Metal Products, Except Machinery & Transportation Equipment	208,253	37	151
	Industrial & Commercial Machinery & Computer Equipment	71,209	0	0
HAVERHILL	Rubber & Miscellaneous Plastics Products	336,358	0	0
HOLDEN	Industrial & Commercial Machinery & Computer Equipment	530,440	0	0
	Rubber & Miscellaneous Plastics Products	435,506	45	0
HOLYOKE	Electric, Gas & Sanitary Services	81,660	0	329
	Fabricated Metal Products, Except Machinery & Transportation Equipment	185,165	0	0
LAWRENCE	Fabricated Metal Products, Except Machinery & Transportation Equipment	407,109	0	0

CHROMIUM AND CHROMIUM COMPOUNDS (cont.)

City/Town	Industry Type (SIC Code)	Use (lbs)	Fugitive Air Releases (lbs)	Pt. Air Releases (lbs)
LAWRENCE	Industrial & Commercial Machinery & Computer Equipment	285,644	0	0
	Textile Mill Products	451,405	0	0
LEOMINSTER	Primary Metal Industries	59,835	0	0
	Rubber & Miscellaneous Plastics Products	1,195,508	313	285
LUDLOW	Rubber & Miscellaneous Plastics Products	44,386	0	0
LUNENBURG	Rubber & Miscellaneous Plastics Products	35,459	5	0
LYNN	Leather & Leather Products	445,743	0	0
	Transportation Equipment	1,847,041	780	770
NATICK	Fabricated Metal Products, Except Machinery & Transportation Equipment	970	0	0
NEW BEDFORD	Fabricated Metal Products, Except Machinery & Transportation Equipment	1,410,021	14	3
	Measuring, Analyzing & Controlling Instruments; Photographic, Medical & Optical Goods; Watches & Clocks	321,664	0	0
	Primary Metal Industries	35,565,510	0	8
NEWTON	Industrial & Commercial Machinery & Computer Equipment	164,673	15	43
NORTH ATTLEBORO	Fabricated Metal Products, Except Machinery & Transportation Equipment	132,568	10	0
	Primary Metal Industries	162,985	0	0
NORTH BILLERICA	Fabricated Metal Products, Except Machinery & Transportation Equipment	38,195	0	0
NORTHAMPTON	Primary Metal Industries	7,180,963	0	0
NORWOOD	Stone, Clay, Glass & Concrete Products	681,560	73	1
PALMER	Fabricated Metal Products, Except Machinery & Transportation Equipment	229,264	0	0
	Primary Metal Industries	250,329	0	0
PEABODY	Leather & Leather Products	1,007,777	10	0
	Transportation Equipment	110,305	0	0
PLYMOUTH	Fabricated Metal Products, Except Machinery & Transportation Equipment	34,896	35	314
RAYNHAM	Measuring, Analyzing & Controlling Instruments; Photographic, Medical & Optical Goods; Watches & Clocks	150,673	0	0
READVILLE	Lumber & Wood Products, Except Furniture	196,771	5	5
ROCKLAND	Rubber & Miscellaneous Plastics Products	66,900	10	5
SALEM	Electric, Gas & Sanitary Services	187,989	958	1,214
	Leather & Leather Products	1,037,800	0	299
SHREWSBURY	Fabricated Metal Products, Except Machinery & Transportation Equipment	1,203,141	0	0
	Primary Metal Industries	76,332	5	5
SOMERSET	Electric, Gas & Sanitary Services	730,355	607	4,006
SOUTH DEERFIELD	Fabricated Metal Products, Except Machinery & Transportation Equipment	25,418	0	0
SOUTH LANCASTER	Chemicals & Allied Products	33,477	0	0
	Lumber & Wood Products, Except Furniture	483,230	15	5
SOUTH WALPOLE	Industrial & Commercial Machinery & Computer Equipment	1,471,120	7,873	0
SOUTHBRIDGE	Fabricated Metal Products, Except Machinery & Transportation Equipment	408,357	0	0
SPRINGFIELD	Chemicals & Allied Products	3,709,866	7	12
	Fabricated Metal Products, Except Machinery & Transportation Equipment	2,471,941	30	1,586
	Industrial & Commercial Machinery & Computer Equipment	402,168	0	0
	Primary Metal Industries	716,571	0	0
SUTTON	Rubber & Miscellaneous Plastics Products	44,100	0	0
TAUNTON	Miscellaneous Manufacturing Industries	15,591	0	15

CHROMIUM AND CHROMIUM COMPOUNDS (cont.)

City/Town	Industry Type (SIC Code)	Use (lbs)	Fugitive Air Releases (lbs)	Pt. Air Releases (lbs)
TAUNTON	Primary Metal Industries	508,516	0	0
	Rubber & Miscellaneous Plastics Products	679,816	2	3
WALPOLE	Industrial & Commercial Machinery & Computer Equipment	242,592	20	800
WALTHAM	Measuring, Analyzing & Controlling Instruments; Photographic, Medical & Optical Goods; Watches & Clocks	105,583	2	0
WARE	Transportation Equipment	184,341	0	0
WATERTOWN	Electronic & Other Electrical Equipment & Components, Except Computer Equipment	16,770	0	0
	Fabricated Metal Products, Except Machinery & Transportation Equipment	395,143	0	0
WEST BROOKFIELD	Primary Metal Industries	1,598,801	0	0
WEST SPRINGFIELD	Fabricated Metal Products, Except Machinery & Transportation Equipment	287,804	0	0
WESTBOROUGH	Chemicals & Allied Products	941,578	0	0
WESTFIELD	Fabricated Metal Products, Except Machinery & Transportation Equipment	47,400	5	0
	Furniture & Fixtures	120,808	660	100
WILMINGTON	Chemicals & Allied Products	103,976	255	255
	Fabricated Metal Products, Except Machinery & Transportation Equipment	91,598	0	2,520
WINCHESTER	Electronic & Other Electrical Equipment & Components, Except Computer Equipment	61,904	2,199	0
WOBURN	Transportation Equipment	201,200	470	0
WORCESTER	Fabricated Metal Products, Except Machinery & Transportation Equipment	5,474,362	428	1,178
	Industrial & Commercial Machinery & Computer Equipment	197,240	0	0
	Primary Metal Industries	3,660,381	770	1,125
	Stone, Clay, Glass & Concrete Products	1,228,089	867	376
WRENTHAM	Fabricated Metal Products, Except Machinery & Transportation Equipment	800,288	25	770

DIISOCYANTES

City/Town	Diisocyanate Type	Industry Type (SIC Code)	Use (lbs)	Fugitive Air Releases (lbs)	Pt. Air Releases (lbs)
ACUSHNET	DIISOCYANATES GROUP	Miscellaneous Manufacturing Industries	880,708	0	0
	4,4' MDI	Miscellaneous Manufacturing Industries	34,000	0	0
ASSONET	TDI	Measuring, Analyzing & Controlling Instruments; Photographic, Medical & Optical Goods; Watches & Clocks	17,470	2	0
AVON	DIISOCYANATES GROUP	Fabricated Metal Products, Except Machinery & Transportation Equipment	65,450	0	0
BARRE	4,4' MDI	Primary Metal Industries	11,495	255	0
BOSTON	DIISOCYANATES GROUP	Leather & Leather Products	979,691	0	0
	4,4' MDI	Leather & Leather Products	769,696	0	0
	DIISOCYANATES GROUP	Wholesale Trade-non-durable Goods	111,132	0	0

DIISOCYANATES (cont.)

City/Town	Diisocyanate Type	Industry Type (SIC Code)	Use (lbs)	Fugitive Air Releases (lbs)	Pt. Air Releases (lbs)
BOSTON	TDI	Wholesale Trade-non-durable Goods	455,877	0	0
BRAINTREE	DIISOCYANATES GROUP	Primary Metal Industries	779,748	0	0
	4,4' MDI	Primary Metal Industries	145,072	0	0
CANTON	4,4' MDI	Chemicals & Allied Products	20,638	0	0
CHICOPEE	DIISOCYANATES GROUP	Miscellaneous Manufacturing Industries	471,046	2	0
	4,4' MDI	Miscellaneous Manufacturing Industries	1,320,100	356	760
DANVERS	DIISOCYANATES GROUP	Chemicals & Allied Products	524,017	0	0
DARTMOUTH	DIISOCYANATES GROUP	Miscellaneous Manufacturing Industries	27,000	0	0
DUDLEY	DIISOCYANATES GROUP	Chemicals & Allied Products	476,226	0	0
	TDI	Chemicals & Allied Products	2,200,344	0	0
FALL RIVER	DIISOCYANATES GROUP	Chemicals & Allied Products	3,094,556	161	0
	4,4' MDI	Chemicals & Allied Products	1,701,477	0	0
	TDI	Chemicals & Allied Products	7,382,810	47	770
FITCHBURG	DIISOCYANATES GROUP	Furniture & Fixtures	414,626	56	0
	4,4' MDI	Furniture & Fixtures	234,810	0	0
	POLYMERIC DIPHENYLMETHANE DIISOCYANATE	Furniture & Fixtures	11,281	0	0
FREETOWN	DIISOCYANATES GROUP	Fabricated Metal Products, Except Machinery & Transportation Equipment	275,300	124	1,114
	4,4' MDI	Fabricated Metal Products, Except Machinery & Transportation Equipment	1,392,215	245	2,611
GARDNER	DIISOCYANATES GROUP	Furniture & Fixtures	153,450	0	0
	POLYMERIC DIPHENYLMETHANE DIISOCYANATE	Furniture & Fixtures	35,050	0	0
HANOVER	DIISOCYANATES GROUP	Chemicals & Allied Products	676,126	0	0
HOLLISTON	DIISOCYANATES GROUP	Rubber & Miscellaneous Plastics Products	149,850	0	0
LAWRENCE	DIISOCYANATES GROUP	Chemicals & Allied Products	205,289	626	0
LOWELL	4,4' MDI	Industrial & Commercial Machinery & Computer Equipment	39,556	0	0
LYNN	DIISOCYANATES GROUP	Chemicals & Allied Products	5,209,653	0	0
	4,4' MDI	Chemicals & Allied Products	640,399	5	4,000
	TDI	Chemicals & Allied Products	687,193	11	1,970
	DIISOCYANATES GROUP	Transportation Equipment	580,142	0	0
	4,4' MDI	Transportation Equipment	185,813	10	11
MALDEN	Dicyclohexylmethane 4,4-diisocyanate	Chemical & Allied Products	32,444	0	0
MIDDLETON	DIISOCYANATES GROUP	Chemicals & Allied Products	1,806,951	915	515
	4,4' MDI	Chemicals & Allied Products	710,106	0	0
	TDI	Chemicals & Allied Products	766,556	0	0
NEW BEDFORD	DIISOCYANATES GROUP	Miscellaneous Manufacturing Industries	154,000	0	0
	DIISOCYANATES GROUP	Rubber & Miscellaneous Plastics Products	22,461	46	151
	4,4' MDI	Rubber & Miscellaneous Plastics Products	8,728	31	167

DIISOCYANATES (cont.)

City/Town	Diisocyanate Type	Industry Type (SIC Code)	Use (lbs)	Fugitive Air Releases (lbs)	Pt. Air Releases (lbs)
NEWBURYPORT	DIISOCYANATES GROUP	Chemicals & Allied Products	1,844,128	0	0
	Dicyclohexylmethane 4,4-diisocyanate	Chemical & Allied Products	161,460	10	10
	DIISOCYANATES GROUP	Rubber & Miscellaneous Plastics Products	8,978,697	0	0
	4,4' MDI	Rubber & Miscellaneous Plastics Products	2,126,911	0	0
	TDI	Rubber & Miscellaneous Plastics Products	94,559,059	3,632	3,307
NORTH ANDOVER	DIISOCYANATES GROUP	Electronic & Other Electrical Equipment & Components, Except Computer Equipment	320,250	35	0
	4,4' MDI	Electronic & Other Electrical Equipment & Components, Except Computer Equipment	58,000	20	20
NORTH BILLERICA	4,4' MDI	Rubber & Miscellaneous Plastics Products	546,518	255	0
NORTH BROOKFIELD	DIISOCYANATES GROUP	Rubber & Miscellaneous Plastics Products	445,152	72	0
	4,4' MDI	Rubber & Miscellaneous Plastics Products	282,681	2	0
PALMER	DIISOCYANATES GROUP	Primary Metal Industries	154,747	12	0
PEABODY	DIISOCYANATES GROUP	Chemicals & Allied Products	11,415,639	11	252
	4,4' MDI	Chemicals & Allied Products	46,964	2	4
	TDI	Chemicals & Allied Products	849,577	22	1,566
PITTSFIELD	4,4' MDI	Electronic & Other Electrical Equipment & Components, Except Computer Equipment	22,300	100	0
RAYNHAM	DIISOCYANATES GROUP	Rubber & Miscellaneous Plastics Products	87,603	5	25
	4,4' MDI	Rubber & Miscellaneous Plastics Products	0	0	0
ROCKLAND	DIISOCYANATES GROUP	Rubber & Miscellaneous Plastics Products	53,439	2,672	0
	TDI	Transportation Equipment	439,836	0	9,690
SALEM	TDI	Miscellaneous Manufacturing Industries	1,360,201	0	12
SOMERSET	DIISOCYANATES GROUP	Electric, Gas & Sanitary Services	18,874	0	0
SPRINGFIELD	DIISOCYANATES GROUP	Rubber & Miscellaneous Plastics Products	10,495,123	31	0
	4,4' MDI	Rubber & Miscellaneous Plastics Products	36,167,544	458	0
THREE RIVERS	DIISOCYANATES GROUP	Transportation Equipment	64,000	0	0
	4,4' MDI	Transportation Equipment	30,420	0	0
TURNERS FALLS	DIISOCYANATES GROUP	Industrial & Commercial Machinery & Computer Equipment	47,230	0	0
WESTMINSTER	DIISOCYANATES GROUP	Electronic & Other Electrical Equipment & Components, Except Computer Equipment	66,753	863	0
WEYMOUTH	DIISOCYANATES GROUP	Chemicals & Allied Products	488,614	1,275	0
	4,4' MDI	Chemicals & Allied Products	285,486	571	0
WILMINGTON	DIISOCYANATES GROUP	Chemicals & Allied Products	16,495,456	890	0
	ISOPHORONE DIISOCYANATE	Chemicals & Allied Products	73,464	38	0
	4,4' MDI	Chemicals & Allied Products	125,424	0	1
	TDI	Chemicals & Allied Products	5,889,580	2,089	258
WOBURN	DIISOCYANATES GROUP	Chemicals & Allied Products	886,323	264	0

FORMALDEHYDE

City/Town	Industry Type (SIC Code)	Use (lbs)	Fugitive Air Releases (lbs)	Pt. Air Releases (lbs)
ACTON	Chemicals & Allied Products	45,799	255	255
BOSTON	Electronic & Other Electrical Equipment & Components, Except Computer Equipment	65,000	0	5
CAMBRIDGE	Chemicals & Allied Products	11,530,495	3,592	3,341
CHICOPEE	Chemicals & Allied Products	1,353,415	7,729	5,331
DALTON	Paper & Allied Products	189,450	0	65,818
EVERETT	Electric, Gas & Sanitary Services	105,251	255	105,239
FALL RIVER	Textile Mill Products	22,947	726	909
	Wholesale Trade-non-durable Goods	16,049,862	40,955	6,340
FITCHBURG	Chemicals & Allied Products	440,724	790	35
	Paper & Allied Products	996,667	9,800	475,200
HOLLISTON	Wholesale Trade-non-durable Goods	58,313	0	255
HOPKINTON	Electric, Gas & Sanitary Services	46,720	0	46,720
LEE	Paper & Allied Products	600,613	1,768	49,810
LEOMINSTER	Chemicals & Allied Products	84,150	255	255
	Wholesale Trade-non-durable Goods	26,385	255	0
MARLBOROUGH	Chemicals & Allied Products	12,138,037	850	369
MILLBURY	Textile Mill Products	373,618	1,872	457
ROCKLAND	Paper & Allied Products	10,258	0	1,000
SANDWICH	Electric, Gas & Sanitary Services	12,882	255	12,869
SOUTH LEE	Paper & Allied Products	678,240	1,748	67,517
WEST GROTON	Paper & Allied Products	277,000	290	126,900
WESTBOROUGH	Stone, Clay, Glass & Concrete Products	10,742	0	750
WILMINGTON	Electronic & Other Electrical Equipment & Components, Except Computer Equipment	173,897	6,362	25,362
	Transportation Equipment	208,112	354	3,186
WOBURN	Electronic & Other Electrical Equipment & Components, Except Computer Equipment	198,300	2,639	2,714
WORCESTER	Leather & Leather Products	360,996	0	1,040
	Stone, Clay, Glass & Concrete Products	2,889,298	5,352	1,230

NITROGEN DIOXIDE

City/Town	Industry Type (SIC Code)	Use (lbs)	Fugitive Air Releases (lbs)	Pt. Air Releases (lbs)
BILLERICA	Electronic & Other Electrical Equipment & Components, Except Computer Equipment	232,126	0	26,077
GRAFTON	Fabricated Metal Products, Except Machinery & Transportation Equipment	373,778	92,000	192,420
NORTH ADAMS	Fabricated Metal Products, Except Machinery & Transportation Equipment	177,340	9,300	39,100
NORTH ATTLEBORO	Miscellaneous Manufacturing Industries	10,439	0	423
PLYMOUTH	Fabricated Metal Products, Except Machinery & Transportation Equipment	12,267	1,227	11,040
SPRINGFIELD	Chemicals & Allied Products	28,000	0	28,000
	Electric, Gas & Sanitary Services	230,000	0	230,000

STYRENE

City/Town	Industry Type (SIC Code)	Use (lbs)	Fugitive Air Releases (lbs)	Pt. Air Releases (lbs)
ATHOL	Rubber & Miscellaneous Plastics Products	140,424	0	0
CANTON	Chemicals & Allied Products	22,905,291	80	1,080
CHELSEA	Chemicals & Allied Products	5,778,769	30	1,785
DANVERS	Chemicals & Allied Products	327,304	2,859	2,326
FALL RIVER	Chemicals & Allied Products	300,026	8,604	15,978
FITCHBURG	Chemicals & Allied Products	26,247,109	3,222	131
HOLYOKE	Chemicals & Allied Products	516,242,112	59,602	10,268
HUDSON	Miscellaneous Manufacturing Industries	141,140	256	752
LEOMINSTER	Chemicals & Allied Products	259,788,770	16,681	27,734
	Rubber & Miscellaneous Plastics Products	231,702	3,500	0
	Wholesale Trade-non-durable Goods	99,569	15	1
LOWELL	Primary Metal Industries	404,736	0	0
	Transportation Equip.	180,581	685	0
LUDLOW	Rubber & Miscellaneous Plastics Products	1,422,114	104,277	27,385
MALDEN	Chemicals & Allied Products	363,471	1,270	520
MEDWAY	Miscellaneous Manufacturing Industries	1,969,576	1,062	8,244
NEWBURYPORT	Electronic & Other Electrical Equip. & Components, Except Computer Equip.	214,434	6,247	5,511
NORTON	Rubber & Miscellaneous Plastics Products	422,755	42,597	0
OXFORD	Chemicals & Allied Products	1,021,363,012	23,439	43,829
PALMER	Transportation Equip.	25,556	0	5
ROCKLAND	Transportation Equip.	176,691	0	176,771
SPRINGFIELD	Rubber & Miscellaneous Plastics Products	70,000	28	255
	Chemicals & Allied Products	3,419,873,492	33,611	214,021
TEWKSBURY	Wholesale Trade-non-durable Goods	1,832,767	8	17
THREE RIVERS	Transportation Equip.	74,686	13,844	5
WALPOLE	Wholesale Trade-non-durable Goods	1,269,103	10	16
WESTMINSTER	Chemicals & Allied Products	10,537,862	4,342	20,764
WILMINGTON	Chemicals & Allied Products	7,927,586	1,133	107
	Wholesale Trade-non-durable Goods	17,320	0	0

SULFURIC ACID

City/Town	Industry Type (SIC Code)	Use	Fugitive Air Releases (lbs)	Pt. Air Releases (lbs)
ADAMS	Chemicals & Allied Products	100,750	0	0
	Paper & Allied Products	62,900	0	62,900
AGAWAM	Electric, Gas & Sanitary Services	571,778	0	19,008
	Food & Kindred Products	1,185,573	0	410
	Personal Services	12,750	0	0
AMESBURY	Industrial & Commercial Machinery & Computer Equip.	1,281,448	0	0

Sulfuric Acid (Cont.)

City/Town	Industry Type (SIC Code)	Use (lbs)	Fugitive Air Releases (lbs)	Pt. Air Releases (lbs)
AMESBURY	Electronic & Other Electrical Equip. & Components, Except Computer Equip.	905,881	0	1,051
ANDOVER	Chemicals & Allied Products	101,174	0	0
	Electronic & Other Electrical Equip. & Components, Except Computer Equip.	1,232,440	960	1,367
ASHLAND	Chemicals & Allied Products	27,100,998	0	0
	Measuring, Analyzing & Controlling Instruments; Photographic, Medical & Optical Goods; Watches & Clocks	10,381	5	255
ASSONET	Chemicals & Allied Products	1,833,753	0	0
	Measuring, Analyzing & Controlling Instruments; Photographic, Medical & Optical Goods; Watches & Clocks	2,399,915	750	85
ATHOL	Industrial & Commercial Machinery & Computer Equip.	416,106	0	6,568
ATTLEBORO	Chemicals & Allied Products	7,631,798	4,176	1,295
	Fabricated Metal Products, Except Machinery & Transportation Equip.	1,589,844	4,732	3,684
	Measuring, Analyzing & Controlling Instruments; Photographic, Medical & Optical Goods; Watches & Clocks	7,300,167	95	15,000
	Miscellaneous Manufacturing Industries	111,979	10	10
	Primary Metal Industries	5,513,537	2,040	2,040
	Transportation Equip.	215,350	26	612
AUBURN	Rubber & Miscellaneous Plastics Products	13,709	0	0
AYER	Food & Kindred Products	336,778	0	0
BALDWINVILLE	Paper & Allied Products	8,581,804	0	0
BEDFORD	Chemicals & Allied Products	56,357	14	1,348
BELLINGHAM	Electric, Gas & Sanitary Services	6,205,684	0	0
BELMONT	Fabricated Metal Products, Except Machinery & Transportation Equip.	840,127	1,824	0
BEVERLY	Electronic & Other Electrical Equip. & Components, Except Computer Equip.	146,644	0	2,508
BILLERICA	Fabricated Metal Products, Except Machinery & Transportation Equip.	201,456	10	31
	Measuring, Analyzing & Controlling Instruments; Photographic, Medical & Optical Goods; Watches & Clocks	134,202	843	531
BOSTON	Electric, Gas & Sanitary Services	19,424,932	4,517	2,616,479
	Electronic & Other Electrical Equip. & Components, Except Computer Equip.	1,870,194	0	10,808
	Fabricated Metal Products, Except Machinery & Transportation Equip.	2,283,151	74	36,738
	Food & Kindred Products	317,323	0	0
	Personal Services	220,533	0	0
	Paper & Allied Products	836,173	0	0
BROCKTON	Personal Services	92,188	0	0
BURLINGTON	Electronic & Other Electrical Equip. & Components, Except Computer Equip.	404,754	560	2,198
CAMBRIDGE	Electronic & Other Electrical Equip. & Components, Except Computer Equip.	472,834	237	1,171
	Electric, Gas & Sanitary Services	5,649,618	0	42,215
	Chemicals & Allied Products	259,101	13	1,217
	Fabricated Metal Products, Except Machinery & Transportation Equip.	209,127	630	5,600
CANTON	Chemicals & Allied Products	211,082	0	1,220
	Food & Kindred Products	645,150	0	0
CHARLESTOWN	Chemicals & Allied Products	6,808,553	43,813	81,872
CHARLTON	Electric, Gas & Sanitary Services	549,305	50	2,795
CHICOPEE	Textile Mill Products	1,561,035	271	0
	Chemicals & Allied Products	6,367,583	1	47
	Fabricated Metal Products, Except Machinery & Transportation Equip.	1,257,982	0	0
	Food & Kindred Products	230,337	0	0

Sulfuric Acid (Cont.)

City/Town	Industry Type (SIC Code)	Use (lbs)	Fugitive Air Releases (lbs)	Pt. Air Releases (lbs)
CHICOPEE	Personal Services	1,646,250	0	0
CLINTON	Electronic & Other Electrical Equip. & Components, Except Computer Equip.	103,096	255	265
	Primary Metal Industries	22,378	0	0
COLRAIN	Textile Mill Products	30,451,960	0	5,415
CONCORD	Primary Metal Industries	461,397	0	780
DALTON	Paper & Allied Products	5,975,734	0	0
DARTMOUTH	Electric, Gas & Sanitary Services	1,451,821	0	94
DIGHTON	Chemicals & Allied Products	7,588,700	3,570	3,602
DORCHESTER	Electric, Gas & Sanitary Services	244,144	0	0
DRACUT	Electronic & Other Electrical Equip. & Components, Except Computer Equip.	70,685	5	5
EAST BRIDGEWATER	Measuring, Analyzing & Controlling Instruments; Photographic, Medical & Optical Goods; Watches & Clocks	104,765	0	0
EAST LONGMEADOW	Fabricated Metal Products, Except Machinery & Transportation Equip.	22,875	0	0
EASTHAMPTON	Textile Mill Products	31,528	0	0
ERVING	Paper & Allied Products	25,641,602	0	0
EVERETT	Electric, Gas & Sanitary Services	24,446,261	24	4,158,479
	Fabricated Metal Products, Except Machinery & Transportation Equip.	606,991	91	61
FALL RIVER	Chemicals & Allied Products	580,175	0	0
	Fabricated Metal Products, Except Machinery & Transportation Equip.	3,062,067	11,012	11,405
	Wholesale Trade-non-durable Goods	80,520,720	6,126	73
	Textile Mill Products	798,909	0	0
	Electronic & Other Electrical Equip. & Components, Except Computer Equip.	672,515	0	6,982
FITCHBURG	Measuring, Analyzing & Controlling Instruments; Photographic, Medical & Optical Goods; Watches & Clocks	670,211	764	6,869
	Chemicals & Allied Products	3,529,872	1,167	5
	Paper & Allied Products	133,326	5	5
FOXBORO	Measuring, Analyzing & Controlling Instruments; Photographic, Medical & Optical Goods; Watches & Clocks	346,840	0	0
FRAMINGHAM	Food & Kindred Products	141,913	0	0
FRANKLIN	Food & Kindred Products	153,408	0	806
GLOUCESTER	Chemicals & Allied Products	446,519	0	0
	Food & Kindred Products	373,139	0	0
GRAFTON	Fabricated Metal Products, Except Machinery & Transportation Equip.	250,923	0	0
HAVERHILL	Electronic & Other Electrical Equip. & Components, Except Computer Equip.	996,044	1,150	1,945
	Electric, Gas & Sanitary Services	1,299,867	0	0
	Paper & Allied Products	170,235	7,133	143,431
HOLDEN	Electronic & Other Electrical Equip. & Components, Except Computer Equip.	727,495	1,852	11,049
HOLLISTON	Wholesale Trade-non-durable Goods	9,431,682	0	5
HOLYOKE	Electric, Gas & Sanitary Services	1,580,700	0	452,700
	Fabricated Metal Products, Except Machinery & Transportation Equip.	5,352,374	4,030	4,255
	Printing, Publishing & Allied Industries	2,324,550	893	1,066
HUDSON	Fabricated Metal Products, Except Machinery & Transportation Equip.	93,843	0	0
	Electronic & Other Electrical Equip. & Components, Except Computer Equip.	4,887,086	0	681
LAWRENCE	Electronic & Other Electrical Equip. & Components, Except Computer Equip.	77,016	0	0
	Fabricated Metal Products, Except Machinery & Transportation Equip.	4,013,740	245	1

Sulfuric Acid (Cont.)

City/Town	Industry Type (SIC Code)	Use (lbs)	Fugitive Air Releases (lbs)	Pt. Air Releases (lbs)
LAWRENCE	Paper & Allied Products	981,750	0	0
	Personal Services	808,821	30	30
	Textile Mill Products	37,968	0	0
LEE	Paper & Allied Products	4,665,054	34,215	232,524
LEOMINSTER	Chemicals & Allied Products	117,810	255	255
LITTLETON	Food & Kindred Products	70,854	0	0
LOWELL	Fabricated Metal Products, Except Machinery & Transportation Equip.	177,170	0	2,375
	Electronic & Other Electrical Equip. & Components, Except Computer Equip.	326,161	306	2,807
	Electric, Gas & Sanitary Services	2,062,261	0	7,742
LYNN	Transportation Equip.	328,620	10	132,365
	Leather & Leather Products	653,715	0	0
	Fabricated Metal Products, Except Machinery & Transportation Equip.	118,881	0	0
MALDEN	Fabricated Metal Products, Except Machinery & Transportation Equip.	1,131,923	7,533	2
	Chemicals & Allied Products	556,309	525	525
MARLBOROUGH	Chemicals & Allied Products	7,213,879	55	690
	Electronic & Other Electrical Equip. & Components, Except Computer Equip.	323,871	1,555	1,555
	Fabricated Metal Products, Except Machinery & Transportation Equip.	1,389,343	8,861	4,399
	Wholesale Trade-non-durable Goods	26,787	0	0
MEDFORD	Fabricated Metal Products, Except Machinery & Transportation Equip.	179,999	765	765
MERRIMAC	Fabricated Metal Products, Except Machinery & Transportation Equip.	171,233	0	0
METHUEN	Electronic & Other Electrical Equip. & Components, Except Computer Equip.	3,162,888	5,064	1,382
	Food & Kindred Products	48,657	0	0
MILFORD	Electric, Gas & Sanitary Services	2,798,787	0	0
	Fabricated Metal Products, Except Machinery & Transportation Equip.	45,048	796	0
MILLBURY	Electric, Gas & Sanitary Services	1,986,982	0	31
NATICK	Fabricated Metal Products, Except Machinery & Transportation Equip.	1,775,535	0	0
NEEDHAM	Food & Kindred Products	45,000	0	0
	Electronic & Other Electrical Equip. & Components, Except Computer Equip.	62,115	0	0
NEW BEDFORD	Textile Mill Products	3,077,336	0	0
	Electric, Gas & Sanitary Services	92,636	0	0
	Electronic & Other Electrical Equip. & Components, Except Computer Equip.	867,575	52	5,030
	Primary Metal Industries	15,987,898	262,522	47,846
	Fabricated Metal Products, Except Machinery & Transportation Equip.	636,954	0	0
	Measuring, Analyzing & Controlling Instruments; Photographic, Medical & Optical Goods; Watches & Clocks	1,922,541	0	14,400
	Miscellaneous Manufacturing Industries	62,266	0	500
	Personal Services	240,062	0	0
NEWBURYPORT	Electronic & Other Electrical Equip. & Components, Except Computer Equip.	136,135	110	60
	Fabricated Metal Products, Except Machinery & Transportation Equip.	120,305	255	255
	Chemicals & Allied Products	242,599	886	550
	Personal Services	190,120	0	0
NEWTON	Primary Metal Industries	1,855,274	0	1,564

Sulfuric Acid (Cont.)

City/Town	Industry Type (SIC Code)	Use (lbs)	Fugitive Air Releases (lbs)	Pt. Air Releases (lbs)
NORTH ADAMS	Fabricated Metal Products, Except Machinery & Transportation Equip.	10,345,891	91,300	9,625
NORTH ANDOVER	Electronic & Other Electrical Equip. & Components, Except Computer Equip.	1,139,500	45	41,900
	Electric, Gas & Sanitary Services	1,110,216	0	3
NORTH ATTLEBORO	Fabricated Metal Products, Except Machinery & Transportation Equip.	321,895	26	1,646
	Miscellaneous Manufacturing Industries	93,392	15	25
	Primary Metal Industries	2,139,394	0	21
NORTH DIGHTON	Textile Mill Products	281,130	0	0
NORWOOD	Electronic & Other Electrical Equip. & Components, Except Computer Equip.	16,915	0	5
	Fabricated Metal Products, Except Machinery & Transportation Equip.	108,305	10	10
PALMER	Chemicals & Allied Products	722,920	0	0
PEABODY	Chemicals & Allied Products	40,344,258	12	0
	Leather & Leather Products	206,958	35	0
PELHAM	Primary Metal Industries	30,600	0	0
PEPPERELL	Paper & Allied Products	607,054	0	0
	Industrial & Commercial Machinery & Computer Equip.	1,116,947	0	2,708
PITTSFIELD	Electronic & Other Electrical Equip. & Components, Except Computer Equip.	599,280	2,126	29
	Electric, Gas & Sanitary Services	8,706,133	0	5,225
PLYMOUTH	Leather & Leather Products	15,000	0	0
	Fabricated Metal Products, Except Machinery & Transportation Equip.	1,582,097	1,564	14,059
QUINCY	Chemicals & Allied Products	11,879,595	66	84
RANDOLPH	Stone, Clay, Glass & Concrete Products	691,542	0	0
	Fabricated Metal Products, Except Machinery & Transportation Equip.	621,882	1,260	1,755
	Electronic & Other Electrical Equip. & Components, Except Computer Equip.	128,557	1,005	0
ROCHESTER	Electric, Gas & Sanitary Services	1,046,129	0	0
ROXBURY	Fabricated Metal Products, Except Machinery & Transportation Equip.	15,204	255	5
RUSSELL	Paper & Allied Products	314,787	0	2,594
SAGAMORE	Electric, Gas & Sanitary Services	885,870	0	0
SALEM	Wholesale Trade-non-durable Goods	1,645,301	0	0
	Leather & Leather Products	508,056	0	0
	Electric, Gas & Sanitary Services	3,095,240	0	1,083,640
	Chemicals & Allied Products	8,642,204	30	15
SANDWICH	Electric, Gas & Sanitary Services	26,310,015	0	4,040,213
SAUGUS	Electric, Gas & Sanitary Services	1,373,619	0	12
	Chemicals & Allied Products	535,730	2,768	505
SHREWSBURY	Industrial & Commercial Machinery & Computer Equip.	81,813	0	6
SOMERSET	Electric, Gas & Sanitary Services	8,863,915	0	3,844,425
SOMERVILLE	Personal Services	182,409	0	0
	Fabricated Metal Products, Except Machinery & Transportation Equip.	10,722	5	5
SOUTH HADLEY	Industrial & Commercial Machinery & Computer Equip.	3,437,796	1,304	2,835
SPRINGFIELD	Chemicals & Allied Products	37,461,753	15	103,015
	Electric, Gas & Sanitary Services	4,740,910	0	13,977
	Wholesale Trade-non-durable Goods	37,754,161	1,214	612
	Transportation Services	169,227	0	0
	Personal Services	229,971	0	0
	Fabricated Metal Products, Except Machinery & Transportation Equip.	3,910,518	120	11,143
TAUNTON	Textile Mill Products	1,083,598	0	0
	Miscellaneous Manufacturing Industries	155,688	265	265

Sulfuric Acid (Cont.)

City/Town	Industry Type (SIC Code)	Use (lbs)	Fugitive Air Releases (lbs)	Pt. Air Releases (lbs)
TAUNTON	Fabricated Metal Products, Except Machinery & Transportation Equip.	159,950	0	1,613
TEMPLETON	Paper & Allied Products	9,130,139	4,315	159,464
THORNDIKE	Paper & Allied Products	190,709	0	0
WAKEFIELD	Electronic & Other Electrical Equip. & Components, Except Computer Equip.	132,380	0	1,551
WALPOLE	Paper & Allied Products	771,000	0	0
WALTHAM	Transportation Equip.	41,940	0	0
	Measuring, Analyzing & Controlling Instruments; Photographic, Medical & Optical Goods; Watches & Clocks	781,892	237	21,283
	Fabricated Metal Products, Except Machinery & Transportation Equip.	2,449,907	2,727	4,234
	Electronic & Other Electrical Equip. & Components, Except Computer Equip.	828,851	464	97
WARD HILL	Electronic & Other Electrical Equip. & Components, Except Computer Equip.	126,261	0	0
WARREN	Textile Mill Products	240,499	0	0
WATERTOWN	Electronic & Other Electrical Equip. & Components, Except Computer Equip.	462,760	370	8,817
WEBSTER	Chemicals & Allied Products	2,945,416	86	42
	Textile Mill Products	6,528,107	6,278	2
WEST GROTON	Paper & Allied Products	3,351,000	0	205,000
WEST SPRINGFIELD	Paper & Allied Products	22,050	0	0
	Food & Kindred Products	972,931	0	0
	Fabricated Metal Products, Except Machinery & Transportation Equip.	667,289	0	280
WESTFIELD	Furniture & Fixtures	22,984	0	0
	Fabricated Metal Products, Except Machinery & Transportation Equip.	311,079	1,048	2,384
WESTFORD	Fabricated Metal Products, Except Machinery & Transportation Equip.	174,418	255	255
WEYMOUTH	Electric, Gas & Sanitary Services	243,569	0	0
WHITMAN	Fabricated Metal Products, Except Machinery & Transportation Equip.	10,500	0	0
WILBRAHAM	Primary Metal Industries	86,490	21	0
	Food & Kindred Products	874,094	0	147
WILMINGTON	Transportation Equip.	3,369,473	35	1,785
	Industrial & Commercial Machinery & Computer Equip.	59,554	0	0
	Chemicals & Allied Products	28,723	0	0
	Electronic & Other Electrical Equip. & Components, Except Computer Equip.	5,953,539	1,422	12,441
WOBURN	Rubber & Miscellaneous Plastics Products	88,364	15	20
	Food & Kindred Products	52,803,568	9,400	26,276
	Electronic & Other Electrical Equip. & Components, Except Computer Equip.	2,282,050	3,728	10,122
	Chemicals & Allied Products	65,251	0	0
WORCESTER	Stone, Clay, Glass & Concrete Products	1,792,255	0	5,015
	Personal Services	652,841	0	0
	Fabricated Metal Products, Except Machinery & Transportation Equip.	3,526,286	100,732	11,995
	Electronic & Other Electrical Equip. & Components, Except Computer Equip.	8,164,111	1,720	31,146
	Chemicals & Allied Products	264,338	0	378

Zinc & Zinc Compounds

City/Town	Industry Type (SIC Code)	Use (lbs)	Fugitive Air Releases (lbs)	Pt. Air Releases (lbs)
ACTON	Textile Mill Products	416,340	0	0
ACUSHNET	Miscellaneous Manufacturing Industries	3,080,162	1,765	2,670
ANDOVER	Chemicals & Allied Products	80,648	0	0
	Rubber & Miscellaneous Plastics Products	141,713	0	0
ASHLAND	Primary Metal Industries	927,099	25	0
ASSONET	Chemicals & Allied Products	37,657	0	0
	Measuring, Analyzing & Controlling Instruments; Photographic, Medical & Optical Goods; Watches & Clocks	94,470	0	0
ATTLEBORO	Chemicals & Allied Products	650,552	355	110
	Primary Metal Industries	2,389,405	560	1,440
BOSTON	Fabricated Metal Products, Except Machinery & Transportation Equipment	637,034	0	0
	Petroleum Refining & Related Industries	2,726,778	0	0
BRAINTREE	Rubber & Miscellaneous Plastics Products	1,380,228	1,827	564
CAMBRIDGE	Chemicals & Allied Products	245,090	0	0
CANTON	Chemicals & Allied Products	270,451	0	0
	Fabricated Metal Products, Except Machinery & Transportation Equipment	1,700,535	0	228
	Rubber & Miscellaneous Plastics Products	837,319	255	5
CHELMSFORD	Rubber & Miscellaneous Plastics Products	267,567	0	0
CHICOPEE	Chemicals & Allied Products	475,782	20	131
	Fabricated Metal Products, Except Machinery & Transportation Equipment	22,638	0	0
	Miscellaneous Manufacturing Industries	85,220,926	255	0
	Primary Metal Industries	36,000	255	255
CLINTON	Chemicals & Allied Products	0	0	0
	Primary Metal Industries	111,517	89	0
	Rubber & Miscellaneous Plastics Products	320,000	510	5
	Textile Mill Products	103,369	0	0
DANVERS	Chemicals & Allied Products	755,743	0	20
DARTMOUTH	Miscellaneous Manufacturing Industries	55,219,796	25	25
EVERETT	Chemicals & Allied Products	35,053	0	0
	Fabricated Metal Products, Except Machinery & Transportation Equipment	7,731,576	17,930	0
FALL RIVER	Chemicals & Allied Products	3,236,621	0	66
	Fabricated Metal Products, Except Machinery & Transportation Equipment	119,240	255	25
	Rubber & Miscellaneous Plastics Products	4,566,131	3,065	765
	Wholesale Trade-non-durable Goods	237,000	50	0
FITCHBURG	Chemicals & Allied Products	2,227,025	0	0
	Industrial & Commercial Machinery & Computer Equipment	30,705	0	0
FRANKLIN	Chemicals & Allied Products	146,714	1,065	54
	Primary Metal Industries	102,916	0	0
GLOUCESTER	Chemicals & Allied Products	484,308	0	0
HANOVER	Chemicals & Allied Products	7,448	255	0
	Rubber & Miscellaneous Plastics Products	603,796	0	0
HAVERHILL	Rubber & Miscellaneous Plastics Products	1,184,826	0	0
HOLBROOK	Chemicals & Allied Products	762,045	0	0
HOLDEN	Rubber & Miscellaneous Plastics Products	2,013,095	80	0
HOLYOKE	Chemicals & Allied Products	421,167	30	10
	Electric, Gas & Sanitary Services	148,200	0	472
LAWRENCE	Chemicals & Allied Products	357,526	0	510
	Rubber & Miscellaneous Plastics Products	750,586	0	0
LEOMINSTER	Primary Metal Industries	308,936	0	0
	Rubber & Miscellaneous Plastics Products	5,817,740	1,303	2,037
LOWELL	Fabricated Metal Products, Except Machinery & Transportation Equipment	13,250	0	0
	Textile Mill Products	448,034	0	0

Zinc & Zinc Compounds (Cont.)

City/Town	Industry Type (SIC Code)	Use (lbs)	Fugitive Air Releases (lbs)	Pt. Air Releases (lbs)
LOWELL	Transportation Equipment	1,320,823	0	0
LUNENBURG	Rubber & Miscellaneous Plastics Products	1,242,435	37	0
LYNN	Chemicals & Allied Products	126,000	5	255
	Rubber & Miscellaneous Plastics Products	1,099,930	0	40
MALDEN	Fabricated Metal Products, Except Machinery & Transportation Equipment	136,816	175	0
MANSFIELD	Rubber & Miscellaneous Plastics Products	254,061	535	35
MARLBOROUGH	Chemicals & Allied Products	350,500	0	0
MERRIMAC	Fabricated Metal Products, Except Machinery & Transportation Equipment	78,000	0	0
MILFORD	Chemicals & Allied Products	5,586,204	3,344	0
	Fabricated Metal Products, Except Machinery & Transportation Equipment	332,451	0	0
NEW BEDFORD	Electronic & Other Electrical Equipment & Components, Except Computer Equipment	8,909,739	3,585	17,848
	Fabricated Metal Products, Except Machinery & Transportation Equipment	2,363,358	0	0
	Miscellaneous Manufacturing Industries	10,457,903	0	0
	Primary Metal Industries	5,424,052	0	10
	Rubber & Miscellaneous Plastics Products	2,380,358	815	41
NEWBURYPORT	Chemicals & Allied Products	426,366	6	5
NEWTON	Rubber & Miscellaneous Plastics Products	158,602	57	57
NEWTON UPPER FALLS	Rubber & Miscellaneous Plastics Products	55,817	23	0
NORTH ADAMS	Electronic & Other Electrical Equipment & Components, Except Computer Equipment	929,841	0	5,232
NORTH ANDOVER	Rubber & Miscellaneous Plastics Products	76,613	0	0
NORTH ATTLEBORO	Primary Metal Industries	361,346	15	765
NORTH BILLERICA	Rubber & Miscellaneous Plastics Products	153,304	0	0
NORTH BROOKFIELD	Rubber & Miscellaneous Plastics Products	1,104,696	0	0
NORTH DIGHTON	Primary Metal Industries	813,513	0	0
NORTHBRIDGE	Primary Metal Industries	198,866	0	0
	Rubber & Miscellaneous Plastics Products	155,545	30	30
NORTON	Primary Metal Industries	193,940	510	0
NORWOOD	Stone, Clay, Glass & Concrete Products	902,303	54	0
OXFORD	Chemicals & Allied Products	785,670	2,680	251
PALMER	Primary Metal Industries	14,504	0	0
PEABODY	Leather & Leather Products	94,939	30	0
PITTSFIELD	Electronic & Other Electrical Equipment & Components, Except Computer Equipment	6,573,320	1,321	24,100
ROCKLAND	Chemicals & Allied Products	263,224	233	787
	Paper & Allied Products	199,255	0	0
RUSSELL	Paper & Allied Products	4,790	0	0
SALEM	Electric, Gas & Sanitary Services	363,127	343	4,864
SANDWICH	Electric, Gas & Sanitary Services	661,074	0	11,556
SOMERSET	Electric, Gas & Sanitary Services	911,421	15	2,615
SOMERVILLE	Lumber & Wood Products, Except Furniture	28,650	0	2
SOUTH HADLEY	Paper & Allied Products	9,544,290	0	0
SPRINGFIELD	Chemicals & Allied Products	4,673,752	582	1,055
TAUNTON	Miscellaneous Manufacturing Industries	128,327	0	209
	Rubber & Miscellaneous Plastics Products	723,246	0	3
TEMPLETON	Chemicals & Allied Products	21,000	510	510
	Paper & Allied Products	17,105	0	0
TURNERS FALLS	Primary Metal Industries	427,803	0	0

Zinc & Zinc Compounds (Cont.)

City/Town	Industry Type (SIC Code)	Use (lbs)	Fugitive Air Releases (lbs)	Pt. Air Releases (lbs)
WAKEFIELD	Fabricated Metal Products, Except Machinery & Transportation Equipment	338,526	2,805	0
WALPOLE	Chemicals & Allied Products	557,500	2,795	1,915
	Paper & Allied Products	355,690	0	0
WALTHAM	Electronic & Other Electrical Equipment & Components, Except Computer Equipment	29,179	0	0
	Fabricated Metal Products, Except Machinery & Transportation Equipment	35,933	0	0
	Measuring, Analyzing & Controlling Instruments; Photographic, Medical & Optical Goods; Watches & Clocks	8,167,641	7	0
WARE	Paper & Allied Products	209,955	0	0
WATERTOWN	Apparel & Other Finished Products Made From Fabrics & Similar Materials	229,795	0	0
	Electronic & Other Electrical Equipment & Components, Except Computer Equipment	21,330	0	0
WEST BOYLSTON	Wholesale Trade-non-durable Goods	291,147	0	0
WEST GROTON	Paper & Allied Products	592,000	0	0
WESTBOROUGH	Chemicals & Allied Products	165,281	0	0
WESTMINSTER	Electronic & Other Electrical Equipment & Components, Except Computer Equipment	137,360	0	0
WILLIAMSTOWN	Primary Metal Industries	41,732	0	0
WILMINGTON	Fabricated Metal Products, Except Machinery & Transportation Equipment	490,935	0	0
WOBURN	Chemicals & Allied Products	173,322	32	22
	Rubber & Miscellaneous Plastics Products	36,374	0	0
WORCESTER	Fabricated Metal Products, Except Machinery & Transportation Equipment	2,346,180	884	18,921
	Petroleum Refining & Related Industries	448,501	0	0
	Stone, Clay, Glass & Concrete Products	89,987	0	0
WRENTHAM	Fabricated Metal Products, Except Machinery & Transportation Equipment	637,360	823	965