Minnesota Pollution Control Agency

Staff Paper on Air Toxics

INITIAL REPORT
November 1999

Members of Air Toxics Technical Team:

Mary Jean Fenske
Cynthia Hollerbach
Margaret McCourtney
Chris Nelson
Fardin Oliaei
Kari Palmer
Greg Pratt
Gretchen Rohweder
Chun Yi Wu

With special assistance from Sherryl Livingston

The team wishes to thank the following for their review and comments:

Onsoon Berglund
Todd Biewen
Shelley Burman
Peter Ciborowski
Joe Esker
Marvin Hora
Anne Jackson
Frank Martin (U of M)
Leo Raudys
Dave Richfield
John Seltz
Dale Thompson
David Thornton
Ken Sexton (U of M)
Minnesota Department of Health

The team wishes to thank the Air Monitoring Unit for their efforts in field operations, calibration, quality assurance, sample analysis, and data management:

Don Bock
Michael Conley
Jeff Cooley
Pat Cornette
Robert Eckart
Gary Eckhardt
Dennis Fenlon
Dean Fundine
Don Meerdink
Ray Monson
Binh Nguyen
Susan Randall-Johnson
Mark Schifsky
Rick Strassman
Tim Whiteneck

The team wishes to acknowledge the contributions to this report of the following individuals:

Sam Brungardt
Janet Eckart
Becky Helgesen

Forward

The primary purpose of this staff paper is to share the most current information about ambient concentrations of air toxics with decision-makers inside and outside the Minnesota Pollution Control Agency (MPCA). We believe we must begin to share our knowledge of air toxics in the environment on a regular and routine basis, so that business and society at large can use the information to help plan future development.

This paper suggests the need to re-examine how MPCA resources are directed at air toxics issues as well as the need to influence national efforts to reduce risks associated with air toxics. This staff paper is a first step to characterizing our concerns by using data on air toxics (e.g., toxics monitoring data, toxics emissions inventory data, knowledge of health impacts, toxics modeling studies, etc.)

Currently, the majority of the MPCA's air toxics resources goes to individual air toxics review of new or expanding facilities. Since air toxics reviews are time intensive, only a handful of facilities are reviewed each year in Minnesota.

This paper suggests that we make our resource decisions with knowledge of the areas of greatest risk. For example, mobile sources (cars, trucks, buses, etc.) account for more than half the total risk attributed to air toxics. We need to develop a state strategy to address this risk.

This staff paper has certain limitations, which will be better addressed in future editions:

- The distinction between cancer and non-cancer health effects of toxic pollutants is only touched on in this paper. Some believe that, in fact, it is more likely that non-cancer is the primary issue with toxics, rather than cancer. More work is needed to clarify this.
- Cancer and non-cancer health benchmarks were used as the criteria to judge whether a problem may exist with a given pollutant. Further explanation and justification for this approach is needed.
- Health risks described in this paper are limited by inherent uncertainties. Health benchmarks are not definitive lines or absolute boundaries. Unknowns such as gaps in data, differences in individual susceptibility, and extrapolation of animal studies to humans are accounted for by incorporating a margin of safety when establishing a health benchmark. Assessments of risk to human health are often limited to available emissions data. A pollutant that turns into another toxic pollutant cannot be adequately addressed when risk is based only on emission data.
- In the paper, we examined only outdoor concentrations and did not take into account indoor sources/concentrations/exposures from sources such as off-gassing of carpets or second-hand smoke.
- Individual choices about where people live, work and play, as well as lifestyle choices were not addressed in this paper, although those choices significantly affect exposure.
- We have characterized risk in terms of individual risk, not risk to the population. We did not include the size of the Minnesota population likely to be affected. Where we have an assessment of risk at specific monitoring sites, we did not include information about the size of the population near the sites.

- The paper does not include epidemiological data about the trend in number of cancer cases, asthma and other conditions that may result from exposure to air toxics.
- The paper does not cover ecological damage caused by air toxics.
- Information on the sources of these pollutants is based primarily on the 1990 CEP data and therefore is not as detailed nor as up-to-date as desired. Some databases used to determine the sources of toxics are limited. For example, the Toxics Release Inventory (TRI) contains information from facilities only over a certain size that perform certain processes and emit more than a threshold quantity of a specific list of toxic pollutants.
- Diesel particulate (from both trucks and generators) is considered by California to be a bigger contributor to risk than all other toxic air pollutants combined. This pollutant is only briefly touched upon in this document.
- This document only briefly discusses a major and highly complex issue that could be a staff paper by itself: the effect of exposure to multiple pollutants.
- This document does not cover hydrogen sulfide, although the MPCA has devoted many resources to this pollutant.
- Within the time available, staff were unable to resolve and answer some questions raised by the data, such as the reason for the recent slight decline in benzene concentrations or the reason for high ethylene dibromide concentrations in Pipestone in western Minnesota.
- Health effects that result from the combined effects of air toxics and criteria pollutants were not within the scope of this paper, although we believe this point is significant. In particular, health effects from emissions of PM2.5, ozone, NOx and SO2 are related to toxics issues.

Some reviewers of early drafts of this document felt that concentrations above a health benchmark merely suggests a need to look more closely at that pollutant, not that there is a potential problem. We did not agree with this approach and chose to share what we know right now, along with our professional opinions of the data. At that point, we will learn what others think and use the whole of this information to help determine actions that may be necessary.

Throughout this paper, the term "we" refers to the authors of this paper.

TABLE OF CONTENTS

Page

Executive Summary

Air toxics: the invisible threat

The U.S. Environmental Protection Agency's (EPA's) recent national study, the Cumulative Exposure Project (CEP), alerted the nation to the possible risk of cancer faced by Americans over a lifetime of breathing toxic air pollutants in outdoor air. This risk is in addition to other risks, for instance, lifestyle choices such as smoking. The CEP's conclusions resulted from computer modeling to estimate air toxics emissions and, therefore, potential exposure, for each state. The CEP predictions for Minnesota parallel their predictions for other states with similar population centers.

The CEP marked the first time that the EPA had attempted comprehensive modeling to predict ambient concentrations at a census-tract level for each of the 48 contiguous states. The study used 1990 emissions data and a computer model to calculate air toxics concentrations. Few actual measurements of these pollutants are available nationally. Unlike criteria air pollutants, such as carbon monoxide and sulfur dioxide (which have been monitored since the 1970s), there is no national air toxics monitoring system. Minnesota is fortunate to have one of the best toxics monitoring systems in the nation in terms of number of pollutants monitored, duration of monitoring and diversity of monitoring locations.

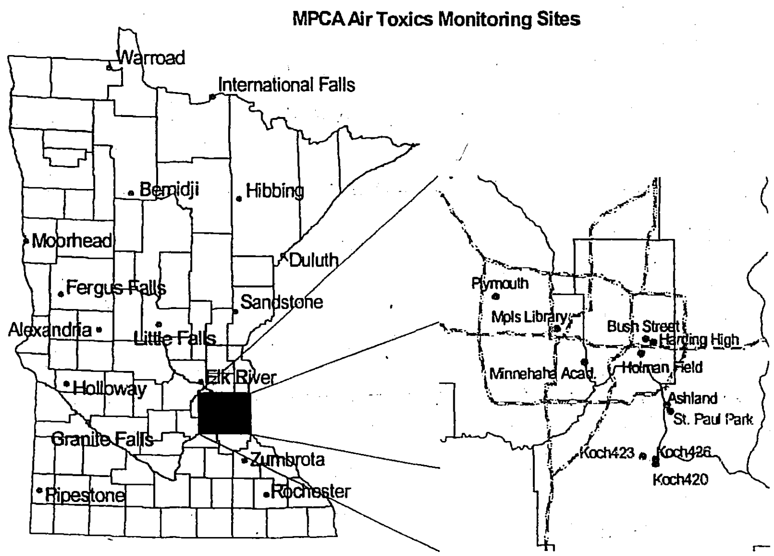
The Minnesota Pollution Control Agency's (MPCA's) ambient (outdoor) monitoring data generally supports the CEP's conclusion. According to both CEP models and the MPCA's monitoring data, ambient concentrations of 10 toxic compounds exceed health benchmarks[1] in some or all regions of Minnesota. Most of the increased cancer risk that can be attributed to these compounds are due to motor vehicle emissions. *In fact, a comparison of the CEP's modeled average concentrations with Minnesota's monitored concentrations indicates that, for almost two-thirds of the air toxics with both modeled and monitored data, the CEP's model actually **underestimated** current concentrations.* In other words, the situation appears to be even more serious than the CEP indicates.

This staff paper is intended to encourage further dialog and research on air toxics, and provides the first comprehensive analysis of the air toxics data collected from Minnesota's monitoring system. This analysis points to the need to re-examine MPCA resources and how they may be directed to air toxics issues, and to the need to influence national efforts to most effectively reduce public health risks associated with air toxics.

---

[1] *A health benchmark is a concentration of the pollutant below which there is likely to be no public health concern. If the Minnesota Department of Health (MDH) has drafted a health risk value for a pollutant, that value was used as the health benchmark in this paper.*

Shown are the locations where monitoring data for this paper were collected.



Pollutants of concern

The CEP evaluated 148 toxic air pollutants using computer models. The MPCA monitors (actually measures in the air) 75 air toxics. When compared against health benchmarks, 10 pollutants exceeded health benchmarks in either modeled or monitored concentrations or both.

All 10 of Minnesota's pollutants of concern appear on the list of 33 hazardous air pollutants that the EPA judged to pose greatest threat to public health in urban areas. Taking into account current information, the 10 pollutants fall into two groups:

1. ***current information warrants action***. Enough information exists now to say we are concerned about levels in the ambient air and the potential adverse long-term health effects posed by **formaldehyde, benzene, carbon tetrachloride** and **chloroform**. The first action recommended is sharing information about the chemicals in this group with our partners and the public.

2. ***current information highlights need for more study***. Current data suggest that **ethylene dibromide, 1,3–butadiene, acrolein, arsenic, nickel** and **chromium** are pollutants of concern, but additional information is necessary to confirm their significance. Of the six pollutants in this group, it appears likely that, with additional data, nickel will fall from the list. In addition, diesel particulate matter and/or polycyclic organic matter (POM) may be added after further study.

Group 1: current information warrants action

- **Formaldehyde:** The mean ambient air concentration of formaldehyde measured at every site (25 sites total, both urban and rural) exceeded the cancer health benchmark of 0.8 micrograms (μg) per cubic meter (m^3). Concentrations appear to be stable over the past four years. The widespread exceedances of health benchmarks for formaldehyde, which is a respiratory irritant and probable carcinogen, suggest that a public health issue exists. Roughly two-thirds of the formaldehyde in the ambient air is due to mobile sources — cars and trucks.
- **Benzene:** Both monitoring and modeling data show benzene concentrations above the lower range of the health benchmark in the Twin Cities metropolitan area and in the state's smaller cities, including Duluth, Rochester, Mankato and St. Cloud. About two-thirds of benzene emissions can be attributed to mobile sources. In the metropolitan area, there has been a slight decrease in benzene concentrations since 1991, for which the reason is unclear. Given the magnitude of the measured concentrations, it would appear that benzene, a known human carcinogen, presents a potential health problem in both the Twin Cities metropolitan area and in smaller population centers.
- **Carbon tetrachloride:** Although production of carbon tetrachloride has been banned in the United States since 1996, both monitoring and modeling data show that carbon tetrachloride concentrations in the air exceed cancer health benchmarks everywhere in Minnesota (as well as throughout the nation, according to the CEP). Minnesota's monitoring data do not show a decrease in concentrations since the ban. Carbon tetrachloride is very persistent in the atmosphere and can take decades to degrade. Carbon tetrachloride is a probable human carcinogen and also causes damage to the liver and kidneys.
- **Chloroform:** According to monitoring data, chloroform concentrations pose a concern at one location in Minnesota (the CEP did not predict any exceedances of the health benchmark). This location is in International Falls, adjacent to a U.S. paper mill and across the river from a Canadian paper mill, both of which are likely sources of the chloroform emissions. In addition to being classified as a probable carcinogen, chloroform may be involved in reproductive and developmental disorders. Target organs for chronic chloroform toxicity are the liver and the central nervous system.

Group 2: current information highlights need for more study

- **Ethylene dibromide:** Monitored ethylene dibromide concentrations exceed health benchmarks is some rural locations of Minnesota (the CEP did not predict any exceedances). Measured concentrations were highest in Pipestone, in western Minnesota. More investigation is needed to determine the reasons for the high concentrations in that location. Ethylene dibromide was formerly used as a fumigant for agricultural purpose, but has been banned for this purpose since the 1980s.
- **1,3-butadiene:** Because the CEP model predicted that this chemical would exceed health benchmarks in the Twin Cities metropolitan area and smaller cities, the MPCA has begun to develop the capacity to monitor 1,3-butadiene (the agency currently has no such capacity). Monitoring data will help confirm the reliability of the CEP model

for this pollutant. About two-thirds of 1,3-butadiene emissions are predicted to come from mobile sources.

- **Acrolein:** The CEP estimates that acrolein concentrations exceed the health benchmark in the Twin Cities metropolitan area and in many smaller cities across Minnesota. As with 1,3-butadiene, the MPCA currently has no monitoring data to confirm the accuracy of this prediction, but is studying resources available to begin monitoring. Acrolein is a respiratory irritant emitted mostly by area (64 percent) and mobile (36 percent) sources.
- **Arsenic:** The method used for measuring arsenic concentration in the ambient air is more of a screening tool, as the lower detection limit of the method is greater than the health benchmark. It appears that arsenic concentrations may exceed health benchmarks at some locations, but more refined measurement is needed to confirm this.
- **Nickel:** The CEP predicts nickel to exceed the health benchmark in two census tracts in the Twin Cities metropolitan area. Monitoring data from all locations were well below the health benchmark and, in some cases, even lower than model predictions. More work is needed to measure nickel concentrations in the air in different locations, such as those near suspected point sources. More sensitive techniques might also confirm whether this chemical should be of concern.
- **Chromium:** Minnesota's monitoring data indicate that chromium concentrations may exceed the health benchmark at some locations, but not necessarily those predicted by the CEP. The health benchmark for chromium is less than the lower detection limit for the chromium measurement method used. Most of the monitoring data are below the lower detection limit of this method. More work is needed to be able to better quantify chromium concentrations and to speciate chromium, so that it is possible to determine how much of the most toxic form of this chemical exists in the ambient air.
- **Diesel particulate matter/POM:** Another group of pollutants may be added as a pollutant of concern in Minnesota after more study. Diesel particulate matter contains a "soup" of chemicals, most of which are organic (carbon-based) substances generated from the incomplete combustion of diesel fuel. Polycyclic organic matter (POM) consists of more than 100 compounds, including the group of organic compounds known as polycyclic aromatic hydrocarbons (PAHs). The California Air Resources Board (CARB) lists POM, PAHs and their derivatives as toxic air contaminants. CARB has identified diesel particulate matter as the primary air toxic pollutant of concern and a significant contributor to the overall cancer risk from air toxics. EPA is considering diesel particulate matter for classification as a hazardous air pollutant.

Additive effects of air toxics

It is important to remember that compounds modeled in the CEP and monitored by the MPCA are just a fraction of the anthropogenic (human-caused) pollutants emitted into the air each day. In other words, ambient air contains very many pollutants, of which the MPCA monitors only a few. These pollutants can have synergistic effects, each compound having its own toxicity and, in addition, having more complex toxicities when combined with other air pollutants.

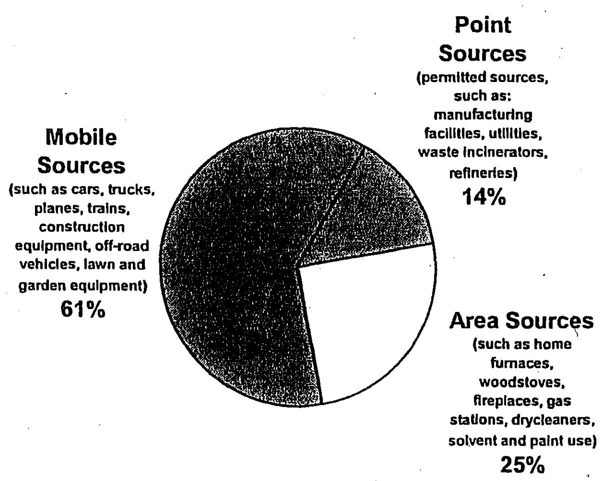
There is little research available on risk to public health from exposure to multiple ambient air toxics. The additive effects of pollutants or the characteristic of a local emission source may make other pollutants, including those not singled out in this paper, a concern.

Currently, the primary health concern from exposure to multiple air pollutants is increased cancer risk. Cancer is the toxicological endpoint of concern for nine of the 10 air toxics targeted in this paper. More work needs to be done to determine the significance of noncancer endpoints, such as cardiopulmonary, neurologic, immunologic and reproductive/developmental systems effects.

Majority of risk is from mobile sources

The majority of the risk posed by all the pollutants modeled in the CEP comes from mobile sources (cars, trucks, buses, etc.). Area and point sources account for about equal portions of the remainder of the risk. In the past, the MPCA has focused most of its resources on regulating point sources. The EPA's recently-published *Urban Air Toxics Strategy* focuses on regulation of area and point sources, and gives less emphasis to specific regulation of toxics from mobile sources. While point sources have an impact at a local level and it remains important to ensure that their emission levels are protective of health, mobile sources impact a much wider geographic area. We believe this is important and must be reflected when the MPCA designs its five-year work plans.

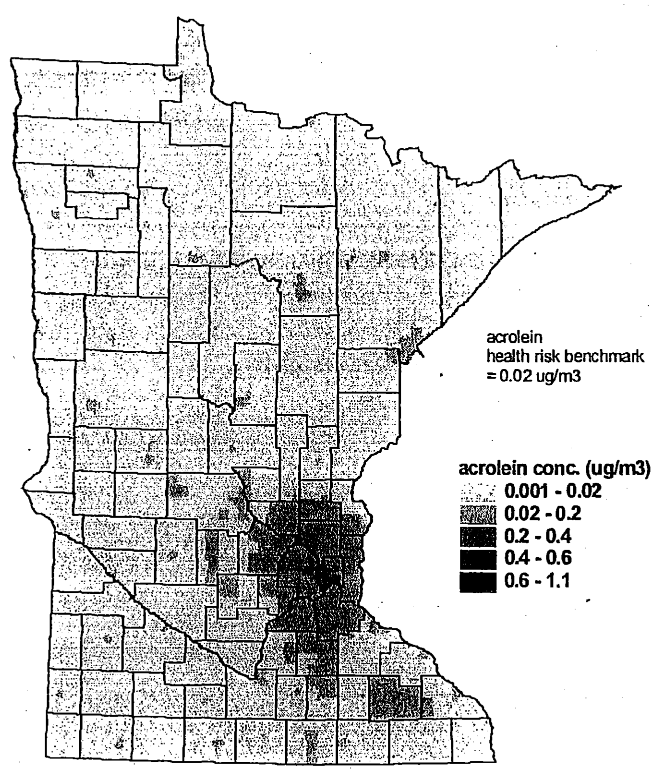
Shown are the contributions by source to excess lifetime cancer risk based on CEP data.



Urban areas most affected

Air pollution is not evenly distributed geographically (except for certain pollutants, such as carbon tetrachloride, which is very persistent and relatively uniform in concentration across the state). A pattern exists for many of the toxics emitted in significant amounts from mobile and area sources (*e.g.*, acrolein, formaldehyde, benzene and 1,3-butadiene). The highest concentrations of toxics tend to be found in the center of the Minneapolis-St. Paul metropolitan area, with concentrations decreasing as one moves away from the urban center. In the rest of the state, most areas have lower concentrations than the metropolitan area. However, many smaller cities (*e.g.*, Duluth, St. Cloud, Rochester, Mankato and Moorhead) also have elevated concentrations of these pollutants that come from mobile and area sources. Quite clearly, where an individual chooses to live, work and play affects exposure.

This map shows predicted acrolein concentrations based on modeling data. Other pollutants in the paper show a similar pattern. The map illustrates the fact that air toxics are not just a metropolitan area issue.



Public sees air toxics as priority environmental issue

The MPCA recently completed extensive public participation efforts aimed at learning about the environmental values of Minnesota citizens. These efforts included seven locations around the state for the "Governor's Forum: Citizens Speak Out on the Environment," a telephone survey to 800 households, and a project called "Comparing Environmental Risks." In each of the three, air toxics issues ranked as a high priority with the public.

- In the Governor's Forums: Citizens Speak Out on the Environment, 100 citizens from the Twin Cities metropolitan area ranked air-quality-related issues as two of their three most important environmental issues. The forums were held in the spring of 1999.

- In the public values survey, also conducted in the spring of 1999, two of the top four environmental threats as ranked by the 800 respondents were related to toxic air emissions (exhaust from cars, trucks and buses and emissions from manufacturing facilities and refineries).

- In the Comparing Environmental Risks project, conducted in 1996 and 1997, the citizens jury, stakeholder and MPCA staff groups all ranked the three sources of air pollution (industrial, mobile and area) at the top of the list in the risk-based environmental priorities project.

Based on this information, it appears that the public, especially in the Twin Cities metropolitan area, is concerned about air toxics and air-quality-related issues. However, results from the public values survey also indicate that members of the public feel that air quality in their own communities is good to excellent and likely to remain so for the next 10 years. These differing perceptions may present a challenge to creating solutions, especially for mobile source issues, which may involve asking individuals to make changes in driving habits.

What's next?

The MPCA has created an Air Toxics Lateral Team, which began work in September 1999. This lateral team consists of three subteams:
1. Technical Team,
2. Communications and Reduction Strategies Team and
3. Mobile Source Reduction Strategies Team.

The overall goals of this lateral team are:

- to identify, communicate and, when possible, address problems associated with toxic air pollutants, and
- to protect human health and the environment from the effects of air toxics.

The Technical Team continues to study the pollutants themselves. The initial focus of the Communications and Reductions Strategies Team will be on sharing the information contained in this staff paper with the public, and on identifying partners to work with. Communication pieces will be developed for various audiences using information from this paper as well as other information. The Mobile Source Reduction Strategies Team is beginning to develop a work plan that will encompass all of the MPCA's activities directed at mobile sources of air toxics.

1.0 WHAT IS THE PURPOSE OF THIS PAPER?

This paper intends to:

- further define the air toxics issues in Minnesota; and
- provide a blueprint for actions needed to learn more about air toxics and to address the problems identified.

This information is necessary for managers to determine the priority that air toxics issues merit for action by the Minnesota Pollution Control Agency (MPCA) and the resources that need to be devoted to air toxics issues in the future. This paper also serves as a resource from which communication pieces may be prepared.

1.1 Why did we start this project?

This paper was prepared as an initial step in addressing air toxics issues highlighted by (1) the modeling results in the U.S. Environmental Protection Agency's (EPA's) Cumulative Exposure Project (CEP) and (2) a preliminary look at the MPCA's own data, which showed that some air toxics are above the Minnesota Department of Health's proposed draft health risk values.

The CEP is a national study designed to describe human exposures to a wide variety of environmental hazards, including contaminants in food and drinking water, as well as air pollution.

The air pollution part of the CEP is the only part with results at this time, and it indicates that there is reason to be concerned about human health throughout the country due to certain air toxics concentrations. The study suggests that concentrations of air toxics were above levels of concern in many areas of the country, including Minnesota. Seven of the 148 air pollutants modeled and evaluated by the EPA were indicated to be at levels higher than the health-risk cancer benchmark in some areas of Minnesota. The health risk level for cancer set by the Minnesota Department of Health is one additional case of cancer per 100,000 people over a lifetime. The group of seven compounds that were found to be at levels higher than the health-risk cancer benchmark includes formaldehyde, benzene, 1,3-butadiene, arsenic, chromium, nickel and carbon tetrachloride. One other compound — acrolein — was indicated to be at concentrations higher than benchmark levels for noncancer serious health effects.

The CEP used computer models to estimate air toxics, rather than actually measuring air toxics at specific points across the country. A preliminary comparison of the CEP results to Minnesota's statewide air toxics monitoring data, suggests, overall, that the modeled concentrations are relatively accurate. The CEP model was run using 1990 emissions data. Although the MPCA believes that more accurate emission data were available in some circumstances than the data the EPA used, the EPA's overall findings are consistent with information the MPCA has and with studies that the MPCA has conducted. The EPA is currently working on using 1996 emissions data to run the model, and hopes to release the results of this work in spring of 2000. The model results using 1996 data will be released under a new name, the "National Air Toxics Assessment;" the EPA will no longer use the "Cumulative Exposure Project" name.

The food component of the CEP estimates average exposures to 37 contaminants in 34 foods for 110 population subgroups, characterized by age, gender, income, geographic region and race. The EPA expects to complete the analysis in late 1999 as part of the National Air Toxics Assessment.

The drinking water component of the CEP estimates national exposure levels for 23 chemical contaminants found in public and private drinking water supplies. The study also characterizes how different groups in the population are exposed to those contaminants. EPA expects to complete this part of the study in late 1999 as part of its National Air Toxics Assessment.

1.2 How was this summary prepared?

Two teams were formed at the MPCA to address the air toxics issue: a technical team and a consent-building team. (Team membership may be found in Appendix O.) The Technical Team was charged to:

- further refine our knowledge of issues in Minnesota associated with air toxics using existing data to determine pollutants of concern, sources of pollutants, geographic areas of concern, and trends.
- put the information into perspective (How big a deal is this? What are the concentrations and risks involved?).
- identify: data gaps, additional activities and resources needed to further define the issues and to put the information into perspective, and a broad range of possible emission-reduction strategies.

Given the short time frame to accomplish the purpose, some technical work (such as further analyzing ambient monitoring data) has begun, but the focus of the team was to summarize existing air toxics information and identify actions for the future.

The consent-building team was charged with designing a citizen participation program based on issues identified by the CEP study. Due to numerous scheduling conflicts, the work of this team was postponed.

2.0 WHAT ARE THE PRIMARY POLLUTANTS OF CONCERN?

This section describes pollutants that, based on current information, are of primary concern in Minnesota. The pollutants are broken into two groups:

1. those that exceed inhalation health benchmarks either based on monitoring data, modeling data, or both (section 2.1) and
2. persistent, bioaccumulative toxic (PBT) pollutants (section 2.2).

A third group of additional chemicals is not covered in this paper, but has been identified as being of potential concern in the 1999 *Toxic Air Pollutant Update* to the Minnesota Legislature. MPCA staff developed an indexing system that takes the toxicity and environmental persistence of a pollutant into account (Pratt, G. C. *et. al,* 1993). Using emissions data and the index value for a given pollutant, a weighted emissions value can be derived. The top 10 pollutants emitted from point sources in 1996 based on weighted emissions were methylene chloride (dichloromethane), methyl bromide (bromomethane), manganese, antimony, cadmium, copper, lead, nickel, arsenic and chloroform. All of these pollutants except copper were modeled in the CEP. Additional future activities are recommended to further investigate these pollutants and others that may be identified through tools used to rank risks from air toxics (see section 6.1).

Some background of the MPCA toxics-monitoring program is important to understanding how the pollutants of concern were selected. The MPCA has been monitoring toxic air pollutants since 1991. The monitoring sites are shown in Figure 2.0.1. The times monitoring was conducted at each site are shown in Figure 2.0.2. Over the course of the next two years, monitoring will be conducted at 14 additional sites. Table 2.1.1 lists the chemicals monitored as part of the MPCA air toxics-monitoring program. Appendix G contains additional information about monitoring methods used. Appendix H describes the specific location of monitors.

Figure 2.0.1 Map showing the locations of the air toxics-monitoring sites in Minnesota

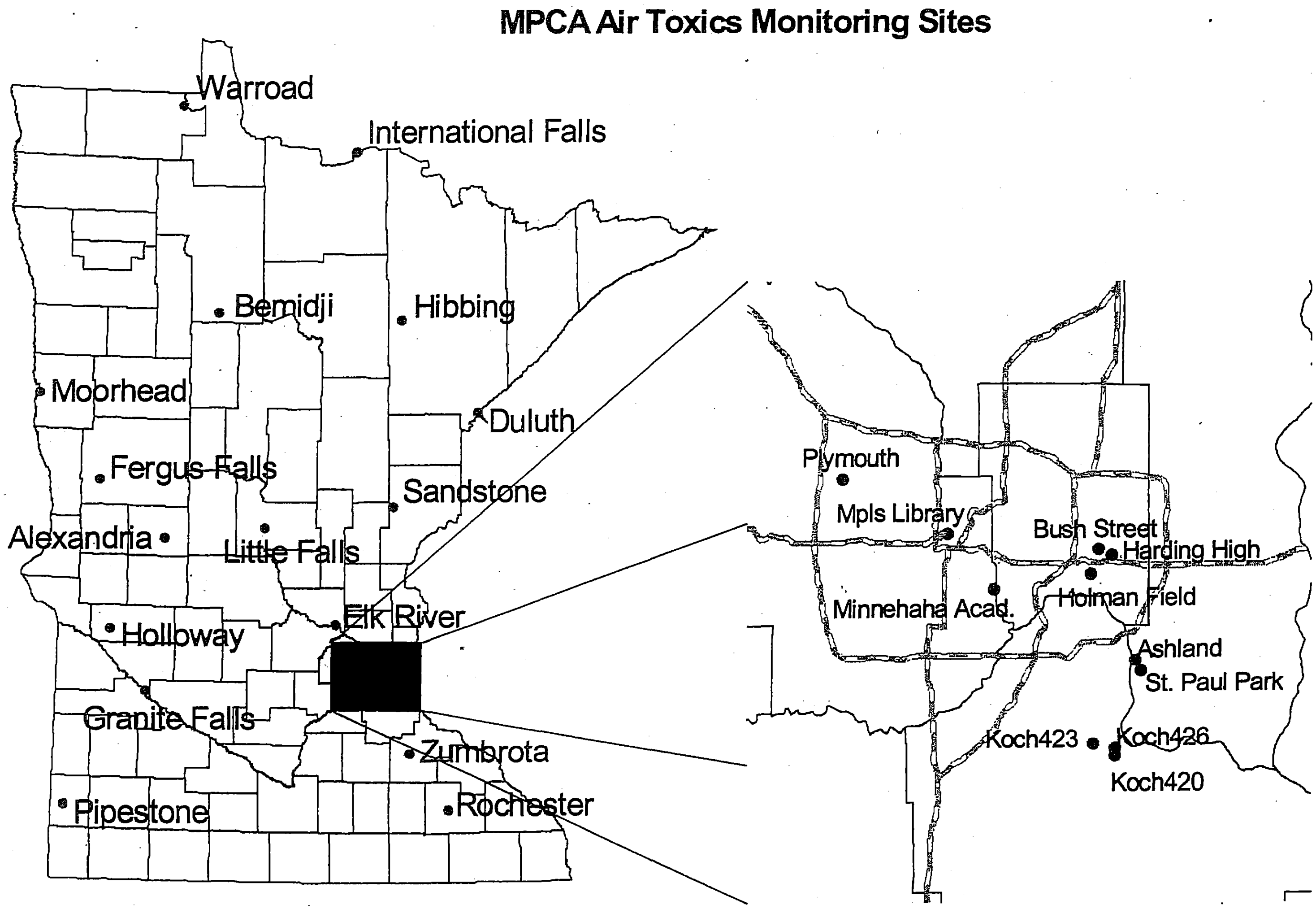


Figure 2.0.2 Timeline of measurements at each monitoring site

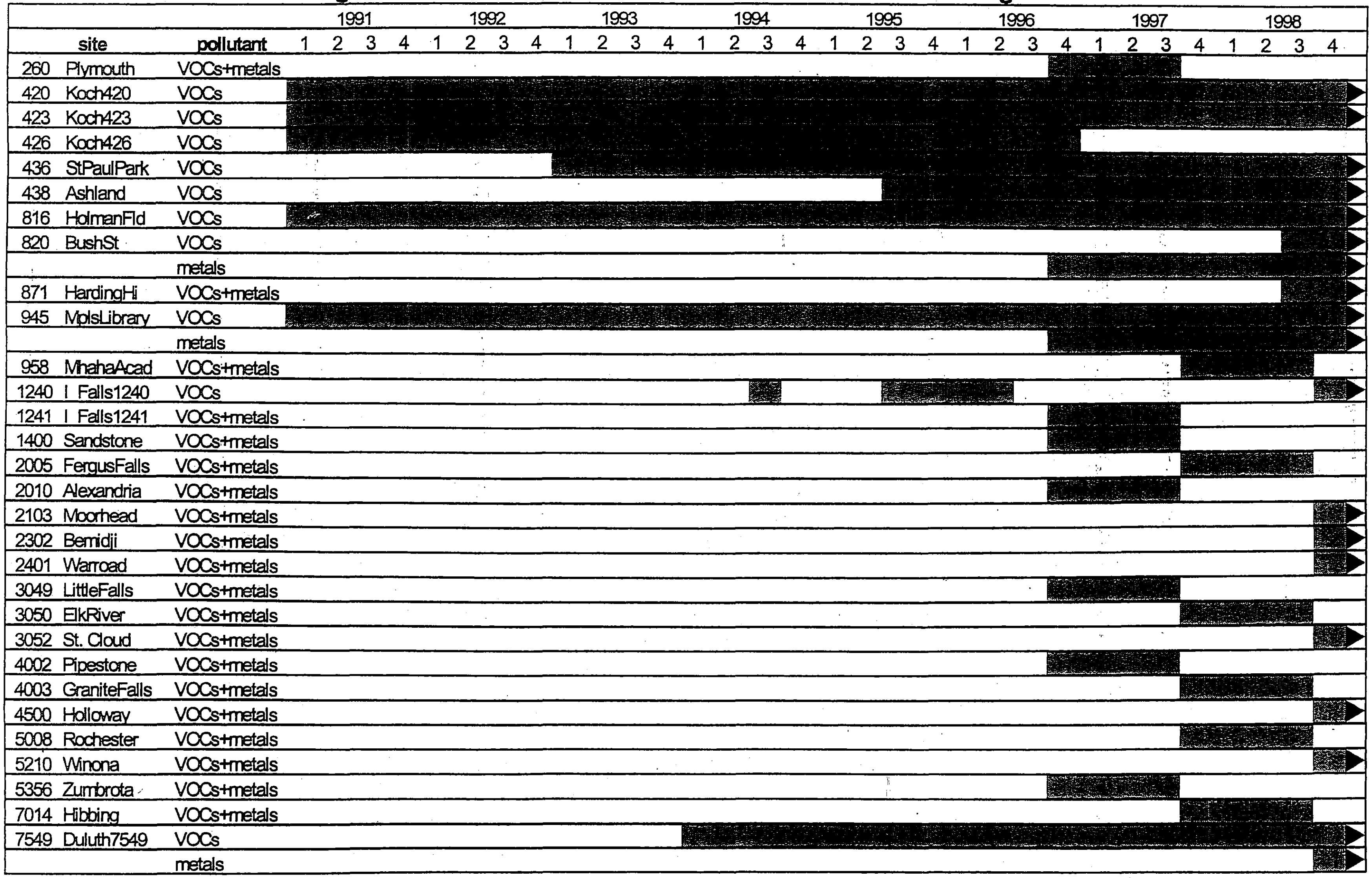


Table 2.1.1 Tabulation of toxic air pollutants considered in this report

Carbonyls are a class of chemical substances characterized by the presence of a carbon-oxygen double bond. "VOCs" refers to volatile organic carbon compounds. TO-11A and TO-15 are U.S. Environmental Protection Agency (EPA) reference methods for monitoring these substances. Personal monitoring is a special study done using personal organic vapor monitors (OVMs). Health benchmarks for individual pollutants may be found in Appendix D. "CEP" refers to the EPA's Cumulative Exposure Project.

Substance	CAS #	Monitored carbonyls (TO-11A)	Monitored VOCs (TO-15)	Personal monitoring with OVMs	Personal particle monitoring	Exceed health benchmark in CEP model	Exceed health benchmark in monitoring data
Acetaldehyde	75-07-0	y					
Acetone	67-64-1	y					
Acrolein	107-02-8					Y	
Benzaldehyde	100-52-7	y					
Benzene	71-43-2		y	y		y	y
Bromomethane	74-83-9		y				
Butadiene (1,3-)	106-99-0		**	y		y	
Butyraldehyde	123-72-8	y					
Carbon Tetrachloride	56-23-5		y	y		y	y
Chlorobenzene	108-90-7		y				
Chloroform	67-66-3		y	y			y
Chloroprene	126-99-8			y			
Crotonaldehyde	4170-30-3	y					
Dichlorobenzene (1,2- or o-)	95-50-1		y	y			
Dichlorobenzene (1,3- or m-)	541-73-1		y				
Dichlorobenzene (1,4- or p-)	106-46-7		y				
Dichlorodigluoromethane (CFC12)	75-71-8		y				
Dichloroethane (1,1-)	75-34-3		y				
Dichloroethane (1,2-)	107-06-2		y				
Dichloroethylene (cis-1,2-)	156-59-2		y				
Dichloromethane	75-09-2		y				
Dichloropropane (1,2-)	78-87-5		y				
Dichloropropene (cis-1,3-)	10061-01-5		y				
Dichlorotetrafluoroethane (CFC114)	76-14-2		y				
Ethylbenzene	100-41-4		y	y			
Ethylene Dibromide	106-93-4		y				y
Formaldehyde	50-00-0	y				y	y
Hexachloro-1,3-Butadiene	87-68-3		y				
Methyl Chloride	74-87-3			y			
Methyltertiarybutylether (MTBE)	1634-04-4			y			
PM10/PM2.5 (XRF for metals)	#N/A				y		
Arsenic	7440-38-2				y	y	y *
Chromium	7440-47-3				y	y	y *
Nickel	7440-02-0				y	y	

Table 2.1.1 (cont.) Tabulation of toxic air pollutants considered in this report

Substance	CAS No.	Monitored carbonyls (TO-11A)	Monitored VOCs (TO-15)	Personal monitoring with OVMs	Personal particle monitoring	Exceed health benchmark in CEP model	Exceed health benchmark in monitoring data
Propionaldehyde	123-38-6	y					
Styrene	100-42-5		y	y			
Tetrachloroethane (1,1,2,2-)	79-34-5		y				
Tetrachloroethylene	127-18-4		y	y			
Toluene	108-88-3		y	y			
Xylenes (total)	1330-20-7		y	y			
Trichloroethanes	25323-89-1		y	y			
Trichlorofluoromethane (CFC11)	75-69-4		y				
Trichlorotrifluoroethane (CFC113)	76-13-1		y				
Trimethylbenzene (1,2,4-)	95-63-6		y				
Trimethylbenzene (1,3,5-)	108-67-8		y				
Vinyl Chloride	75-01-4		y				
Vinylidine Chloride	75-35-4		y				
Xylene (m-)	108-38-3		y				
Xylene (o-)	95-47-6		y				
trans-1,3-Dichloropropene	10061-02-6		y				
number in category	**50**	**7**	**35**	**14**	**4**	**8**	**7**

* The data for As and Cr are mostly below the minimum quantifiable level, but there is an indication that concentrations may be above health benchmarks.

** Initial steps are being taken to try to monitor 1,3-butadiene.

2.1 Which pollutants exceed health benchmarks?

A health benchmark is, for the purposes of this paper, a concentration of the pollutant in the ambient air below which there is likely to be no public health concern. Health benchmarks are based upon a combination of scientific data and policy judgments. They are generally a conservative estimate based primarily upon occupational and animal studies. A health benchmark concentration is, in essence, a concentration of a pollutant below which it is unlikely to cause an adverse health effect to the general public over a lifetime exposure.

Health benchmarks for cancer-causing and noncancer-causing chemicals are derived using two distinct methods. Historically, the reason for this difference has been that, for noncarcinogens, it is assumed that there is a safe or "threshold" level of exposure below which various protective mechanisms within the body act to prevent adverse health effects. No such thresholds have been assumed for cancer-causing chemicals.

The Minnesota Department of Health (MDH) uses the term "draft health risk values" (draft HRV). The cancer draft HRV is a 1 in 100,000 excess probability of contracting cancer over a lifetime of exposure. MDH policy defines negligible risk as one cancer per 100,000 persons, which is consistent with the policy of the EPA, pursuant to which negligible risk ranges from one cancer in 10,000 persons to one cancer in 1 million persons. If the MDH has proposed a draft health risk value for a pollutant, that value was used as the health benchmark. Draft HRVs were the first order of preference because these values have already undergone extensive review by the MDH. If a draft HRV for inhalation did not exist for a particular compound, benchmarks were selected in the following order of preference:

- U.S. Environmental Protection Agency IRIS and Health Effects Assessment Summary Tables (HEAST) databases.
- California Reference Exposure Levels (RELs)
- Agency for Toxic Substances and Disease Registry Minimal Risk Levels

Eight substances exceeded the health benchmarks in the CEP modeling study, and seven substances exceeded the health benchmarks in the monitoring data. Exceeding the health benchmark is defined as (1) the model-predicted concentration exceeded the health benchmark in at least one census tract or (2) the monitored annual average concentration at one or more monitoring sites exceeded the health benchmark. Ten substances exceeded health benchmarks either in the modeling analysis and/or the monitoring data. Health benchmarks for these 10 substances may be found in Appendix D of this paper. These substances are:

POLLUTANT	Exceeded Health Benchmark Based on CEP Modeling	Exceeded Health Benchmark Based on Monitoring
• Formaldehyde (2.1.1)	X	X
• Benzene (2.1.2)	X	X
• Carbon tetrachloride (2.1.3)	X	X
• Chloroform (2.1.4)		X
• Ethylene dibromide (2.1.5)		X
• 1,3-butadiene (2.1.6)	X	*No monitoring data*
• Acrolein (2.1.7)	X	*No monitoring data*
• Arsenic (2.1.8)	X	X*
• Nickel (2.1.9)	X	
• Chromium (2.1.10)	X	X*

*Data for arsenic and chromium are mostly below the minimum quantifiable level, but there is an indication (see sections 2.1.8 and 2.1.10) that concentrations may exceed health benchmarks at some sites.

In the sections that follow (2.1.1 through 2.1.10), the following information is provided about each of these 10 substances:
- the information that indicates the pollutant is a concern,
- health effects of exposure to the pollutant,
- how people are exposed to the pollutant,
- what happens to the pollutant in the atmosphere,
- which sources emit the pollutant, and
- conclusions.

After further study, diesel particulate matter may be added to the list of primary pollutants of concern in Minnesota. Additional information on this pollutant may be found in Section 5.1.1.

2.1.1 Formaldehyde

Formaldehyde (CAS 50-00-0), HCHO, is a nearly colorless, combustible gas with a pungent, suffocating odor. It dissolves easily in water, alcohols and other polar solvents. It is very reactive with many substances. In the presence of air and moisture, formaldehyde readily polymerizes to paraformaldehyde at room temperature. Formaldehyde is also formed from the photooxidations of other organic compounds in the atmosphere. Therefore, the removal and formation of formaldehyde occur at the same time.

2.1.1.1 What information indicates formaldehyde is a concern?

Ambient data: A summary of the monitoring data is given in Table 1 of Appendix A and in Figure 2.1.1.1.1, which shows a boxplot with the median, 25th and 75th percentile values and information about the range of values. The data show that the median concentration at every monitoring site except International Falls site 1240 was above the health benchmark of 0.8 micrograms per cubic meter ($\mu g/m^3$). Sites near the center of the Twin Cities metropolitan area had the highest concentrations. Figure 2.1.1.1.2 is a map showing mean concentrations at each monitoring site.

In May 1995, the monitoring technique was changed by adding ozone scrubbing to the carbonyl sampling method (EPA federal reference method TO-11A). This change resulted in systematically higher measurements from that point forward. Ozone present in ambient air will react with and destroy formaldehyde in the sample, so scrubbing the ozone will lead to higher and more accurate measurements. Thus, formaldehyde concentrations can be considered to have a bias toward low values in the monitoring data before May 1995. Only data obtained since May 1995 should be used to characterize a site, since some sites have data from before ozone scrubbing was instituted (and no sites have only pre-ozone-scrubbing data). Figure 2.1.1.1.1 presents only data obtained since May 1995.

Frequency distributions showed that there is some skewedness in the data. For this reason, the mean value may not be the best indicator of the central tendency (see Appendix B). The question arises, "What is the most appropriate statistic to represent the data for comparison to health benchmarks, which represent acceptable exposure concentrations?" An arithmetic mean concentration best represents exposure over a long period of time. Therefore, although the mean may not be the best indicator of the central tendency of the data, it may be a good value for comparison with a health benchmark.

Figure 2.1.1.1.1 Boxplot showing formaldehyde concentrations by site

The plot includes only data collected since May 1, 1995, when ozone-scrubbing was instituted. The center line within each box represents the median for the site. The box itself encompasses the 25th percentile to the 75th percentile. The bars at each end of the box represent the highest and lowest values that are not considered outliers. The horizontal dotted line is located at the formaldehyde health benchmark (0.8 µg/m³).

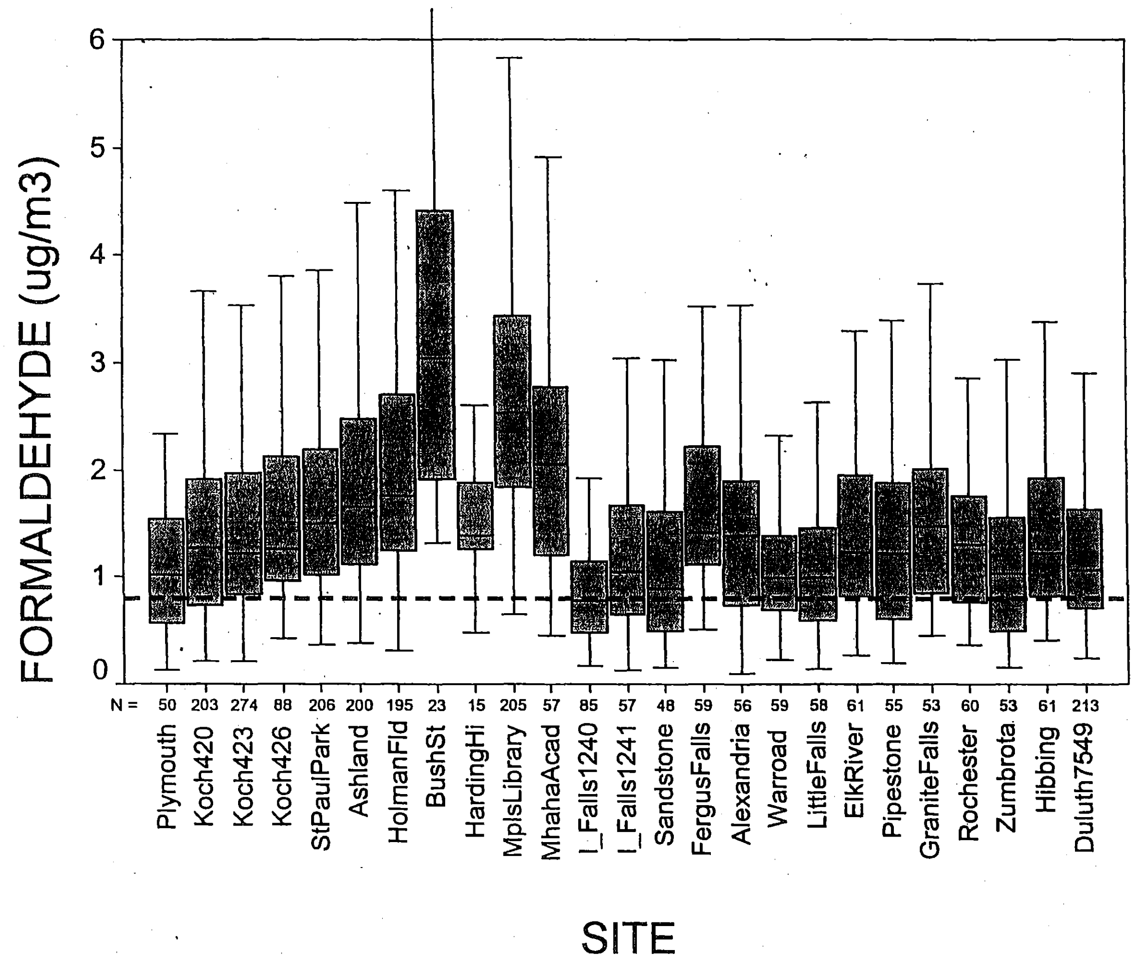
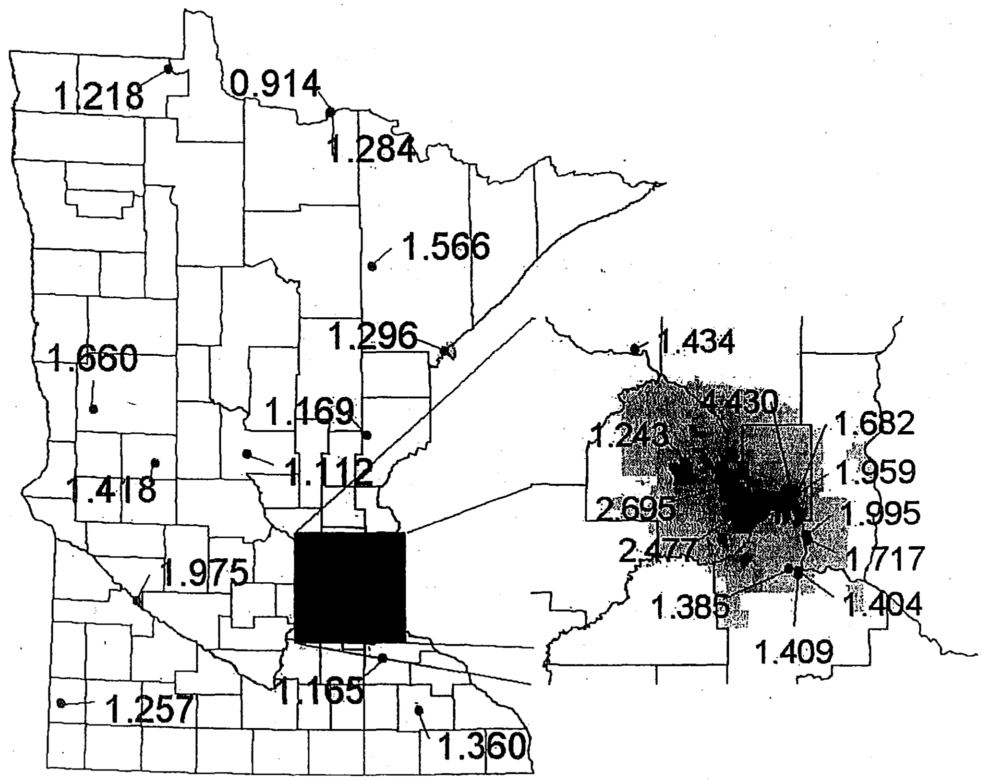


Figure 2.1.1.1.2 Map showing the mean formaldehyde concentrations (1995-98) at each monitoring site in Minnesota

The monitored values are indicated by the dots with the attached numerical values. They are superimposed over background maps showing the results of the CEP modeling for formaldehyde (see modeling section below).



Modeling data: According to the EPA's Cumulative Exposure Project (CEP), which is based on 1990 emissions data, the average modeled concentration of formaldehyde exceeded the health benchmark in areas of higher population density. Figure 2.1.1.1.3 shows the areas of the Twin Cities metropolitan area that exceeded the health benchmark. Table 2.1.1.1.1 compares the concentrations of formaldehyde measured by the MPCA with modeled values from the CEP. On average, measured values were 0.58 $\mu g/m^3$ higher than the CEP estimates. Model underestimates were greatest in rural areas.

Figure 2.1.1.1.3 Map of the Twin Cities metropolitan area showing mean formaldehyde concentrations predicted by EPA's Cumulative Exposure Project for a given census tract

This map can be seen in color at http://www.pca.state.mn.us/air/at-cep.html.

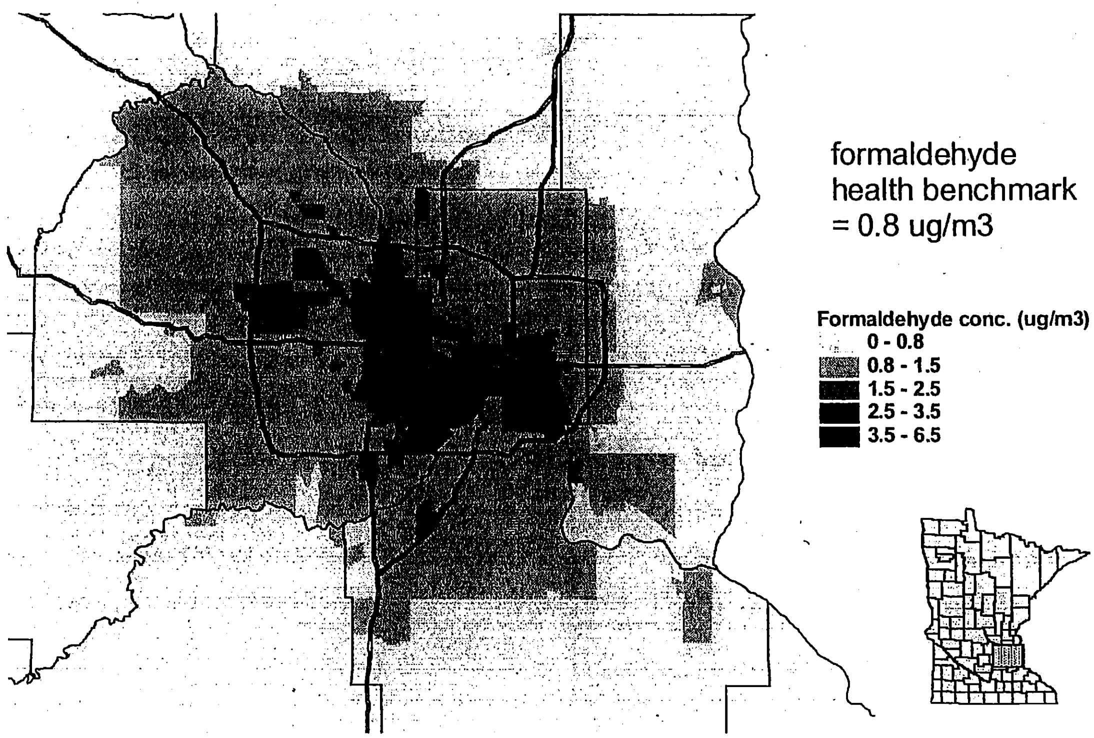


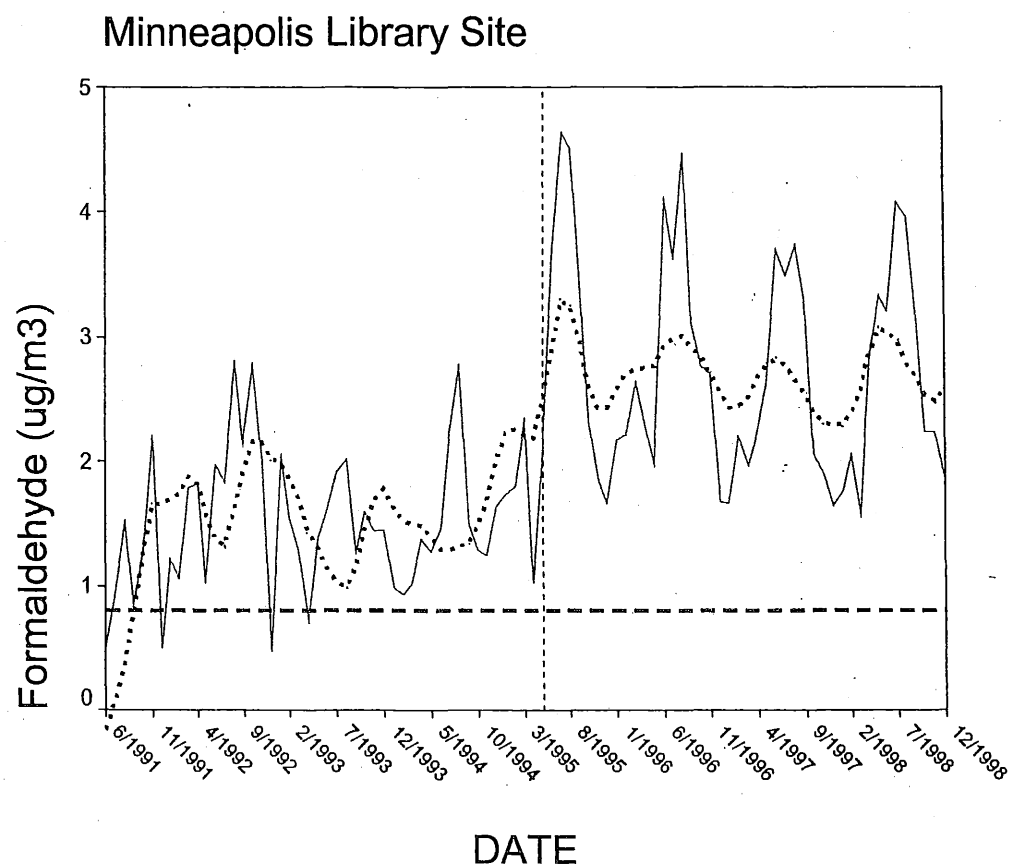
Table 2.1.1.1.1 MPCA-measured formaldehyde concentrations (µg/m3, 1995-98 average) versus concentrations estimated in the EPA Cumulative Exposure Project model

Site No.	Site Name	monitored mean value (1995-1998)	U.S. EPA CEP modeled value	difference (model – monitor)
260	Plymouth	1.243	1.523	0.280
420	Koch420	1.409	1.199	-0.210
423	Koch423	1.385	1.199	-0.186
426	Koch426	1.404	1.199	-0.205
436	StPaulPark	1.717	1.683	-0.033
438	Ashland	1.995	1.135	-0.860
816	HolmanFld	1.959	1.718	-0.241
820	BushSt	4.430	1.643	-2.787
871	HardingHi	1.682	2.781	1.099
945	MplsLibrary	2.695	2.034	-0.661
958	MhahaAcad	2.477	2.638	0.161
1240	I_Falls1240	0.914	0.523	-0.392
1241	I_Falls1241	1.284	0.523	-0.761
1400	Sandstone	1.169	0.290	-0.879
2005	FergusFalls	1.660	0.549	-1.111
2010	Alexandria	1.418	0.504	-0.914
2401	Warroad	1.218	0.287	-0.931
3049	LittleFalls	1.112	0.482	-0.630
3050	ElkRiver	1.434	0.560	-0.874
4002	Pipestone	1.257	0.417	-0.840
4003	GraniteFalls	1.975	0.300	-1.675
5008	Rochester	1.360	1.094	-0.266
5356	Zumbrota	1.165	0.364	-0.801
7014	Hibbing	1.566	0.931	-0.635
7549	Duluth7549	1.296	1.075	-0.221

Trend: There are 25 formaldehyde-monitoring sites. Formaldehyde concentrations have been measured since 1991 at the Minneapolis Public Library, Holman Field in St. Paul and in Pine Bend (Koch sites 420, 423 and 426), and since 1993 in St. Paul Park. Plots of the data (*e.g.*, Figure 2.1.1.1.4) appear to show that the measured concentrations have increased since measurements were begun; however, upon closer analysis, there is neither an increase nor a decrease in formaldehyde concentrations over time. The figure also shows that the data are seasonal, with maximum concentrations occurring in the summer and minimums in the winter. Figure 2.1.1.1.4 shows data from the Minneapolis Public Library site, but the data are similar in terms of the seasonal and trend components to the other sites listed above.

Figure 2.1.1.1.4 Trend in formaldehyde measurements at site 945, the Minneapolis Public Library site

The solid line shows monthly average concentrations. The dotted line is a deseasonalized, smoothed trend line. The horizontal dashed line is at the health benchmark for formaldehyde (0.8 μg/m^3). The vertical dotted line is at May 1, 1995, the date when the measurement technique was changed to add ozone scrubbing.



Since Figure 2.1.1.1.4 shows an apparent increase in formaldehyde concentrations over time, and since the formaldehyde measurement technique changed during the course of the apparent increase, it is important to understand whether there has indeed been an increase, or whether the apparent increase can be attributed to other factors. Over the period of record, two changes might have influenced formaldehyde levels. First, the measurement technique was changed to include ozone scrubbing in May 1995 (ozone present in the ambient air will react with, and destroy, formaldehyde in the sample; scrubbing the ozone will lead to higher and more accurate measurements). Second, oxygenated fuel use has increased from about 15 percent in 1991 to over 90 percent in 1998. There is speculation that increased use of oxygenated fuel may lead to higher emissions of certain VOCs, such as formaldehyde (see Figures 2.1.1.1.5 and 2.1.1.1.6).

Figure 2.1.1.1.5 A brief history of clean fuels improvements in the Twin Cities, 1990-99

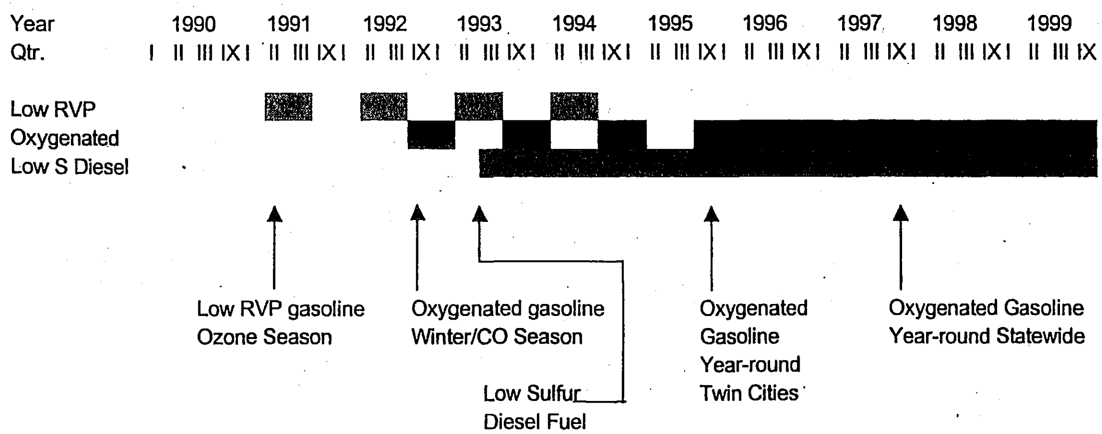


Figure 2.1.1.1.6 Percentage of oxygenated fuel sold in Minnesota, 1990-98.

To investigate the influence of these changes, a trend analysis was conducted on the formaldehyde data. First the data were "deseasonalized" (seasonal component was removed). Next, two additional variables (in addition to the time, or trend, variable) were included in the analysis, one to account for the change in measurement technique and a second to account for the percentage of gasohol sold each month since 1991. Multiple linear regression showed that the only variable that was a statistically significant predictor of deseasonalized formaldehyde concentrations was measurement technique. The trend over time and the percentage of gasohol were not significant. This finding was true for all sites. Thus, we conclude that formaldehyde concentrations have not increased over time in our measurements. We can further conclude that the increased use of ethanol-containing fuel does not appear to have led to an increase in formaldehyde concentrations.

The importance of the change in measurement technique can be seen from Figure 2.1.1.1.4. Measurements are systematically lower before ozone scrubbing. After May 1995, the measurements are not only systematically higher, but the seasonal component is much more apparent. The masking of the seasonal component in the non-ozone-scrubbed data occurs because ozone concentrations are higher in summer, leading to greater formaldehyde destruction during the times concentrations would otherwise be expected to be highest. As can be seen in Figure 2.1.1.1.4, the deseasonalized data (dotted line) still show some seasonality in the years 1995-98. This is because the deseasonalization was done for the entire time series, including data obtained before 1995, when seasonality was masked. An alternative method would be to treat data obtained from May 1995 onwards separately.

2.1.1.2 What are the health effects of formaldehyde?

Short-term and chronic inhalation exposure to formaldehyde can cause irritation to the eyes, nose, throat and respiratory system in humans. Higher levels of formaldehyde exposure in humans have caused coughing, wheezing, chest pains and bronchitis. Long-term repeated exposure to formaldehyde may result in cancer of the nasal passages. This is supported by animal inhalation studies and limited human studies, which report an association between formaldehyde exposure and lung and nasopharyngeal cancer. The EPA has classified formaldehyde as a probable human carcinogen. The MPCA uses the Minnesota Department of Health draft HRV as the health benchmark for formaldehyde. This value is 0.8 $\mu g/m^3$ and corresponds to an excess lifetime cancer risk of 1 in 100,000. California EPA Office of Environmental Health Hazard Assessment (OEHHA) has adopted a cancer unit risk of 6.0×10^{-6} for fomaldehyde, which corresponds to 1.67 $\mu g/m^3$ at 1-in-100,000 risk level. OEHHA is proposing a chronic noncancer (REL) of 3.0 $\mu g/m^3$ to protect from respiratory system effects and eye irritation.

<u>**Uses of formaldehyde**</u>: Formaldehyde is used in manufacturing plastics, urea-formaldehyde insulation foam, and resins used in making paper, paint, carpet, construction materials, textiles and furniture. Formaldehyde is used also to disinfect animal housing and to control bacteria and fungi on hospital equipment, floors and walls.

2.1.1.3 How are people exposed to formaldehyde?

Most formaldehyde exposure among humans is due to direct inhalation of formaldehyde in air. Persons living in heavily populated industrial areas are likely to be exposed to higher levels of formaldehyde than those living in lightly populated areas. Because formaldehyde is released from various consumer products and indoor levels exceed outdoor levels, indoor air can significantly contribute to overall formaldehyde exposure. Persons with potentially high exposures to formaldehyde include those living in mobile homes and homes less than one year old. Persons who work in the medical profession and as embalmers might also be exposed to higher amounts of formaldehyde. People can also be exposed to formaldehyde from tobacco smoke.

2.1.1.4 What happens to formaldehyde in the atmosphere?

Formaldehyde is removed from the atmosphere through direct photolysis and oxidation by photochemically produced hydroxyl radicals (OH). Formaldehyde reacts with the hydroxyl radicals to form carbon monoxide, water and formyl radicals. Because hydroxyl radicals are the dominant reactive species in the transformation of organic compounds, formaldehyde has a longer half-life in areas where the air is cleaner, such as rural areas, than in areas that have more polluted air, such as urban areas. During winter, rain or snow can be important in removing formaldehyde from the atmosphere.

Many air toxics undergo atmospheric transformation, in which the parent compound is removed from the atmosphere only to produce secondary products. Because virtually all atmospheric reactions of VOCs will eventually produce some formaldehyde, secondary formation becomes the major source of formaldehyde in the atmosphere. In the report, *Modeling Cumulative Outdoor Concentrations of Hazardous Air Pollutants*, 23 precursor species were considered for their contribution to formaldehyde formation. The 23 precursor species are listed in Table 2.1.1.4 below.

Table 2.1.1.4 Precursors species contributing to formaldehyde formation*

Ethene	1,3-butadiene
Propene	3-methyl-1-butene
1-butene	3-methyl-1-pentene
1-pentene	2,3-dimethyl-1-butene
1-hexene	Isoprene
1-heptene	2-ethyl-1-butene
1-octene	2-methyl-1-pentene
1-nonene	4-methyl-1-pentene
1-decene	2,4,4-trimethyl-1-pentene
Isobutene	Acetaldehyde
Methanol	MTBE
2-methyl-1-butene	

*Systems Applications International, Inc., February 1998

In addition to the precursors listed above, several other hazardous air pollutants known to react in the atmosphere and result in formaldehyde formation include acrolein, acrylonitrile, styrene, vinyl chloride and xylene.

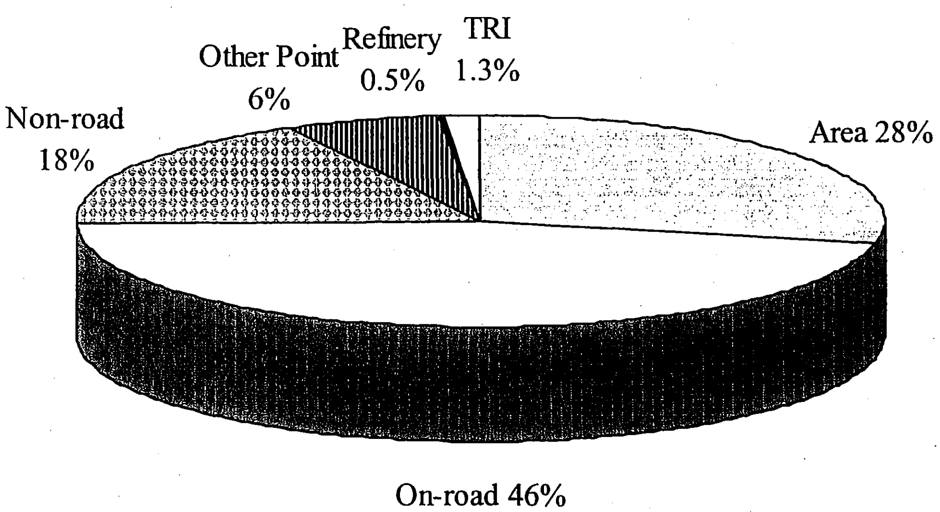
2.1.1.5 Which sources emit formaldehyde?

Formaldehyde in the atmosphere is from two routes: (1) direct emissions and (2) secondary formation. The secondary formation of formaldehyde from its precursors is the major route for formaldehyde to enter the ambient air.

Direct emissions of formaldehyde: As a product of incomplete combustion, motor vehicle exhaust is a primary source of direct formaldehyde emissions. Other emission sources include petroleum industry, chemical production, electrical services, and manufacturing processes that involve fuel combustion. Solid waste incineration and sewage treatment also emit formaldehyde.

Figure 2.1.1.5.1 shows Minnesota direct emissions of formaldehyde by source category. This figure is based on 1990 emissions data from EPA's CEP study. Overall, mobile sources (on-road and nonroad) account for about 58 percent of direct formaldehyde emissions, area sources are responsible for about 33 percent and point source contributions total less than 10 percent. The definition of each source category is shown in Appendix C.

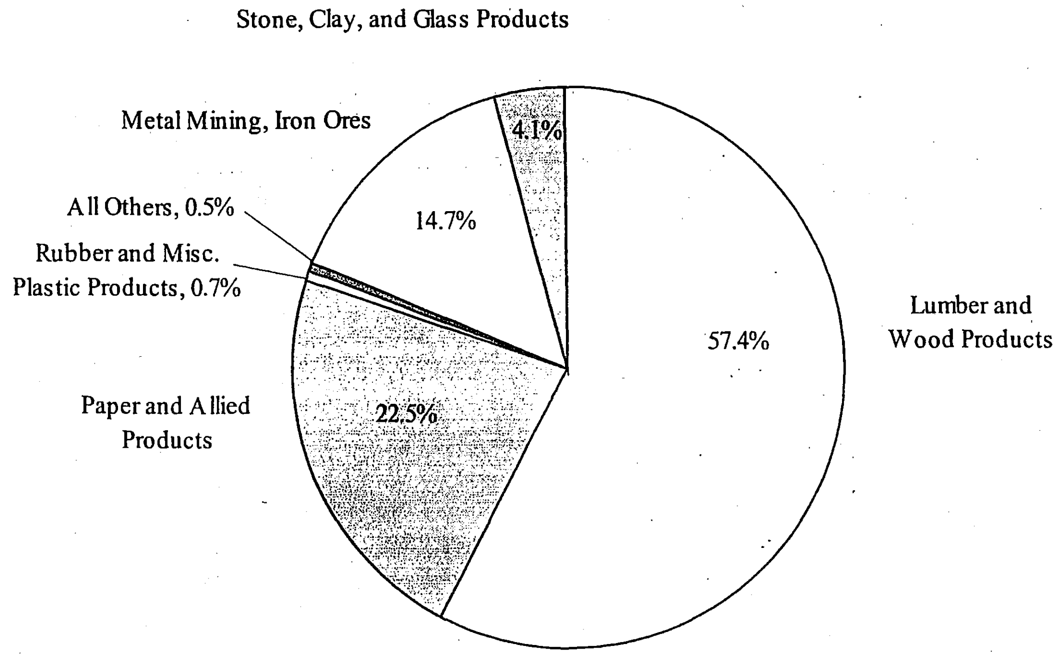
Figure 2.1.1.5.1 Direct emissions of formaldehyde by source category
(Data are from the EPA CEP study for the State of Minnesota.)



According to the preliminary results of the 1996 Minnesota air toxics emission inventory for point sources (including TRI, metal mining and electric services), about 57 percent and 23 percent of the direct emissions from point sources are attributed to the manufacture of lumber and wood products and paper and allied products, respectively (Figure 2.1.1.5.2).

Figure 2.1.1.5.2 1996 Formaldehyde emissions by principal source category for point sources

(Data are from the preliminary 1996 Minnesota emission inventory.)



The 1989-to-1996 trend in direct emissions of formaldehyde for the Minnesota TRI point sources is shown in Figure 2.1.1.5.3. Formaldehyde emissions had a slow reduction trend after 1990, with a small fluctuation from 1994 to 1995.

Figure 2.1.1.5.3 Trend in direct formaldehyde emissions

Based on TRI point source data

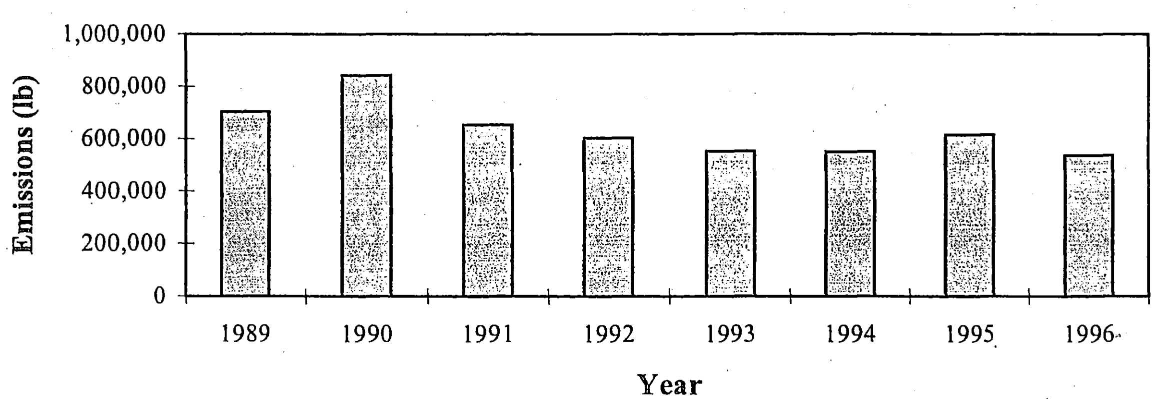
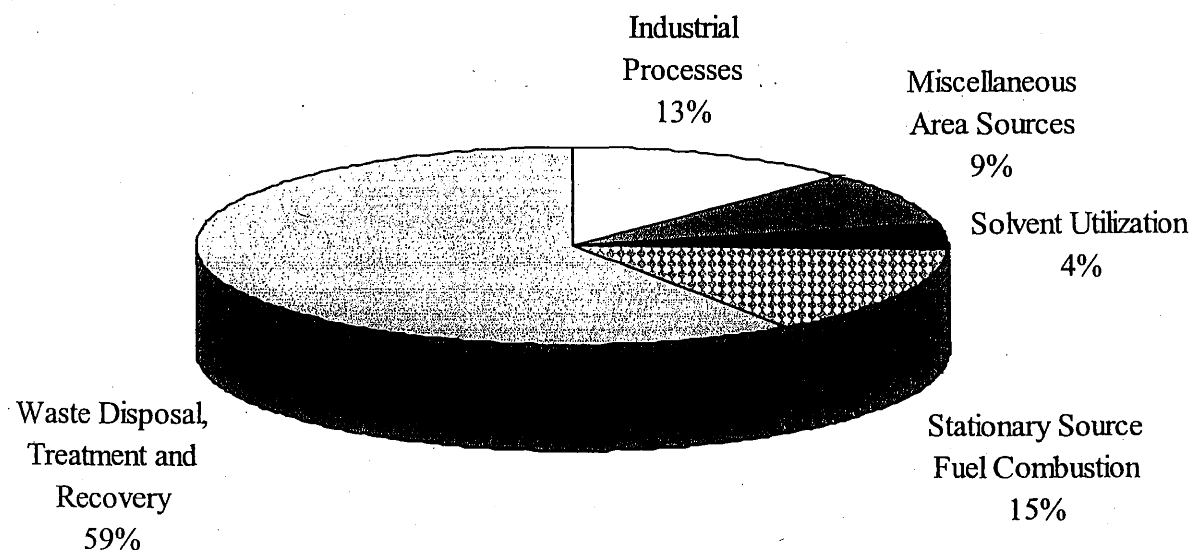


Figure 2.1.1.5.4 shows 1990 direct emissions of formaldehyde by principal source categories for area sources. The data are from the EPA's CEP study for Minnesota. Waste disposal, treatment and recovery dominate the area source direct emissions, with a contribution of 59 percent. The other notable sources are industrial processes and stationary source fuel combustion. Solvent utilization and miscellaneous area sources also have some contributions.

Figure 2.1.1.5.4 1990 direct emissions of formaldehyde by principal source category for area sources

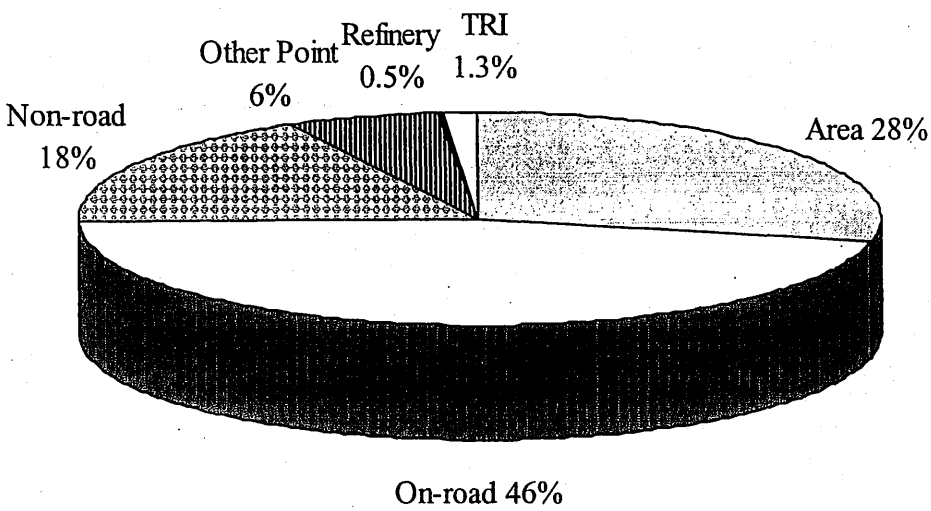
(Data are from the EPA's CEP study for the State of Minnesota.)



<u>**Secondary formation of formaldehyde:**</u> The formation of formaldehyde from photochemical oxidation is the largest source of formaldehyde concentrations. Studies in California indicated that photooxidation could account for as much as 88 percent of formaldehyde concentrations in air. Analysis of the 1990 EPA CEP data shows that about 75 percent of formaldehyde emissions were from photooxidation of its precursors.

Figure 2.1.1.5.5 shows emissions of formaldehyde precursors by source category based on the 1990 EPA CEP data for all of the United States, not just Minnesota. Overall, mobile sources (on-road and nonroad) account for about 64 percent of secondary-formed formaldehyde emissions. Area sources contribute about 28 percent of the precursor pollutants that result in formaldehyde formation. Point source contributions are less than 10 percent.

Figure 2.1.1.5.5 Emissions of formaldehyde precursors by source category
(Data are from the EPA CEP study for the United States.)



2.1.1.6 Formaldehyde summary

Statewide air monitoring data (1991-98) showed that the mean ambient air concentrations of formaldehyde at 25 sites were above the health benchmark of 0.8 $\mu g/m^3$ everywhere in Minnesota. The highest values were observed at the sites in and near the Twin Cities metropolitan area. The EPA's Cumulative Exposure Project modeling study showed a similar pattern of formaldehyde concentrations in Minnesota, as well as comparable concentrations. However, the CEP study suggested that air concentrations would be below health benchmarks in most of Minnesota outside the metro area. The monitoring data show that the CEP modeling analysis underestimated formaldehyde concentrations in nonmetro areas. On average, the measured values were 0.58 $\mu g/m^3$ higher than the CEP estimates. Model underestimates were greatest in rural areas. Formaldehyde concentrations appear to be stable over the past four years.

Formaldehyde is a strong irritant to mucous membranes and the respiratory system. The EPA has classified formaldehyde as a probable human carcinogen and Minnesota Department of Health has established a draft HRV at 0.8 $\mu g/m^3$. California's OEHHA is also proposing to adopt chronic noncancer reference exposure level (REL) of 3.0 $\mu g/m^3$. Widespread exceedances of health benchmarks for formaldehyde suggest that a public health issue exists.

Formaldehyde is a byproduct of combustion. It can be emitted directly into the atmosphere from chemical processes or from combustion (primary formaldehyde), or it can be formed in chemical processes in the atmosphere (secondary formaldehyde) beginning with precursor chemicals that also typically come from combustion processes. Mobile sources are the main source (58 percent) of primary formaldehyde emissions. Mobile sources are also believed to be the main source of precursor emissions that lead to secondary-formaldehyde formation, although the exact percentage cannot be stated with certainty.

2.1.2 Benzene

Benzene (CAS 71-43-2), C6H6, is a clear, volatile, colorless, highly flammable liquid with a characteristic, sweet odor. It evaporates easily, and its vapor mixes with air very quickly. It breaks down in air within a few days, but more slowly in water. Benzene does not accumulate to high levels in plants and animals.

2.1.2.1 What information indicates benzene is a concern?

Ambient data: A summary of the monitoring data is given in Table 2 of Appendix A and in Figure 2.1.2.1.1, which shows a boxplot with the median and 25th and 75th percentile values for each site. The health risk benchmark for benzene, unlike other pollutants, is given as a range (1.3-4.5 $\mu g/m^3$). The data show that mean benzene concentrations at most of the monitoring sites in the Twin Cities metropolitan area exceeded the lower value in the range. The mean value also exceeded 1.3 $\mu g/m^3$ at Duluth and at one of the International Falls sites. The boxplot shows that median concentrations exceeded 1.3 $\mu g/m^3$ at most of the metro area sites and at the Duluth site. The median concentrations are uniformly lower than the means. Figure 2.1.2.1.2 is a map showing mean concentrations at each of the monitoring sites. The upper bound on the benzene health benchmark (4.5 $\mu g/m^3$) was not exceeded by the mean or median values at any of the sites.

Figure 2.1.2.1.1 Boxplot showing benzene concentrations (μg/m³) by site
The center line within each box represents the median for the site. The box itself encompasses the 25th percentile to the 75th percentile. The bars at each end of the box represent the highest and lowest values that are not considered outliers. The horizontal dotted lines are located at the values of the benzene health benchmark range (1.3-4.5 μg/m³).

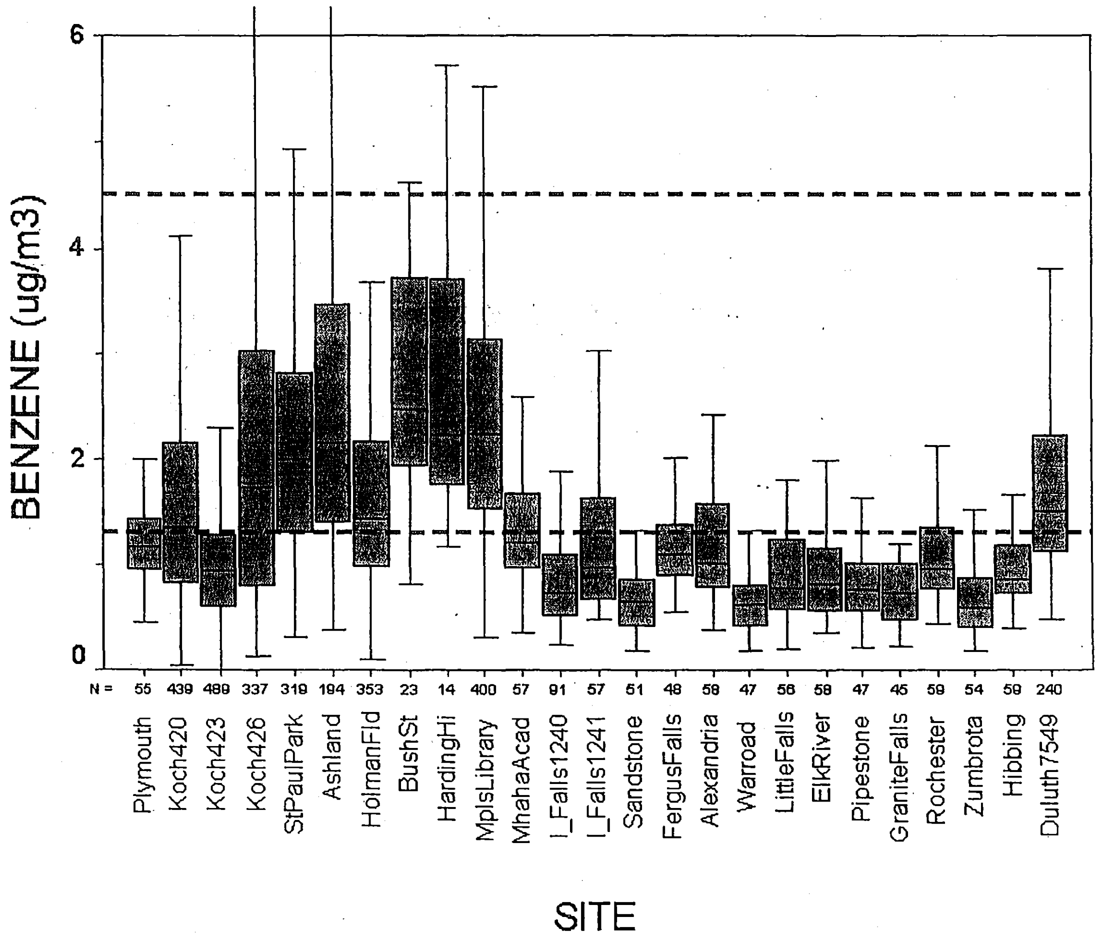
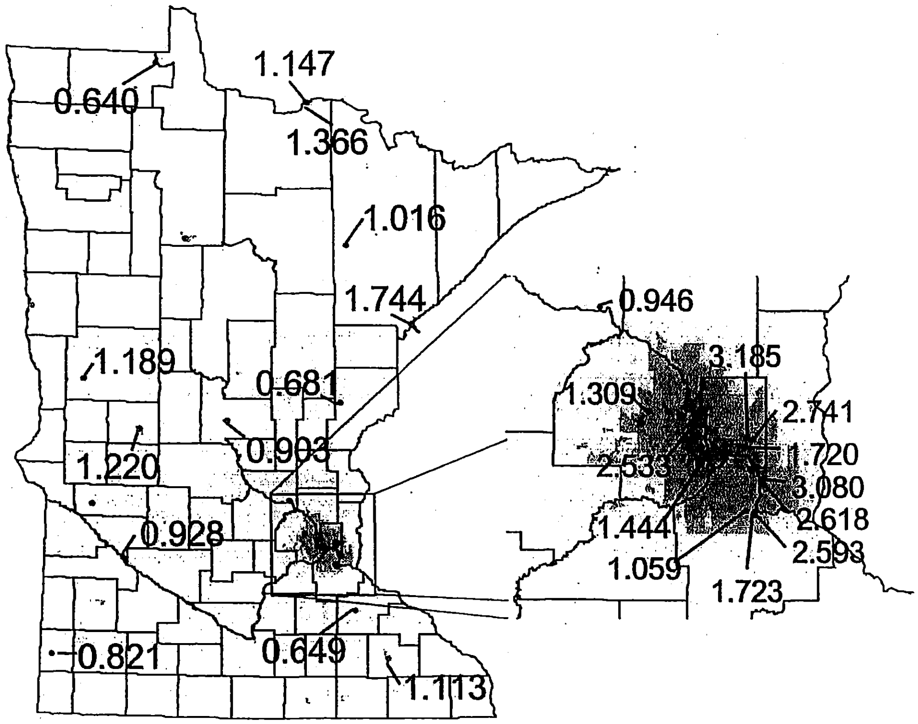


Figure 2.1.2.1.2 Map showing the mean benzene concentrations at each monitoring site in Minnesota

The monitored values are indicated by the dots with the attached numerical values. They are superimposed over background maps showing the results of the CEP modeling for benzene (see modeling section below).



<u>Modeling data</u>: According to the EPA's CEP modeling analysis, which is based on 1990 emissions data, the modeled concentration of benzene exceeded the lower bound of the health benchmark in areas of higher population density. Figure 2.1.2.1.3 shows areas of the Twin Cities metropolitan area that exceeded the health benchmark according to the model. Table 2.1.2.1.2 gives a comparison of the concentrations of benzene measured by the MPCA compared to the modeled values from the CEP. On average, measured mean values were 0.15 $\mu g/m^3$ lower than the CEP estimates.

Figure 2.1.2.1.3 Map of the Twin Cities metropolitan area showing benzene concentrations predicted by the EPA Cumulative Exposure Project for each census tract.
This map can be seen in color on the Internet at http://www.pca.state.mn.us/air/at-cep.html.

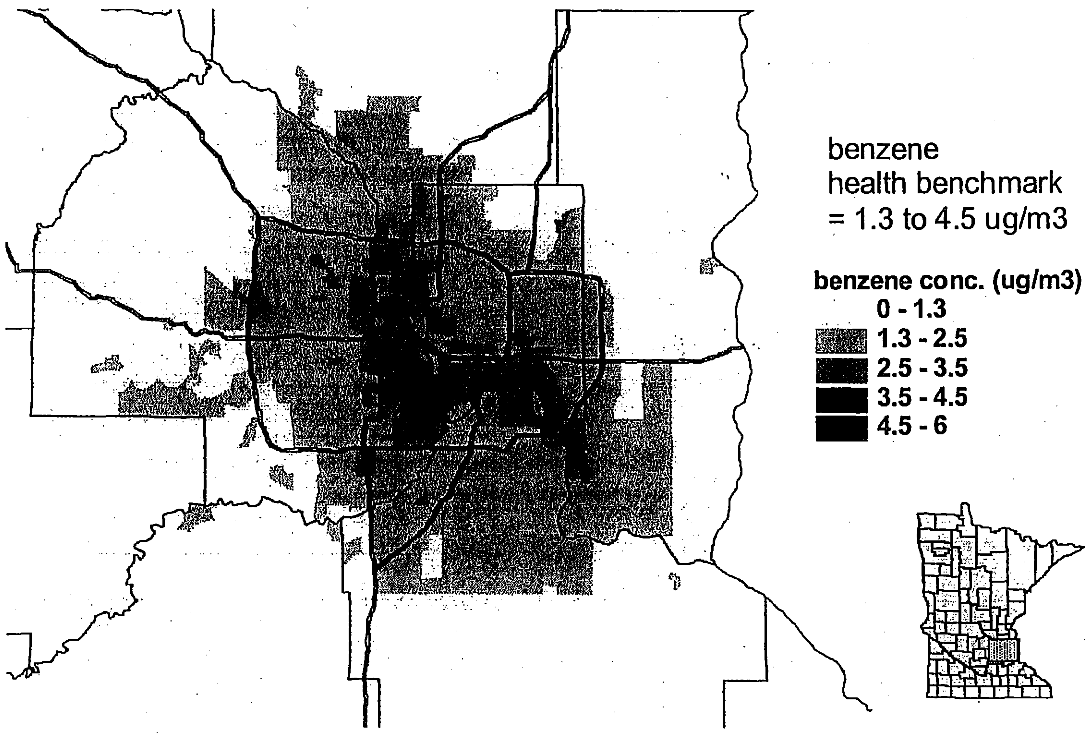


Table 2.1.2.1.1 MPCA-measured benzene concentrations (µg/m³, see Figure 2.0.2 for period of record for each site) versus concentrations estimated for 1990 in the EPA Cumulative Exposure Project model

Site No.	Site Name	monitored mean value	U.S. EPA CEP modeled value	difference (model - monitor)
260	Plymouth	1.309	1.660	0.351
420	Koch420	1.723	1.447	-0.276
423	Koch423	1.059	1.447	0.388
426	Koch426	2.593	1.447	-1.146
436	StPaulPark	2.618	3.429	0.811
438	Ashland	3.084	2.655	-0.429
816	HolmanFld	1.720	2.649	0.929
820	BushSt	3.185	2.348	-0.837
871	HardingHi	2.741	2.935	0.194
945	MplsLibrary	2.533	3.306	0.773
958	MhahaAcad	1.444	2.860	1.416
1240	I_Falls1240	1.147	1.207	0.060
1241	I_Falls1241	1.366	1.207	-0.159
1400	Sandstone	0.681	0.549	-0.132
2005	FergusFalls	1.189	1.221	0.032
2010	Alexandria	1.220	1.465	0.245
2401	Warroad	0.640	0.545	-0.095
3049	LittleFalls	0.903	0.993	0.090
3050	ElkRiver	0.946	0.848	-0.098
4002	Pipestone	0.821	0.927	0.106
4003	GraniteFalls	0.928	0.568	-0.360
5008	Rochester	1.113	2.128	1.015
5356	Zumbrota	0.649	0.623	-0.026
7014	Hibbing	1.016	2.031	1.015
7549	Duluth7549	1.744	1.653	-0.091

Trend: Benzene concentrations have been measured since 1991 at the Minneapolis Public Library, Holman Field in St. Paul and near Koch Refinery in Pine Bend. At each of these long-term monitoring sites, plots of the data over time (*e.g.*, Figures 2.1.2.1.4 and 2.1.2.1.5) show that measured concentrations appear to have decreased slightly since measurements were begun. A seasonal decomposition analysis was unable to show a significant seasonality in the data; however, concentrations were generally slightly higher in winter than in summer (*e.g.*, 1.82 µg/m³ in November through March versus 1.57 µg/m³ for April through October at Koch site 420).

A regression analysis was done with the data from each of the long-term monitoring sites. These analyses showed that the decrease in benzene concentrations over time were statistically significant, although small. The regression coefficients (R^2 values) ranged from 0.02 to 0.03, meaning that the change over time accounts for little of the variation in the data. The regression equations show that the benzene concentrations have been decreasing by 0.02 µg/m³ per year

(Koch423) to 0.07 µg/m^3 per year (Holman Field) to 0.11 µg/m^3 per year (Minneapolis Library and Koch420). Possible reasons for the decrease in benzene concentrations are uncertain. Over the period 1991-1998, there have been changes in the vehicle fleet toward generally cleaner vehicles. In addition, the metro-area vehicle inspection and maintenance program was operative over that period. Finally, there have been changes in fuel composition. Any or all of these factors, or some combination of them, may be involved in the trend toward lower benzene concentrations in the atmosphere.

Figure 2.1.2.1.4 Trend in benzene measurements at site 945, the Minneapolis Public Library site

All measured values are plotted. The horizontal dashed lines are at the bound of the health benchmark range for benzene (1.3 and 4.5 µg/m^3).

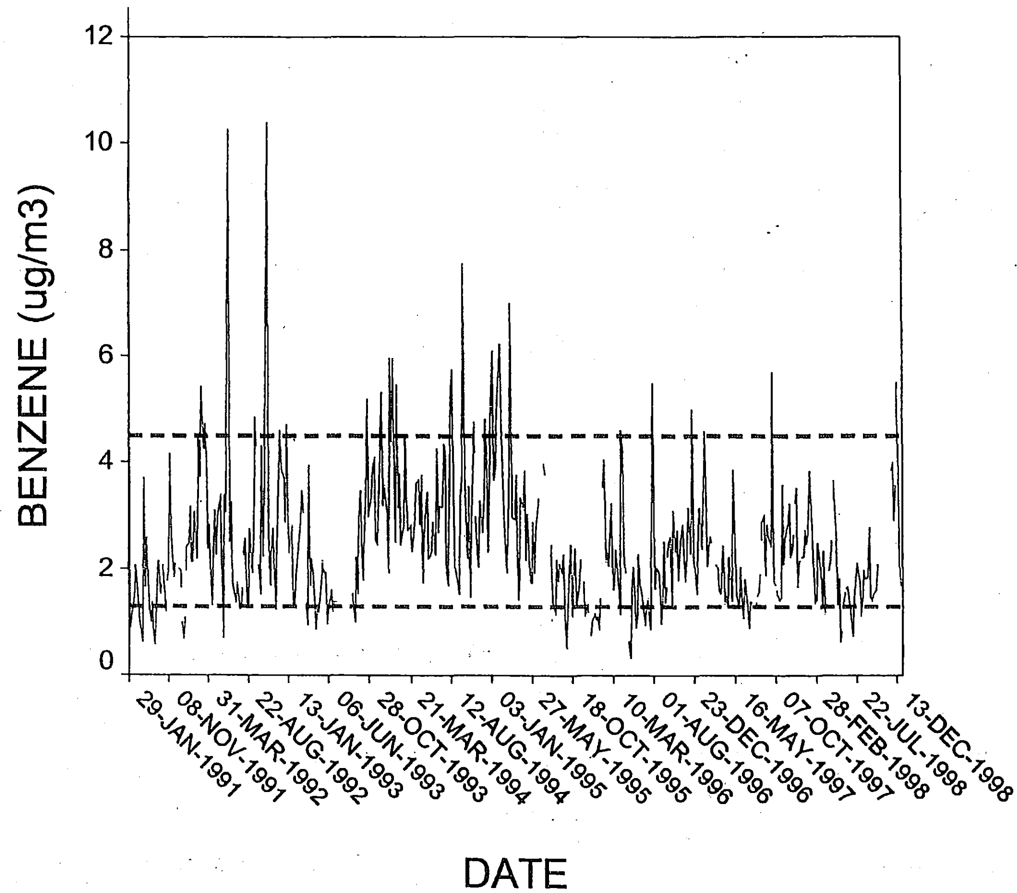
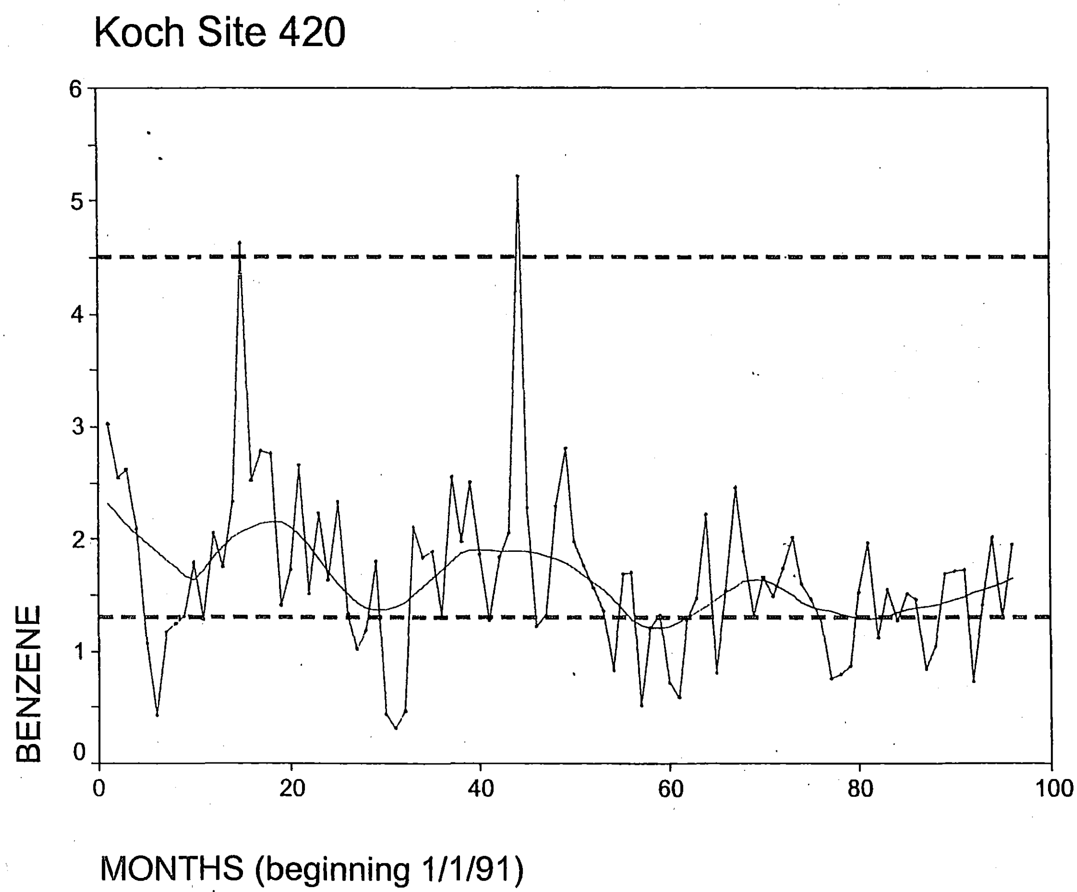


Figure 2.1.2.1.5 Trend in benzene measurements at Koch Site 420
Monthly mean values are plotted and a smoothed trend line is shown. The horizontal dashed lines are at the bounds of the health benchmark range for benzene (1.3 and 4.5 μg/m³).



2.1.2.2 What are the health effects of benzene?

Short-term inhalation exposure to benzene affects the central nervous system and may cause drowsiness, dizziness, headaches and unconsciousness in humans. Death may result from exposure to very high levels of benzene. Once inhaled, benzene enters the bloodsteam and is temporarily stored in bone marrow and fat. It is then metabolized by the liver and in the bone marrow, altering cell populations in the bone marrow and causing different types of toxicities of the blood and immune systems. It has been clearly established and accepted that long-term exposure to benzene causes various blood-related disorders in humans, including anemia and leukemia. The EPA has characterized benzene as a known human carcinogen for all routes of exposure. The MPCA uses the draft HRV established by the Minnesota Department of Health as the health benchmark for benzene. This value is a range from 1.3 $\mu g/m^3$ to 4.5 $\mu g/m^3$ and corresponds to an excess lifetime cancer risk of 1 in 100,000. The draft HRV is based upon the EPA's evaluation of the carcinogenic effects of benzene, in which the magnitude of risk was calculated using more than one exposure measurement, hence, a range of risk values. California EPA Office of Environmental Health Hazard Assessment (OEHHA) has adopted a cancer unit risk of 2.9×10^{-5} for benzene, which corresponds to 0.3 µg/m^3 at 1-in-100,000 risk level. A chronic noncancer REL of 60 µg/m^3 is being proposed to protect against cardiovascular, developmental, nervous and immune system effects.

The risk of leukemia and other toxic effects could be greater for children. Because children are generally more active and have higher respiratory and metabolic rates than adults, they may have higher exposures per unit of body weight. Furthermore, infants and children may be more vulnerable to the toxic effects of benzene exposure, because their blood cell populations are differentiating and undergoing maturation.

Uses of Benzene: Benzene is a widely used industrial chemical, used in the manufacture of products such as medicinal chemicals, shoes, dyes, detergents, explosives, linoleum, oil cloth and artificial leather. Benzene is also used as a solvent for waxes, fats, resins, paints, plastics and fast-drying inks. It also can be used as a raw material in the synthesis of organic compounds, such as cyclohexane, styrene, phenol and rubber. Benzene is not present in household products except in small amounts in some automotive and cleaning products.

2.1.2.3 How are people exposed to benzene?

The general population is exposed to benzene primarily by breathing air contaminated with benzene. People are exposed to benzene via motor vehicle exhaust, evaporation at gasoline service stations, exposure to tobacco smoke and industrial emissions. Exposure to higher levels of benzene in the air may occur for people who live around hazardous wastes sites, petroleum refining operations, petrochemical manufacturing sites or gas stations. Benzene has been detected in some bottled water, liquor and food; however, air is the primary exposure pathway unless people are exposed to benzene-contaminated well water. People who have benzene-contaminated tap water can be exposed by drinking it, eating foods prepared with it and breathing vapors while they shower, bathe or cook with it.

2.1.2.4 What happens to benzene in the atmosphere?

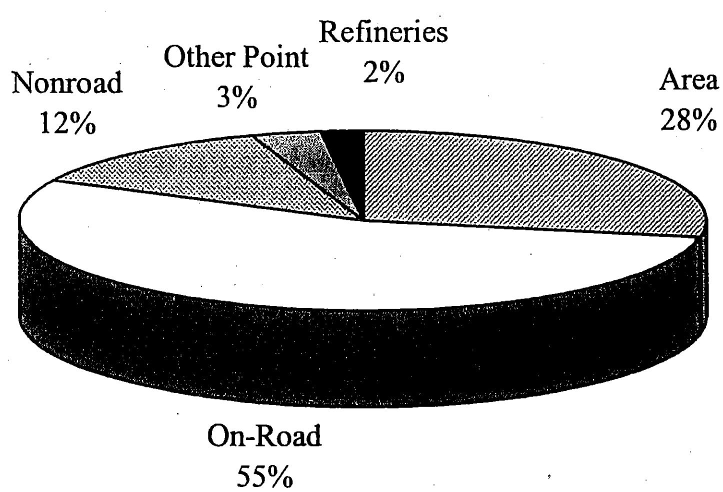
The structure of benzene is the aromatic ring, which is extremely stable and resistant to chemical attack. Reaction of benzene with the hydroxyl radical is the only important reaction in the lower atmosphere, and even this reaction is relatively slow. The primary reaction products are phenol, nitrophenol and glyoxal. Because of its low solubility in water, benzene will not be removed to any large degree through destruction in clouds or by rain. The calculated residence times of benzene ranged from two days under clear-sky summer conditions to several months under cloudy winter conditions. Hence, one can expect a significant carryover of benzene concentrations in ambient air from one day to the next.

2.1.2.5 What sources emit benzene?

Emissions of Benzene: Benzene emissions occur primarily from fossil fuel combustion, solid waste incineration and petroleum refining. Its emissions are also from agricultural burning, forest management burning, wildfires and tobacco smoke. Use of oil and gasoline is the main source of benzene to the environment. Benzene occurs naturally in crude oil. Benzene imparts desirable properties to gasoline, such as raising the octane level. In the past, lead was added to gasoline because of its desirable properties, but the use of lead has been discontinued because of its toxicity. Some refineries have raised benzene concentrations in gasoline to make up for the loss of lead.

Figure 2.1.2.5.1 shows emissions of benzene by source category in Minnesota. This figure is based on the 1990 emission data from the EPA's CEP study. According to the study, approximately two-thirds of benzene emissions are attributed to mobile sources, area sources contribute 28 percent of benzene emissions, and point sources contribute only 5 percent. In Minnesota, on-road motor vehicles contribute about 82 percent of mobile source benzene emissions, with the remainder coming from nonroad mobile sources. The definition of each source category is shown in Appendix C.

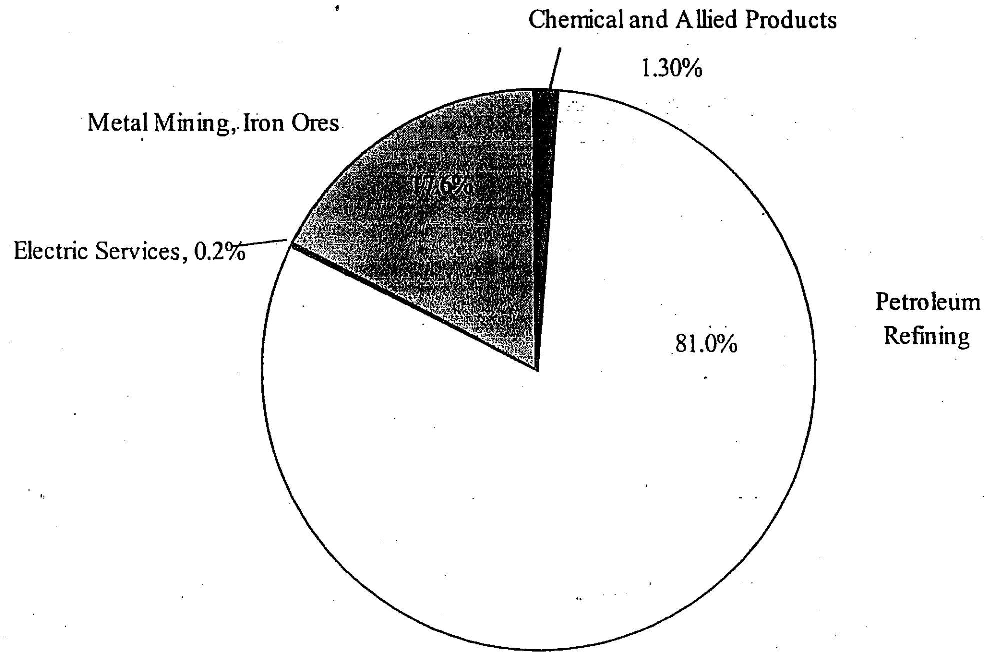
Figure 2.1.2.5.1 1990 emissions of benzene by source category
(Data are from the EPA CEP study for the State of Minnesota.)



Benzene emissions by principal source category for point sources are shown in Figure 2.1.2.5.2. According to the preliminary results of the 1996 Minnesota air toxics emission inventory for point sources, about 81 percent of benzene emissions from point sources are attributed to manufacturing petroleum and coal products. Metal mining, iron ores, contributes about 18 percent of emissions.

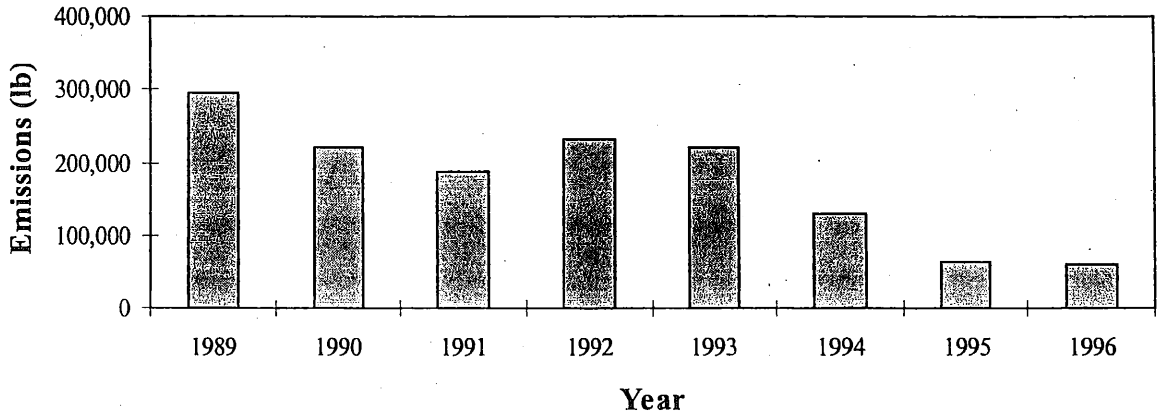
Figure 2.1.2.5.2 1996 benzene emissions by principal source category for point sources

(Data are from the preliminary 1996 Minnesota emission inventory.)



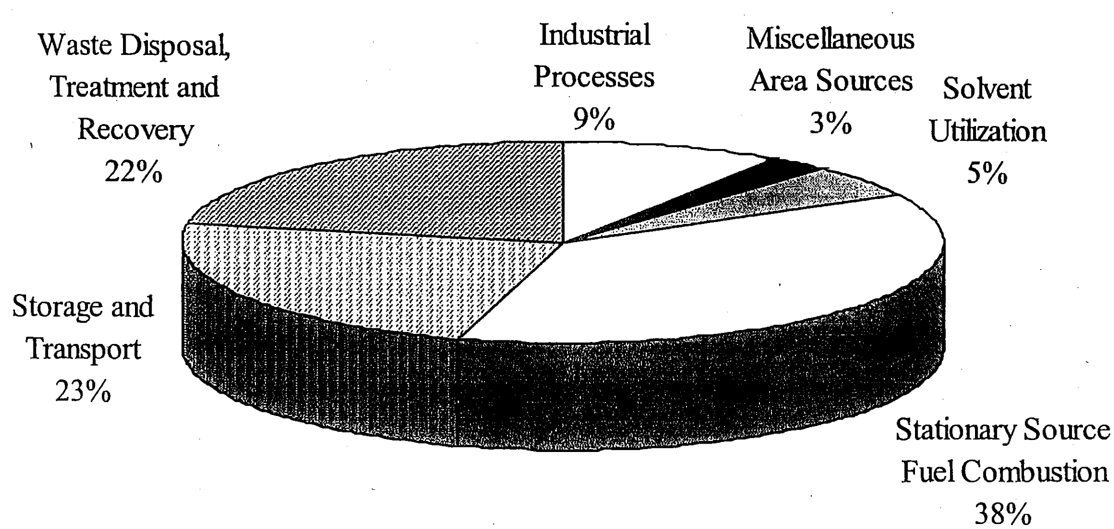
The 1989-to-1996 trend in benzene emissions for the Minnesota TRI point sources is shown in Figure 2.1.2.5.3. Benzene emissions reduced significantly after 1993. The reduction was about 40 to 50 percent per year from 1993 to 1995, then was relatively stable from 1995 to 1996. It is important to remember that TRI point sources, including refineries, contribute only 2 percent of benzene emissions, according to the data from the 1990 CEP study.

Figure 2.1.2.5.3 Trend in benzene emissions based on TRI point source data



Benzene emissions for Minnesota area sources are shown in Figure 2.1.2.5.4, where the data are from the EPA's CEP study for 1990. A variety of sources contribute to benzene emissions: stationary source fuel combustion; storage and transport; waste disposal, treatment and recovery; industrial processes; solvent utilization; and miscellaneous area sources. Each of the first three categories contributes more than 20 percent of total area source emissions. The total contribution of the other sources is 17 percent.

Figure 2.1.2.5.4 1990 benzene emissions by principal source category for area sources
(Data are from the EPA CEP study for the State of Minnesota.)



2.1.2.6 Benzene summary

Monitoring data and modeling studies show that benzene concentrations in Minnesota are elevated above the lower bound of the health benchmark (1.3 $\mu g/m^3$) in the Twin Cities metropolitan area and in other smaller population centers (*e.g.*, Duluth, St. Cloud, Rochester, Mankato). At least 67 percent of benzene emissions can be attributed to mobile sources (this does not include emissions from petroleum transport and storage at such places as gas stations). Since 1991, it appears that benzene concentrations in the metropolitan area have decreased slightly. The reason for the decrease is unclear, but it may be associated with cleaner vehicles, vehicle inspection and maintenance and/or changes in fuel composition.

Long-term exposure to benzene is known to cause blood-related disorders in humans, including anemia and leukemia. The EPA has characterized benzene as a known human carcinogen. Given the magnitude of the measured concentrations, especially in the metropolitan area and other smaller population centers, it would appear that benzene in the air presents a potential public health problem in Minnesota.

2.1.3 Carbon Tetrachloride

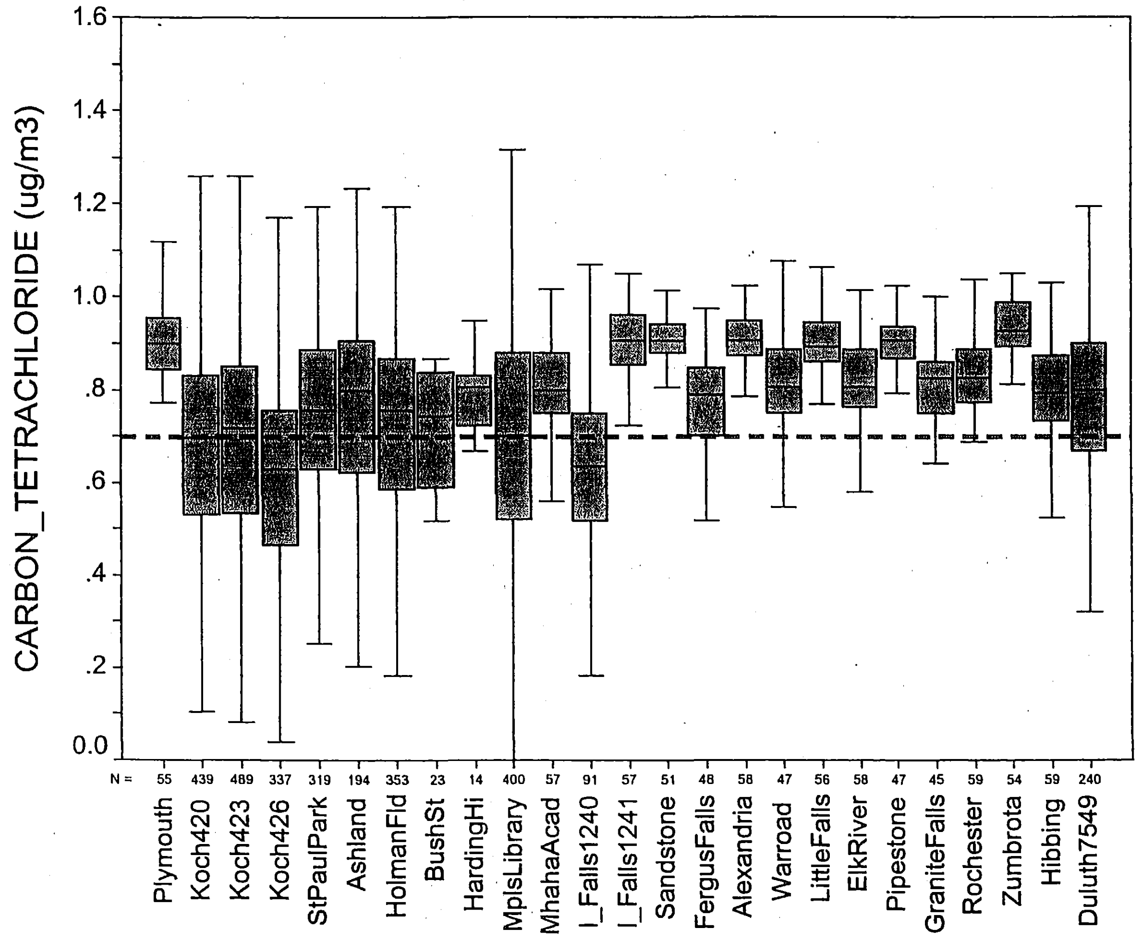
Carbon tetrachloride (CAS 56-23-5), CCl4, is a colorless, nonflammable liquid with a characteristic odor. Carbon tetrachloride may take many years to degrade in air, but much less time in soil and water. Production by developed countries has been banned internationally under the Montreal Protocol on substances that degrade the stratospheric ozone layer.

2.1.3.1 What information indicates carbon tetrachloride is a concern?

Ambient data: A summary of the monitoring data is given in Table 3 of Appendix A and in Figure 2.1.3.1.1, which shows a boxplot with median and 25th and 75th percentile values for each site. The boxplot shows that the median concentrations exceeded the carbon tetrachloride health benchmark of 0.7 $\mu g/m^3$ at all sites except Koch 426, Koch 420 and International Falls 1240. The median concentrations are generally higher than the means. The boxplot shows that the concentrations appear to be lower at the sites in the Twin Cities metropolitan area. However, upon closer inspection, the duration of measurement rather than site location seems to be the more important factor, with longer records of measurement resulting in lower carbon tetrachloride concentrations. This observation suggests that carbon tetrachloride concentrations may have increased over time, an issue that will be addressed in the section on trends below.

Figure 2.1.3.1.1 Boxplot showing carbon tetrachloride concentrations by site

The center line within each box represents the median for the site. The box itself encompasses the 25th percentile to the 75th percentile. The bars at each end of the box represent the highest and lowest values that are not considered outliers. The horizontal dotted line is located at the carbon tetrachloride health benchmark (0.7 µg/m³).



Modeling data: According to the EPA Cumulative Exposure Project (CEP) modeling analysis, which is based on 1990 emissions data, the modeled concentration of carbon tetrachloride exceeded the health benchmark throughout the state. Table 2.1.3.1. gives a comparison of the concentrations of carbon tetrachloride measured by the MPCA compared to the modeled values from the CEP. On average, measured mean values were 0.10 µg/m³ lower than CEP estimates. The CEP model tended to overpredict most at sites with a long period of record. In other words, the CEP model results are most comparable with the most recent MPCA measurements. Color maps of carbon tetrachloride concentrations in Minnesota can be viewed at *http://www.pca.state.mn.us/air/at-cep.html.*

Table 2.1.3.1. MPCA-measured carbon tetrachloride concentrations (μg/m³) versus concentrations estimated in the EPA Cumulative Exposure Project model

Site No.	Site Name	monitored mean value	U.S. EPA CEP modeled value	difference (model - monitor)
260	Plymouth	0.91	0.882	-0.032
420	Koch420	0.67	0.882	0.217
423	Koch423	0.67	0.882	0.210
426	Koch426	0.61	0.882	0.274
436	StPaulPark	0.74	0.884	0.147
438	Ashland	0.76	0.884	0.126
816	HolmanFld	0.71	0.895	0.184
820	BushSt	0.72	0.903	0.186
871	HardingHi	0.78	0.958	0.176
945	MplsLibrary	0.68	0.886	0.207
958	MhahaAcad	0.80	0.927	0.126
1240	I_Falls1240	0.63	0.881	0.248
1241	I_Falls1241	0.91	0.881	-0.026
1400	Sandstone	0.91	0.881	-0.031
2005	FergusFalls	0.78	0.881	0.106
2010	Alexandria	0.92	0.881	-0.038
2401	Warroad	0.82	0.881	0.065
3049	LittleFalls	0.91	0.881	-0.025
3050	ElkRiver	0.81	0.881	0.073
4002	Pipestone	0.92	0.881	-0.037
4003	GraniteFalls	0.79	0.881	0.093
5008	Rochester	0.81	0.881	0.067
5356	Zumbrota	0.93	0.881	-0.049
7014	Hibbing	0.79	0.884	0.095
7549	Duluth7549	0.77	0.884	0.118

Trend: Carbon tetrachloride concentrations have been measured since 1991 at the Minneapolis Public Library, Holman Field in St. Paul and near Koch Refinery in Pine Bend (Figures 2.1.3.1.2, 2.1.3.1.3 and 2.1.3.1.4). At each of these long-term monitoring sites, plots of the data over time show that the measured concentrations appear to have increased during the first few years of measurements. In the later years, the concentrations clearly show a decline. The increasing trend in the early years is somewhat different from measurements at other sites (*e.g.*, the California state system and the National Oceanic and Atmospheric Administration (NOAA) at several remote sites), where there has been a consistent decrease in carbon tetrachloride concentrations in the 1990s. The Duluth site (Figure 2.1.3.1.4), where data collection began in 1994, clearly shows a decreasing trend.

A consistent feature in the Minnesota data that confounds the trend issue is a drop in concentrations from about August 1995 to about May 1996. This period of low concentrations can also be found in some of the California and NOAA sites although the Minnesota concentrations appear to reach lower values. There was an analytical change that occurred in

November 1995, when new cryogenic focusing equipment was installed. There is a clear difference in the data before and after this analytical change, with the earlier data showing more scatter. This analytical change is bracketed by low concentrations both before and after the change and thus is unlikely to account for the 1995-96 dip in concentrations. There were no other changes in field or laboratory methodology or in data management that would account for the differences found between Minnesota and elsewhere.

Carbon tetrachloride is a persistent gas that lasts a long time in the atmosphere (atmospheric lifetime about 50-100 years). It is one of the "ozone-depleting" substances responsible for damaging the stratospheric ozone layer. Under the international agreement known as the Montreal Protocol, developed countries agreed to phase out production of carbon tetrachloride by the end of 1995 (developing countries are required to phase out the chemical by 2015).

Figure 2.1.3.1.2 Trend in carbon tetrachloride measurements at Koch site 420

All measured values are plotted. The solid vertical line is at November 23, 1995, the date new cryogenic focusing was installed. The curved solid diagonal line is a smoothed (Loess) trend line.

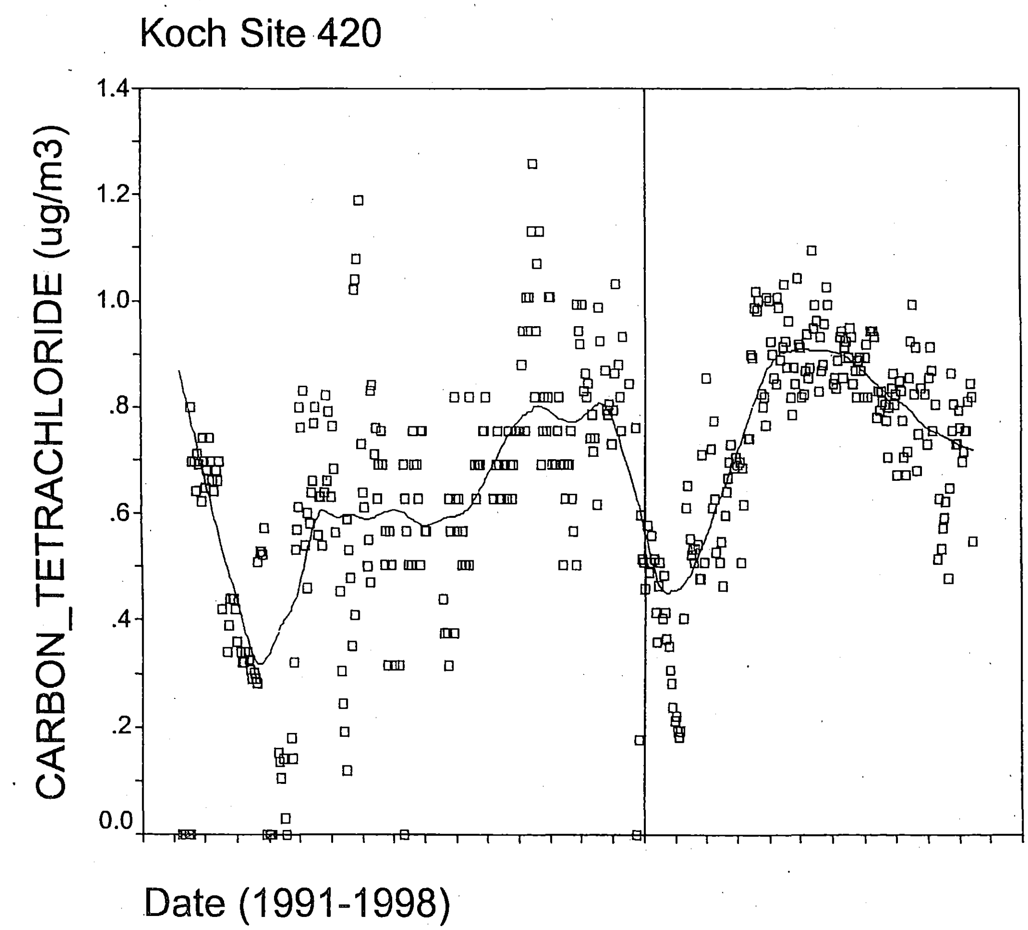


Figure 2.1.3.1.3 Trend in carbon tetrachloride measurements at the Holman Field site

All data points are plotted and a smoothed trend line is shown. The horizontal dashed line is at the carbon tetrachloride health benchmark of 0.7μg/m³. The solid vertical line is at November 23, 1995, the date new cryogenic focusing equipment was installed. The horizontal dashed line is at the health benchmark of 0.7 μg/m³. The curved solid line represents a smoothed (Lowess) trend line.

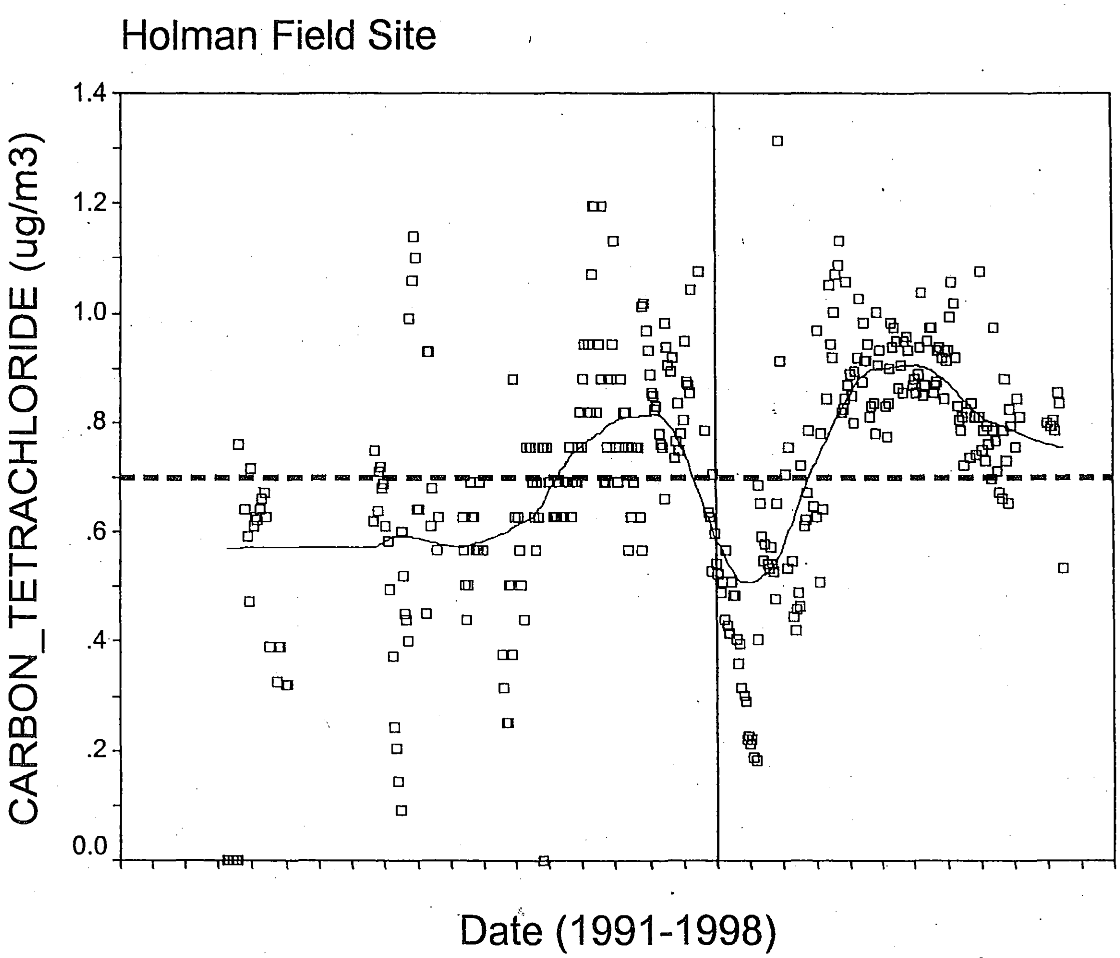
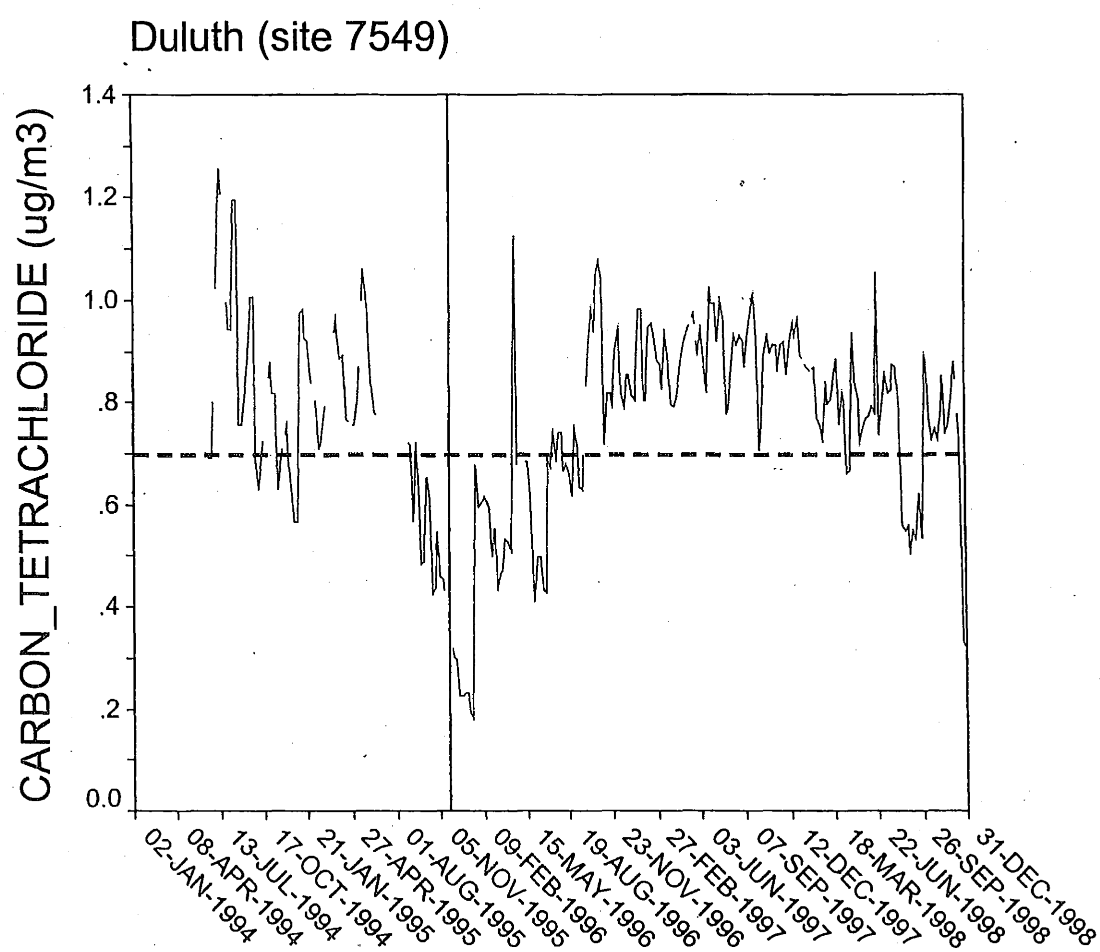


Figure 2.1.3.1.4 Trend in carbon tetrachloride measurements at the Duluth site

The horizontal dashed line is at the carbon tetrachloride health benchmark of 0.7 µg/m³. The solid vertical line is at November 23, 1995, the date new cryogenic focusing equipment was installed. The horizontal dashed line is at the health benchmark of 0.7 µg/m³.



2.1.3.2 What are the health effects of carbon tetrachloride?

Acute and chronic inhalation and oral exposure to carbon tetrachloride cause damage primarily to the liver and kidneys. Some of the carbon tetrachloride entering the body temporarily accumulates in body fat and some may change to chloroform and hexachloroform. The liver is especially sensitive to carbon tetrachloride due to fat buildup inside the organ. Exposure to high levels of carbon tetrachloride affects the nervous system; symptoms of intoxication, including headache, dizziness, sleepiness, nausea and vomiting, are experienced. No information is available on the reproductive or developmental effects of carbon tetrachloride in humans. While animal studies indicate that carbon tetrachloride does not cause birth defects, reproductive effects, such as degenerative changes in testes and decreased fertility, have been observed. Although human data on the carcinogenic effects of carbon tetrachloride are limited, animal studies have shown that ingestion of carbon tetrachloride increases the risk of liver cancer. The

EPA has classified carbon tetrachloride as a probable human carcinogen. The MPCA uses as the health benchmark the cancer-risk level established by the EPA of 0.7 $\mu g/m^3$, corresponding to an excess lifetime cancer risk of 1 in 100,000. California EPA Office of Environmental Health Hazard Assessment has adopted a cancer unit risk for carbon tetrachloride and an acute REL to protect for potential reproductive and developmental effects.

Uses of Carbon Tetrachloride: In the past, carbon tetrachloride was produced in large quantities for making refrigeration fluid and propellants for aerosol cans. It was used as a cleaning agent in dry cleaning and degreasing. It was also used as a fire-extinguishing agent and as a pesticide. The production of carbon tetrachloride in the United States was phased out by 1996. As a result, the manufacture and use of carbon tetrachloride have also declined.

2.1.3.3 How are people exposed to carbon tetrachloride?

Although many uses of carbon tetrachloride are now banned, it is still found in air, water and soil because of past releases. The general population is most likely to be exposed to carbon tetrachloride through ambient air and drinking water. When carbon tetrachloride is inhaled, the body absorbs about 40 percent of the chemical. Exposure to carbon tetrachloride in excess of that of the general population is likely to occur near a chemical waste site where emissions into air, water or soil are not properly controlled. Exposure at such sites could occur by breathing carbon tetrachloride in the air, by drinking contaminated water or by children handling or ingesting contaminated soil.

2.1.3.4 What happens to carbon tetrachloride in the atmosphere?

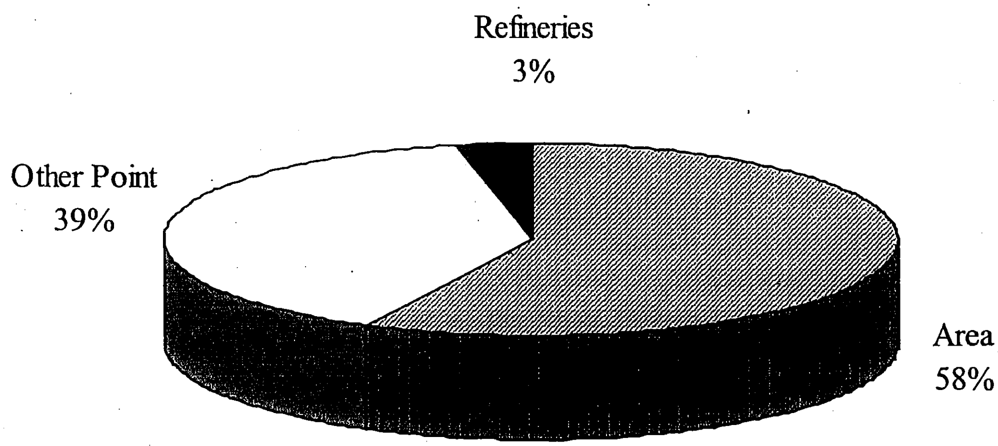
Nearly all carbon tetrachloride released to the environment exists in the atmosphere. Carbon tetrachloride released to soil and water evaporates within a few days due to its relatively high rate of volatilization. Because carbon tetrachloride does not readily degrade in the atmosphere, significant global transport of this pollutant has occurred. Since carbon tetrachloride does not react with hydroxyl radicals that initiate breakdown and transformation reactions, it is very stable in the troposphere. The rate of oxidation is so slow that the estimated half-life of carbon tetrachloride in the troposphere exceeds 330 years. Carbon tetrachloride eventually diffuses into the stratosphere, where it is photodegraded by shorter-wavelength ultraviolet light, which is prevalent in this region of the atmosphere. The transformation products are the trichloromethyl radical and chlorine atoms. Chlorine atoms catalyze reactions that destroy ozone. The estimated atmospheric lifetime of carbon tetrachloride in the troposphere and stratosphere combined ranges from 50 to 100 years.

2.1.3.5 Which sources emit carbon tetrachloride?

Emissions of Carbon Tetrachloride:
Due to its extremely stable characteristic, carbon tetrachloride in the atmosphere is primarily from an accumulation of past emissions. Therefore, the measured ambient concentration does not correlate with current emissions. Carbon tetrachloride emissions occur from chemical-manufacturing processes, wastewater-treatment processes, waste incineration, disposing of

wastes in landfills and petroleum refining. The emissions were reduced significantly after a 1996 ban on carbon tetrachloride production, but still exist. Figure 2.1.3.5.1 shows emissions of carbon tetrachloride by source category in Minnesota. This figure is based on the 1990 emissions data from the EPA's CEP study. According to the CEP study, area sources dominate carbon tetrachloride emissions (58 percent), point sources contribute 39 percent of emissions and the remaining 3 percent of emissions are attributed to refineries. The definition of each source category is shown in Appendix C.

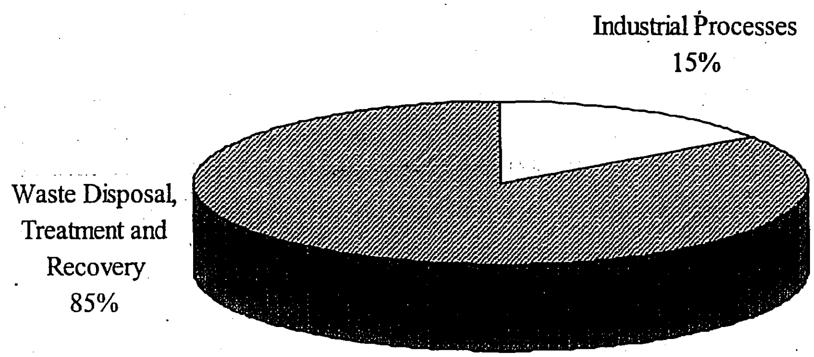
Figure 2.1.3.5.1 1990 emissions of carbon tetrachloride by source category
(Data are from the EPA CEP study for the State of Minnesota.)



Carbon tetrachloride emissions by principal source category for Minnesota area sources are shown in Figure 2.1.3.5.2, where the data are from the EPA's CEP study for 1990. Waste disposal, treatment and recovery contribute 85 percent of emissions from area sources and industrial processes account for the remaining 15 percent.

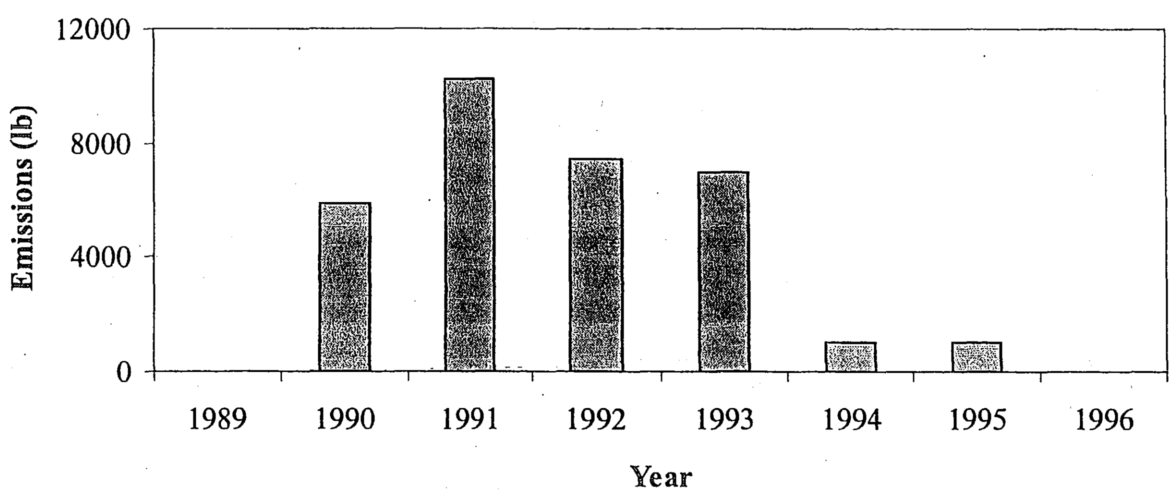
Figure 2.1.3.5.2 1990 carbon tetrachloride emissions by principal source category for area sources

(Data are from the EPA CEP study for the State of Minnesota.)



The 1989-to-1996 trend in carbon tetrachloride emissions for TRI point sources is shown in Figure 2.1.3.5.3. The emissions were solely from refineries. Carbon tetrachloride emissions tended to increase before 1991 and to decrease after 1991; the reduction was significant from 1993 to 1994. Reported emissions dropped to zero in 1996 because of the phaseout of this chemical's production. It is important to remember that refineries contribute only 3 percent of carbon tetrachloride emissions according to the 1990 CEP study data.

Figure 2.1.3.5.3 Trend in carbon tetrachloride emissions based on TRI point source data



2.1.3.6 Carbon tetrachloride summary

Both monitoring data and modeling analyses show that carbon tetrachloride exceeds health benchmarks throughout Minnesota. Carbon tetrachloride production by developed countries has been banned internationally under the Montreal Protocol treaty, which limits production and emission of substances that destroy the stratospheric ozone layer. Despite the ban and the end of U.S. production in 1996, the monitoring data do not yet show a clear trend toward decreasing concentrations. Carbon tetrachloride is a very stable gas that can persist for decades in the atmosphere. Therefore, concentrations now being measured are likely due to historical emissions.

The primary target organs for carbon tetrachloride toxicity are the liver and kidneys. The EPA has classified carbon tetrachloride as a probable human carcinogen. The high measured concentrations suggest a potentially important public health issue from carbon tetrachloride in the atmosphere.

2.1.4 Chloroform

Chloroform (CAS 67-66-3), CHCl3, is a clear, colorless, nonflammable liquid with a characteristic odor. Chloroform degrades in several months in air, soil and surface water. It may take several years to degrade in ground water.

2.1.4.1 What information indicates chloroform is a concern?

Ambient data: A summary of the monitoring data is given in Table 4 of Appendix A and in Figure 2.1.4.1.1, which shows a boxplot with median and 25th and 75th percentile values for each site. The data show that the mean and median concentrations exceeded the chloroform health benchmark of 0.4 $\mu g/m^3$ at International Falls site 1240, but were well below the health benchmark at all other sites. Median concentrations are generally higher than the means. The boxplot shows that concentrations appear to be higher at sites in the Twin Cities metropolitan area. In the metropolitan area, there were numerous measurements that exceeded the health benchmark, although the mean and median values did not. In contrast, aside from International Falls site 1240, only four measurements exceeded the health benchmark outside the metro area. Figure 2.1.4.1.2. is a map showing mean concentrations at the International Falls monitoring sites.

Figure 2.1.4.1.1 Boxplot showing chloroform concentrations by site

The center line within each box represents the median for the site. The box itself encompasses the 25th percentile to the 75th percentile. The bars at each end of the box represent the highest and lowest values that are not considered outliers. The circles represent outliers and the stars represent extreme values. The horizontal dashed line is located at the chloroform health benchmark (0.4 μg/m^3).

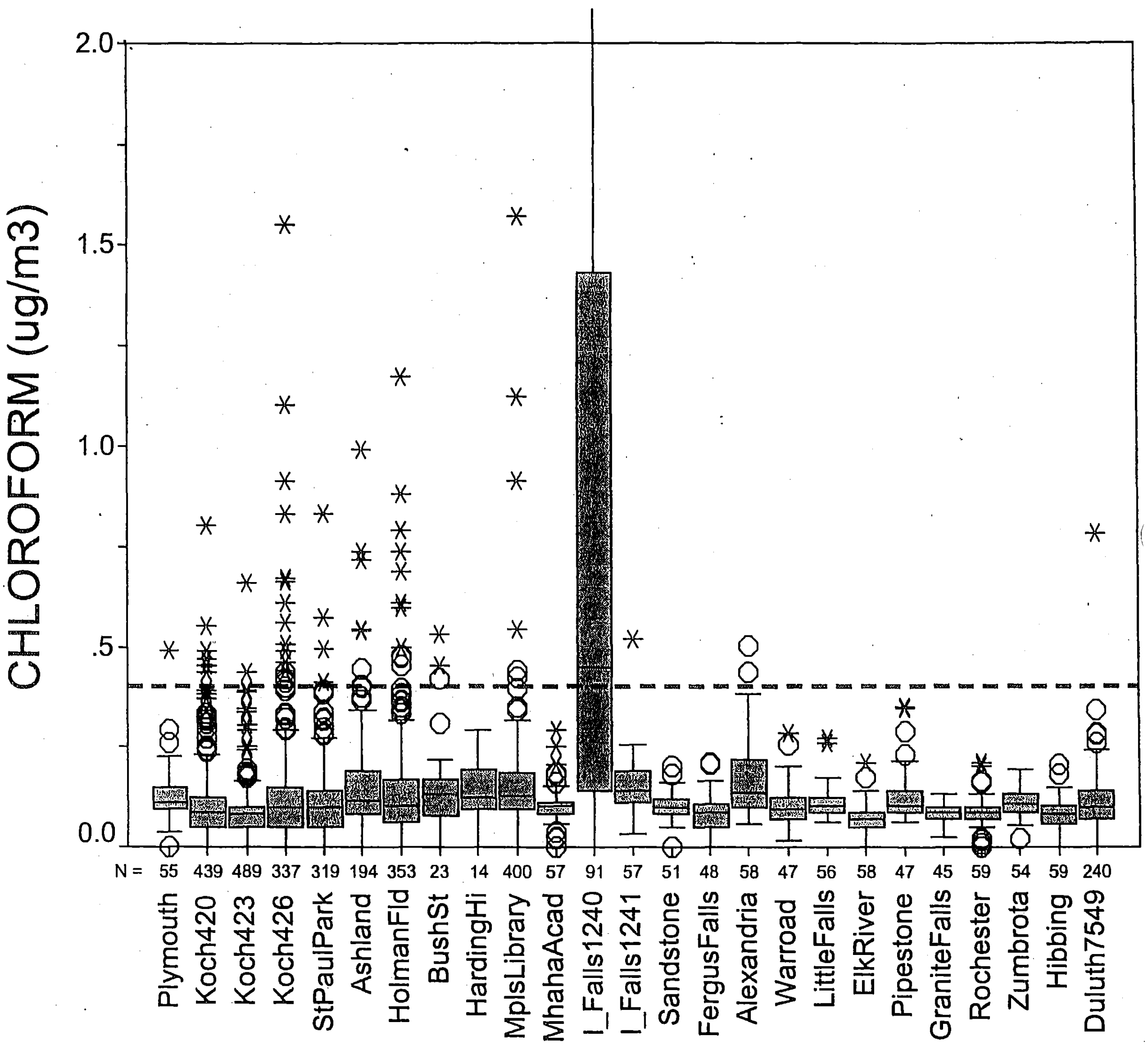
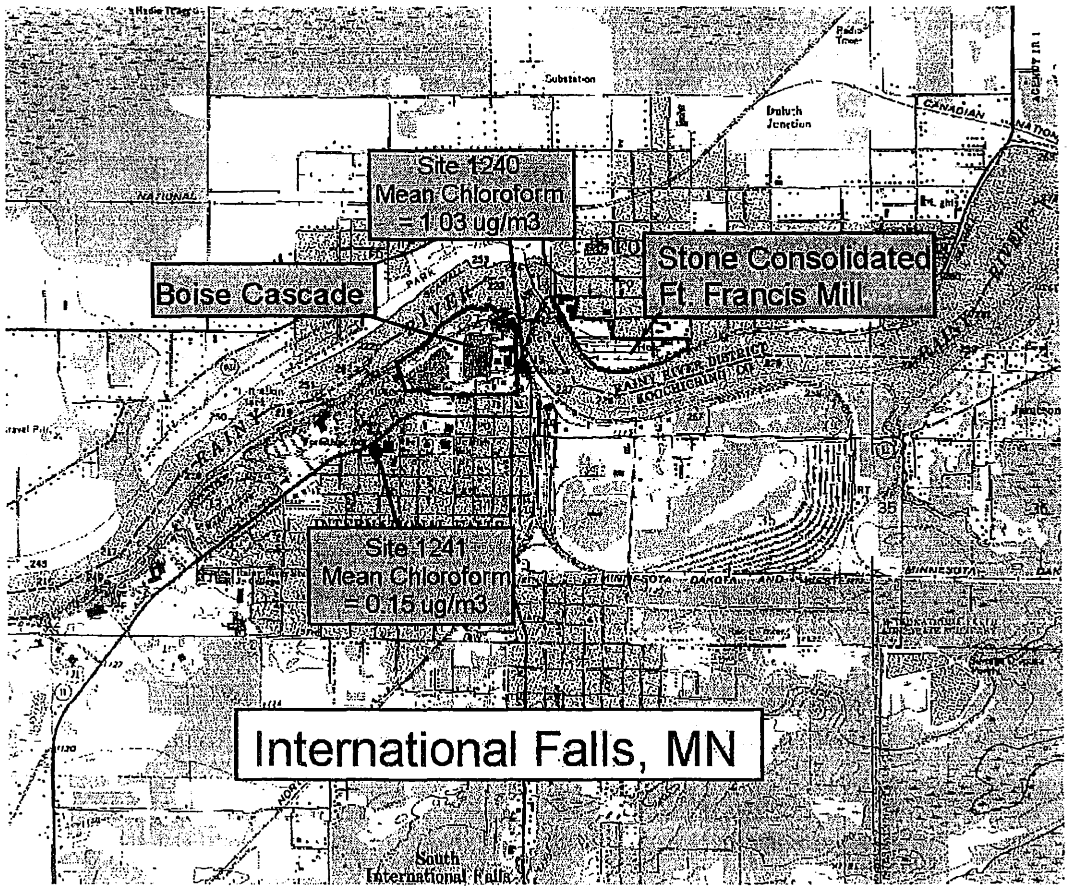


Figure 2.1.4.1.2 Map showing the mean chloroform concentrations at the International Falls monitoring sites



__Modeling data__: According to the EPA Cumulative Exposure Project (CEP) modeling analysis, which is based on 1990 emissions data, the modeled concentration of chloroform did not exceed the health benchmark anywhere in the state. Table 2.1.4.1.1 gives a comparison of the concentrations of chloroform measured by the MPCA compared to the modeled values from the CEP. On average, measured mean values were 0.046 $\mu g/m^3$ higher than the CEP estimates. Color maps of chloroform concentrations in Minnesota can be viewed at *http://www.pca.state.mn.us/air/at-cep.html.*

Table 2.1.4.1.1 MPCA measured chloroform concentrations (µg/m³, see Figure 2.0.2 for the period of record for each site) versus concentrations estimated for 1990 in the EPA Cumulative Exposure Project model

Site No.	Site Name	monitored mean value	U.S. EPA CEP modeled value	difference (model - monitor)
260	**Plymouth**	0.129	0.087	-0.042
420	**Koch420**	0.100	0.085	-0.015
423	**Koch423**	0.083	0.085	0.003
426	**Koch426**	0.127	0.085	-0.041
436	**StPaulPark**	0.114	0.086	-0.028
438	**Ashland**	0.155	0.087	-0.067
816	**HolmanFld**	0.138	0.099	-0.039
820	**BushSt**	0.162	0.106	-0.055
871	**HardingHi**	0.141	0.152	0.011
945	**MplsLibrary**	0.143	0.092	-0.051
958	**MhahaAcad**	0.105	0.125	0.020
1240	**I_Falls1240**	1.031	0.283	-0.747
1241	**I_Falls1241**	0.153	0.283	0.131
1400	**Sandstone**	0.101	0.083	-0.017
2005	**FergusFalls**	0.085	0.086	0.000
2010	**Alexandria**	0.169	0.084	-0.085
2401	**Warroad**	0.102	0.083	-0.019
3049	**LittleFalls**	0.110	0.084	-0.026
3050	**ElkRiver**	0.073	0.084	0.011
4002	**Pipestone**	0.126	0.084	-0.042
4003	**GraniteFalls**	0.084	0.083	-0.001
5008	**Rochester**	0.089	0.085	-0.004
5356	**Zumbrota**	0.108	0.083	-0.025
7014	**Hibbing**	0.082	0.084	0.002
7549	**Duluth7549**	0.108	0.095	-0.013

Trend: Chloroform concentrations have been measured since 1991 at the Minneapolis Public Library, Holman Field in St. Paul and near Koch Refinery in Pine Bend. At each of these long-term monitoring sites, plots of the data over time (e.g. Figure 2.1.4.1.3) show that the measured concentrations have remained nearly constant, although there appears to have been some tendency for a slight increase since measurements began.

Linear regression analyses of the trend over time were done with the data from each of the long-term monitoring sites. Analyses were done individually for each site. These analyses showed that the increase in chloroform concentrations over time were small (on the order of 0.009 µg/m³ for the period 1991-1998) but statistically significant, accounting for 1-2 percent of the variance in the data (r^2=0.01 to 0.02).

The time series of measurements at site 1240 in International Falls is shown in Figure 2.1.4.1.4. The chart shows that most measurements were above the health benchmark of 0.4 µg/m³. The slope of the linear regression was not significantly different from zero, suggesting that concentrations have not significantly increased or decreased over time.

Figure 2.1.4.1.3 Trend in chloroform measurements at the Minneapolis Library site

All measured values are plotted. The horizontal dashed line is at the chloroform health benchmark of 0.4 μg/m^3.

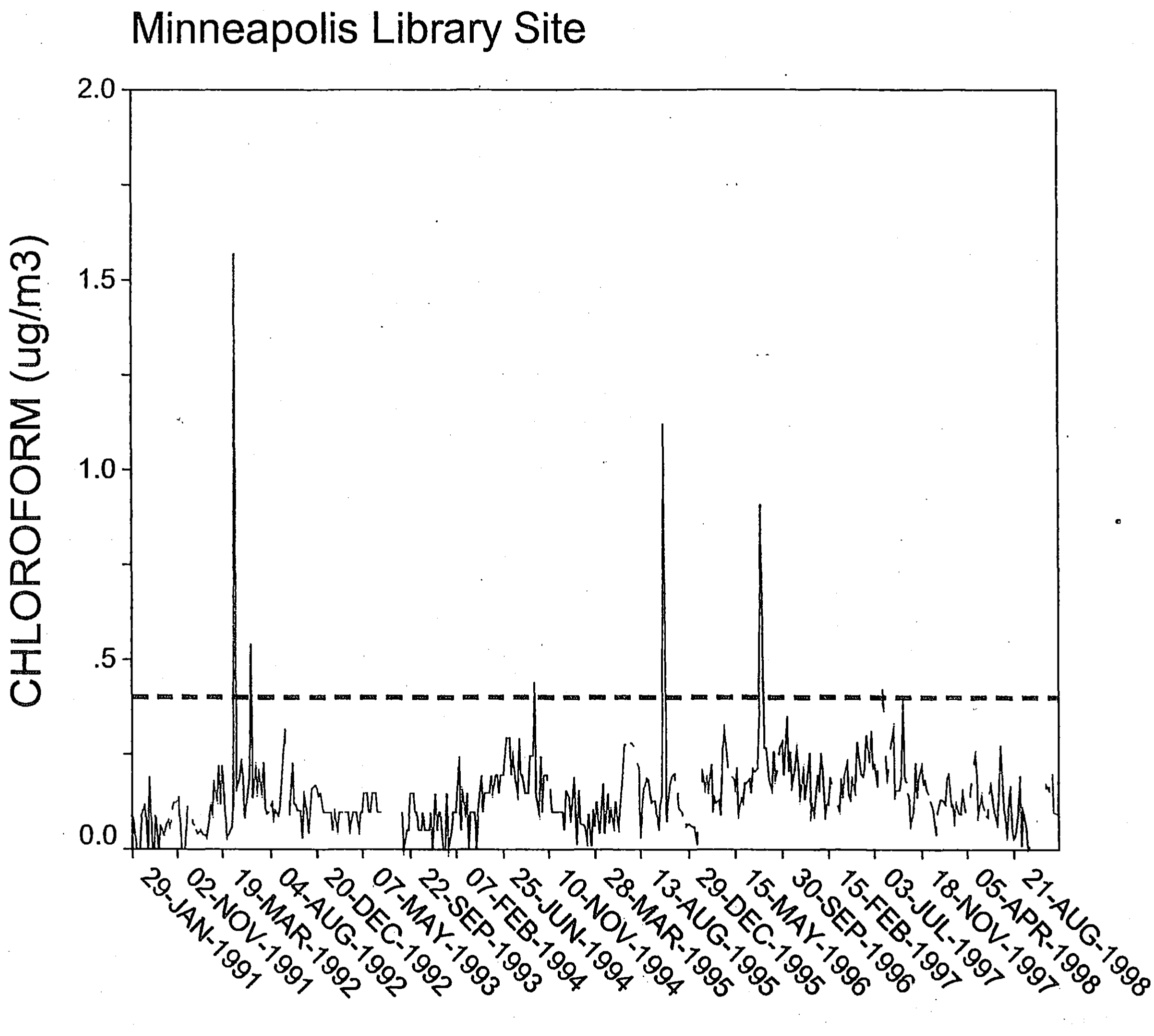
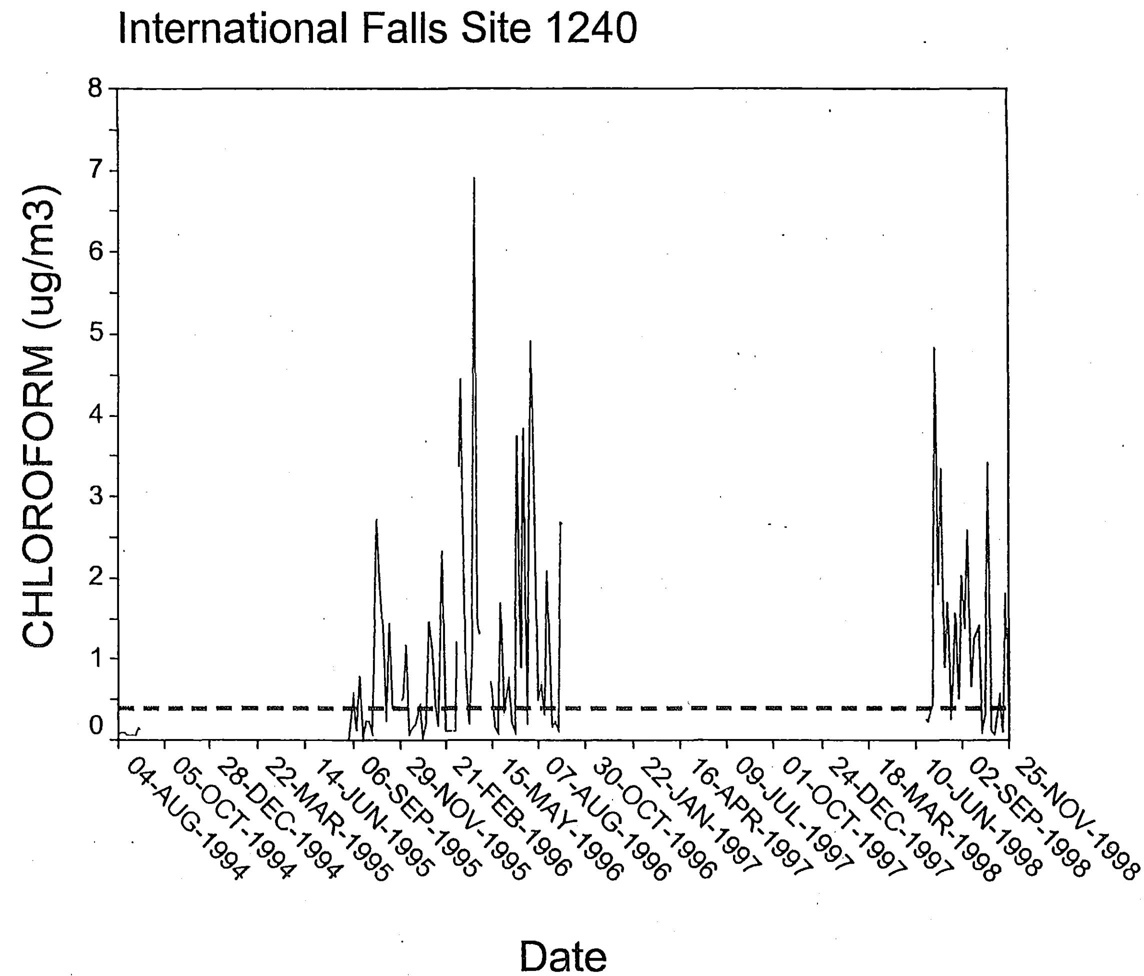


Figure 2.1.4.1.4 Trend in chloroform measurements at International Falls site 1240

The horizontal dashed line is at the chloroform health benchmark of 0.4 µg/m³.



2.1.4.2 What are the health effects of chloroform?

Acute inhalation exposure to chloroform in humans affects the central nervous system, causing dizziness, headache, fatigue and other effects. Exposure to very high levels of chloroform will cause death. Chronic exposure to chloroform by inhalation affects the liver, including hepatitis and jaundice, and the central nervous system, causing depression and irritability. It is not known whether chloroform causes harmful reproductive or developmental effects. However, animal studies have reported developmental effects, such as miscarriages, decreased fetal body weight and birth defects, and reproductive effects, such as abnormal sperm and decreased conception rates. Based on animal studies, the EPA has classified chloroform as a probable human carginogen. The MPCA uses as the health benchmark the cancer-risk level established by the EPA of 0.4 µg/m3, corresponding to an excess lifetime cancer risk of one in 100,000. California EPA Office of Environmental Health Hazard Assessment has adopted a cancer unit risk and an acute REL to protect for potential reproductive/developmental effects. A chronic noncancer REL of 300 $\mu g/m^3$ is being proposed to protect the alimentary system and against kidney effects.

Uses of Chloroform: In the United States, 93 percent of the chloroform manufactured is used to produce fluorocarbon-22. The remaining 7 percent is produced either for export or for miscellaneous uses. In the past, chloroform was used in various products, including fire extinguishers, dry cleaning spot removers, solvents, as a fumigant and as an anesthetic. However, chloroform has now been phased out in these products.

2.1.4.3 How are people exposed to chloroform?

Chloroform formation is the direct result of chlorination of drinking water or chlorination to eliminate pathogens in discharged wastes or other process waters. Hence, most people are being exposed to small amounts of chloroform in their drinking water and in beverages and food made with water that contains chloroform. The Agency for Toxic Substances and Disease Registry reports that concentrations of chloroform are greater in drinking water than in air. Chloroform can also be absorbed through skin contact with water (*e.g.*, while showering, bathing, cleaning, washing and swimming). Higher exposures to chloroform might occur to workers at drinking water-treatment plants, waste water-treatment plants, paper and pulp mills, chemical plants and factories that make or use chloroform, and from drinking well water contaminated with chloroform-containing leachate from a hazardous waste site.

2.1.4.4 What happens to chloroform in the atmosphere?

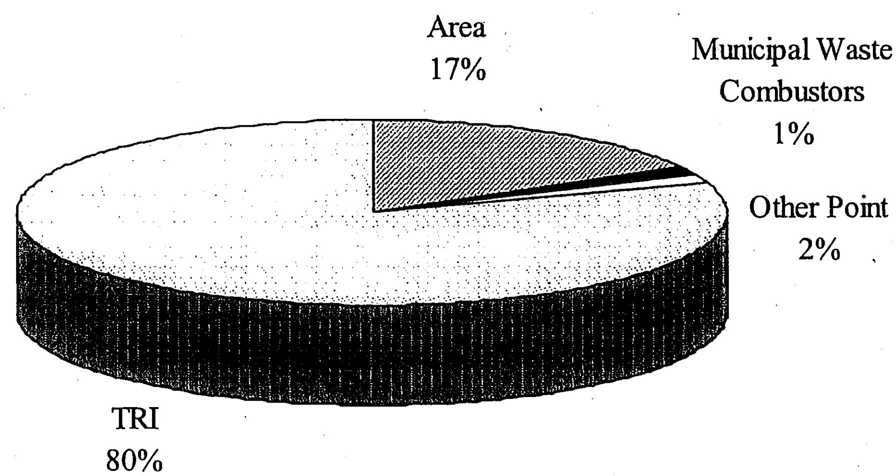
Based upon its vapor pressure, chloroform is expected to exist almost entirely in the vapor phase in the atmosphere. Because chloroform is significantly soluble in water, large amounts may be removed from the atmosphere by rain or snow; however, it is likely to reenter the atmosphere by volatilization. Chloroform is relatively nonreactive in the atmosphere, making long-range transport possible. Evidence supports this in that trace amounts of chloroform have been detected in samples from remote, often relatively pristine, areas of the world. Degradation of chloroform occurs primarily through reaction with photochemically-generated hydroxyl radicals. Transformation products are primarily phosgene, which is more toxic than the parent compound, and hydrogen chloride. The estimated atmospheric lifetime of chloroform is two to three months. Chloroform is more reactive in photochemical smog conditions where the half-life is estimated to be 11 days.

2.1.4.5. Which sources emit chloroform?

Emissions of Chloroform: Chloroform can be man-made or occur naturally. Most of the chloroform in the environment is from human activities. The primary sources of chloroform emissions are pulp and paper mills, pharmaceutical manufacturing plants, chemical manufacturing plants and chlorinated wastewater treatment plants. Minor sources of chloroform emissions include automobile exhaust, use of chloroform as a pesticide, burning of tobacco products treated with chlorinated pesticides, evaporation during shipping and transport of chloroform, decomposition of trichloroethylene, evaporation from chlorinated tap water during showering and from chlorinated swimming pool water, biological production of chloroform from marine algae, reaction of chlorinated pollutants with decayed vegetation, and burning of plastics.

Figure 2.1.4.5.1 shows Minnesota emissions of chloroform by source category. This figure is based on the 1990 emissions data from the EPA's CEP study. According to the CEP study, about 80 percent of chloroform emissions are attributed to TRI point sources, area sources are responsible for 17 percent, the contributions of other point sources and municipal waste combustors are 2 percent and 1 percent, respectively. The definition of each source category is shown in Appendix C.

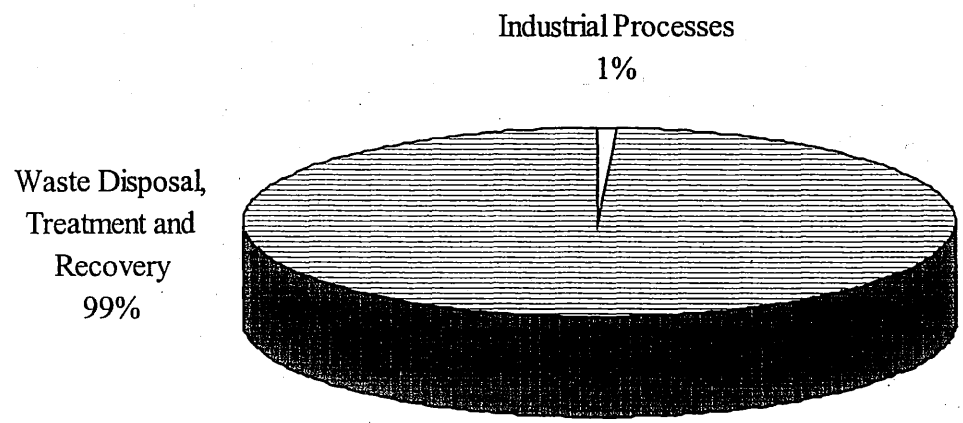
Figure 2.1.4.5.1 1990 Emissions of chloroform by source category
(Data are from the EPA CEP study for the State of Minnesota.)



Chloroform emissions by principal source category for Minnesota area sources are shown in Figure 2.1.4.5.2, where data are from the EPA's CEP study for 1990. More than 99 percent of area source emissions are from waste disposal, treatment and recovery; industrial processes contribute the reminder.

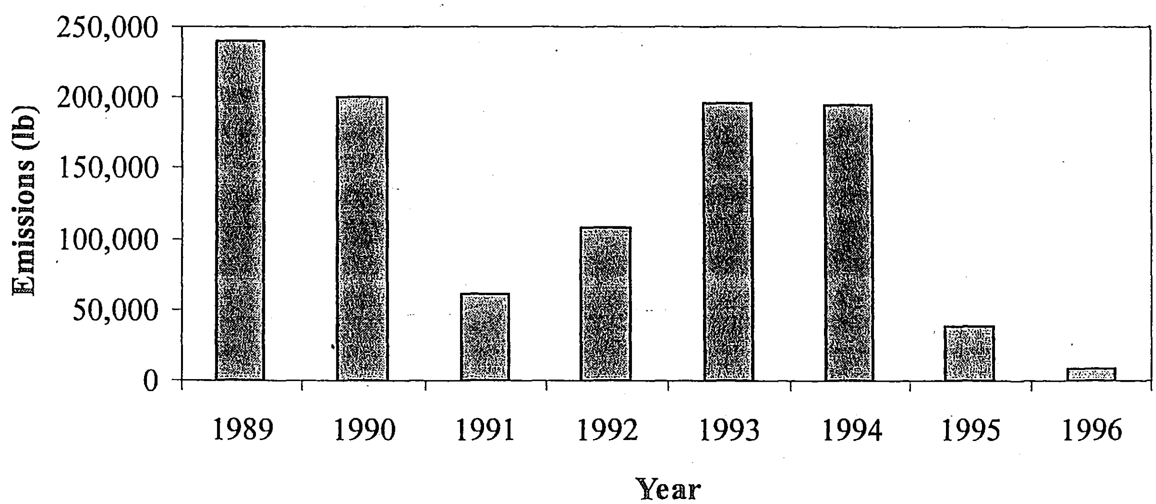
Figure 2.1.4.5.2 1990 Chloroform emissions by principal source category for area sources

(Data are from the EPA CEP study for the States of Minnesota.)



The 1989-to-1996 trend in chloroform emissions for the Minnesota TRI point sources is shown in Figure 2.1.4.5.3. Chloroform emissions dropped significantly from 1988 to 1991, then increased from 1991 to 1993. Reported emissions in 1994 were almost the same as those in 1993. After 1994, chloroform emissions declined rapidly, from 194,100 lb. in 1994 to 8,600 lb. in 1996. According to the 1990 and 1996 TRI databases, pulp and paper mills are the only sources reporting chloroform emissions in Minnesota.

Figure 2.1.4.5.3 Trend in chloroform emissions based on TRI point source data



2.1.4.6 Chloroform summary

Ambient air monitoring data show that chloroform concentrations are below health benchmarks at all sites in Minnesota except one. The mean and median chloroform concentrations at the customs station site in International Falls exceeded the health benchmark. This site is adjacent to the Boise Cascade paper mill and across the river from the Stone Consolidated paper mill in Fort Francis, Ontario. It would appear that emissions from one or both of these facilities is causing the elevated chloroform concentrations at the customs station monitoring site. Chloroform concentrations at a second International Falls monitoring site about one mile southwest of the customs station are below the health benchmark.

The targets for chronic chloroform toxicity are the liver and the central nervous system. Chloroform may also be involved in reproductive and developmental disorders. It is classified as a probable human carcinogen.

The vast majority of chloroform emissions (80 percent) come from point sources. The only point sources reporting chloroform emissions in Minnesota under the Toxics Release Inventory are pulp and paper mills.

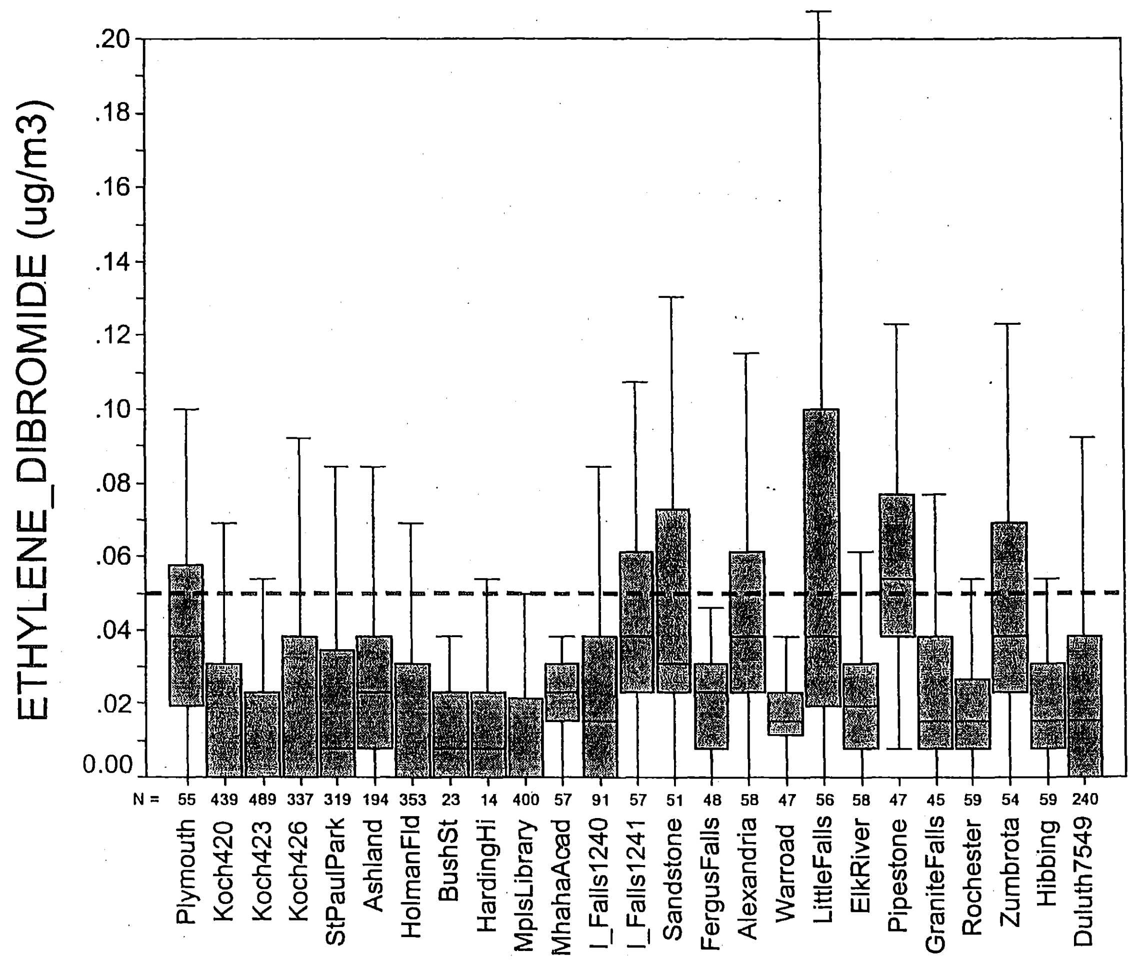
2.1.5 Ethylene dibromide

Ethylene dibromide (CAS 106-93-4), BrCH2CH2Br, is a colorless, nonflammable liquid with a chloroform-like odor. Ethylene dibromide may persist for several months in the atmosphere and longer in soil and water.

2.1.5.1 What information indicates ethylene dibromide is a concern?

Ambient data: A summary of the monitoring data is given in Table 5 of Appendix A and Figure 2.1.5.1.1, which shows a boxplot with median and 25th and 75th percentile values for each site. The data show that the mean and median concentrations exceeded the ethylene dibromide health benchmark of 0.05 $\mu g/m^3$ at the Pipestone site, but were below the health benchmark at all other sites. In contrast, the mean ethylene dibromide concentrations (over all monitoring times, see Table 5 of Appendix A) exceeded the health benchmark at Koch sites 423 and 426, Sandstone, Alexandria, Little Falls, Pipestone and Zumbrota. Individual yearly means exceeded the health benchmark in Fergus Falls (1997), International Falls sites 1240 (1994) and 1241 (1996), Minneapolis Library (1991), Holman Field (1996 and 1997), Ashland (1996 and 1997), St. Paul Park (1997), Koch site 420 (1991, 1996 and 1997), and Plymouth (1996). The boxplot (Figure 2.1.5.1.1) shows that the concentrations appear to be higher at some rural sites. In addition, sites with longer periods of record appear to have lower concentrations. This might suggest that concentrations have increased over time. This will be discussed in the section on trends below.

Figure 2.1.5.1.1 Boxplot showing ethylene dibromide concentrations by site
The center line within each box represents the median for the site. The box itself encompasses the 25th percentile to the 75th percentile. The bars at each end of the box represent the highest and lowest values that are not considered outliers. The horizontal dotted line is located at the ethylene dibromide health benchmark (0.05 µg/m³).



<u>Modeling data</u>: The EPA Cumulative Exposure Project (CEP) modeling analysis did not predict any ethylene dibromide in Minnesota. That study indicated that concentrations throughout the state would approximate "background" concentrations found in monitoring data from remote sites (*i.e.*, 0.0077 µg/m³). Table 2.1.5.1.1. gives a comparison of the concentrations of ethylene dibromide measured by the MPCA compared to the modeled values from the CEP. On average, measured mean values were 0.03 µg/m³ higher than the CEP estimates. Color maps of ethylene dibromide concentrations in Minnesota can be viewed at *http://www.pca.state.mn.us/air/at-cep.html.*

Table 2.1.5.1.1 MPCA-measured ethylene dibromide concentrations (µg/m³) versus concentrations estimated in the U.S. EPA Cumulative Exposure Project model

Site No.	Site Name	Monitored mean value	EPA CEP modeled value	Difference (model - monitor)
260	Plymouth	0.0493	0.00769	-0.0416
420	Koch420	0.0426	0.00769	-0.0349
423	Koch423	0.0771	0.00769	-0.0694
426	Koch426	0.0649	0.00769	-0.0572
436	StPaulPark	0.0239	0.00769	-0.0162
438	Ashland	0.0337	0.00769	-0.0260
816	HolmanFld	0.0272	0.00769	-0.0195
820	BushSt	0.0207	0.00769	-0.0130
871	HardingHi	0.0154	0.00769	-0.0077
945	MplsLibrary	0.0243	0.00769	-0.0166
958	MhahaAcad	0.0267	0.00769	-0.0190
1240	I_Falls1240	0.0337	0.00769	-0.0260
1241	I_Falls1241	0.0445	0.00769	-0.0368
1400	Sandstone	0.0705	0.00769	-0.0628
2005	FergusFalls	0.0247	0.00769	-0.0170
2010	Alexandria	0.0554	0.00769	-0.0477
2401	Warroad	0.0196	0.00769	-0.0119
3049	LittleFalls	0.0698	0.00769	-0.0621
3050	ElkRiver	0.0261	0.00769	-0.0184
4002	Pipestone	0.0695	0.00769	-0.0618
4003	GraniteFalls	0.0242	0.00769	-0.0165
5008	Rochester	0.0203	0.00769	-0.0126
5356	Zumbrota	0.0532	0.00769	-0.0455
7014	Hibbing	0.0238	0.00769	-0.0161
7549	Duluth7549	0.0303	0.00769	-0.0226

<u>**Trend:**</u> Ethylene dibromide concentrations have been measured since 1991 at the Minneapolis Public Library, Holman Field in St. Paul and near Koch Refinery in Pine Bend. At each of these long-term monitoring sites, plots of the data over time (*e.g.*, Figure 2.1.5.1.2) show there were some high concentrations measured early in the record. In addition, the early years of monitoring (before 1996) show the presence of many low or nondetectable values. Later data seem to show an improved capability to detect low concentrations, which may be a result of a changeover to new cryogenic focusing equipment in the laboratory. The result of better detection of low values in recent data is that mean values may show a slight bias toward lower values in the early data. Figure 2.1.5.1.3 shows a time series of measurements from the Pipestone site.

Figure 2.1.5.1.2 Trend in ethylene dibromide measurements at the Holman Field site

All measured values are plotted. The horizontal dashed line is at the ethylene dibromide health benchmark of 0.05 µg/m^3.

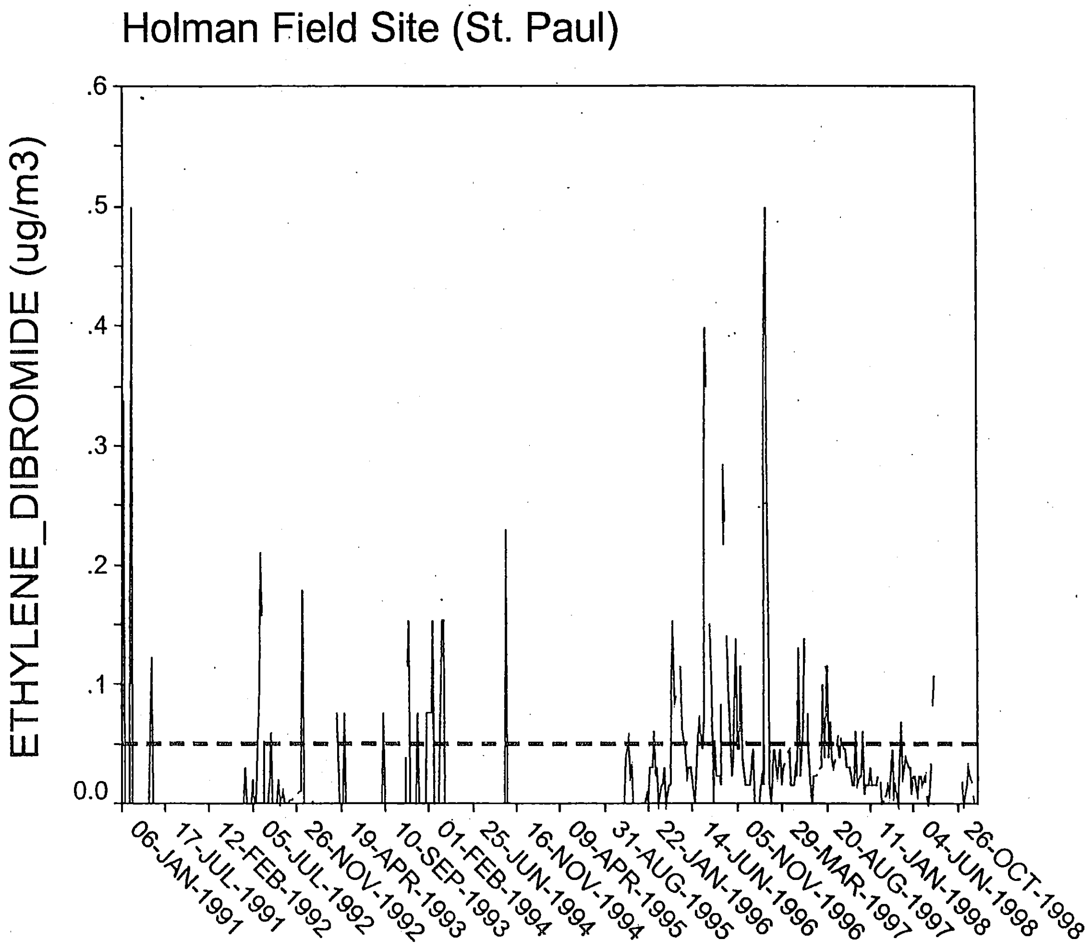
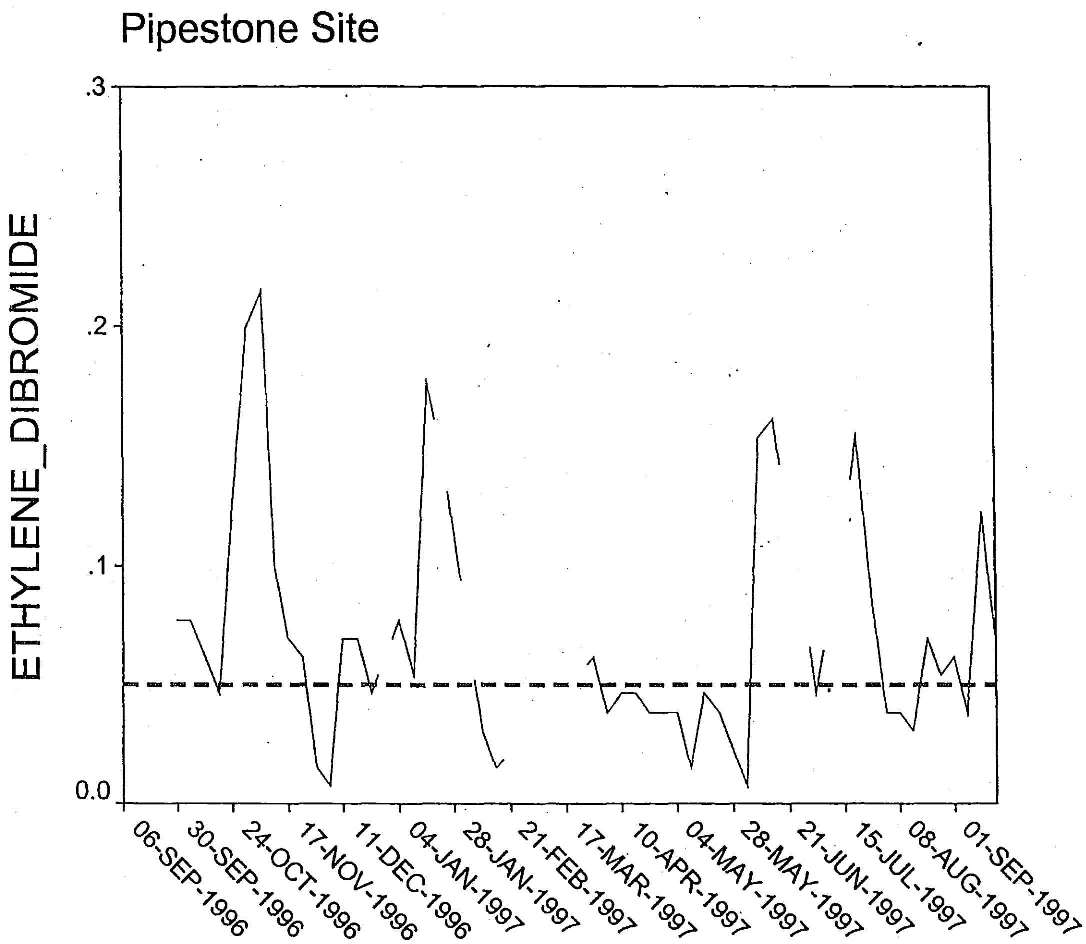


Figure 2.1.5.1.3 Trend in ethylene dibromide measurements (µg/m³) at the Pipestone site

The horizontal dashed line is at the ethylene dibromide health benchmark of 0.05 µg/m³.



2.1.5.2 What are the health effects of ethylene dibromide?

Ethylene dibromide is extremely toxic to humans, and exposure to high concentrations through inhalation, ingestion or skin contact can result in death. Ethylene dibromide is a severe skin irritant and is capable of causing chemical burns and blistering at high exposures. Ethylene dibromide is a respiratory tract, eye and skin irritant. Inhalation can produce delayed-onset pulmonary edema and lesions as well as central nervous system effects. Long-term exposure to ethylene dibromide is toxic to the liver, kidney and the testes, regardless of route of exposure. Reproductive and developmental effects from ethylene dibromide exposure have been demonstrated in animal studies in which short- and long-term exposure resulted in decreased fertility or abnormal sperm. Pregnant animals sick from exposure to ethylene dibromide have borne offspring with birth defects. Male workers exposed to ethylene dibromide have had impaired reproduction due to damaged sperm cells in the testicles. Long-term exposure to ethylene dibromide increases the incidence of a variety of tumors in both female and male rats.

The EPA classifies ethylene dibromide as a probable human carcinogen. The MPCA uses the draft HRV established by the Minnesota Department of Health as the health benchmark for ethylene dibromide. This value is 0.05 $\mu g/m^3$ and corresponds to an excess lifetime cancer risk of one in 100,000. California EPA Office of Environmental Health Hazard Assessment has adopted a cancer unit risk.

Uses of ethylene dibromide: The primary use of ethylene dibromide is as a scavenger for lead in anti-knock gasoline mixtures in aviation fuel. Other uses are as a solvent for resins, gums and waxes; in waterproofing preparations; as a chemical intermediate in the synthesis of dyes and pharmaceuticals; and as an insecticide. Ethylene dibromide was used as a fumigant for soil, grains and fruits, but the EPA banned these uses in 1984.

2.1.5.3 How are people exposed to ethylene dibromide?

Historically, past releases to the atmosphere were primarily due to fugitive emissions of leaded gasolines, automobile exhaust and the former use of the compound as a fumigant. Before 1984, ethylene dibromide was used as a pesticide in citrus, vegetable and grain crops, and a common exposure was through consumption of foods that contained residues of this pesticide. Since the EPA has banned ethylene dibromide's use as a soil and grain fumigant, exposure to the general population is primarily from breathing air and drinking contaminated water, particularly groundwater. Persons with potentially higher exposures than the general population include those living near industries that produce or use ethylene dibromide. Higher exposures could occur from contact with contaminated hazardous waste sites, particularly in soil and ground water.

2.1.5.4 What happens to ethylene dibromide in the atmosphere?

Ethylene dibromide has a high vapor pressure, high water solubility and low sorption potential. Volatilization is the most important removal process for ethylene dibromide released to surface waters. These properties suggest that ethylene dibromide readily partitions to the atmosphere following release to surface waters and soils. Once in the atmosphere, direct photolysis of ethylene dibromide is not likely to occur. Degradation of ethylene dibromide occurs mainly through reaction with hydroxyl radicals in the atmosphere. Transformation products include formyl bromide, $CHOCH_2Br$ and $CBr(O)CH_2Br$. The estimated atmospheric lifetime of ethylene dibromide is 58 days.

2.1.5.5 Which sources emit ethylene dibromide?

Emissions of Ethylene Dibromide: Ethylene dibromide is evaporated from the use, storage and transport of leaded gasoline. It is also identified in exhaust of mobile sources using leaded gasoline. Ethylene dibromide was emitted when it was used as a fumigant for soil, grains and fruits; from wastewater and from its other uses. However, the EPA's CEP study estimated zero emissions for ethylene dibromide in Minnesota for 1990. MPCA staff are working on a comprehensive emission inventory for point, area and mobile sources for 1996. This emission inventory has identified ethylene dibromide emissions from the above sources, but the emission estimates are in a quality-control and quality-assurance process at this time. Further analysis will be performed after the emission inventory is completed.

2.1.5.6 Ethylene dibromide summary

Ambient air measurements of ethylene dibromide concentrations are mostly below health benchmark values. However, the measured values were higher at rural sites, and in Pipestone, Minnesota, the mean and median ethylene dibromide concentrations exceeded health benchmarks.

Ethylene dibromide has been used in petroleum production and may be emitted from such processes. It was also used as a fumigant for soil, grains and fruits, although the EPA banned these agricultural uses in the 1980s. It is possible that some stockpiled ethylene dibromide is still being used in agriculture. The reason for the high concentrations in Pipestone and other rural areas is uncertain at present.

Ethylene dibromide is very toxic and irritating to the skin, eyes and respiratory tract. It has been implicated in chronic toxicity to the liver, kidneys and testes, and in reproductive and developmental abnormalities. The EPA has classified ethylene dibromide as a probable human carcinogen.

2.1.6 1,3-butadiene

1,3-butadiene (CAS 106-99-0), C4H6, is a colorless, flammable gas with a mild, gasoline-like odor. It evaporates very easily and moves quickly from water or soil to air. It also breaks down quickly in air by sunlight.

2.1.6.1 What information indicates 1,3-butadiene is a concern?

Ambient data: The MPCA currently has no ambient monitoring data for 1,3-butadiene, but is evaluating monitoring methods and plans to conduct monitoring for 1,3-butadiene in the future.

Modeling data: According to the CEP, which is based on 1990 emissions data, the average modeled concentration of 1,3-butadiene exceeds the health benchmark (0.04 $\mu g/m^3$) in areas of higher population density. Figures 2.1.6.1.1 and 2.1.6.1.2 show those areas that exceed the benchmark according to the model.

Trend: Since there are no ambient data, the ambient concentration trend cannot be analyzed.

Figure 2.1.6.1.1 Modeling results for 1,3-butadiene
This map can be seen in color at http://www.pca.state.mn.us/air/at-cep.html.

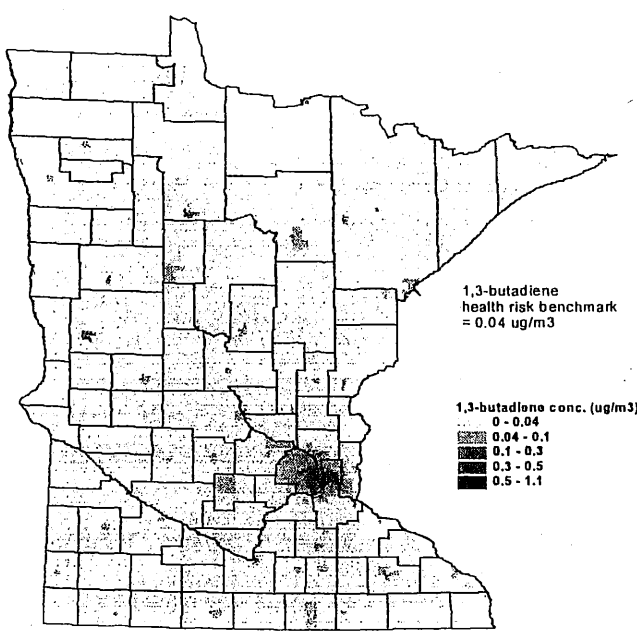
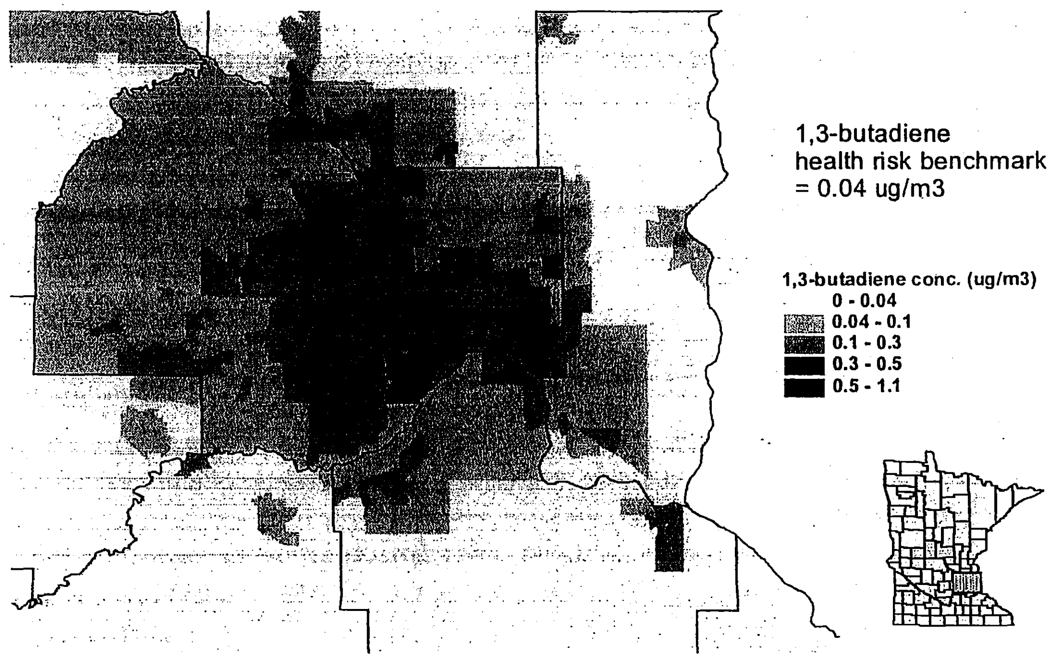


Figure 2.1.6.1.2 Modeling results for 1,3-butadiene
This map can be seen in color at http://www.pca.state.mn.us/air/at-cep.html.



2.1.6.2 What are the health effects of 1,3-butadiene?

Short-term exposure to low levels of 1,3-butadiene by inhalation may result in irritation of the eyes, nose and throat. Short-term exposure to higher levels of 1,3-butadiene affects the central nervous system, causing blurred vision, fatigue, headache and possibly unconsciousness. Low-level and long-term exposure to 1,3-butadiene may cause heart and lung damage in humans, but this effect has not been fully studied. Animal studies show that inhalation of 1,3-butadiene can cause kidney and liver disease, lung damage and birth defects. The EPA has classified 1,3-butadiene as a probable human carcinogen. However, review is currently underway at the EPA that would reclassify this compound as a known human carcinogen based on evidence of leukemia in humans. Furthermore, sufficient data exist on reproductive and developmental effects in animals for the EPA to propose a reference concentration for 1,3-butadiene. The MPCA uses the draft HRV established by the Minnesota Department of Health as the health benchmark for 1,3-butadiene. This value is 0.04 $\mu g/m^3$ and corresponds to an excess lifetime cancer risk of one in 100,000. California EPA Office of Environmental Health Hazard Assessment has adopted a cancer unit risk of 1.7×10^{-4} for 1,3-butadiene, which corresponds to 0.06 $\mu g/m^3$ at one-in-100,000 risk level.

Uses of 1,3-butadiene: The largest use of 1,3-butadiene in the United States is in the production of synthetic rubber for use in vehicle tires. It is also used in copolymers, including acrylics.

2.1.6.3 How are people exposed to 1,3-butadiene?

Most of the 1,3-butadiene that people are exposed to is due to direct inhalation of contaminated air. 1,3-butadiene is mostly present in suburban/urban air due to the exhaust of cars and trucks, and the smoke from wood fires and cigarettes. The amount of 1,3-butadiene in the air may be much higher near high-traffic areas, oil refineries, chemical manufacturing plants and plastic and rubber factories, where this chemical is made or used. Persons who live near, or work at, these types of facilities or who live near high-traffic areas may have higher exposures than the general population. While 1,3-butadiene has been found in drinking water and in plastic and rubber food containers, it is either at very low or nondetectable concentrations in the water and food samples.

2.1.6.4 What happens to 1,3-butadiene in the atmosphere?

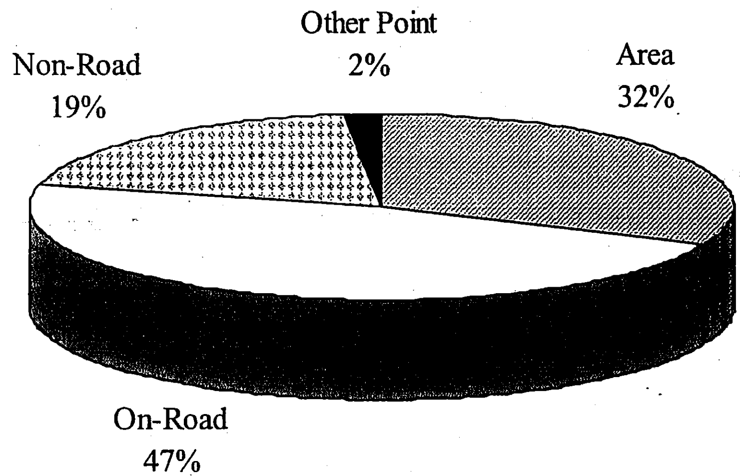
The structure of 1,3-butadiene contains two double bonds that make it react rapidly with hydroxyl radicals, ozone and nitrate radicals. Although it breaks down quickly in the atmosphere, 1,3-butadiene transforms into two species which are themselves toxic — formaldehyde and acrolein. While 1,3-butadiene is not expected to significantly contribute to secondary production of formaldehyde, it can be considered to be the major precursor species for atmospheric formation of acrolein. At night, when concentrations of hydroxyl radicals are low, 1,3-butadiene reacts with NO_3, producing much less acrolein and primarily nitrates. Due to its low solubility and rapid reaction with hydroxyl radicals, rain is not an important removal process of 1,3-butadiene from the atmosphere. The residence times of 1,3-butadiene depend upon the season, time of day and cloud conditions. 1,3-butadiene is not expected to have day-to-day carryover during clear-sky, summer conditions. However, day-to-day carryover is possible under cloudy, nighttime conditions, and carryover of 1,3-butadiene is expected to be significant during cloudy conditions in winter.

2.1.6.5 Which sources emit 1,3-butadiene?

Emissions of 1,3-butadiene: 1,3-butadiene emissions are primarily from incomplete combustion of gasoline and diesel fuels. According to California estimates, mobile sources contribute about 96 percent of the total emissions for quantified sources. Other sources of 1,3-butadiene include vehicle tire wear, petroleum refining, plastic or synthetic rubber production, chemical manufacturing and secondary metal production. 1,3-butadiene emissions are also released from biomass burning, including sewage treatment, wood combustion, agricultural burning and forest fires.

Figure 2.1.6.5.1 shows emissions of 1,3-butadiene by source category. This figure is based on 1990 national emissions data from the EPA's CEP study. According to that study, approximately two-thirds of 1,3-butadiene emissions are attributed to mobile sources. Area sources contribute 32 percent of 1,3-butadiene emissions, and the contribution of other point sources is only 2 percent. In Minnesota, on-road motor vehicles contribute about 71 percent of mobile source 1,3-butadiene emissions, with the remainder attributed to nonroad mobile sources. The definition of each source category is shown in Appendix C.

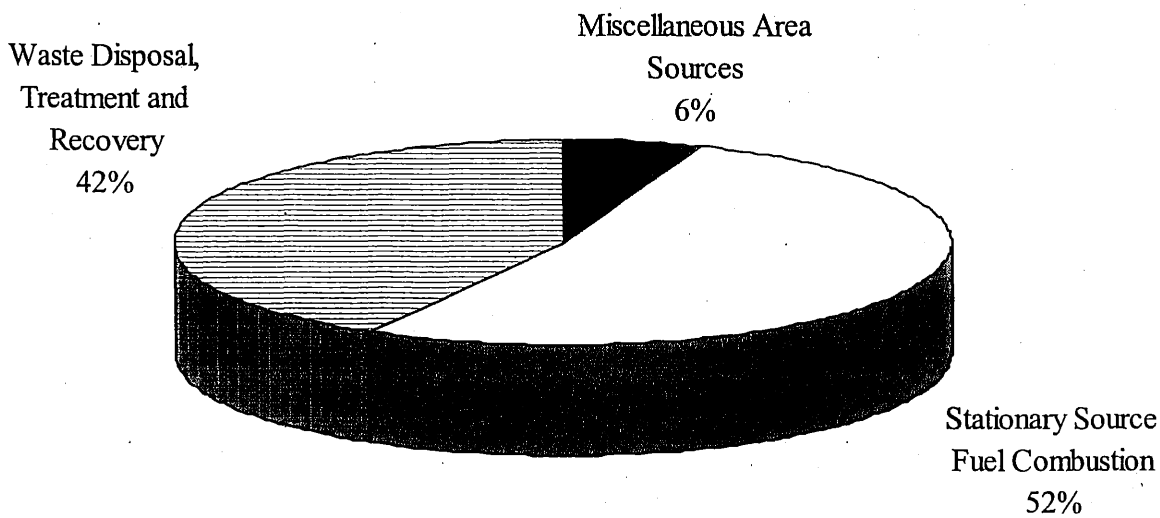
Figure 2.1.6.5.1 1990 emissions of 1,3-butadiene by source category
(Data are from the EPA CEP study for the State of Minnesota.)



1,3-butadiene emissions by principal source category for Minnesota area sources are shown in Figure 2.1.6.5.2, based on 1990 emissions data from the EPA's CEP study. Stationary source fuel combustion contributes 52 percent to 1,3-butadiene emissions. Waste disposal, treatment and recovery is responsible for 42 percent of area source emissions.

Figure 2.1.6.5.2 1990 1,3-butadiene emissions by principal source category for area sources

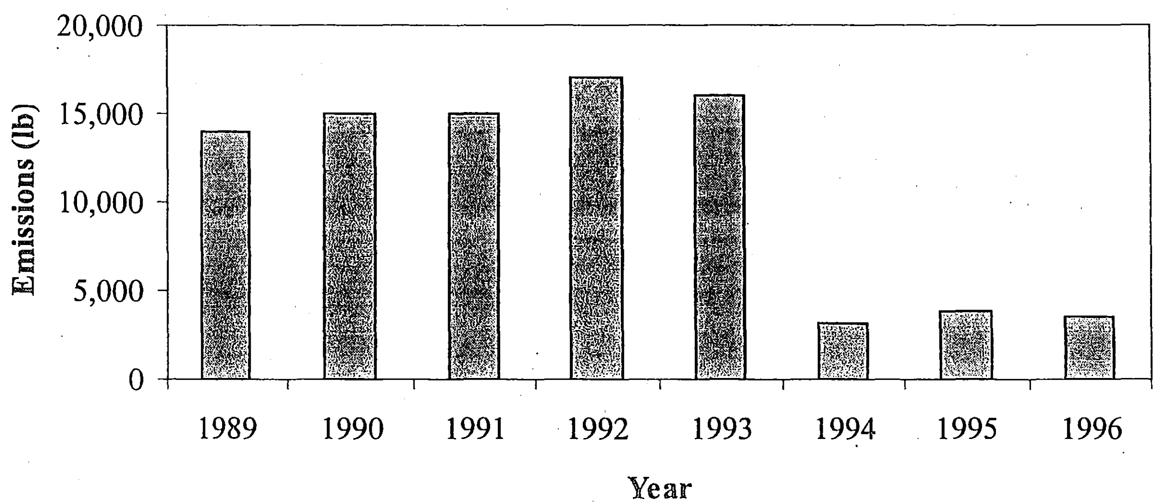
(Data are from the EPA CEP study for the State of Minnesota.)



Petroleum refineries are the only source category in Minnesota which reported 1,3-butadiene to the TRI in both 1990 and 1996.

The 1989-to-1996 trend in 1,3-butadiene emissions for the Minnesota TRI point sources is shown in Figure 2.1.6.5.3. 1,3-butadiene emissions were relatively stable from 1989 to 1993. There was a big drop of reported 1,3-butadiene emissions between 1993 and 1994. Emissions again tend to be stable after 1994.

Figure 2.1.6.5.3 Trend in 1,3-butadiene emissions based on TRI point source data



2.1.6.6 1,3-butadiene summary

Model predictions from the EPA Cumulative Exposure Project show 1,3-butadiene concentrations exceeding the health benchmark over much of the Twin Cities metropolitan area, as well as in other, smaller population centers throughout the state. Due to this finding, the MPCA has started developing the capacity to monitor 1,3-butadiene.

In acute exposures, 1,3-butadiene irritates the eyes, respiratory system and central nervous system. Chronic exposures may adversely affect the kidneys, lungs, liver and heart. 1,3-butadiene has been implicated in reproductive abnormalities. Although it is now classified as a probable human carcinogen, it may be reclassified as a known human carcinogen. Approximately 66 percent of 1,3-butadiene emissions are attributed to mobile sources and result from fuel combustion.

2.1.7 Acrolein

Acrolein (CAS 107-02-8), CH2CHCHO, is a clear, yellowish liquid with a piercing, disagreeable odor. It reacts to heat, light and air.

2.1.7.1 What information indicates acrolein is a concern?

Ambient data: The MPCA currently has no ambient monitoring data for acrolein.

Modeling data: According to the EPA CEP study, which is based on 1990 emissions data, average modeled concentration of acrolein exceeds the health benchmark (0.02 $\mu g/m^3$) in areas of higher population density. Figures 2.1.7.1.1 and 2.1.7.1.2 show those areas that exceed the benchmark according to the model.

Trend: Since there are no ambient data, the ambient concentration trend cannot be analyzed.

Figure 2.1.7.1.1 Modeling results for acrolein
This map can be seen in color at http://www.pca.state.mn.us/air/at-cep.html.

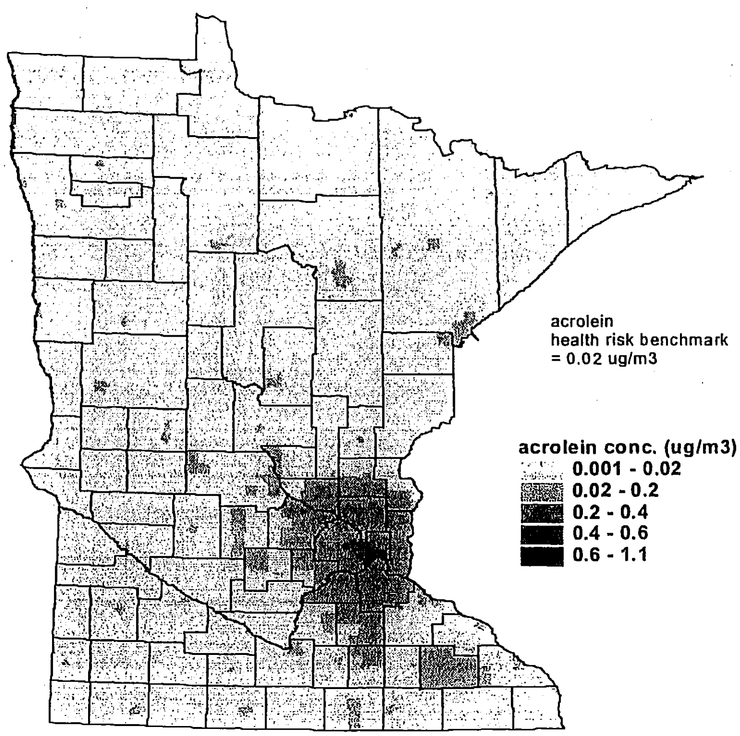
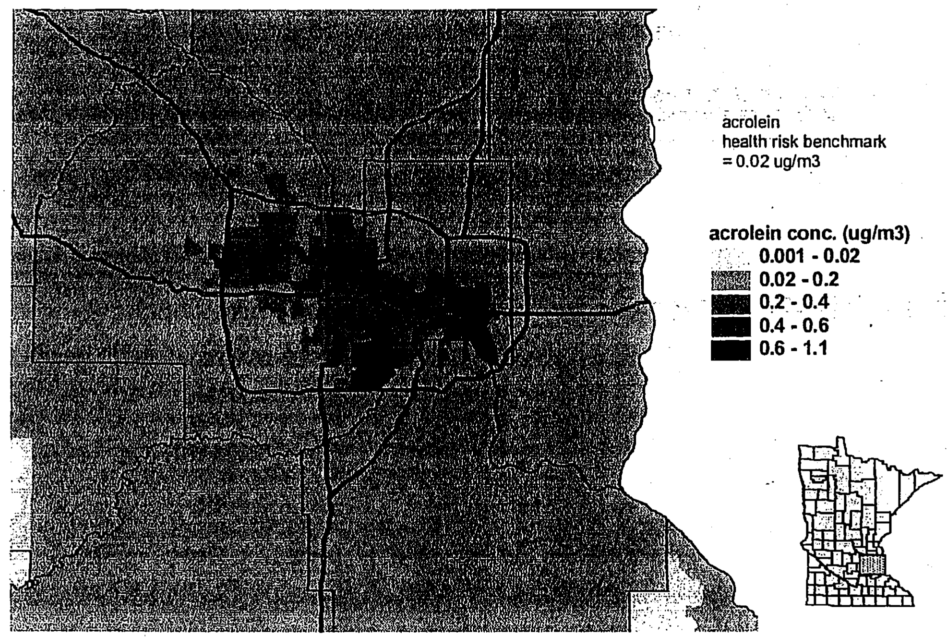


Figure 2.1.7.1.2 Modeling results for acrolein
This map can be seen in color at http://www.pca.state.mn.us/air/at-cep.html.



2.1.7.2 What are the health effects of acrolein?

Acrolein causes intense irritation to the eyes and mucous membranes of the respiratory tract and is extremely toxic to humans. Prolonged or repeated contact may result in skin burns and dermatitis. Short-term and long-term inhalation exposure will cause congestion in the upper respiratory tract and irritate the eyes, nose, throat and respiratory system. Acrolein is considered to have high acute toxicity based on short-term animal tests. Hence, short-term exposure to high levels of acrolein in humans may result in death. The EPA rates acrolein as a "high-concern" pollutant based on its acute and chronic toxicity. There is limited evidence of carcinogenicity in animals; however, acrolein is structurally similar to substances possibly carcinogenic to humans, and one of its metabolites has potential carcinogenicity. EPA classifies acrolein as a possible human carcinogen. The MPCA uses the reference concentration (RfC) established by the EPA as the health benchmark for acrolein. The RfC is set at 0.02 $\mu g/m^3$ to protect for chronic upper respiratory effects. California EPA Office of Environmental Health Hazard Assessment has adopted an acute REL for acrolein to protect for potential eye irritation.

Uses of Acrolein: Acrolein is used as an intermediate to make other organic chemicals, such as glycerine, methionine and glutaraldehyde. Acrolein is also used as a pesticide for control of fungi and bacteria in secondary oil recovery injection systems. It is also used as a herbicide to control algae and water-borne weeds in lakes, ponds, reservoirs and other aquatic areas.

2.1.7.3 How are people exposed to acrolein?

Acrolein can enter the human body through inhalation of vapor, absorption through the skin, ingestion or eye contact. Exposure to acrolein is mainly due to breathing contaminated air. Acrolein is a product of burning gasoline, coal, wood and tobacco. Persons with potentially higher exposure to acrolein than the general population would include those who come in frequent or prolonged contact with tobacco or marijuana smoke, those who are occupationally exposed, and those who live or work near high-traffic areas or downwind from an industrial point source. Acrolein forms during the heating of fats. It can be found in foods, such as roasted coffee, fried foods and cooking oils. Consumption of these types of food is the cause of widespread exposure to small amounts of acrolein. Acrolein is not commonly found in surface or drinking water.

2.1.7.4 What happens to acrolein in the atmosphere?

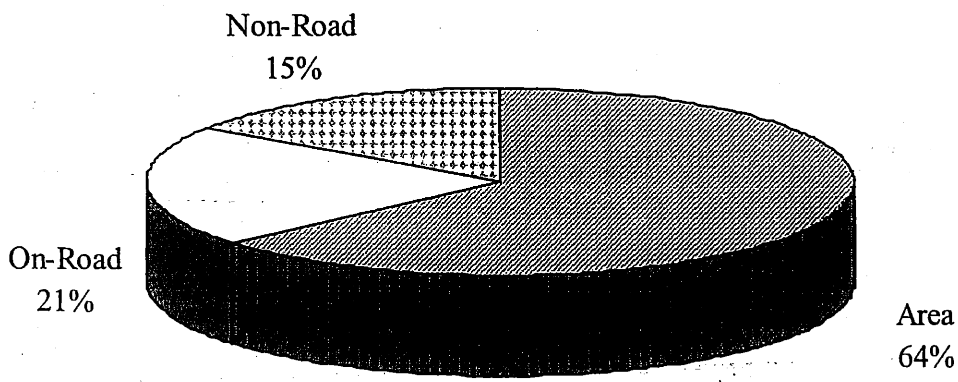
In addition to being emitted directly into the atmosphere, acrolein is also a photooxidation product of various hydrocarbon pollutants emitted into the air. Two such pollutants are propylene and 1,3-butadiene. Atmospheric transport of acrolein is expected to be limited, since acrolein is relatively unstable in the atmosphere. With its relatively high vapor pressure, it is expected that acrolein will not partition from the vapor phase into the particulate phase. The dominant removal mechanism for acrolein in ambient air is predicted to be the reaction with photochemically generated hydroxyl radicals. The estimated lifetime of acrolein in the atmosphere is 10 to 17 hours. Transformation products include formaldehyde, glyoxal, glyoxylic acid, formic acid and carbon dioxide, which are all toxics except for carbon dioxide, a primary greenhouse gas.

2.1.7.5 Which sources emit acrolein?

Emissions of Acrolein: Acrolein is emitted directly from sources where it is manufactured and processed. Acrolein has been identified in motor vehicle exhaust, paper mills, sewage treatment, asphalt concrete, sugar beet processing, secondary metal production and organic chemical manufacturing. It is also found in fossil fuel combustion, tobacco smoke and forest fire emissions. Acrolein can be photooxidated from various hydrocarbons, including 1,3-butadiene.

Figure 2.1.7.5.1 shows emissions of acrolein by source category in Minnesota. This figure is based on the 1990 emission data from the EPA's CEP study. According to the study, the primary sources of acrolein emissions are area sources, contributing approximately 64 percent of acrolein emissions in the state. Mobile sources contribute the remaining 36 percent, and the contribution of point sources is less that 1 percent (not shown in the figure). The definition of each source category is shown in Appendix C.

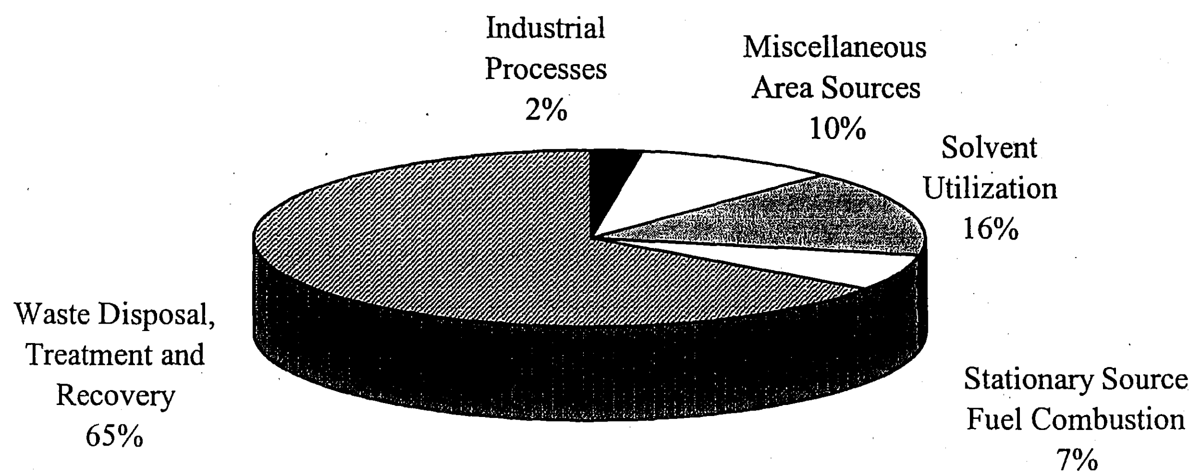
Figure 2.1.7.5.1 1990 emissions of acrolein by source category
(Data are from the EPA CEP study for the State of Minnesota.)



Acrolein emissions by principal source category for Minnesota area sources are shown in Figure 2.1.7.5.2, where the data are from the EPA's CEP study for 1990. Waste disposal, treatment and recovery are responsible for the majority (65 percent) of area source acrolein emissions. Solvent utilization and miscellaneous area sources contribute 16 percent and 10 percent of acrolein emissions from area sources, respectively. Other contributors are stationary source fuel combustion and industrial processes. However, the Minnesota air toxics emission inventory does not show high emissions from waste disposal, treatment and recovery. The CEP study used generic speciation profiles for the emission estimation. These profiles may not represent Minnesota emissions. Therefore, work is needed to identify emission sources of acrolein when more information becomes available.

Figure 2.1.7.5.2 1990 acrolein emissions by principal source category for area sources

(Data from the EPA CEP study for the State of Minnesota)



2.1.7.6 Acrolein summary

Model predictions from the EPA Cumulative Exposure Project show acrolein concentrations exceeding the health benchmark over much of the Twin Cities metropolitan area, as well as in other smaller population centers. The MPCA does not currently monitor acrolein concentrations in the ambient air, but is evaluating the feasibility of monitoring in the future.

In acute exposures, acrolein is irritating to the eyes, nose, throat, and respiratory system. Primary emissions of acrolein come mainly from area sources (64 percent) and mobile sources (36 percent). It is a product of combustion and also may be emitted from manufacturing processes. Acrolein may also be formed in the atmosphere (secondary formation) in chemical reactions involving precursor chemicals such as 1,3-butadiene and other hydrocarbons.

2.1.8 Arsenic

Arsenic (CAS 7440-38-2), As, is a gray metal. Arsenic is usually combined with one or more other elements. The majority of arsenic in air exists as inorganic arsenic particulate matter smaller than 2.5 micrometers that are highly respirable. When arsenic is combined with oxygen, chlorine and sulfur, it is referred to as "inorganic arsenic."

2.1.8.1 What information indicates arsenic is a concern?

Ambient data: Figure 2.1.8.1.1 shows a boxplot of arsenic concentrations with median and 25th and 75th percentile values for each site. The data show that the vast majority of the measurements fall below the lower detection limit (LDL = 0.0053 μg/m^3) for arsenic. Specifically, of 717 valid measurements, only 27 (or 3.8 percent) were higher than the LDL (see Table 6 of Appendix A and Table 2.1.8.1.1 below). Arsenic (and other metals) are measured using energy dispersive X-ray fluorescence analysis of PM_{10} samples collected according to the federal reference method. This procedure is used as a screening method to determine whether problems with specific elements might exist. The fact that the LDL exceeds the health benchmark, together with the fact that a considerable number of measurements appear to exceed the health benchmark, but only a few exceed the quantifiable level, suggest that the measurement technique for arsenic should be refined to better quantify lower concentrations. Table 6 of Appendix A lists the descriptive statistics for arsenic at each site.

Although there is an indication that a significant number of measurements may exceed the health benchmark at several sites, this conclusion cannot be stated with great certainty, because the vast majority of measurements fall below the LDL. Figure 2.1.8.1.2 shows trend lines for arsenic at the Bush Street site.

Figure 2.1.8.1.1 Boxplot of arsenic concentrations for each monitoring site

The dashed horizontal line is located at the arsenic health benchmark of 0.002 g/m^3. The solid horizontal line is located at the LDL (0.0053 g/m^3). The center line within each box represents the median for the site. The box itself encompasses the 25th percentile to the 75th percentile. The bars at each end of the box represent the highest and lowest values that are not considered outliers. The circles represent values that are more than 1.5 bos-lengths from the 75th percentile (outliers). The stars represent values more than three box-lengths from the 75th percentile (extreme values).

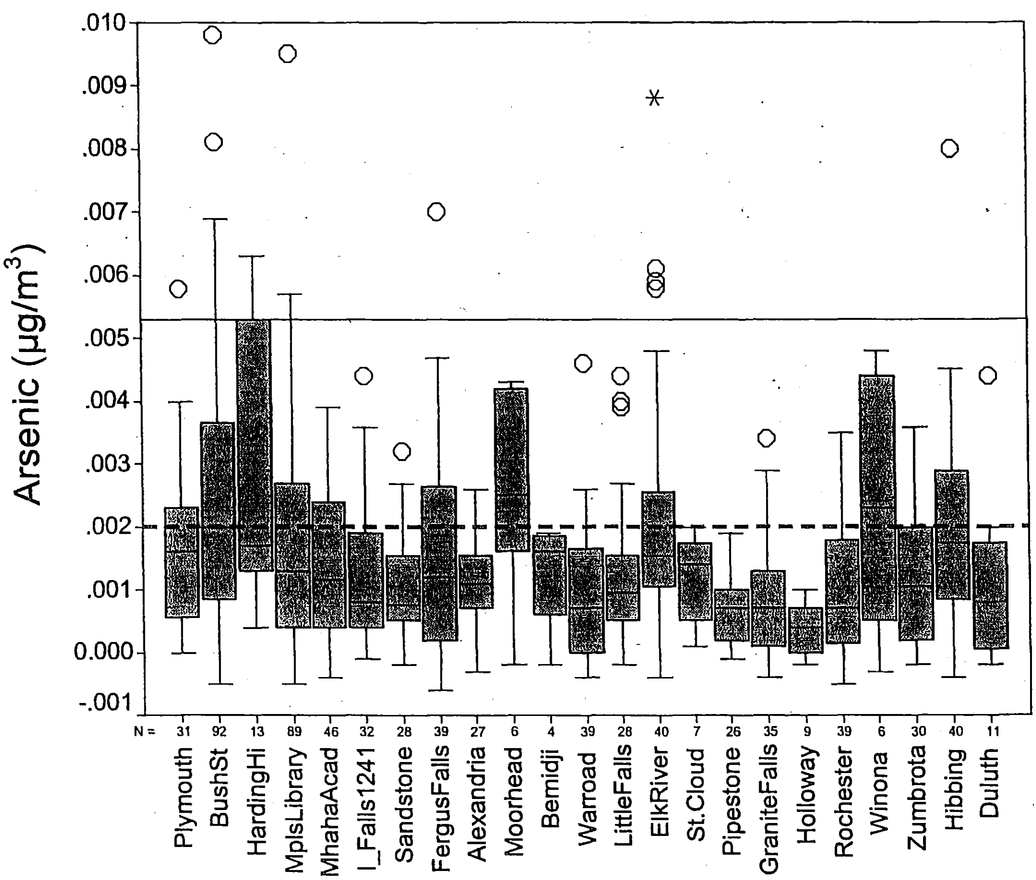
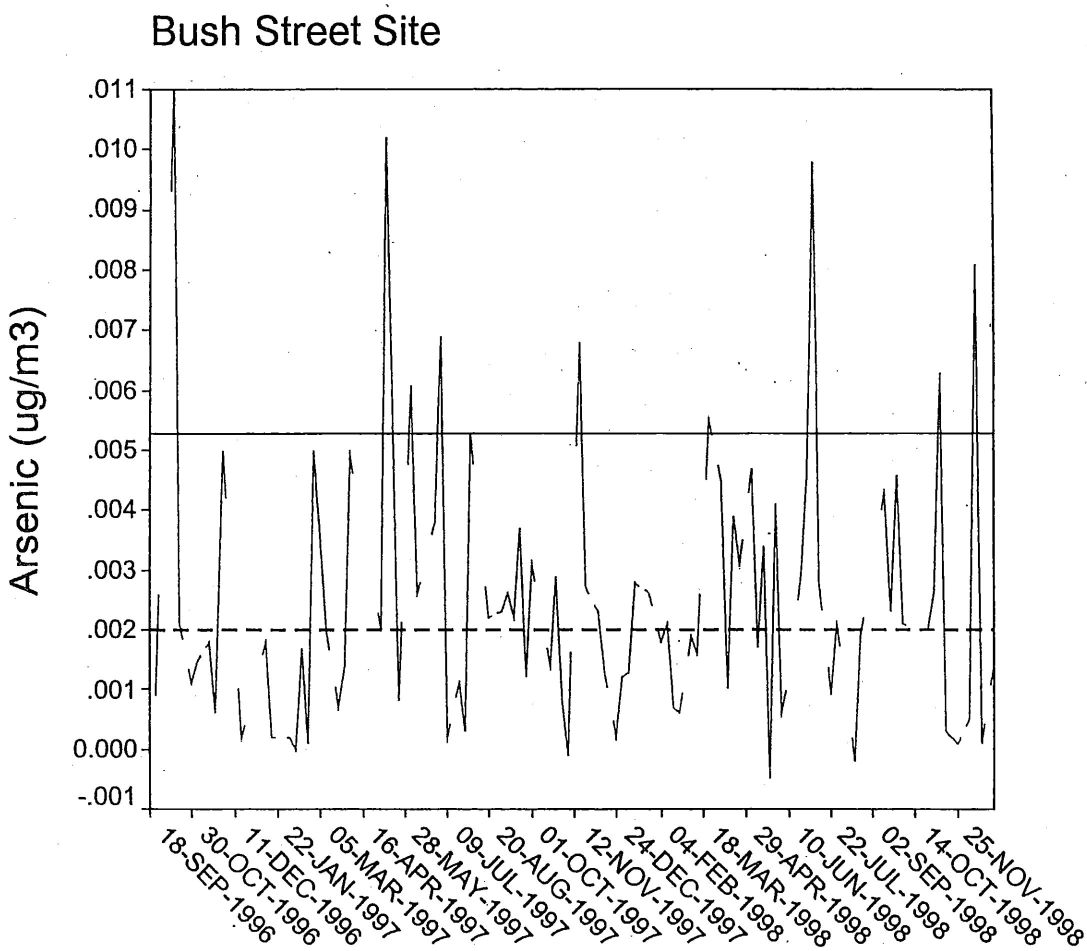


Table 2.1.8.1.1 Measurements above the LDL

Site	No. of valid measurements	No. above LDL
Plymouth	31	1
Bush Street	92	11
Harding High	13	4
Minneapolis Library	89	3
Fergus Falls	39	1
Elk River	40	6
Hibbing	40	1

Figure 2.1.8.1.2 Time line of measurements at the Bush Street site
The dashed horizontal line is located at the arsenic health benchmark of 0.002 g/m^3. The solid horizontal line is located at the LDL (0.0053 g/m^3).



Modeling data: According to the EPA's CEP study, which is based on 1990 emissions data, the average modeled concentration of arsenic exceeds the health benchmark on the Iron Range in northeastern Minnesota and in a few census tracts in the Twin Cities metropolitan area. Figures 2.1.8.1.3. and 2.1.8.1.4. show those areas that exceed the benchmark according to the model. Table 2.1.8.1.2. gives a comparison of the CEP modeling results with the MPCA monitoring results. This comparison should be viewed cautiously since the bulk of the measurements were below the reliably quantifiable level. Nevertheless, it appears that the monitoring data show generally higher concentrations than were predicted by the model.

Figure 2.1.8.1.3 Modeling results for arsenic
This map can be seen in color at http://www.pca.state.mn.us/air/at-cep.html.

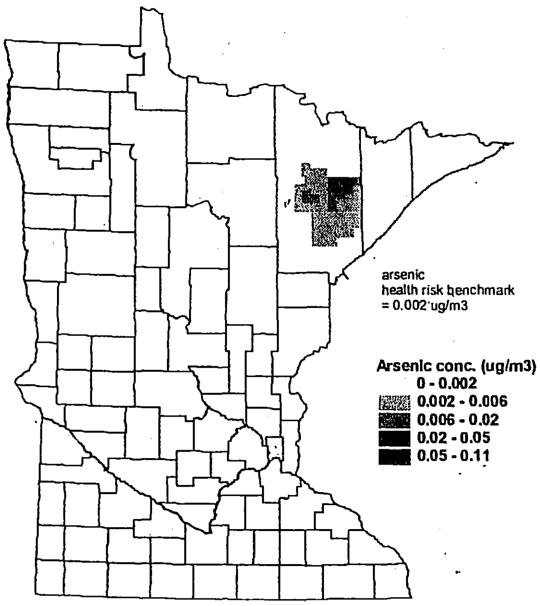


Figure 2.1.8.1.4 Modeling results for arsenic
This map can be seen in color at http://www.pca.state.mn.us/air/at-cep.html.

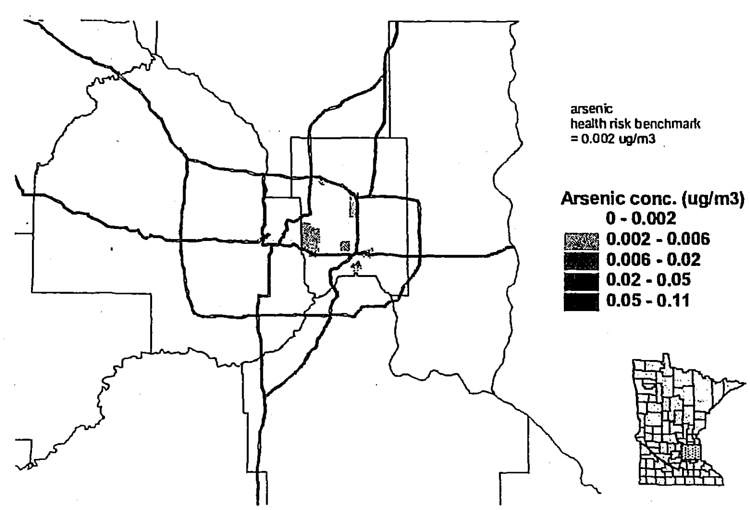


Table 2.1.2.1.2 MPCA-measured arsenic concentrations (µg/m³) versus concentrations estimated in the EPA Cumulative Exposure Project model

Site No.	Site Name	Monitored Mean Value	EPA CEP Modeled Value	Difference (Model - Monitor)
260	Plymouth	0.00170	0.00036	-0.00134
820	BushSt	0.00250	0.00104	-0.00146
871	HardingHi	0.00290	0.00215	-0.00075
945	MplsLibrary	0.00170	0.00137	-0.00033
958	MhahaAcad	0.00140	0.00087	-0.00053
1241	I_Falls1241	0.00120	0.00008	-0.00112
1400	Sandstone	0.00110	0.00001	-0.00109
2005	FergusFalls	0.00160	0.00017	-0.00143
2010	Alexandria	0.00110	0.00009	-0.00101
2401	Warroad	0.00090	0.00001	-0.00089
3049	LittleFalls	0.00130	0.00007	-0.00123
3050	ElkRiver	0.00260	0.00009	-0.00251
4002	Pipestone	0.00070	0.00006	-0.00064
4003	GraniteFalls	0.00080	0.00010	-0.00070
5008	Rochester	0.00010	0.00015	0.00005
5356	Zumbrota	0.00120	0.00003	-0.00117
7014	Hibbing	0.00200	0.00270	0.00070
7549	Duluth7549	0.00110	0.00016	-0.00094

2.1.8.2 What are the health effects of arsenic?

Short-term inhalation exposure to inorganic arsenic affects the gastrointestinal system and may cause nausea, diarrhea and abdominal pain. It may also result in disorders to the blood system and to the central and peripheral nervous systems. These systems, as well as the cardiovascular system, liver and kidneys, are also impacted by acute and chronic oral exposure to inorganic arsenic. Long-term inhalation exposure to inorganic arsenic can irritate the skin, mucous membranes and lungs. Of much greater concern from long-term inhalation exposure to inorganic arsenic is the increased risk of lung cancer. This is supported by human studies, primarily those exposed to arsenic in or around smelting operations. Arsenic crosses the placenta and some studies suggest that arsenic exposure may cause low birth weight and spontaneous abortions. The EPA classifies inorganic arsenic as a known human carcinogen. The MPCA uses the draft HRV established by the Minnesota Department of Health as the health benchmark for inorganic arsenic. This value is 0.002 µg/m³ and corresponds to an excess lifetime cancer risk of 1 in 100,000. California EPA Office of Environmental Health Hazard Assessment has adopted a cancer unit risk of 3.3×10^{-3} for inorganic arsenic, which corresponds to 0.003 µg/m³ at 1-in-100,000 risk level.

Uses of Arsenic: Arsenic is used as a hardening alloy and in glass manufacturing. Semiconductor manufacturers use arsine and arsenic compounds in manufacturing printed circuits and microchips.

2.1.8.3 How are people exposed to arsenic?

Arsenic is a natural part of the environment and low levels are present in soil, water and food. Therefore, people are exposed to arsenic in the food and water they consume and by breathing air and dust containing arsenic particles. While soil usually has the highest concentrations of arsenic, food is the largest source of exposure. Persons who live in areas that have unusually high levels of arsenic in rock may be exposed to higher levels of arsenic. In such areas, there are above-average amounts of arsenic in the surrounding soil and water. Persons who live near hazardous waste sites may be exposed to above-average levels of arsenic also. Occupations, such as copper or lead smelting, pesticide application and wood treating, can result in above-average arsenic exposures.

Children are exposed to arsenic in many of the same ways as adults and exhibit the same effects. Some children may receive significant exposure if they ingest food, juice or infant formula made with arsenic-contaminated water. In addition, because children often play in the dirt and put their hands in their mouths, ingestion of contaminated soil can be an important source of arsenic exposure.

2.1.8.4 What happens to arsenic in the atmosphere?

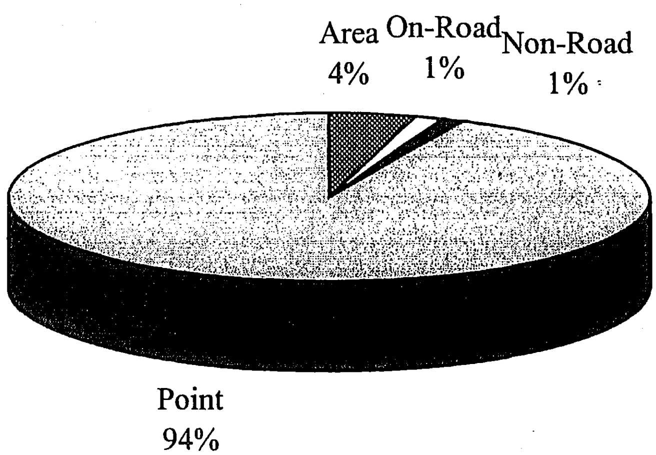
Arsenic is emitted into the atmosphere from both natural and anthropogenic sources. Large cities generally have higher arsenic air concentrations than smaller ones due to emissions from coal-fired power plants. Arsenic exists in the atmosphere as particulate matter mostly less than 2 microns in diameter. Particles are transported and then removed from the atmosphere by dry and wet deposition. Although atmospheric residence time depends on the particle size and meterological conditions, a typical time is about nine days. Arsenic is released to the atmosphere primarily as arsenic trioxide or, in specific areas of pesticide application, as methyl arsines. Trivalent arsenic and methyl arsines undergo oxidation in the atmosphere to the pentavalent state, so arsenic in the atmosphere is usually a mixture of trivalent and pentavalent forms.

2.1.8.5. What sources emit arsenic?

Emissions of Arsenic: Arsenic is usually combined with one or more other elements. When arsenic is combined with oxygen, chlorine and sulfur, it is referred to as "inorganic arsenic." The majority of arsenic in air exists as inorganic arsenic particulate matter smaller than 2.5 micrometers that are highly respirable. The primary sources of inorganic arsenic emissions to the atmosphere are combustion and high-temperature processes. Other sources include the primary metal industry, secondary metal industry, and mineral product industry. Agricultural burning, waste incineration and tobacco smoking also release arsenic emissions.

Figure 2.1.8.5.1 shows emissions of arsenic by source category in Minnesota. This figure is based on the 1990 emission data from the EPA's CEP study. According to that study, approximately 94 percent of arsenic emissions are attributed to other point sources, area sources contribute 4 percent of arsenic emissions, and the contribution of mobile sources is only 2 percent. Refineries, municipal waste combustors and TRI point sources emit insignificant amounts of arsenic; the total contribution of these three sources to the statewide arsenic emissions is less than 1 percent (this is not shown in the figure). The definition of each source category is explained in Appendix C.

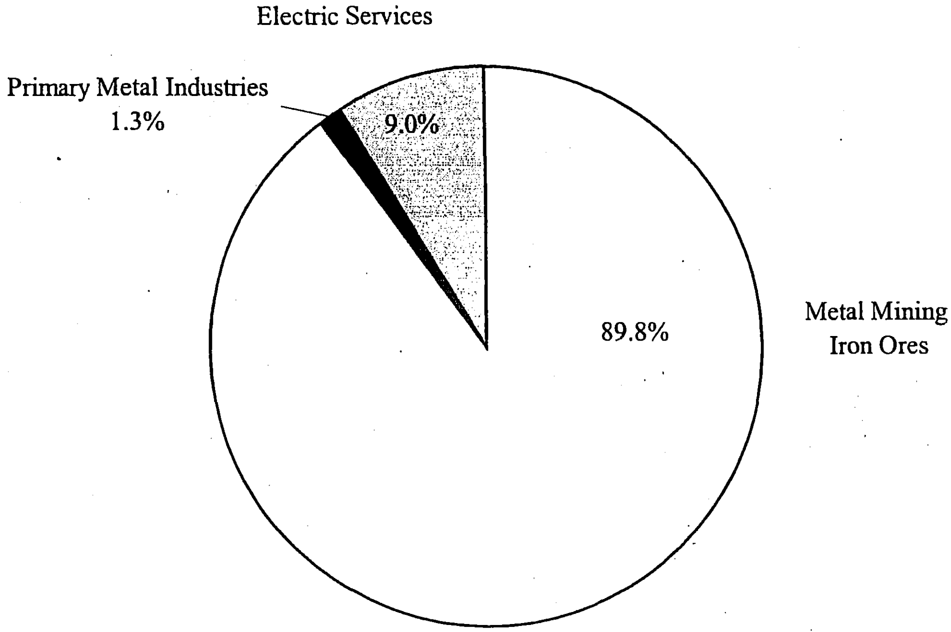
Figure 2.1.8.5.1 1990 Emissions of arsenic by source category
(Data are from the EPA CEP study for the State of Minnesota.)



Arsenic emissions by principal source category for point sources are shown in Figure 2.1.8.5.2. According to the preliminary results of the 1996 Minnesota air toxics emission inventory for point sources, about 90 percent of arsenic emissions from point sources are attributed to metal mining/iron ores. Electric services contribute 9 percent. Primary metal industries are responsible for the remaining 1 percent of arsenic emissions.

Figure 2.1.8.5.2 1996 arsenic emissions by principal source category for point sources

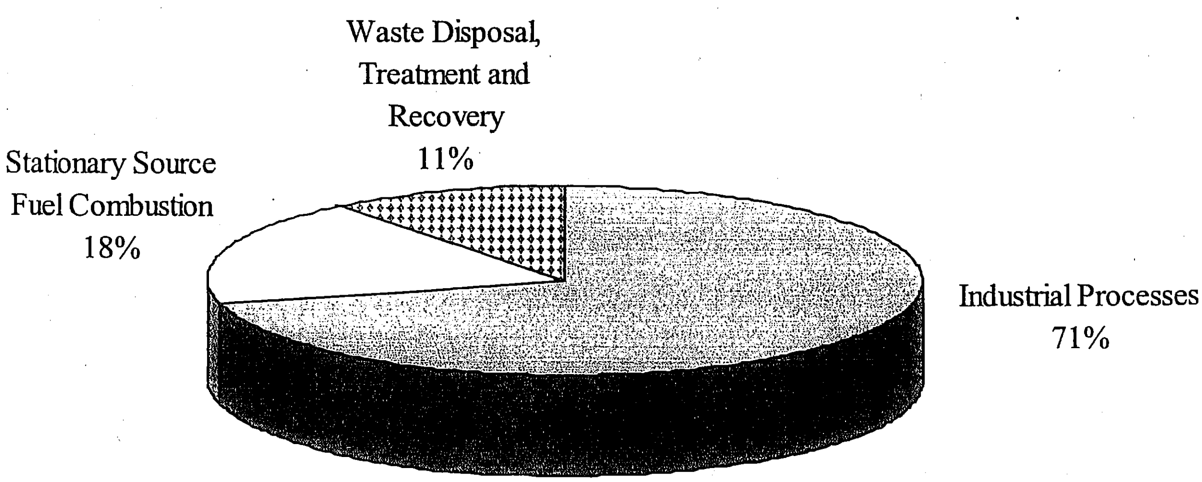
(Data are from the preliminary 1996 Minnesota emission inventory.)



Arsenic emissions by principal source category for Minnesota area sources in 1990 are shown in Figure 2.1.8.5.3. About 71 percent of area source arsenic emissions are attributed to industrial processes. The remainder is attributed to stationary source fuel combustion and waste disposal, treatment and recovery.

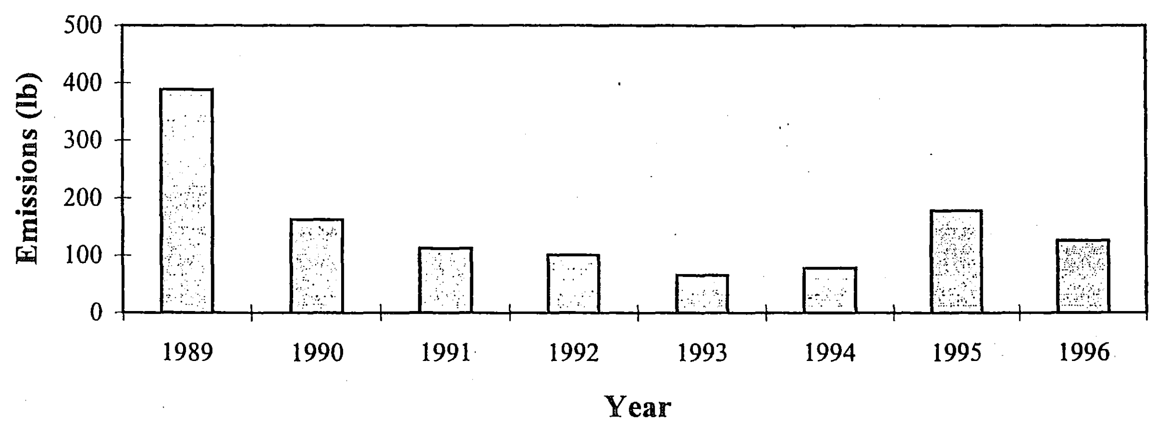
Figure 2.1.8.5.3 1990 Arsenic emissions by principal source category for area sources

(Data are from the EPA CEP study for the State of Minnesota.)



The 1989-to-1996 trend in arsenic emissions for the Minnesota TRI point sources is shown in Figure 2.1.8.5.4. The emissions of arsenic have been less than 400 lb. for many years, and have dropped to less than 200 lb. after 1989. It should be noted that metal mining/iron ores and electric services are not included in the TRI report, and that the TRI point sources contribute only 1.3 percent of point source emissions.

Figure 2.1.8.5.4 Trend in arsenic emissions based on TRI point source data



2.1.8.6 Arsenic summary

Model predictions from the EPA Cumulative Exposure Project show arsenic concentrations exceeding the health benchmark on the Iron Range and in a few census tracts in the Twin Cities metropolitan area. Monitoring data are mostly below the lower detection limit of the method used, but there is an indication that concentrations may exceed health benchmarks at some sites. More refined measurement methods are needed to confirm this conclusion.

Arsenic has been implicated in both acute and chronic effects on the cardiovascular system, liver, kidneys, gastrointestinal system and nervous system. It is classified as a known human carcinogen by the EPA. Arsenic exists in the atmosphere as small particles, which are emitted from metal extraction and processing, waste combustion, agricultural burning, and entrainment of crustal materials.

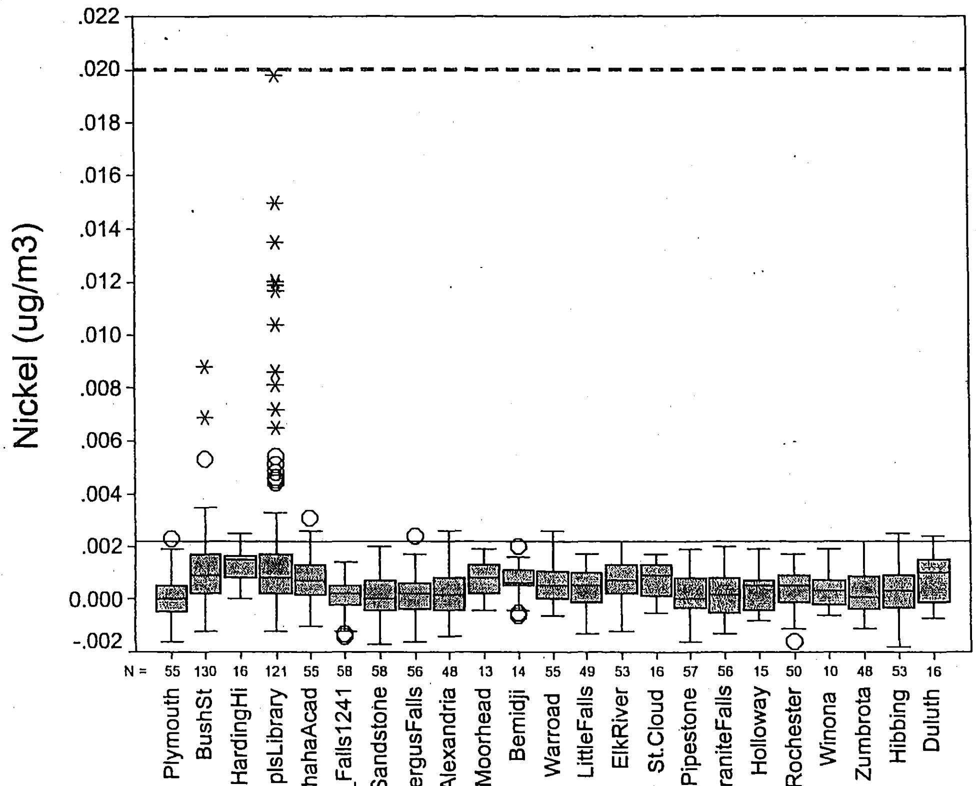
2.1.9 Nickel

Nickel (CAS 7440-02-0), Ni, is a hard, silver, nonflammable metal. However, its dust or powder is combustible and can form explosive mixtures in air. Nickel is insoluble in water. It also combines with other chemicals, such as chlorine, sulfur and oxygen, to form nickel compounds. When released to the air, nickel attaches to small dust particles and stays in the air for months. This nickel dust may settle to the ground or be washed from the air by rain and snow; then, it becomes attached to soil or sediment particles. Nickel will not build up in fish, but may accumulate in plants and land animals.

2.1.9.1 What information indicates nickel is a concern?

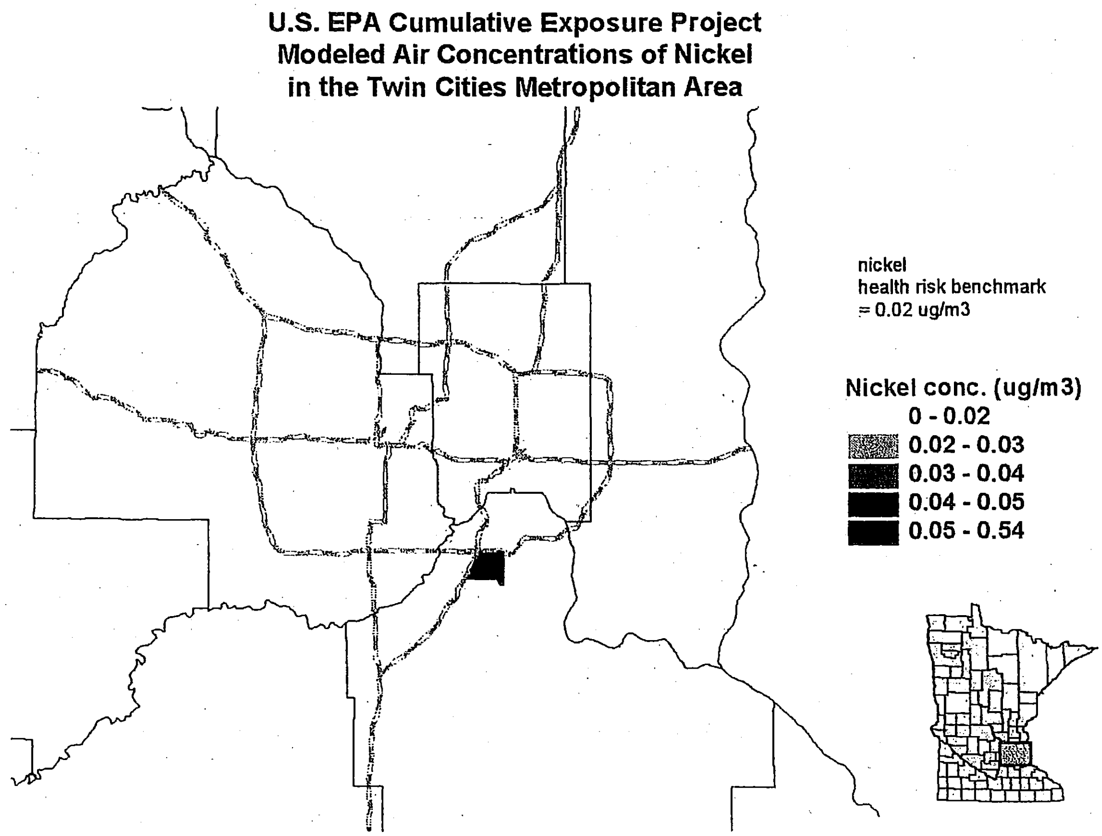
Ambient data: Figure 2.1.9.1.2 shows boxplots of the nickel measurements at individual sites. The data show that the majority of the measurements fall below the lower detection limit (LDL = 0.053 $\mu g/m^3$). In addition, all of the measurements fall below the health benchmark (0.02 $\mu g/m^3$). This figure also shows that only a few measurements at a few sites exceeded the LDL and virtually no measurements exceeded the health benchmark. For these reasons, further details of the nickel monitoring data are not included.

Figure 2.1.9.1.2 Boxplot of nickel concentrations for each monitoring site
The dashed horizontal line is located at the nickel health benchmark of 0.02 µg/m³. The solid horizontal line is located at the LDL (0.0022 µg/m³). The center line within each box represents the median for the site. The box itself encompasses the 25th percentile to the 75th percentile. The bars at each end of the box represent the highest and lowest values that are not considered outliers.



Modeling data: According to the CEP, which is based on 1990 emissions data, the average modeled concentration of nickel exceeded the health benchmark in two census tracts in the Minneapolis-St. Paul metropolitan area. The highest concentrations were predicted in the census tract in which Gopher Smelter is located. No monitoring data are available for that area. No model-predicted concentrations were higher than the health benchmark in the areas outside the metro area. Figure 2.1.9.1.2 is a map showing the parts of the metropolitan area with model-predicted nickel concentrations greater than the health benchmark. At most sites, the model predictions exceed monitored values, sometimes by a wide margin, although this conclusion should be tempered by the recognition that most of the measurements are near or below the LDL.

Figure 2.1.9.1.2 Map showing model-predicted concentrations of nickel
This map can be seen in color at http://www.pca.state.mn.us/air/at-cep.html.



2.1.9.2 What are the health effects of nickel?

While very small amounts of nickel may be essential to humans, high-level exposure to nickel can harm human health. Acute exposure to nickel carbonyl targets the lungs and kidneys. Symptoms, such as headache, vomiting, chest pains, dry coughing and visual disturbances, have been reported due to acute inhalation exposure. The most common effect from long-term exposure in humans is an allergic reaction to nickel and nickel compounds. Allergic skin reactions result in contact dermatitis, causing itching of the fingers, wrists and forearms. Chronic inhalation exposure can result in direct respiratory effects, causing chronic respiratory tract infections and asthma due to primary irritation or an allergic response. Animal inhalation studies have reported effects on the lungs, kidneys and immune system. Occupational studies have reported an increased risk of lung and nasal cancers among nickel refinery workers exposed to nickel refinery dust (Minnesota has no nickel refineries). This dust is composed of a mixture of many nickel compounds, including nickel subsulfide. Animal inhalation studies also report lung tumors from exposure to nickel refinery dusts. The EPA classifies nickel refinery dust and nickel subsulfide as human carcinogens, and nickel carbonyl as a probable human carcinogen. The MPCA uses the draft HRVs for nickel refinery dust and nickel subsulfide established by the

Minnesota Department of Health as the health benchmarks for nickel exposure. These values are 0.04 $\mu g/m^3$ and 0.02 $\mu g/m^3$, respectively, and correspond to a excess lifetime cancer risk of one in 100,000. California EPA Office of Environmental Health Hazard Assessment (OEHHA) has adopted a cancer unit risk of 2.6 x 10^{-4} for nickel and nickel compounds, which corresponds to 0.04 $\mu g/m^3$ at one-in-100,000 risk level. OEHHA is proposing a chronic REL of 0.05 $\mu g/m^3$ to protect against respiratory and immune system effects from nickel exposure.

Uses of nickel: The primary use of nickel is for the production of various metal alloys, cast irons and electroplated goods. Other uses are for the production of catalysts and nickel-cadmium batteries and as a catalyst in the petroleum, plastic and rubber industries.

2.1.9.3 How are people exposed to nickel?

Nickel can enter the human body through inhalation, ingestion and skin contact. Skin contact with soil, water or metals containing nickel as well as nickel-plated metals can result in exposure. Nickel is so strongly attached to soil dust and particles that it is not readily taken up by plants and animals and does not easily affect health by this route of exposure. However, food does contain nickel and is a source of exposure for the general population. Foods naturally high in nickel include chocolate, soy beans, nuts and oatmeal. Exposure to higher levels of nickel would be a concern for persons living near or working in facilities that produce stainless steel and other nickel-containing alloys. Persons living near or working in oil-fired power plants, coal-fired power plants and refuse incinerators may be exposed to high levels of nickel in airborne dust, soil and vegetation or by handling the bottom ash or fly ash from these facilities. Nickel from waste sites, particularly electroplating waste, can contaminate groundwater and people who drink the contaminated groundwater may be exposed to higher nickel concentrations.

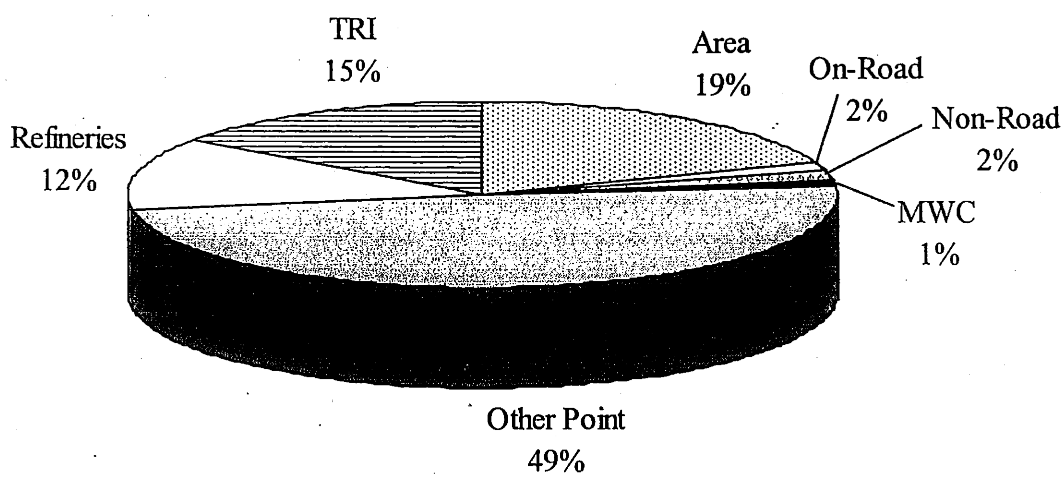
2.1.9.4 What happens to nickel in the atmosphere?

Nickel is released to the atmosphere in the form of particulate matter or adsorbed to particulate matter and is removed by dry and wet deposition. Although specific information is lacking, nickel oxide has been identified in industrial emissions and is assumed to be the form of nickel emanating from combustion sources. Nickel is presumed to oxidize in the atmosphere in the presence of sulfur dioxide and form nickel sulfate. Studies indicate that nickel has a broad range of particulate sizes (*e.g.*, approximately 1.0 to 7.2 microns). Removal of particles larger than 5.0 microns is governed by gravitational settling, whereas smaller particles are removed by wet and dry deposition. Removal of coarse particles may occur in a matter of hours, while very small particles may have an atmospheric half-life of 30 days and be transported over long distances. Emission sources in North America, Greenland and Europe have been shown to be responsible for the elevated atmospheric nickel concentrations in the Norwegian arctic, demonstrating the long-range transport of nickel.

2.1.9.5. *Which sources emit nickel?*

Emissions of nickel: Fuel combustion (oil and coal) is responsible for the majority of nickel emissions. Nickel is also identified in motor vehicle exhaust. Figure 2.1.9.5.1 shows emissions of nickel by source category in Minnesota. This figure is based on the 1990 emission data from the EPA's CEP study. According to the CEP study, a variety of sources contribute to nickel emissions. However, point sources, including other point sources, TRI emitters, refineries and municipal waste combustors, dominate nickel emissions, with a contribution of 77 percent. Area sources contribute 19 percent of nickel emissions, and the contribution of mobile sources is only 4 percent. The definition of each source category is shown in Appendix C.

Figure 2.1.9.5.1 1990 Emissions of nickel by source category
(Data are from the EPA CEP study for the State of Minnesota.)



Nickel emissions by principal source category for point sources are shown in Figure 2.1.9.5.2. According to the preliminary results of the 1996 Minnesota air toxics emission inventory for point sources, about 60 percent of nickel emissions from point sources are attributed to electric services. Other sources include manufacturing petroleum and coal products, metal mining/iron ores, manufacturing transportation equipment, and primary metal industries. These sources each contribute from 6 to 12 percent to point source nickel emissions in the state.

Nickel emissions by principal source category for Minnesota area sources are shown in Figure 2.1.9.5.3, where the data are from the EPA's CEP study for 1990. Stationary source fuel combustion is the primary source of nickel emissions, contributing 92 percent. Waste disposal, treatment and recovery and industrial processes are responsible for the remaining 8 percent of nickel emissions from area sources.

Figure 2.1.9.5.2 1996 nickel emissions by principal source category for point sources

(Data are from the preliminary 1996 Minnesota emission inventory.)

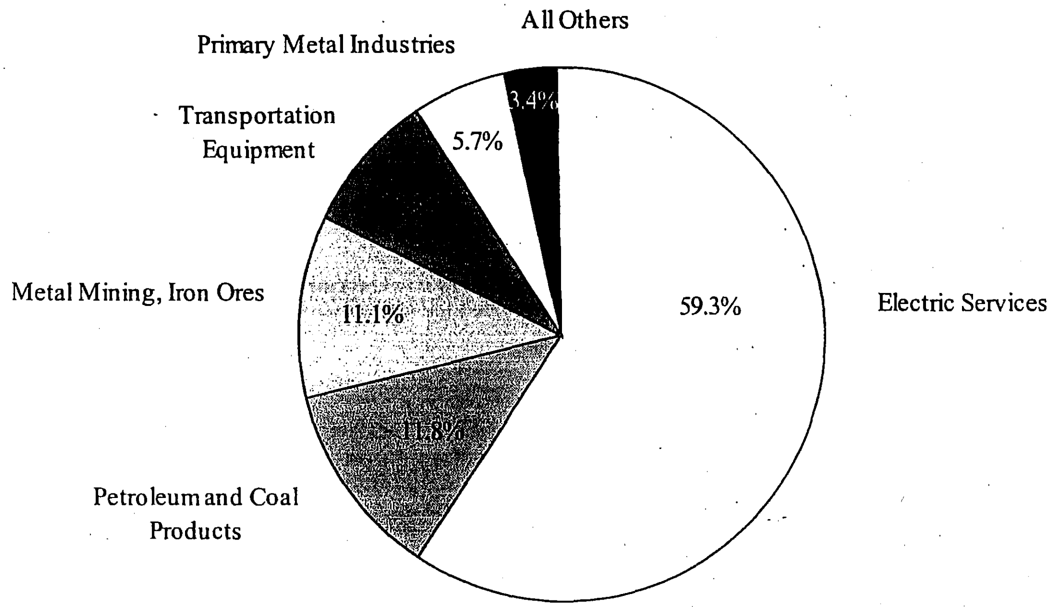
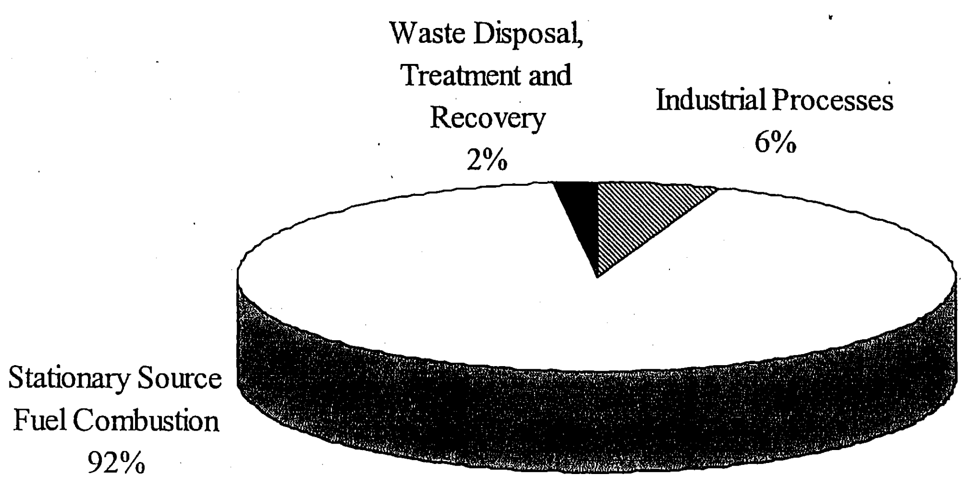


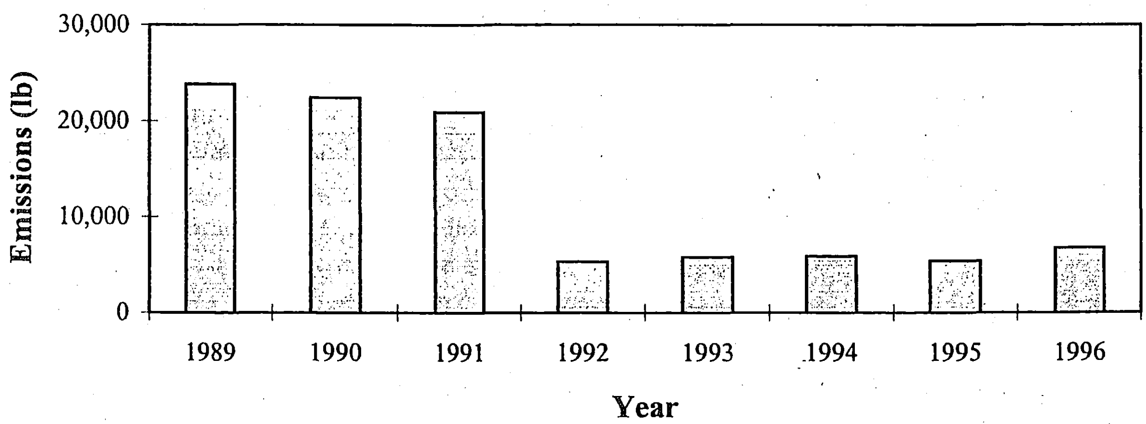
Figure 2.1.9.5.3 1990 nickel emissions by principal source category for area sources

(Data are from the EPA CEP study for the State of Minnesota.)



The 1989-to-1996 trend in nickel emissions for the Minnesota TRI point sources is shown in Figure 2.1.9.5.4. Reported nickel emissions dropped about three-fourths from 1991 to 1992, then remained at about 6,000 lb. per year.

Figure 2.1.9.5.4 Trend in nickel emissions based on TRI point source data



2.1.9.6 Nickel summary

Model predictions from the EPA Cumulative Exposure Project show nickel concentrations exceeding the health benchmark in two census tracts in the Twin Cities metropolitan area. All monitoring data were below the health benchmark, and the data from most sites were lower than the model predictions, although most measurements were near or below the lower detection limit.

Although humans may need very small amounts of nickel, higher-level exposures can cause toxicity to the lungs and kidneys, among other target organs. The EPA classifies nickel as a known human carcinogen. Most nickel emissions (about 77 percent) come from point sources, such as refineries, metal processing and waste combustion. The level of public health concern about air emissions of nickel in Minnesota is uncertain at present. The data appear to show concentrations below levels of concern, but in combination with other pollutants and/or adjacent to certain industries, nickel concentrations may be of concern. More work is needed to measure nickel concentrations in different locations and with more sensitive techniques.

2.1.10 Chromium

Chromium (CAS 7440-47-3), Cr, exists in the environment in one of three major states: chromium metal, chromium (III) and chromium (VI). Chromium (III) and chromium (VI) are in the trivalent form and hexavalent form, respectively. Chromium (III) compounds are stable, and a very small amount of chromium (III) is an essential nutrient. A daily ingestion of 50-200 μg per day has been estimated to be safe and adequate. Chromium (VI), which is almost always bound to oxygen, is the most toxic form of chromium.

2.1.10.1 What information indicates chromium is a concern?

Ambient data: Figure 2.1.10.1.1 shows a boxplot of total chromium concentrations for each monitoring site. The data show that the majority of the measurements fall below the lower detection limit (LDL = 0.0022 $\mu g/m^3$). Since a large fraction of the measurements fall below the LDL, other measurement techniques should be evaluated for quantifying chromium.

Although there is an indication in the measurements that a significant number of measurements may exceed the health benchmark for hexavalent chromium at several sites, this conclusion cannot be stated with great certainty because the majority of the measurements fall below the LDL. This health benchmark is for hexavalent chromium [Cr(VI)]. Thus, the implicit assumption in comparing monitored values to this benchmark is that the measured chromium is all in the hexavalent form.

Table 7 of Appendix A lists the descriptive statistics for chromium at each site. Figure 2.1.10.1.2 shows the concentrations over time for total chromium at the Bush Street site, which is one of the sites with the longest period of record.

Figure 2.1.10.1.1 Boxplot of total chromium concentrations for each monitoring site

The dashed horizontal line is located at the hexavalent chromium health benchmark of 0.0008 μg/m^3. The solid horizontal line is located at the LDL (0.0022 μg/m^3). The center line within each box represents the median for the site. The box itself encompasses the 25th percentile to the 75th percentile. The bars at each end of the box represent the highest and lowest values that are not considered outliers. The circles represent values that are more than 1.5 box-lengths from the 75th percentile value (outliers).

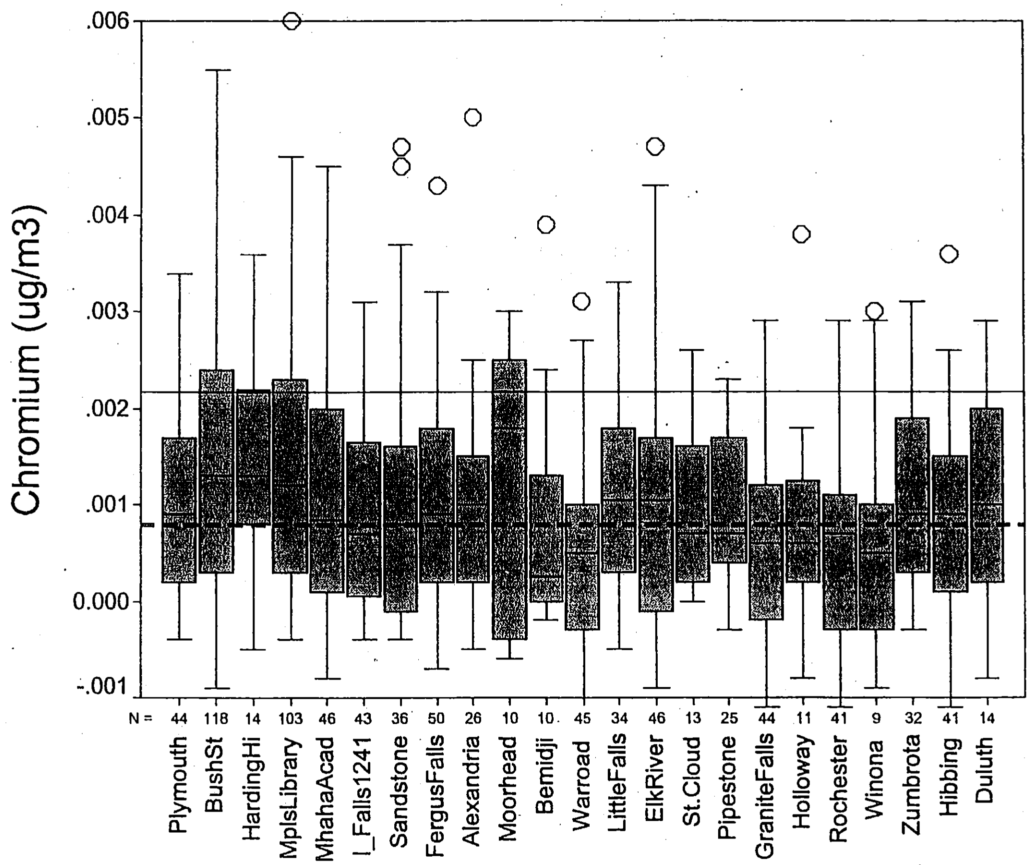
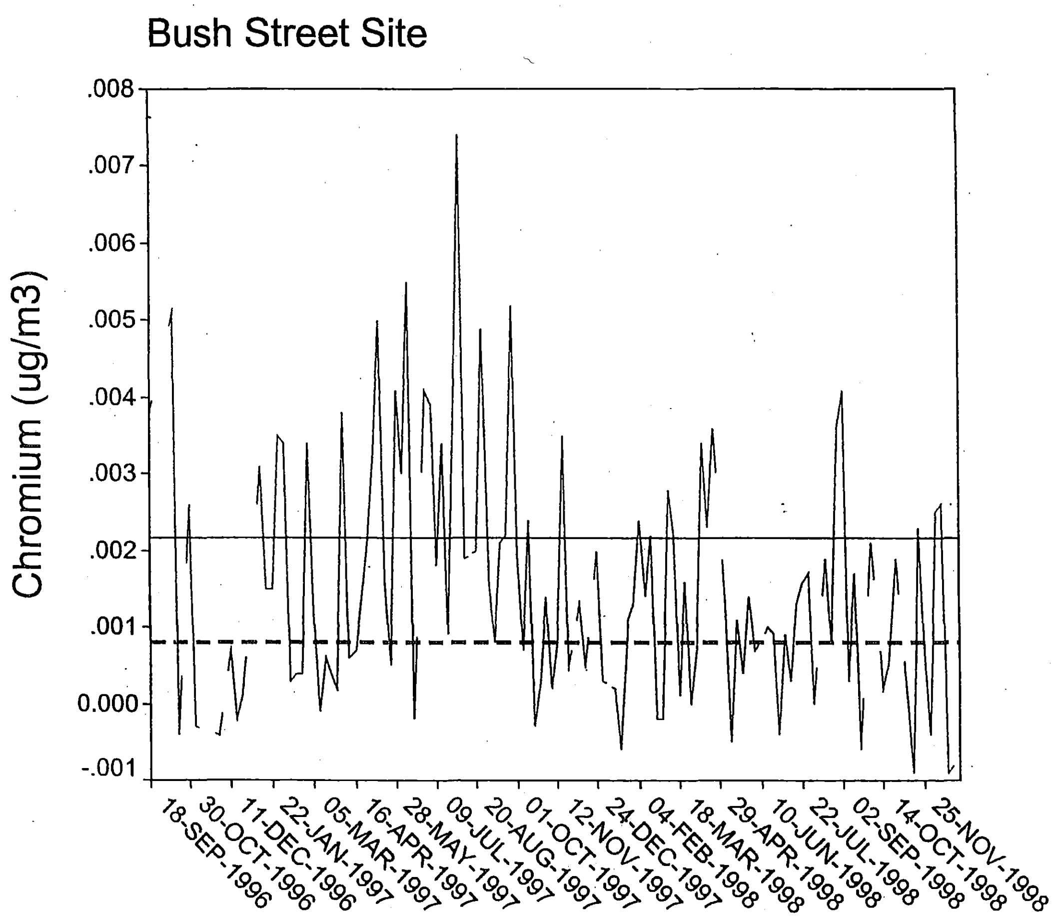


Figure 2.1.10.1.2 Time line of total chromium measurements at the Bush Street site

The dashed horizontal line is located at the hexavalent chromium health benchmark of 0.0008 μg/m³. The solid horizontal line is located at the LDL (0.0022 μg/m³).



__Modeling data__: According to the EPA Cumulative Exposure Project (CEP) modeling analysis, which is based on 1990 emissions data, the average modeled concentration of chromium exceeded the health benchmark for hexavalent chromium in some areas of the state. Figures 2.1.10.1.3 and 2.1.10.1.4 are maps showing the areas in Minnesota where the CEP modeling shows the chromium concentration to exceed the health benchmark for hexavalent chromium. Table 2.1.10.1.1 gives a comparison of the CEP model predictions with monitored values.

Figure 2.1.10.1.3 Map of model-predicted chromium concentrations
This map can be seen in color at http://www.pca.state.mn.us/air/at-cep.html.

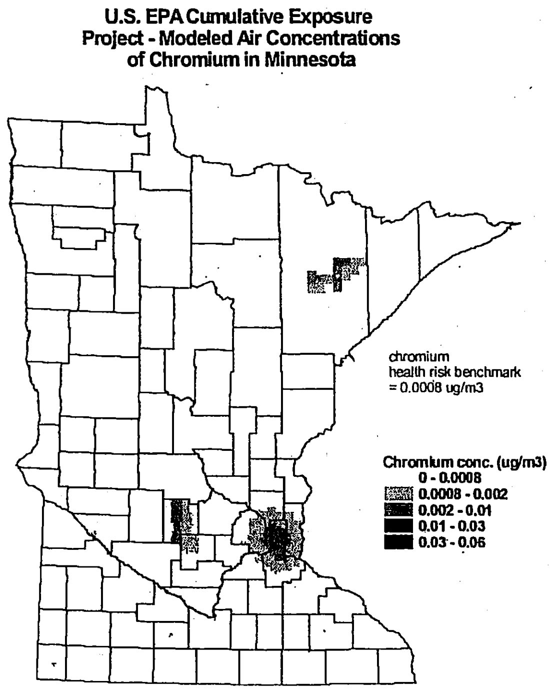


Figure 2.1.10.1.4 Map of model-predicted chromium concentrations
This map can be seen in color at http://www.pca.state.mn.us/air/at-cep.html.

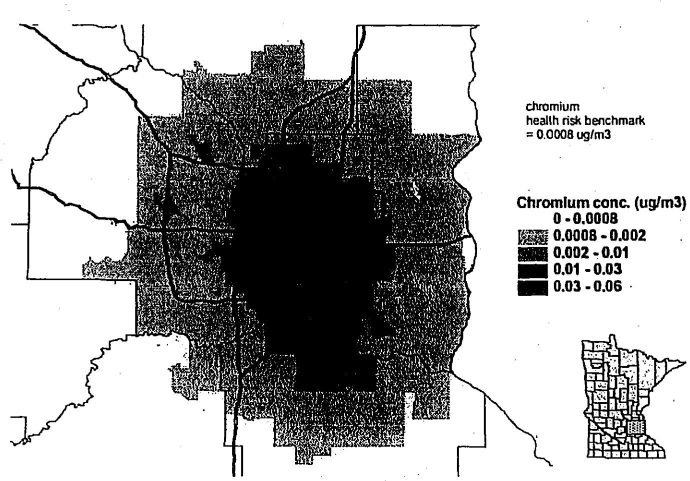


Table 2.1.10.1.1 MPCA-measured total chromium concentrations (µg/m^3) versus concentrations estimated in the EPA Cumulative Exposure Project

Site No.	Site Name	Monitored mean value	EPA CEP modeled value	Difference (model-monitor)	% difference (difference/ monitor*100)
260	Plymouth	0.0010	0.0013	0.0003	33.27
820	BushSt	0.0015	0.0036	0.0021	138.26
871	HardingHi	0.0014	0.0056	0.0042	297.50
945	MplsLibrary	0.0015	0.0036	0.0021	143.15
958	MhahaAcad	0.0011	0.0040	0.0029	261.75
1241	I_Falls1241	0.0009	0.0002	-0.0007	-79.73
1400	Sandstone	0.0011	0.0000	-0.0011	-96.17
2005	FergusFalls	0.0011	0.0005	-0.0006	-58.36
2010	Alexandria	0.0010	0.0002	-0.0008	-80.59
2401	Warroad	0.0005	0.0000	-0.0005	-95.27
3049	LittleFalls	0.0011	0.0001	-0.0010	-88.11
3050	ElkRiver	0.0010	0.0002	-0.0008	-82.06
4002	Pipestone	0.0011	0.0001	-0.0010	-90.22
4003	GraniteFalls	0.0006	0.0001	-0.0005	-81.86
5008	Rochester	0.0005	0.0004	-0.0001	-14.22
5356	Zumbrota	0.0010	0.0003	-0.0007	-67.37
7014	Hibbing	0.0009	0.0006	-0.0003	-33.37
7549	Duluth7549	0.0010	0.0003	-0.0007	-73.90
Average over all sites		0.0010	0.0012	0.0002	-3.74

2.1.10.2 What are the health effects of chromium?

Chromium may exist in several chemical forms in the environment. The most commonly occurring forms in the environment are chromium metal (0), trivalent Cr(III) and hexavalent Cr(VI). Scientific studies support that hexavalent chromium is much more toxic than trivalent chromium. In addition, trivalent chromium is an essential element for animals and humans and potentiates the action of insulin in peripheral tissues. Ingested hexavalent chromium is efficiently reduced to Cr(III), although a small amount may be absorbed. Inhaled hexavalent chromium may be absorbed into the circulation system, transferred to the gastrointestinal tract or remain in the lungs. Following inhalation, a number of factors influence the absorption, but once absorbed, significant amounts are taken up in the bone, liver, kidneys and spleen. However, the respiratory tract is the major target organ from inhalation exposure to chromium. Chronic inhalation exposure may cause perforations and ulcerations of the septum, bronchitis, decreased pulmonary function, pneumonia, asthma and nasal itching and soreness. Chronic dermal exposure may cause contact dermatitis and sensitivity and ulceration of the skin. Results of occupational epidemiologic studies clearly establish that chromium is a carcinogen by the inhalation route. Workers are exposed to both Cr(III) and Cr(VI); however, animal data support the human carcinogenity data only for hexavalant chromium. The EPA classifies Cr(VI) as a Group A, human carcinogen and Cr(III) as a Group D, not classifiable as to human carcinogenicity. The MPCA uses the draft HRV established by the Minnesota Department of Health as the health benchmark for Cr(VI). This value is 0.0008 $\mu g/m^3$, and corresponds to an excess lifetime cancer risk of one in 100,000. The EPA has established inhalation reference concentrations for chromic acid mists [and dissolved Cr(VI) aerosals] and Cr(VI) particulates, at 0.008 $\mu g/m^3$ and 0.1 $\mu g/m^3$, respectively.

__Uses of Chromium:__ The metal chromium is used mainly in steel and other alloy production. Chromium compounds are used for chrome plating, leather tanning and wood treatment. They are also used in manufacturing pigment for paints, rubber and plastic products. Chromium used to be used in treatment of cooling tower water, but that use is now prohibited.

2.1.10.3 How are people exposed to chromium?

Chromium is a naturally occurring element. It is released to the air, water and soil mostly in the form of Cr(III) and Cr(VI) as a result of anthropogenic and natural sources. Chromium binds strongly with soil, and only small amounts move to groundwater. In air, chromium compounds are present mostly as fine dust particles. Persons who live near or work in industries that process chromium or chromium compounds can be exposed to higher-than-normal levels of Cr(VI). These include stainless steel welding, chromate production, chrome plating, ferrochrome industry and chrome pigments. Persons living near cement-producing plants (Minnesota does not have any cement plants) and busy roadways may be exposed to higher-than-normal levels of chromium because cement contains chromium as do emissions from automobile brake linings and catalytic converters. Persons living near landfill sites with chromium-containing wastes or waterways that receive industrial discharges from electroplating may be exposed to higher-than-normal levels of chromium if drinking water sources become contaminated. Tobacco products also contain chromium; thus, persons who use tobacco products are exposed to higher-than-normal levels of chromium. A major source of chromium emissions to the atmosphere is being eliminated through the EPA National Emission Standards for Industrial Cooling Towers, which prohibit the use of chromium as a rust inhibitor in industrial cooling towers.

2.1.10.4 What happens to chromium in the atmosphere?

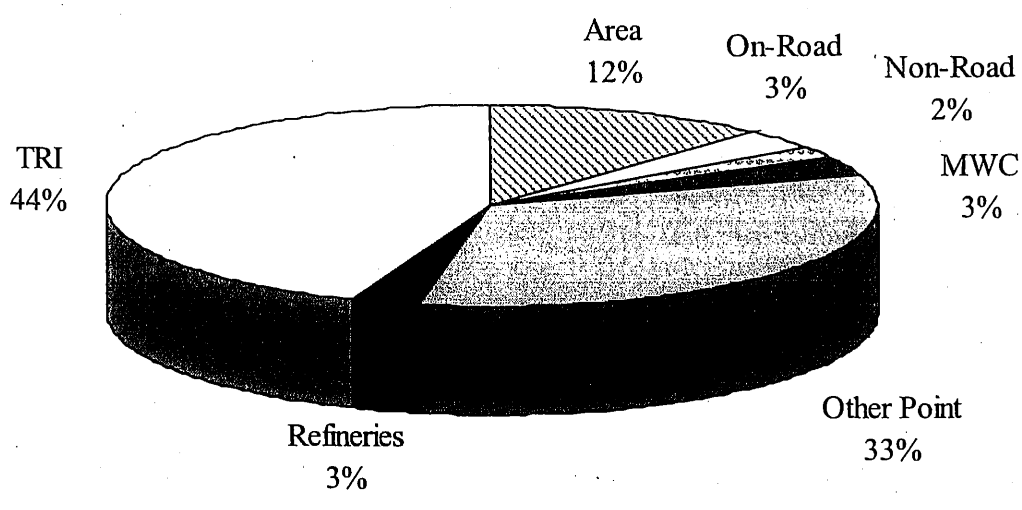
Because chromium is present in the atmosphere mainly in particulate form, the transport and partitioning of chromium in the atmosphere depends largely on particle size and density. The mass median diameter of ambient chromium particulates is quite small (approximately 1.0 micron), which means particles will remain airborne and transported over distances. The expected residence time of atmospheric chromium is expected to be less than 10 days. Chromium is removed from the atmosphere by dry and wet deposition, and acid rain may facilitate removal of acid-soluble chromium compounds. In the atmosphere, Cr(VI) may be reduced at a significant rate to Cr(III) by vanadium (V^{2+}, V^{3+} and VO^{2+}), Fe^{2+}, HSO^{3-} and As^{3+}. In converse, Cr(III) can be oxidized to Cr(VI) in the presence of manganese oxide; however, this is not a very likely atmospheric transformation.

2.1.10.5 Which sources emit chromium?

Emissions of Chromium: Chromium is emitted from ferroalloy and steel production, secondary aluminum and lead production, gray iron foundries, and manufacturing mineral products. It is also emitted from fossil fuel combustion and solid waste incineration. Chromium is detected in motor vehicle exhaust and tobacco smoke. Chrome plating is a major source of chromium (VI) emissions. However, the available data are not adequate to quantify source contributions for chromium (VI). The following analysis is performed for the total chromium, including chromium (III) and chromium (VI).

Figure 2.1.10.5.1 shows emissions of chromium by source category in Minnesota. This figure is based on the 1990 emission data from the EPA's CEP study. According to the study, the primary emission sources are point sources (including TRI, refinery, other point and (municipal waste combustor (MWC) sources), contributing approximately 83 percent of chromium emissions. Area sources contribute 12 percent of chromium emissions, and the contribution of mobile sources is only 5 percent. The definition of each source category is shown in Appendix C.

Figure 2.1.10.5.1 1990 emissions of chromium by source category
(Data are from the EPA CEP study for the State of Minnesota.)



Chromium emissions by principal source category for point sources are shown in Figure 2.1.10.5.2. According to the preliminary results of the 1996 Minnesota air toxics emission inventory for point sources, electric services, manufacturing transportation equipment and metal mining/iron ores each contributes about 20 percent of chromium emissions from point sources. Manufacturing fabricated metal products and primary metal industries have about 10 percent contributions each. The remaining 20 percent of chromium emissions are attributed to other point sources.

Chromium emissions by principal source category for Minnesota area sources are shown in Figure 2.1.10.5.3, where the data are from the EPA's CEP study for 1990. Industrial processes are the primary area sources to chromium emissions, with a contribution of 54 percent. Waste disposal, treatment and recovery contribute 25 percent of chromium emissions from area sources. Other contributors are stationary source fuel combustion and miscellaneous area sources.

Figure 2.1.10.5.2 1996 chromium emissions by principal source category for point sources

(Data are from the preliminary 1996 Minnesota emission inventory.)

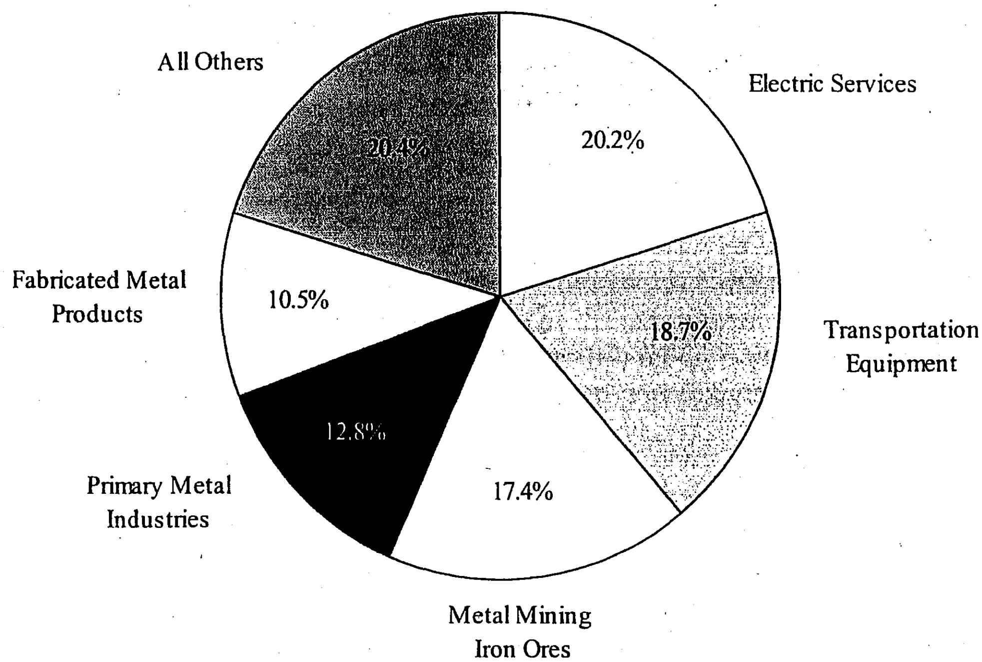
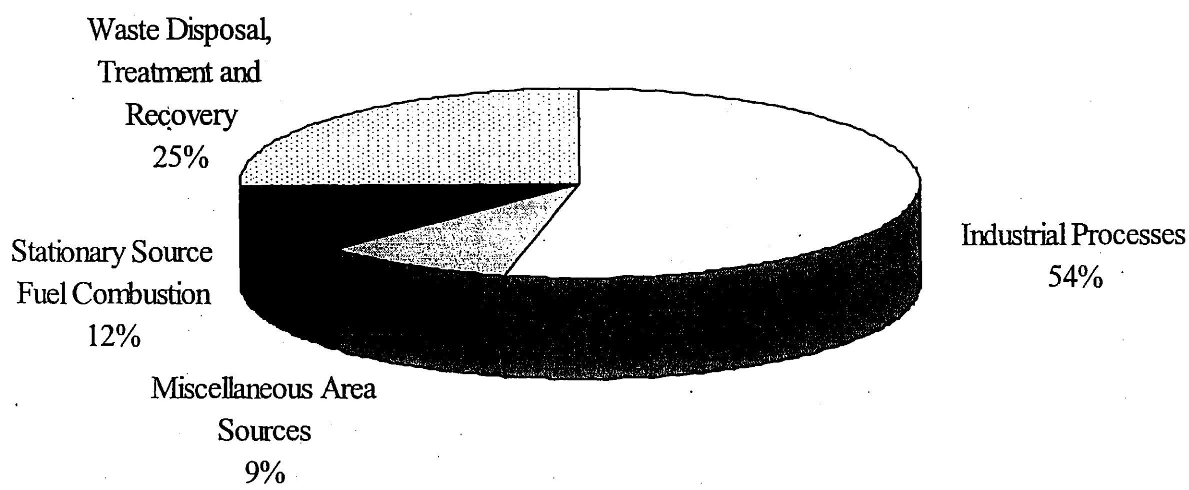


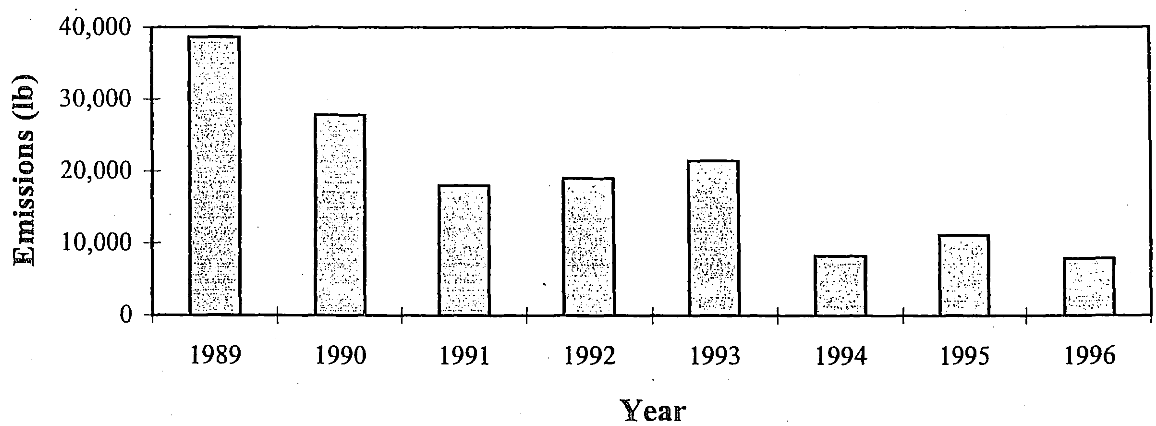
Figure 2.1.10.5.3 1990 Chromium emissions by principal source category for area sources

(Data are from the EPA CEP study for the State of Minnesota.)



The 1989-to-1996 trend in chromium emissions for the Minnesota TRI point sources is shown in Figure 2.1.10.5.4. Chromium emissions reduced from 38,680 lb in 1989 to 7,903 lb in 1996. The most significant reduction — about 61 percent — occurred from 1993 to 1994, due to the prohibition of chromium compounds in treatment of cooling tower water.

Figure 2.1.10.5.4 Trend in chromium emissions based on TRI point source data



2.1.10.6 Chromium summary

Model predictions from the EPA Cumulative Exposure Project show chromium concentrations exceeding the health benchmark on the Iron Range, in the Twin Cities metropolitan area and in a few other places in Minnesota. Monitoring data are mostly below the lower detection limit, but there is a good indication that concentrations exceed health benchmarks at some sites. The health benchmark is for hexavalent chromium [Cr(VI)], so the implicit assumption is that the measured chromium is in the hexavalent form. If this is not the case, the health implications may be overstated.

Humans need very small amounts of elemental chromium. On the other hand, hexavalent chromium is classified as a known human carcinogen, and trivalent chromium [Cr(III)] is considered not classifiable as to human carcinogenicity. Both hexavalent and trivalent chromium have been linked to a variety of health effects, although hexavalent chromium is the more toxic of the two forms. The majority of chromium emissions to the air (about 83 percent) come from point sources, including metals production and processing and chrome plating. The extent of public health concern in Minnesota from air emissions of chromium is uncertain at present. More work is needed to quantify chromium concentrations and to speciate chromium among the various valence states.

2.2 Priority Persistent, Bioaccumulative Toxics (PBTs)

This report describes two groups of air toxic pollutants of primary concern in Minnesota. In the first section (2.1), 10 chemicals were identified as pollutants of concern. For these chemicals, the monitoring concentration, modeling concentration or both exceeded the health benchmarks in some areas of Minnesota.

In this section, a number of persistent, bioaccumulative toxic (PBTs) chemicals of potential concern in Minnesota are introduced. We address PBTs separately because of differences that exist between PBTs and the 10 pollutants discussed in section 2.1.

PBTs are a unique group of chemicals that demonstrate varying degrees of three properties:

1. They are persistent (P) in ecosystems and break down slowly, if at all, in the environment.
2. They are bioaccumulative (B), are not easily metabolized and are collected in the tissues of fish, other animals and plants, often becoming more concentrated as they move up the ecological food chains/webs through consumption or uptake.
3. They are toxic (T) and may be hazardous to human health or ecological receptors in a variety of ways, depending on the chemical and the organism that is exposed. The symptoms of contamination may not be immediate, and dramatic health effects may show up in subsequent generations.

PBTs are long-lasting pollutants that are noticeable due to their ability to travel long distances, transfer and partition among environmental media, and bioaccumulate in aquatic and/or terrestrial organisms. PBTs are pollutants of concern on national and international levels.

Persistence, bioaccumulation and toxicity (the PBT criteria) are three characteristics of PBTs considered to be important determinants of potential adverse health effects to human, wildlife (birds and mammals) and aquatic life associated with actual or potential releases of chemicals. In the standard risk-assessment practices, toxicity is a characteristic reflecting the nature and severity of adverse effects in response to a given exposure, while persistence and bioaccumulation potential are two of the characteristics that influence the extent of exposure to (or contact with) chemicals. The health benchmark used for the pollutants in section 2.1 was based on the toxicity and adverse health effect on the general public, not other biological receptors. Persistence and bioaccumulation potential are not as important for the pollutants in section 2.1 as they are for PBTs in evaluating the adverse health effects on human and other biological receptors.

Unlike the chemicals discussed in section 2.1, PBTs are not of primary concern solely based on their concentrations in the ambient air. Even though they may be emitted directly into the atmosphere, their health benchmarks (if any have been established) do not necessarily directly relate to their concentration in the air. Often, even if not detected in the ambient air, they can adversely affect humans, wildlife or aquatic life in other environmental media. In addition, routine ambient air monitoring does not exist for the PBTs of most concern.

Pollutants with these characteristics remain in the environment for decades, often moving from one medium to another (*e.g.*, from air or water to soil and sediment). Additionally, they enter and are distributed through the food web, accumulating in the tissues of animals, including humans. PBTs may be present at harmful levels in the environment and remain for generations in humans, wildlife and aquatic life. They may interfere with the normal functioning of endocrine or hormone systems, central nervous systems and immune systems. They may cause a variety of problems with development, behavior and reproduction (*i.e.*, birth defects in humans and/or reduced populations and altered community structures within ecosystems) as well as cancer.

For the reasons listed below, PBTs raise unique, often difficult, management challenges that we feel require separate attention from the 10 pollutants previously discussed.

- The priority PBTs listed in this section have all three characteristics of a PBT, while the chemicals discussed in section 2.1 do not necessarily have all, but may have one or two of the three characteristics.
- There is no ambient air monitoring program for these chemicals, but there is for most of the chemicals discussed in section 2.1.
- In order to evaluate PBTs, there is a need for environmental monitoring in multiple media (both biotic and abiotic samples throughout the food web).
- The immediate concern with the chemicals discussed in section 2.1 is the direct health impact on the exposed population. With PBTs, not only are we concerned with the direct impact on the first generation, but also the impact on their offspring and later generations.
- Although many PBTs are banned and have not been produced or consumed for many years, they are still present in environmental samples.
- In order to control the emissions or release of PBTs into Minnesota's environment, not only a multimedia approach within the MPCA and between the state's agencies is required, but there should also be national and international strategies to deal with these ubiquitous chemicals. Therefore, the PBT problem is more of a global and international concern, whereas the pollutants discussed in section 2.1 tend to be more state and local issues.

The PBT chemical products and byproducts are not generated by a single process, do not originate from the same source, and their distribution is not limited to a single medium. Because PBTs easily cross boundaries between environmental media, they are regulated by a variety of laws, regulations and programs. Thus, the MPCA needs a comprehensive and variable strategy for addressing these chemicals.

<u>The recommended PBTs of concern</u>: Both anthropogenic and natural PBTs cause environmental problems. Anthropogenic PBTs have existed for a relatively short time, while other PBTs, such as mercury and cadmium, occur naturally. PBTs also can be grouped as historical problem chemicals (*e.g.*, DDT and PCBs), as PBTs currently in production (*e.g.*, hexachlorobenzene and mercury) and as new PBTs that may enter the environment in the future.

In order to identify the PBTs that should be a priority for the MPCA, we applied the following criteria:

- The chemical in question should demonstrate all three characteristics of a PBT: persistence, bioaccumulation and toxicity.
- The PBT must transfer easily between media — from air and water to the soil and the sediment — thereby facilitating accumulation through food webs.
- The PBT must be present in Minnesota's abiotic and biotic environments (including human, wildlife and aquatic life).

Also, because this paper focuses on air toxics, we ranked the PBTs that are released primarily into the atmosphere as a higher priority.

Following is a list of persistent, bioaccumulative, toxic chemicals of special concern in Minnesota. As shown in Table 2.1, the list was derived from a combination of the Level I substances under the Binational Toxic Strategy, the U.S. Great Lakes Water Quality Guidance, Tier I and Tier II substances that form the baseline commitment under the Canada-Ontario Agreement, and the Resource Conservation and Recovery Act PBTs. All listed chemicals meet the criteria mentioned above. This list is the starting point for implementing Minnesota's PBT strategy. The list will be revised as more information becomes available, and as we receive comments from MPCA managers and staff, and Minnesota Department of Health and other experts. Table 2.2 provides more information about some of the primary sources of the listed priority PBTs.

PBTs of special concern in Minnesota include:

1. Dioxins (PCDD) / furans (PCDF) and dioxin-like compounds *(i.e.*, coplaner PCBs)
2. Mercury and mercury compounds
3. Polycyclic aromatic hydrocarbons (PAHs) (*i.e.*, benzo-a-pyrene) or polychlorinated organic matter (POM)
4. Polychlorinated biphenyls (PCBs)
5. Hexachlorobenzene (HCB)
6. Cadmium and cadmium compounds
7. Toxaphene
8. Other chlorinated pesticides (*e.g.*, chlordane, mirex, aldrin/dieldrin, DDT)
9. Alkyl-lead (tetraethyl lead and tetramethyl lead)

Mercury is the subject of a special MPCA initiative. Mercury has been studied intensively, and its emissions have been quantified separately. Appendix M contains a summary of the initiative, why mercury is a problem in the environment, mercury sources, trends and monitoring.

Table 2.1 Recommended Priority Persistent, Bioaccumulative Toxic (PBT) Chemicals

PBT Chemical	Binational Toxic Strategy	U.S. Great Waters Pollutants	Great Lakes Bioaccumulative Chemicals	EPA Priority PBTs (Level 1)	RCRA PBTs
1. Dioxins (i.e. 2,3,7,8-TCDD)/ furans (i.e. 2,3,7,8-TCDF)	X	X	X	X	X
2. Mercury & mercury compounds	X	X	X	X	X
3. Polycyclic aromatic hydrocarbons (PAHs) or polychlorinated organic matter (POM)	X	X		X	X
4. Polychlorinated biphenyls (PCBs)	X	X	X	X	X
5. Hexachlorobenzene (HCB)	X	X	X	X	X
6. Cadmium and cadmium compounds		*X*			X
7. Toxaphene	X	X	X	X	X
8. Other chlorinated pesticides: DDT (DDD,DDE), chlordane, mirex, aldrin/dieldrin	X	X	X	X	X
9. Alkyl-lead compounds: tetraethyl lead, tetramethyl lead	X	X		X	X

Table 2.2 Sources of Priority Persistent, Bioaccumulative Toxic (PBT) Chemicals

PBT Chemical	CAS #	Sources
1. Dioxins (*i.e.* 2,3,7,8-TCDD) furans (*i.e.* 2,3,7,8-TCDF)	1746016 30402143	Formed as a byproduct in waste incineration, pulp and paper industry, power generation; cement kilns, cigarette combustion, metallurgical processes, chemical manufacturing and forest fires.
2. Mercury and its compounds	7439976	Incidental emissions during energy production from coal, petroleum, wood and natural gases (about 21% of total state emissions), volatilization during product disposal and incineration (about 69%) and emissions incidental to other activities, such as taconite processing, soil roasting and pulp and paper manufacturing (about 10%).
3. Polycyclic aromatic hydrocarbons (PAHs) or polychlorinated organic matter (POM)	N590	Result from incomplete combustion of organic compounds (*e.g.*, coal, petroleum, gasoline and diesel-engine exhaust), residential wood combustion, cigarette smoke, product of petroleum refining processes and iron/steel mill with coke oven. Transportation accounts for 1% of national PAH emissions and may account for 50% of urban PAH exposure
4. Polychlorinated biphenyls (PCBs)	1336363	Used in insulation for electrical cables and wires; production of condensers; used in epoxy, adhesive, calk, plasticizers, additive for lubricants. Improper management, storage and disposal of PCB waste (*i.e.*, transformers). Banned – manufacture and use prohibited.
5. Hexachlorobenzene (HCB)	118741	Used to manufacture chlorinated solvents, as a fungicide, in dye manufacturing, as a degreasing agent. Formerly used as a pesticide.
6. Cadmium and its compounds	7440439	Industrial uses and product sources, such as electroplating, deoxidizer in nickel plating, metal alloys, paints and batteries. Emitted hazardous waste combusters.
7. Toxaphene	8001098	Insecticide for cotton, soybeans, peanuts and maize; used on livestock, vegetables, and for fish management.
8. Other chlorinated pesticides: DDT (DDD, DDE), chlordane, mirex, aldrin/dieldrin	50-29-3 57-74-9 2385-85-5 309-00-2	Control insects that carry disease (*e.g.*, malaria and typhus). Control termites and insecticide for maize. Flame retardant, antioxidant, paint additive. Soil insecticide to control rootworms, beetles. All are banned.
9. Alkyl-lead compounds: tetraethyl lead, tetramethyl lead	NA	Leaded gasoline in aviation fuel, other fuels used by military, and possible use in steel making.

3.0 WHAT ARE THE PRIMARY SOURCES OF THE POLLUTANTS OF CONCERN?

3.1 What are point, area and mobile sources?

Depending on the source of the emissions data, the definition used for a point, area or mobile source can vary. We looked at the EPA National Air Pollutant Trends report, the EPA Cumulative Exposure Project (CEP) and the Minnesota Air Toxics Emission Inventory. Each of these resources grouped emissions into point, area and mobile sources. Source definitions from each of these reports were reviewed to determine their consistency in the use of the terms "point," "area" and "mobile." It is important to understand any differences, because inconsistent definitions can introduce errors into estimated source contributions.

The Minnesota Air Toxics Emission Inventory compiles information for the point source inventory from two sources. The first source is the annual criteria pollutant emission inventory (MCEI) compiled by the MPCA. MCEI sources are required to obtain an air emissions permit and are often large facilities with relatively high emissions. Toxics data are also collected from facility permit applications. Area sources are defined as any stationary sources not required to submit criteria pollutant inventories. Examples of area sources are dry cleaning, gasoline service stations, halogenated solvent cleaners, landfills, agricultural pesticides, publicly-owned treatment works, residential fuel combustion, residential woodburning, and marine vessel loading. A full list of area sources is included in Appendix C. Mobile sources are broken down into on-road vehicles, aircraft, locomotives and nonroad sources. Examples of nonroad sources include construction vehicles, lawn mowers and recreational vehicles, such as snowmobiles, all-terrain vehicles and personal watercraft.

The CEP's source definitions are similar to those used for the Minnesota Air Toxics Emission Inventory. Point sources include facilities reporting to the Toxic Release Inventory (TRI) and point sources from the national Interim VOC or PM_{10} Inventories. Examples of point sources include manufacturing facilities; refineries; municipal waste combustors; hazardous waste treatment, storage and disposal facilities; and combustion sources. CEP area sources are divided into two categories: manufacturing and nonmanufacturing. Chemical manufacturing, degreasing, wood products and industrial surface coating are included in the manufacturing sources. The nonmanufacturing source definition includes dry cleaning, wastewater treatment, gasoline service stations, small stationary combustion and other sources. Mobile sources are comprised of on-road and nonroad sources.

The EPA Trends report defines point, area and mobile sources in a similar way. Large facilities are point sources. Smaller facilities with lower emissions are area sources. However, mobile sources are a subcategory of area sources. The Trends report relies more on a "tier" system to define the emission sources. Each source falls under two tiers. The first tier is a general description, such as solvent utilization, metals processing and industrial fuel combustion. The second tier is more descriptive. Examples include dry cleaning (solvent utilization), nonferrous metal processing and coal combustion (industrial fuel combustion).

The Minnesota Air Toxics Inventory is derived from the state criteria pollutant inventory. Minnesota state law requires point sources in the criteria inventory to report their emissions. The CEP study bases its point source emissions on the TRI and national criteria inventories, which are regulated by their own, different, federal rules. Appendix C includes more specific source definitions.

3.2 What sources are primary contributors to multiple pollutants?

We analyzed available emission information in Minnesota, including the preliminary 1996 Minnesota air toxics emission inventory, 1993 Minnesota air toxics emission inventory, the draft of 1996 national air toxics emission inventory for mobile sources, and the EPA CEP study. We then estimated the relative contribution of each emission source category. A detailed discussion for individual pollutants can be found in Section 2. The findings summarized in Table 3.2.1 are based on the CEP study, because only this study includes all principal emission source categories (point, area and mobile) at this time.

Table 3.2.1 Emissions by principal source category
(Data are from the EPA CEP study for Minnesota.)

Pollutant	Total Emissions (ton/day)	Point Source Contribution (%)	Area Source Contribution (%)	Mobile Source Contribution (%)
Formaldehyde*	15.40	9	33	**58**
Benzene	25.76	5	28	**67**
Carbon Tetrachloride	0.04	42	**58**	
Chloroform	0.34	**83**	17	
Ethylene Dibromide	0.00			
1,3-Butadiene	3.89	2	32	**66**
Acrolein	2.13		**64**	36
Arsenic	0.09	**94**	4	2
Nickel	0.18	**77**	19	4
Chromium	0.07	**83**	12	5
POM	3.79	3	30	**67**

* *The emission amount is for direct emissions of formaldehyde only. The nationwide source contribution for the secondary-formed formaldehyde is similar as Minnesota source contribution for direct formaldehyde emissions.*

Overall, point sources are the top emission sources for metals and chloroform, contributing about 80 percent or more of metals and chloroform emissions. Point sources contribute 42 percent of the carbon tetrachloride emitted in the state. However, point source contributions to formaldehyde, benzene, 1,3-butadiene and acrolein are negligible. This may not necessarily be true for ambient air concentrations next to a particular plant.

Mobile sources have insignificant contributions to emissions of metals, chloroform and carbon tetrachloride, but high emissions of benzene, formaldehyde and 1,3-butadiene. Mobile sources also contribute significantly to acrolein emissions -- the contribution is 36 percent.

Area sources are responsible for emitting of almost all pollutants; they emit more than 12 percent of each pollutant, except arsenic and ethylene dibromide. Area sources are the primary emission sources of acrolein and carbon tetrachloride.

4.0 WHICH GEOGRAPHIC AREAS ARE AFFECTED?

The detailed information about specific pollutants presented in Section 2 shows that a general pattern exists for many of the toxic air pollutants that are emitted in significant amounts from mobile and area sources (*e.g.*, acrolein, formaldehyde, benzene, 1,3-butadiene). That pattern can be described as a situation in which the highest concentrations tend to be found in the center of the Minneapolis-St. Paul metropolitan area, with concentrations decreasing as one moves away from the center. Although areas outside the metro area tend to have lower concentrations, many of the smaller cities (*e.g.*, Duluth, St. Cloud, Rochester, Mankato, Moorhead, Albert Lea) also have elevated concentrations of these pollutants coming from mobile and area sources.

This pattern is not unexpected. The Twin Cities metro area (and other population centers) has a higher population density, a higher density of roads, and more vehicle miles traveled for a given area than rural areas. The metro area also has a higher density of point sources. The maps in Figure 4.0.1 show the population density for the state and the metro area. It is clear there is a relationship between population density and the concentrations of toxic air pollutants. Figure 4.0.2 is a map of the density of vehicle miles traveled in the metro area. Clearly, there is more vehicle traffic in the center of the metro area, where pollutant concentrations are highest.

Figure 4.0.3 is a map of average commute times. This map shows that commuting time tends to be lower in the center of the metro area than in the surrounding suburbs. The highest commute times are found north of the metro area. Thus, it appears that, although residents in the center of the urban core drive less than those in the outer suburbs, they are nevertheless exposed to higher concentrations of toxic air pollutants, the major source of which is mobile source emissions.

Ethylene bromide is an exception to this pattern, in that the highest concentrations were measured in rural areas. The reason for this anomaly is not yet understood and is under investigation.

Chloroform also diverges from the pattern of highest concentrations in the metro area. Chloroform concentrations were above health benchmarks only at the International Falls customs station monitoring site, which is adjacent to a paper mill and near a second paper mill.

Emissions of metals (chromium, nickel, arsenic) are dominated by point sources. The CEP modeling shows that high metal concentrations tend to occur in localized areas around point source activity. Monitoring data are not collected with enough spatial resolution so that localized impact of point sources can be seen in most cases (the exception being chloroform at International Falls).

Figure 4.0.1 Population density in Minnesota

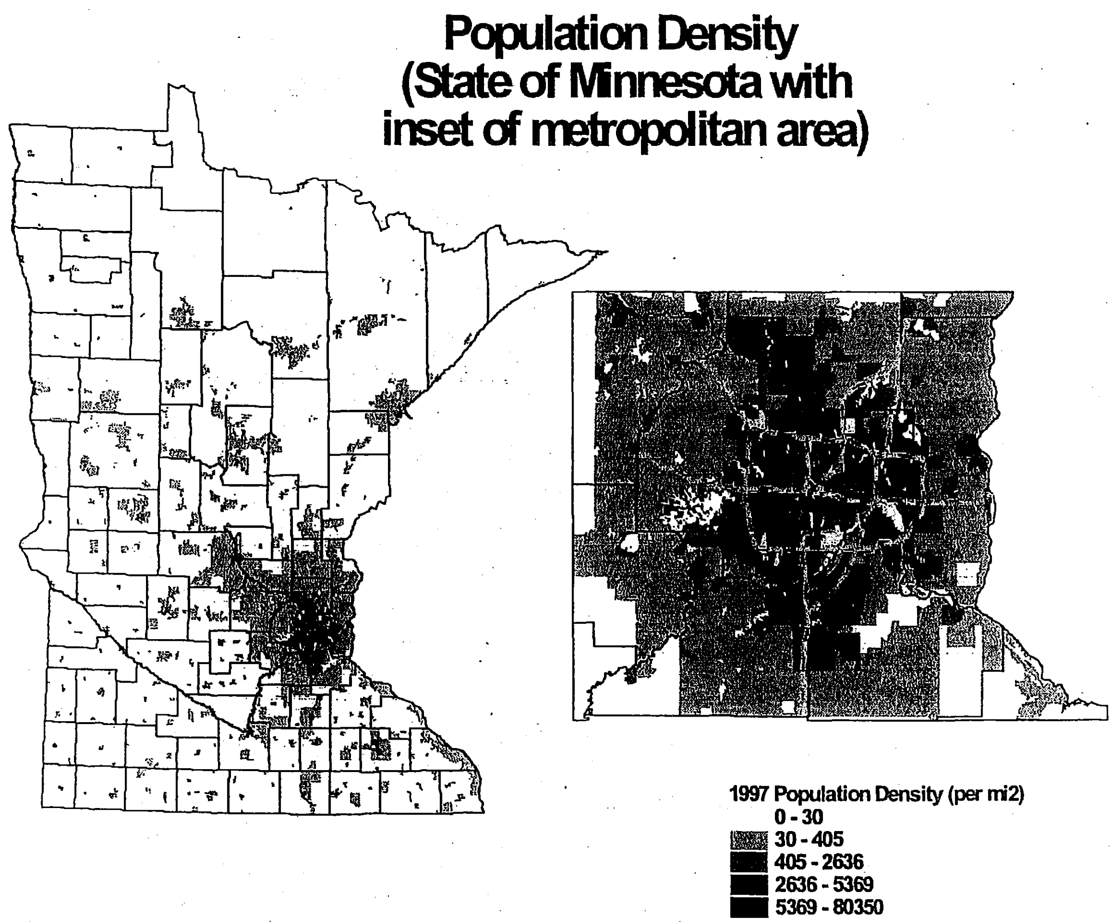


Figure 4.0.2 Vehicle-miles-traveled density in the Minneapolis-St. Paul metropolitan area

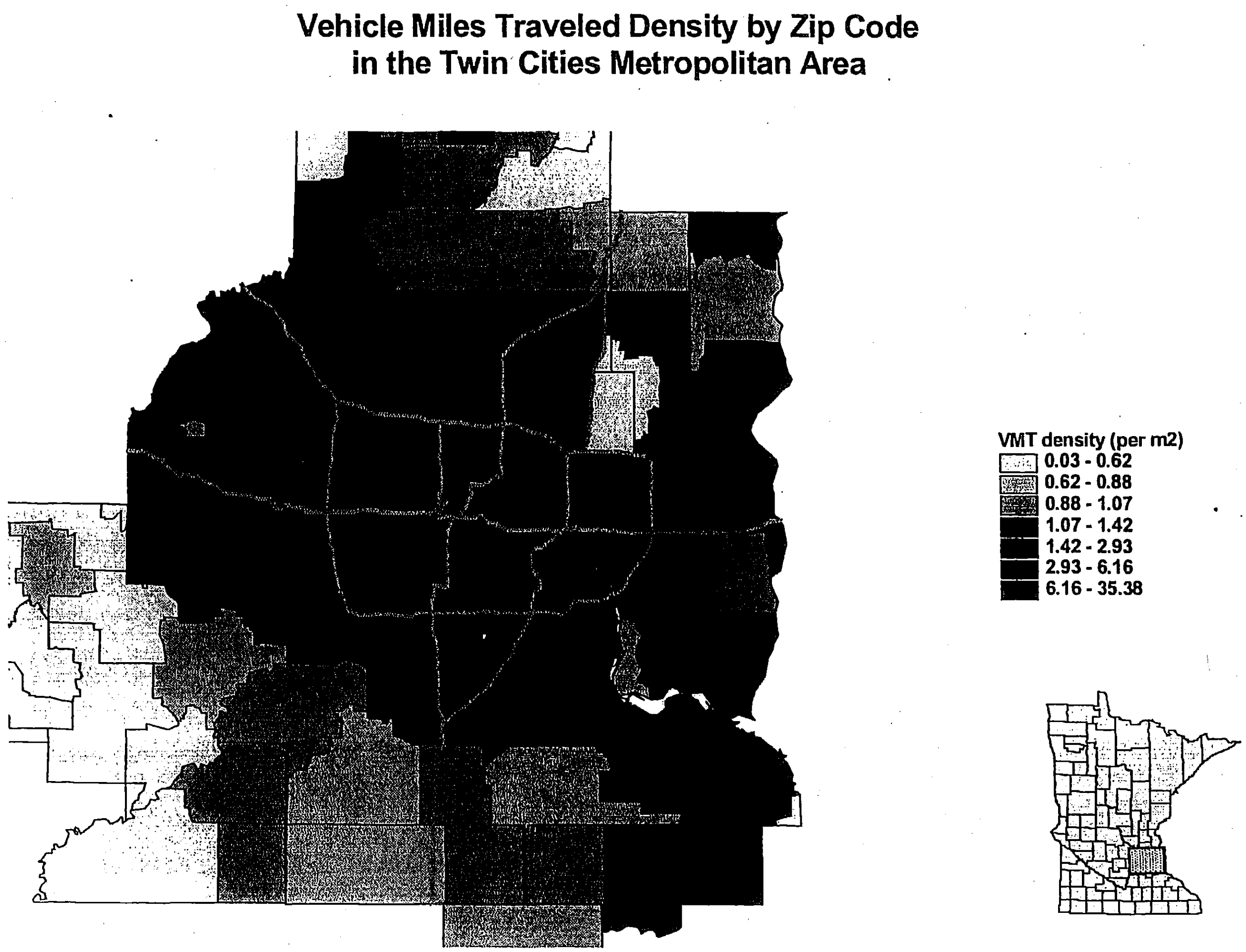
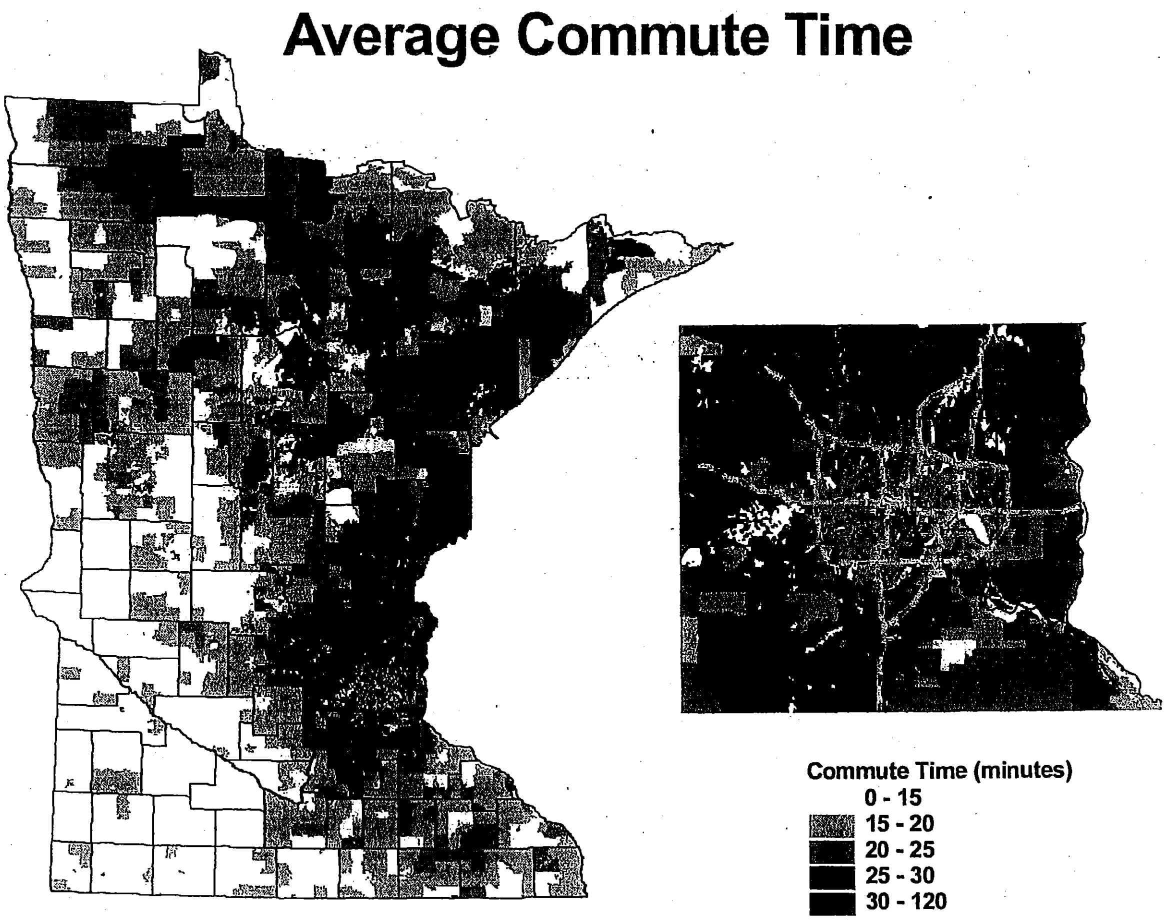


Figure 4.0.3 Average commute times in Minnesota



5.0 HOW SERIOUS IS THE AIR TOXICS THREAT?

While we do not believe there is cause for immediate alarm, we believe air toxic issues are serious and that, to protect human health, the MPCA must take a leadership role in addressing them. We believe that information about air toxics should be brought to the table in a wide variety of state and local decision-making processes.

It is difficult to determine accurately how much human illness or other health consequences (such as respiratory irritation, and reproductive and developmental effects) can be attributed to air toxics. Many illnesses caused by these pollutants develop over many years. There may also be other complicating factors (*e.g.,* genetic predisposition, pre-existing health conditions) that confuse the cause-effect relationship. Therefore, one cannot say specifically how much illness experienced by Minnesota families is entirely or partially due to air toxics.

Although we do not have data on past concentrations, it appears more than likely that concentrations of some toxics have increased in recent years, adding to Minnesotans' cancer or other risk, while others may have decreased over time.

What will happen if nothing is done?

Current emission levels and societal trends suggest that Minnesotans and, indeed, Americans, face a long-term health threat from toxic air pollution. Many of our daily activities emit toxics into the atmosphere. Our housing and other development patterns encourage lifestyles that add to the problem. Specific health effects from air toxics are difficult to determine accurately due to their complex action on the human body, as well as individual factors.

Preliminary findings of the EPA's Cumulative Exposure Project (CEP) predicted that ambient concentrations of eight pollutants would be above health benchmarks proposed by the Minnesota Department of Health. MPCA's own toxics monitoring data show that ambient concentrations for a majority of these pollutants are *higher* than predicted by the CEP study. It is also important to remember that proposed health benchmarks address only health risks from inhaling toxics; several identified pollutants also deposit and persist in other environmental media, such as water, soil and sediment, leading to additional health risks.

Historically, the MPCA has regulated many of the point and area sources of air toxics. Mobile sources, relatively unregulated by the state, have also been recognized for decades as major emitters of large quantities of toxics. The Metropolitan Council predicts that the metro area will experience population increases, increased per capita vehicle miles traveled, and low public transit use in the future. These factors, along with increasing suburban development, is likely to result in increased pollution from motor vehicles.

Action is required to help all Minnesotans and government agencies understand and seek ways to reduce toxic air emissions. We can also work with others to develop strategies to reduce toxic pollution. Possible MPCA partners include local, state and national government and organizations. For example, the Metropolitan Council recently outlined a 40-year growth strategy aimed at building strong communities, fostering economic growth and protecting the natural environment. The Council also plans to assess the impact of development plans on air quality. This is an important opportunity for input from the MPCA and should not be overlooked.

In order to determine our response to the threat from air toxics, the following points must be considered:

- What does each air toxic contribute to increased excess cancer or other known risk?
- How seriously does the general public take air issues?
- What efforts are taking place at the national level to reduce air toxics?

5.1 Contributions to increased excess cancer risk

5.1.1 EPA Cumulative Exposure Project (CEP) modeling data

Figures 5.1.1.1 and 5.1.1.2 are pie charts showing the emissions source categories responsible for the excess cancer risk in Minnesota due to inhalation of those CEP pollutants for which a health benchmark exists. According to the data from the CEP, more than half (53 to 61 percent) the estimated excess cancer risk from all air toxics comes from mobile sources, such as cars, trucks, airplanes and off-road vehicles. Area sources, such as furnaces, woodstoves, fireplaces, gas stations and dry cleaners, contribute about 25 percent of the risk, and stationary or point sources, such as manufacturing facilities, utilities and refineries, contribute about 22 percent of the risk.

Figure 5.1.1.2 includes the pollutant known as POM (polycyclic organic matter). POM consists of more than 100 compounds, and includes the subgroup of organic compounds known as PAHs (polycyclic aromatic hydrocarbons) and PAH-derivatives. POM is listed as a hazardous air pollutant in the Federal Clean Air Act. Carcinogenic PAHs are a recommended MPCA priority as a persistent, bioaccumulative toxic or PBT (see Section 2.2). POM is produced by the incomplete combustion of fossil fuels and vegetable matter. PAHs have been detected in motor vehicle exhaust, smoke from residential wood combustion and fly ash from coal-fired electric-generating plants. POM, including PAHs and their derivatives, are found in diesel exhaust. The California Air Resources Board (CARB) lists POM, PAHs and their derivatives as toxic air contaminants, and is evaluating diesel exhaust as a toxic air contaminant. Furthermore, CARB indicates that diesel particulate matter is likely to contribute significantly to the overall cancer risk from air toxics.

The exact composition of POM is not known precisely. Hence POM was not evaluated as one of the 10 pollutants of concern for this paper. The State of California has determined that several POM compounds, including benzo(a)pyrene and other PAHs, are carcinogens. For the purpose of this discussion, the carcinogenicity of POM is assumed to be equivalent to that of one of its major components, benzo-a-pyrene (BaP).

Figures 5.1.1.1 and 5.1.1.2 were produced by taking the statewide mean modeled concentration of 25 (or 26) carcinogens attributed to point sources, area sources, mobile sources and background levels and dividing by the health benchmark for each carcinogen. The resulting values were summed for each source category. The background contribution was excluded in determining the contribution of each source category to overall cancer risk, under the assumption that the majority of the background concentrations of most of the substances would apportion to point, area and mobile sources in approximately the same ratios as for known (nonbackground) concentrations.

Figure 5.1.1.1 EPA Cumulative Exposure Project: Excess lifetime cancer risk attributed to each source category from inhalation of 25 toxic air pollutants

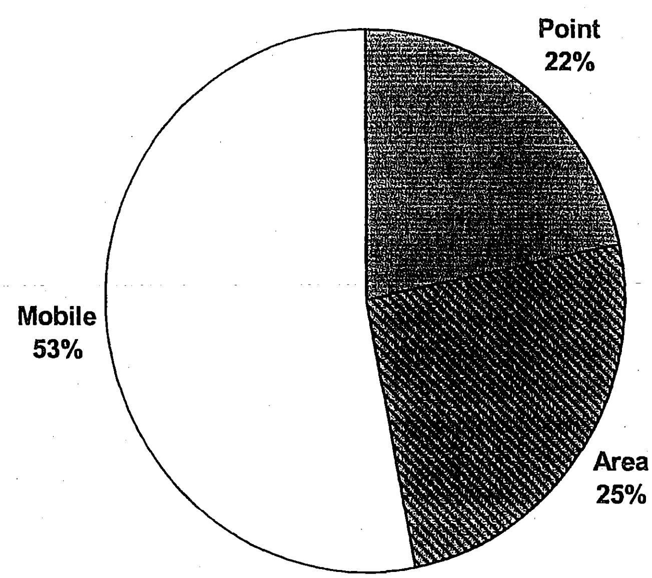
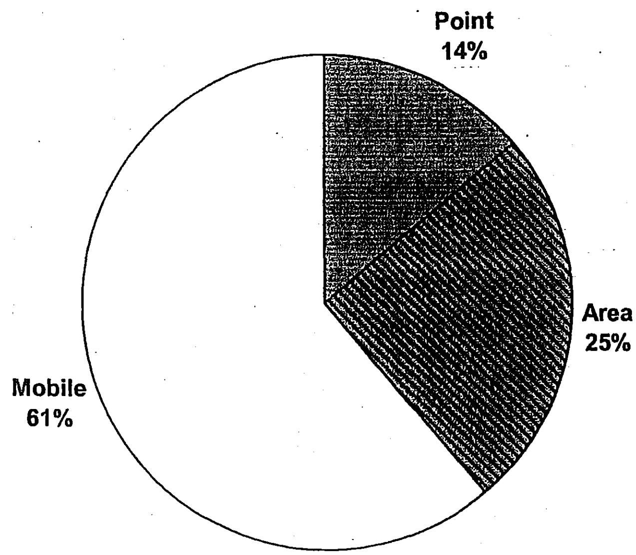


Figure 5.1.1.2 EPA Cumulative Exposure Project: Excess lifetime cancer risk attributed to each source category from inhalation of 26 toxic air pollutants (including polycyclic organic matter, POM).



The total excess lifetime cancer risk from inhaling the 25 carcinogenic air pollutants modeled in the EPA Cumulative Exposure Project ranged from 2.3 to 77.3 in 100,000. Maps showing the statewide distribution of cancer risk can be viewed in color at the Internet site *http://www.pca.state.mn.us/air/at-cep.html*. If POM is included in the calculation (and its carcinogenicity characterized as being equivalent to benzo-a-pyrene), then the total excess lifetime cancer risk ranged from 16.8 to 169.4 in 100,000. These excess lifetime cancer risk values, together with the 1990 U.S. Census population estimates for each census tract, were used to estimate additional cancer cases over a lifetime for each census tract. Figure 5.1.1.3 shows a map of the number of expected excess lifetime cancer cases in each census tract in the Twin Cities metropolitan area due to inhalation of 25 carcinogenic air pollutants as modeled in the EPA Cumulative Exposure Project. Figure 5.1.1.4 shows the same map as in Figure 5.1.1.3, but with POM added to the calculation of number of cancer cases. Although the modeled concentrations at the census tract level are useful for providing a general sense of air toxics concentrations around the state, they do not account for many local conditions. The modeled concentrations provide a more reliable representation of air toxics when aggregated over a larger number of census tracts, such as urban counties. Caution should be used in drawing conclusions about current local conditions based on the modeling data alone.

Figure 5.1.1.3

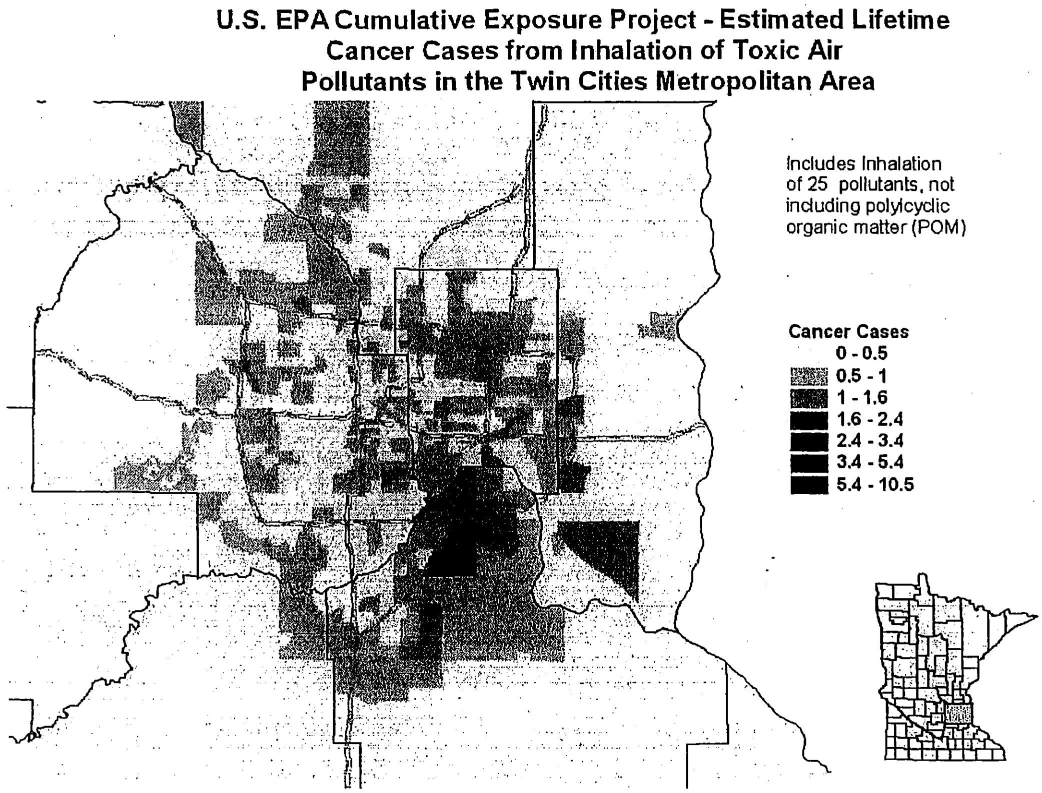
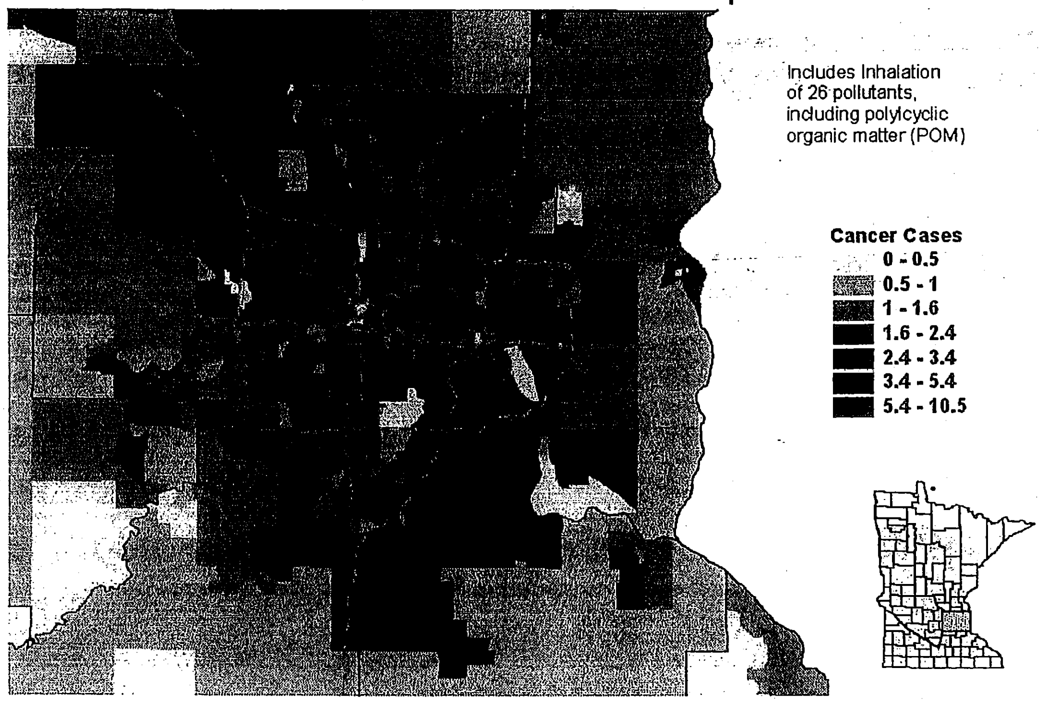

U.S. EPA Cumulative Exposure Project - Estimated Lifetime Cancer Cases from Inhalation of Toxic Air Pollutants in the Twin Cities Metropolitan Area
Includes Inhalation of 25 pollutants, not including polylcyclic organic matter (POM)
Cancer Cases
0 - 0.5
0.5 - 1
1 - 1.6
1.6 - 2.4
2.4 - 3.4
3.4 - 5.4
5.4 - 10.5

Figure 5.1.1.4

U.S. EPA Cumulative Exposure Project - Estimated Lifetime Cancer Cases from Inhalation of Toxic Air Pollutants in the Twin Cities Metropolitan Area



5.1.2 Minnesota ambient air monitoring data

Ambient air monitoring data for the 10 pollutants of concern indicate that exposure to multiple air pollutants may contribute to an increased cancer risk. Cancer is the toxicological endpoint of concern for nine of the 10 pollutants of concern specifically addressed in this paper. Additional health impacts to the respiratory system are of potential concern from exposure to two of the 10 pollutants of concern: formaldehyde and acrolein. Noncancer effects may be attributed to the remaining eight pollutants of concern; however, readily available toxicological data are lacking. Table 5.1.2.1 lists the critical toxicological endpoints for the 10 pollutants of concern.

Table 5.1.2.1 Chronic toxicological endpoints for the 10 pollutants of concern

Pollutant of Concern	*Noncancer*	*Cancer*
Formaldehyde	Eye and respiratory irritant	Nasal
Benzene	Blood-related disorders (*e.g.*, anemia)	Blood (leukemia)
Carbon tetrachloride	Alimentary	Cancer (liver)
Chloroform	Liver, kidney	Cancer (liver, kidney)
Ethylene dibromide	Reproductive system	Nasal
1,3-butadiene	Reproductive and developmental systems	Blood (leukemia)
Acrolein	Respiratory system	Not available
Arsenic	Cardiovascular and nervous systems	Lung
Nickel	Respiratory and immune systems	Lung and nasal
Chromium	Nasal and respiratory system	Lung

While this paper focuses on 10 pollutants of concern, the MPCA air toxics ambient monitoring program samples for 36 volatile organic compounds, 7 carbonyl compounds, approximately 32 metals and PM_{10}. Table 5.1.2 below lists the estimated cancer and noncancer risk for each site based upon the monitoring data collected at each location. All sites exceed the negligible excess lifetime cancer risk of one in 100,000 (*i.e.*, 1×10^{-5}) established by the MDH. The estimated risks are individual lifetime cancer risks. For example, the individual risk for a person exposed during his or her lifetime to the mean concentrations of carcinogens measured at the Minneapolis Library would be an eight-in-100,000 chance of developing cancer. Population risks based upon the number of people living within a specified area of the monitoring site will be calculated at a later date.

Total cancer risks were calculated by dividing the mean ambient air concentration (across all years) for each pollutant by the cancer health benchmark (which corresponds to 1×10^{-5} risk level) and summing the resulting values. Cancer health benchmarks were available for 16 of the 43 monitored VOC/carbonyl compounds. In other words, the total cancer risk is based upon the mean ambient concentration only for those 16 pollutants having readily available toxicity information. The estimated risk excludes potential cancer risk from inhalation exposure to metals, additional VOC/carbonyl compounds, particulate matter, POM, and potential cancer risk from other routes of exposure (*e.g.*, ingestion of contaminated fish, pesticide residue on food, indoor air). Adding multiple pathways and additional air pollutants to the exposure scenario, would increase cancer risks above those estimated in table 5.1.2.2.

Noncancer risks listed in Table 5.1.2.2 were calculated by dividing the mean ambient air concentration (across all years) for each pollutant by the pollutant specific noncancer health benchmark and summing the resulting values, irrespective of toxicological endpoint. Of the VOCs and carbonyls monitored, 7 have nervous system effects, 8 affect the respiratory system, and several have developmental effects, liver effects and/or kidney effects. Excess risk (greater than one) can be attributed primarily to respiratory system effects from concentrations of formaldehyde.

Table 5.1.2.2 Total individual cancer and noncancer risks based upon monitored VOC and carbonyl compounds

Monitoring Location	*Total Cancer Risk (x E-5)*	*Total Noncancer Risk*
METRO AREA		
Bush Street – St. Paul	11.04	1.95
Ashland	8.35	1.14
Minneapolis Library	8.13	1.17
Minnehaha Academy	7.38	1.22
Koch 426	7.11	0.88
Plymouth	7.09	0.89
St. Paul Park	7.06	0.88
Holman Field	6.51	0.90
Koch 420	6.15	0.79
Koch 423	6.13	0.94
Harding High	---	---
GREATER MN		
Pipestone	7.48	0.97
Alexandria	7.43	0.97
Sandstone	7.26	0.92
International Falls 1240	7.20	0.73
Little Falls	7.19	0.84
International Falls 1241	7.02	0.86
Duluth 7549	6.24	0.79
Zumbrota	6.24	0.82
Granite Falls	6.08	0.97
Fergus Falls	6.05	0.97
Hibbing	5.55	0.82
Elk River	5.42	0.80
Rochester	5.34	0.75
Warroad	4.86	0.64

5.1.3 Uncertainties in estimating health risk

Assessment of public health risk associated with air pollutants is often limited to readily available emissions data, since monitoring data are rare in most parts of the country. In reality, the relationship between exposure to air pollutants and resulting health impacts is complex. Many air pollutants undergo atmospheric transformation in which a parent compound is removed from the atmosphere only to produce secondary products associated with different health effects. In fact, the major source of some air pollutants is secondary formation. These secondary formations are not addressed in an assessment of risk based exclusively on emission data.

Furthermore, this paper focuses on 10 pollutants of concern and briefly reflects on potential risk from other monitored VOCs. However, these compounds are just a portion of the 188 hazardous air pollutants regulated by the Clean Air Act Amendments of 1990 and just a fraction of the anthropogenic pollutants emitted into the air on a daily basis. In other words, ambient air contains multiple air pollutants of which only a few are monitored. These multiple pollutants have a complex toxicity, since chemicals may affect more than one organ/system and chemical interaction may be additive, synergistic or antagonistic.

Although it is likely that the MPCA monitors many of the more prominent air pollutants, monitoring of air pollutants, excluding criteria pollutants, is a recent activity. Exposure to air pollution has been going on for some time, and past exposures may have been greater for some pollutants and less for others. Clearly, information is lacking on the risk to public health from exposure to multiple air pollutants. There can be no complete assessment of risk as long as ambient concentrations of air pollutants are not identified, exposure assessments are incomplete and unrealistic, and toxicological information remains unavailable for individual pollutants and chemical mixtures.

5.2 How do air issues rank with the general public?

The MPCA recently completed extensive public participation efforts aimed at learning about the environmental values and views of Minnesota citizens. Two of the recent efforts, *The Governor's Forums: Citizens Speak Out on the Environment* and a telephone survey of 800 households (public values survey), shed some light on how the public currently views air quality issues. The MPCA has also collected information on the relative importance of air pollution sources compared to other environmental issues (Comparing Environmental Risks project, conducted in 1996 and 1997 by the Jefferson Center and sponsored by the MPCA).

The MPCA convened *The Governor's Forums: Citizens Speak Out on the Environment* in seven two-hour meetings held in various locations around the state. The forums were designed to receive input from the general public. Participants at each forum brainstormed a list of priority environmental concerns and, using electronic keypads, ranked them on a high (5) to low (1) scale. Results of the keypad voting were tabulated by a computer and immediately displayed to the group. Two of the forums were held in the Twin Cities metropolitan area. The other forums were held in Duluth, Brainerd, Detroit Lakes, Marshall and Rochester.

Forum results indicate that citizens who live in the Twin Cities metropolitan area view air quality environmental issues as a higher priority than citizens who live outside the metropolitan area. In fact, at both of the metropolitan forums, air quality issues emerged as one or two of the three most important environmental issues. At the first metropolitan forum, "Air Quality" ranked first and "Statewide auto emissions" ranked as the third most important environmental issue out of a list of nine. At the second metropolitan forum, "Air quality- industrial emissions" ranked second in priority out of a list of 20 important environmental issues. At the Duluth forum "Air quality" ranked fifth out of 22. "Air quality" ranked low or was not mentioned as an important environmental issue at the forums in Detroit Lakes, Marshall, Rochester and Brainerd.

Using the same forum format, 100 MPCA staff from across the agency also ranked their highest-priority environmental issues. At the first of two staff forums, "Urban air toxics" ranked first and "Auto emissions/increased traffic" ranked second. At the second staff forum, "Toxic pollutants in air and water" ranked first and "Air mobile sources" ranked second. It is clear that MPCA staff regard air toxics in general and air mobile sources in particular as important environmental issues on which the MPCA should focus.

To learn more about what regular citizens are thinking about their environment, pollution, and environmental values and priorities, the MPCA contracted with a market research firm to conduct a statewide telephone survey of more than 800 randomly-selected Minnesotans. One open-ended questions asked in the survey was, "In your opinion, what is the greatest threat to the Minnesota environment?" The top four perceived greatest threats and the percentage of respondents who chose that threat are listed below.

Statewide Composite of the Four Most Important Environmental Threats

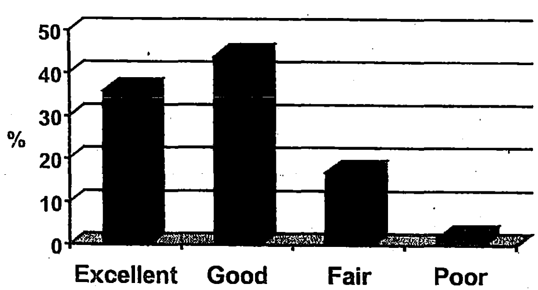
Greatest threat to the Minnesota environment	Percent
Agricultural runoff, like soil erosion from fields, including farm fertilizers	11%
Exhaust from cars, trucks and buses	11%
Industrial chemical waste	10%
Emissions from manufacturing facilities and refineries	9%

Regional Distribution of the Four Most Important Environmental Threats

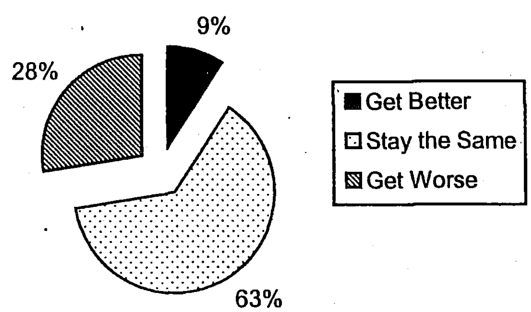
Greatest threat to the Minnesota environment	Metro	North	South
Agricultural runoff, like soil erosion from fields, including farm fertilizers	6.3%	11.9%	20.9%
Exhaust from cars, trucks and buses	14.0%	9.6%	8.2%
Industrial chemical waste	9.3%	10.6%	11.2%
Emissions from manufacturing facilities and refineries	8.0%	11.0%	9.2 %

However, when these same 800 people were asked about the current quality of the air in their community, 80 percent of the respondents felt the air quality was either excellent or good. When asked about the future, 63 percent of the respondents expected the air quality to stay the same over the next 10 years.

Current Air Quality



Future Air Quality



Results from the public values survey (the recent telephone survey of 800 households) seem to corroborate the findings from the metropolitan "Governor's Forums." Two of the top four perceived greatest threats are related to air toxics emissions. The results from this survey and the

"*Governor's Forums*" indicate that the public is indeed concerned about air toxics issues. At the same time, according to the telephone survey, the public feels that the current quality of the air in their communities is good to excellent. This presents a challenge to environmental agencies on how to get public buy-in to emission-reduction measures to address the air toxics problem when the public does not feel there is an air quality crisis.

The Comparing Environmental Risks project also indicates how the general public views air toxics issues. The project asked three groups of people (MPCA staff, citizens jury and stakeholders) to rank 12 environmental issues selected by MPCA technical staff. The technical staff ranked the issues based on their knowledge of the relative seriousness of the effects associated with the issues. The citizens jury and stakeholders ranked the issues based on their perception of seriousness after MPCA staff and other expert witnesses provided presentations on the risks associated with the 12 environmental issues. The citizens jury (20 citizens randomly selected from around the state) met for a five-day information-sharing and ranking session. The MPCA conducted a three-and-one-half-day ranking session with the stakeholders. Stakeholders, in this case, were defined as individuals who had regular contact with the agency (industrial permittees, nonprofit organizations, local units of government, etc.). The process was not conducted in order to set priorities for addressing the issues (*e.g.*, benefits vs. risks), but to evaluate relative seriousness of each issue with regard to human health, ecological health and quality of life, and then to rank issues by comparing them to each other.

Table 5.2.1 includes the overall results of the ranking exercises by the citizens jury, stakeholders and MPCA staff. The bold items indicate the ranked importance of air pollution sources compared to other environmental issues.

Table 5.2.1 Risk-based environmental priorities project ranking results

1 = Most-serious risks, 12 = Least-serious risks

Citizens Jury	Stakeholders	MPCA Staff
1. Industrial Sources of Air Pollution	1. Nonpoint Sources	1. Mobile Sources of Air Pollution
2. Mobile Sources of Air Pollution	2. Mobile Sources of Air Pollution	2. Industrial Sources of Air Pollution
3. Spills & Environmental Emergencies	3. Feedlots	3. Nonpoint Sources
4. Hazardous Waste	4. Area Sources of Air Pollution	4. Area Sources of Air Pollution
5. Superfund	5. Septic Tanks	5. Feedlots
6. Area Sources of Air Pollution	6. Industrial Sources of Air Pollution	6. Wastewater Treatment
7. Wastewater Treatment	7. Superfund	7. Septic Tanks
8. Nonpoint Sources	8. Wastewater Treatment	8. Solid Waste
9. Feedlots	9. Spills & Environmental Emergencies	9. Superfund
10. Solid Waste	10. Hazardous Waste	10. Hazardous Waste
11. Storage Tanks	11. Solid Waste	11. Spills & Environmental Emergencies
12. Septic Tanks	12. Storage Tanks	12. Storage Tanks

Conclusion: In each of the three research projects mentioned above, air pollution or air toxics issues are a high priority with the public.

- In *The Governor's Forums: Citizens Speak Out on the Environment,* citizens from the metropolitan forums ranked air quality issues as two of the three most important environmental issues.
- In the public values survey, two of the four greatest environmental threats (as perceived by the 800 respondents) were related to air toxics emissions.
- In the Comparing Environmental Risks project, the citizens jury, stakeholders and MPCA staff all ranked the three sources of air pollution as the top environmental priorities projects.

Results from the public values survey also indicate that the public feels the current air quality in their communities is good to excellent and likely to remain that way for the next 10 years.

5.3 What efforts are taking place at the national level to reduce air toxics?

The EPA recently developed *The Integrated Urban Air Toxics Strategy*[1] or *Strategy* under the authority of sections 112(k) and 112(c)(3) of the 1990 Clean Air Act Amendments (Act). The Act provides the foundation for the EPA's current air toxics program. The EPA intends that the program "be designed to characterize, prioritize and equitably address the serious impacts of hazardous air pollutants on the public health and the environment through a strategic combination of regulatory approaches, voluntary partnerships, ongoing research and assessments, and education and outreach." Although the title of the *Strategy* includes the word "urban," the *Strategy* itself outlines a program that addresses reduction of toxics nationwide with a special focus on urban areas. Most of the program activities outlined in the *Strategy* are in the planning phase.

The Integrated Urban Air Toxics Strategy includes:
- a description of risk reduction goals;
- a list of 33 hazardous air pollutants (HAPs) judged to pose the greatest potential threat to public health in the largest number of urban areas, including 30 HAPs specifically identified as being emitted from smaller industrial sources known as "area" sources; and
- a list of area source categories which emit a substantial portion of these HAPs, and which are being considered for regulation.

In addition, the EPA states that "because mobile sources are an important contributor to the urban air toxics problem, the *Strategy* also describes actions to reduce toxics from these sources, including those which address diesel particulate matter (PM)."

All of the 10 pollutants targeted as pollutants of concern in this paper are among the 33 HAPs listed in the *Strategy*. Also, six of the 10 persistent, bioaccumulative toxics or BPTs mentioned as pollutants of concern in this report also appear among the 33. Dioxins, toxaphene, "carcinogenic PAHs," and "other chlorinated pesticides" are not among the 33 HAPs specifically listed.

[1] (*National Air Toxics Program: The Integrated Urban Strategy; Notice* published July 19, 1999)

Since 1990, the EPA has focused on reducing emissions of toxic air pollutants from major stationary sources – or point sources – through the implementation of technology-based emissions standards. The EPA believes that these actions have resulted in, or are projected to result in, substantial reductions in HAP emissions. However, these standards are aimed at nonmobile sources and our analysis of the CEP data shows that *mobile source emissions account for about half the excess cancer risk* (see Section 3.3).

In our opinion, the EPA's *Strategy* does not appropriately recognize or address the impact of mobile sources on the overall risk. In part, this may be due to the *Strategy* being developed as a requirement under section 112(k) of the CAA primarily by the EPA's Office of Air Quality Planning and Standards (OAQPS), which does not have the authority to regulate risk from mobile sources. Through section 112(k), Congress instructed the EPA to develop a strategy for air toxics in urban areas that includes specific actions to address the large number of smaller, area sources and that contains broader risk-reduction goals encompassing all stationary sources. It is the EPA's Office of Mobile Sources, not its OAQPS, that is responsible for the risk attributed to mobile sources. However, the Office of Mobile Sources did participate in developing the strategy, which is why it is termed an 'integrated' strategy.

The EPA's overall approach to reducing air toxics consists of four components. The four components as outlined in the *Strategy* are listed below. Other than the technology-based emissions standards already promulgated, most of the program elements described consist of what EPA hopes to do in the future. It is important that the MPCA play a strong role in shaping the four program components and in urging progress. EPA and MPCA resources should be directed toward those activities that will as quickly as possible significantly reduce the overall risk that air toxics pose to Minnesotans.

1. Source-specific standards and sector-based standards

Maximum achievable control technology: Section 112(d) of the Act requires the EPA to use a technology-based approach to reduce emissions air toxics from major sources. Using this approach, the EPA developed standards for emission of air toxics within an industry category. These standards, known as "maximum achievable control technology (MACT) standards," are based on emission levels that are already being achieved by better-controlled sources within an industry. Under this program, the EPA listed 174 industry categories, and as of July 19, 1999, the agency had promulgated 43 standards regulating 78 industry categories. The EPA is continuing to develop the standards. Although all are required to be promulgated by November 2000, it is expected that most will not be promulgated until 2002.

The EPA intends to use the technology-based approach to develop standards for the new area source categories listed in the *Strategy* not already scheduled for regulation. These new categories listed include publicly owned treatment works, gasoline distribution Stage I, paint-stripping operations and municipal landfills plus nine other categories. The EPA generally intends that these new standards will apply to all facilities in these categories regardless of whether they are in urban or rural locations.

Combustion standards: The EPA has issued rules under section 129 to control emissions of some air toxics from some kinds of solid waste combustion facilities. These rules, which affect municipal waste combustors and hospital/medical/infectious waste incinerators, target reductions in mercury and dioxin/furan emissions. The EPA is currently working on additional rules for industrial and commercial waste incinerators and small municipal waste combustor units.

Residual risk: The residual risk program under 112(f) requires that a risk assessment be performed eight years after a MACT standard is promulgated for an industry category. If the EPA finds that the level of remaining or residual risk does not provide an "ample margin of safety to protect public health" or "prevent...an adverse environmental effect," then the EPA must set additional standards. The EPA is currently conducting analyses on 13 of the earliest-promulgated MACT standards. None of these risk assessments has been completed.

Mobile source standards: Most of the EPA's emission standards to date have been aimed at improving urban air quality for the criteria pollutants carbon monoxide, ozone and PM_{10}. The EPA states that there have been corresponding reductions in toxic emissions because of efforts to reduce the criteria pollutants. In its *Strategy,* the EPA states that "because of the time it takes for older vehicles to retire and be replaced with newer vehicles that comply with the latest emission standards, total mobile source toxic emissions will decline for many years into the future." (The MPCA's ambient trend data for formaldehyde do not support EPA's implication of declining concentrations in the ambient air. Concentrations of formaldehyde have been stable for the past four years.)

To achieve reductions in mobile source HAPs, the EPA is relying on section 202(l) of the Act. This section requires the completion of a study of motor vehicle-related air toxics, and promulgation for the control of HAPs from motor vehicles based on that study. The EPA completed the required study in 1993. The agency is now preparing an update to that study, and is considering rulemaking under section 202(l)(2). According to the *Strategy,* the EPA also plans "to study the role of nonroad engines in the air toxics problem over the next couple of years, and may propose standards if appropriate."

2. National, regional and community-based initiatives to focus on multimedia and cumulative risks

Section 112(k)(4) of the Act requires the EPA to "encourage and support areawide strategies developed by the state or local air pollution control agencies." In the *Strategy* under this program component, the EPA describes required risk studies that are underway or completed: Utility study, Great Waters Program, Mercury study and Urban Air Toxics Strategy.

3. National air toxics assessments

Activities under this component of the program include expansion of air toxics monitoring, improving and updating emissions inventories, modeling, continued research on health effects and exposures to both ambient and indoor air, and use and improvement of exposure and assessment tools. For the most part, these activities are still in the planning stages, rather than in the implementation stage.

4. Education and outreach

In this program component, the EPA hopes to do more education and outreach on air toxics in both the ambient air and indoor air.

EPA's 5-year timeline for program implementation

In the *Strategy*, the EPA provided milestones for the next five years. These milestones are listed below. The EPA said it would attempt to meet the "demanding schedule as expeditiously as practicable."

1999
- Publish the *Integrated Urban Air Toxics Strategy*, including the urban HAPs list and the area source category list.
- Issue the first Integrated Urban Air Toxics Strategy report to Congress under section 112(k)(5).
- Complete 1996 National Toxic Inventory update.
- Begin state/local/tribal stakeholder communication and information exchange on implementing the strategy.
- Propose motor vehicle and fuel standards under section 202(l).

2000
- Complete initial national and urban scale assessment.
- Complete motor vehicle and fuels standards development under section 202(l).
- Start development of additional area source standards.

2002
- Complete 1999 National Toxics Inventory update.

2003
- Complete 1999 assessment.
- Finalize source category list.

2004
- Promulgate standards for the area source categories newly listed in the *Strategy*.

6.0 WHAT FUTURE ACTIVITIES ARE RECOMMENDED?

The findings in this paper demonstrate the need for additional activities to further define the issues with air toxics, to communicate the information to internal and external parties, and to develop reduction strategies with appropriate partners. While there is no cause for immediate alarm, this is a serious, long- term problem and the MPCA has a responsibility to examine and further clarify the issue and share the information with others. This will allow us to better determine what priority air toxics issues pose, what level of resources are needed, and where to begin.

Future work on the air toxics issues will be accomplished by an Air Toxics Lateral Team which has already been established. The Air Toxics Lateral Team consists of three subteams:

1. Technical Team,
2. Communication and Reduction Strategies Team
3. Mobile Source Reduction Strategies Team

The overall goals of the Air Toxics Lateral Team will be:

- to identify, communicate, and when possible, address problems associated with air toxic pollutants; and
- to protect human health and the environment from the effects of air toxics.

These goals will need to be further refined by the participants. We expect that these three subteams will begin work in September 1999.

The Technical Team will focus on completing and revising the activities described in section 6.1 to further refine our knowledge of air toxics.

As described in section 6.2, the initial focus of the Communication and Reduction Strategies Team will be to communicate the broad, overall issue and secondarily to develop emission-reduction strategies. However, current knowledge of the large contribution of mobile sources to air toxics in the ambient air (as well as other pollutants, such as ozone and greenhouse gases) necessitates the formation of a team to look at strategies to reduce emissions from mobile sources.

The Mobile Source Reduction Strategies Team will develop and implement a work plan that encompasses all the MPCA's activities directed at mobile sources of air toxics. This would include the Mobile Source Ozone/Air Toxics Task Force, Green Fuel Project, and community-based outreach activities, among others. Initial objectives are to develop a constituency understanding of the environmental concerns associated with motor vehicle use, and to develop proposed emission-reduction strategies for the next biennium.

Sections 6.1 and 6.2 provide further detail about the Technical Team and the Communication and Reduction Strategies Team. Further description of the Mobile Source Reduction Strategies Team is not included in this paper because this team is in the very early stages of development.

6.1 Air Toxics Technical Team

The formation of this team marks the start of Phase 2 of the work on the air toxics problem. The primary audience of the Technical Team will be the Air Toxics Communication and Reduction Strategies Team.

The purpose of the Air Toxics Technical Team will be:

- to perform the activities necessary to further refine knowledge of issues associated with air toxics. We identified the activities listed in Table 6.1 to be carried out beginning in autumn 1999. Examples of products include: a long-term toxics monitoring plan, availability of all ambient monitoring data and analyses in formats understandable to the intended audience (a Web site with this information is a first priority), improved understanding of which sources are responsible for toxics in the ambient air and identification of "hot spots" in Minnesota.
- to communicate air toxics information to the Communication and Reduction Strategies Team and others so that it may be used in planning, priority-setting and decision-making.
- to coordinate the implementation of the technical activities and revise these activities in response to new data gathered and needs identified by the Communication and Reduction Strategies Team.

Table 6.1 Recommended Technical Action Steps

Action Steps	Objective/Goal	Results/Measure	Resources, Skills Needed	Time Frame	Consequences of Not Performing
1. MONITOR					
A. Develop a plan for long-term air toxics monitoring.	To evaluate the future condition of the state's environment regarding air toxics. To track progress on meeting goals. To integrate Minnesota plan with national plan currently under development	A statewide air toxics monitoring plan that will expand monitoring of toxics at least through 2006 (current plan takes us through 2001).	Team effort plus fundraising skills to implement Additional resources needed from monitoring unit	Start once white paper is complete. Plan completed by July 2000.	Funding for statewide toxics-monitoring study ends in 2001, although monitoring is expected to continue. To be able to assess progress on meeting goals and to know if problems arise, planning needs to start now. A national toxics monitoring network plan similar to that for criteria pollutants is currently being developed.
B. Find a more sensitive technique for analysis of certain metals. Research: • Which metals need a more sensitive technique (for example, arsenic). • Where to monitor with more sensitive technique. • Which method is best.	To be able to assess whether ambient levels of certain metals are exceeding health benchmarks	Report on the feasibility of alternative metals analysis techniques.	Subteam effort: expertise in metals analysis techniques	Start in August 1999. Complete report by January 2000.	Lower detection limit of current XRF technique is greater than the health benchmark for certain metals. Without a more sensitive technique, we will not know conclusively whether health benchmarks are being exceeded and where.
C. Routinely analyze 1,3-butadiene in ambient air	To learn whether modeling predictions showing exceedences of health benchmarks are correct.	Ongoing analysis of 1,3 butadiene at all sites. Determine whether sampling/analysis technique is appropriate for detecting 1,3-butadiene. If not, report on feasibility of alternative methods.	Data Management Air Unit – No additional personnel needed but additional analysis time may prevent other activities.	Analysis started in March 1999. Continue through 2003. (Then there will be 4 years of data — enough to determine trends.)	Modeling predicts that 1,3-butadiene concentrations exceed health benchmarks in some areas of Minnesota. Without supporting monitoring data, reduction strategies may be inappropriately targeted.

Table 6.1 (cont.) Recommended Technical Action Steps

Action Steps	Objective/Goal	Results/Measure	Resources, Skills Needed	Time Frame	Consequences of Not Performing
1. MONITOR (cont.)					
D. Begin analyzing ambient air samples for acrolein	To learn whether modeling predictions showing exceedences of health benchmarks are correct.	Ongoing analysis of acrolein beginning in November 1999.	Data Management Air Unit – Additional personnel available when Urban Exposure Study analysis completed in November).	Begin in January 2000. Continue through 2003.	Modeling predicts that acrolein concentrations exceed health benchmarks in some areas of Minnesota. Without supporting monitoring data, reduction strategies and other uses of the information may be inappropriately targeted.
2. ANALYZE MONITORING DATA					
A. Regular analysis of ambient data: • descriptive statistics • trends analysis • geographical analysis	To evaluate the current condition of the state's environment. To measure the success of various programs. To prioritize where resources should be directed both now and in the future	Toxics information, collected 6 months prior, available in format understandable and meaningful to interested parties through an Internet site.	Subteam effort; 1 FTE required ongoing for all analysis activities	Web site operational by October 1999.	Without this information available on a regular basis: • environmental problems may go undetected, • resources may not be appropriately allocated, and • the effectiveness of programs is unknown
B. Identify areas for further research and/or special studies	To detect and prevent environmental problems. To identify emerging air toxics issues.	A system in place to report and recommend new areas for study. Benchmark other states for pollutants of concern.	Subteam effort; 1 FTE required ongoing for all analysis activities	Begin at start of Phase 2.	A coordinated effort is needed to prioritize and work on new activities regarding toxics. Otherwise, environmental problems may go undetected.

Table 6.1 (cont.) Recommended Technical Action Steps

Action Steps	Objective/Goal	Results/Measure	Resources, Skills Needed	Time Frame	Consequences of Not Performing
2. ANALYZE MONITORING DATA (cont.)					
C. Evaluate analysis results for the purpose of developing a long-term toxics monitoring plan.	To ensure the monitoring plan is effective in assessing the state of the environment.	Recommendations for long-term monitoring based on analysis of data.	Subteam effort; 1 FTE required ongoing for all analysis activities.	Begin in Phase 2.	Without in-depth analysis of results, the long-term monitoring plan will not be effective.
D. Communicate analyses in understandable format	To address environmental issues by designing appropriate products and target appropriate audiences.	Products such as Internet sites, fact sheets that are written with audience in mind. Use feedback from audience to improve.	Subteam effort; 1 FTE required ongoing for all analysis activities.	Current team begins putting monitoring information on Web starting in late July 1999, during review of this report.	Effective communication of problem is essential for reduction strategies to succeed.
3. MODEL					
A. Perform receptor modeling to determine source contributions to ambient air concentrations.	To more accurately determine source contributions in certain geographic areas to more effectively target reduction efforts.	Modeling conducted as needed in a timely fashion.	Modelling skills	Specific modeling needs to be determined by Phase II team.	Inaccurate assessment of source contributions through means less effective than modeling can lead to ineffective source-reduction efforts.
4. ASSESS RISK					
A. Research, evaluate and report on: • supporting studies (*e.g.*, NEXHAS, National Urban Exposure Study. • fate and transport. • areas recommended for further study.	To put the ambient toxics data into context so we can better understand "How big a deal" this is. To learn from the work of others in air toxics.	Written products from Phase 2 team put the toxics data into context.	Subteam effort; primarily toxicologists.	Specific research areas and time frame to be determined by Phase 2 team or subteam.	Research in these areas leads to better understanding of the whole system. Failure to understand the system will lead to failure in developing successful reduction strategies.

Table 6.1 (cont.) Recommended Technical Action Steps

Action Steps	Objective/Goal	Results/Measure	Resources, Skills Needed	Time Frame	Consequences of Not Performing
4. ASSESS RISK (cont.)					
B. Update indexing system.	To more effectively characterize pollutants of concern.	Updated indexing system	Subteam effort	Begin in Phase 2. Updated indexing system ready in first half of 2000.	Unable to effectively compare the risks of various pollutants/sources to best determine prioritization of reduction efforts.
C. Account for cumulative risk of air toxics in analyses	To more effectively understand the problem that toxics pose to human health so that activities, programs and resources are aligned appropriately	Cumulative risk assessment a part of certain air toxic reviews and air toxic risk assessments. Development of conceptual models that account for air toxics emissions from area, mobile and point sources.	Subteam effort; primarily risk assessors.	Begin evaluation of how this might be done in Phase 2.	To more accurately assess risk from air toxics and put the risk into context, cumulative risk must be considered. This is an area in which we need to do more work. If cumulative risk is not considered, we may be getting negligible environmental result for significant use of resources.
D. Evaluate CEP results from EPA	To identify areas of potential concern as new information is released on air, water and food exposure	Interpretation of EPA's CEP data on MPCA Web site	Subteam effort	Next release of CEP information from EPA expected in late 1999.	An understanding of the CEP data is necessary to understand the whole system and to put the problem into context.

Table 6.1 (cont.) Recommended Technical Action Steps

Action Steps	Objective/Goal	Results/Measure	Resources, Skills Needed	Time Frame	Consequences of Not Performing
5. ESTIMATE SOURCE CONTRIBUTIONS					
A. Perform further analysis of source contributions to pollutants of concern when 1996 comprehensive emission inventory for point, area, and mobile sources completed.	To have more specific in-depth understanding of what sources contributions are, so that actions are appropriately targeted.	Improved estimates of source contributions to pollutant of concern made in White paper.	Subteam effort	Begin in phase 2	No further analysis of source contributions may lead to misleading information about who is responsible for levels of toxics and inappropriately targeted emissions reductions activities.
B. Identify activities that may be contributing significant amounts of air toxics and areas of local impact.	To proactively identify areas of greater risk for air toxics. Useful in siting of monitors.	Knowledge of sources contributing to "hot spots"	Subteam effort	Begin in phase 2 after "hot spots" have been identified	If we do not investigate where concentrations may be highest based on emissions data, we will not be certain we are protecting all populations. This information is also essential in siting certain toxics monitors.
C. Develop more accurate emission estimates for point, mobile, and area sources by working with individual facilities and gathering stack test data.	To have improved confidence of source contributions, so that actions are appropriately targeted.	Gather specific information from point sources, including stack test data. Conducting surveys and gather more accurate activity data on mobile sources. Elicit information on area sources through trade associations. Include more area source categories in the emissions inventory.	Subteam effort	Begin in phase 2	Reduction strategies may not be targeted to the right source categories if emissions information is not complete and accurate as possible.

Table 6.1 (cont.) Recommended Technical Action Steps

Action Steps	Objective/Goal	Results/Measure	Resources, Skills Needed	Time Frame	Consequences of Not Performing
5. ESTIMATE SOURCE CONTRIBUTIONS (cont.)					
D. Gather locational data from point sources and certain categories of area sources.	To use in estimating ambient concentrations through modeling	Locational data for point sources and some area sources	Subteam effort	Begin in phase 2	Modeling will not be as accurate if locational data is not gathered.
E. Investigate source contributions to help explain trends	To understand why trends are occurring so actions can be appropriately targeted	Work products that provide analysis of source contributions to trends.	Subteam effort	Begin in phase 2. (The ten identified pollutants of concern would be the first priority to take a more detailed look at)	If we do not investigate why trends may be increasing or decreasing, we will not be able to appropriately prioritize reduction efforts.
6. COORDINATE AIR TOXICS TECHNICAL ISSUES/ACTIVITIES					
A. Coordinate air toxics technical issues/activities	To ensure that we are learning from each other and that toxics efforts build on each other.	Regular sharing of information by staff who work with air toxics issues. Work plans that reflect this coordinated effort.	Air Toxics Technical Team (primary function); team members' supervisors must be involved.	Begin in planning efforts for Phase 2 Toxics Technical Team.	We are not effective in addressing air toxics issues.

6.2 Air Toxics Communication and Reduction Strategies Team

The purposes of the Air Toxics Communication and Reduction Strategies Team are to:

- share and receive air toxics information (data and trends analyses) within the MPCA. Sharing this information will help to identify and prioritize issues associated with air toxics, and will assist MPCA activities such as: air permitting, environmental review, small business assistance, facility air toxics reviews, transportation planning and the new Community Outreach project.
- share air toxics information with MPCA stakeholders. Sharing air toxics information increases stakeholders' understanding of air toxics sources, and the environmental and health impacts of air toxics as a result of lifestyle and economic choices. As a result of sharing this information, the MPCA will develop a better understanding of: (1) what stakeholders want to know about air toxics, (2) whether the data the MPCA currently provides is understandable and useful, and (3) what significance stakeholders attach to the air toxics problem.
- develop emission-reduction strategy proposals.

6.2.1 Sharing air toxics information with the rest of the MPCA

It is important to share what has been learned about air toxics with the rest of the MPCA. The data and trends analysis information can help the MPCA identify and prioritize environmental outcomes. The data also can be used to provide background information to enhance air quality permitting, environmental review, individual facility risk assessments, the Mobile Source Ozone/Air Toxics Task Force and the Community Outreach Project.

The Air Toxics Communications and Reduction Strategies Team will be responsible for ensuring that air toxics information is shared with appropriate MPCA staff. The team will have member representation from the Policy and Planning and Environmental Outcomes Divisions, the Metro District, the Public Information Office and possibly the North and South Districts.

6.2.2 Sharing air toxics information with the public

Environmental projects that impact the public can be vulnerable to any saboteur who decides to say "no." The public may view its exposure to air toxic pollutants and the causes of that exposure differently than the MPCA. It is also likely that emission-reduction strategies that the MPCA proposes will be controversial with at least some segment of the public. We cannot change the controversial nature of our work. We can, however, take proactive steps to involve the public early in our discussions, thereby reducing the public's fears that we are fixing problems they don't understand and without their consent.

By sharing air toxics information and involving the public early, the MPCA increases the public's understanding of:

- the sources of air toxic emissions, and
- the environmental and health impacts of air toxics as a result of lifestyle and economic choices.

What the MPCA gets in return is:

- a better gauge of the public's understanding of the air toxics problem;
- technical and political input from experts outside the MPCA, helping to further define the problem and to generate possible solutions; and
- buy-in from members of the public that the MPCA is honestly soliciting their input and is, therefore, conducting a fair process to hear from all interested parties on the issue.

Continuing the public's involvement throughout the problem-solving (emission-reduction) phase maximizes the chances that the MPCA will get:

- input from outside experts who can help generate solutions and possibly help sell those solutions to the general public;
- a better understanding of who might disagree with recommended solutions, what their concerns are and what the MPCA can do to address those concerns; and
- agreement from the public that, while they may not like all the solutions the MPCA generates to address the air toxic pollutant problem, the MPCA is sincere in its desire to address the problem and has actively listened to the public's concerns regarding this issue.

If the public agrees that exposure to air toxic pollutants is a serious problem, that the MPCA is the right organization to attack the problem and that the MPCA has conducted a fair process to solicit the public's input (that is, that their concerns and ideas have honestly been listened to), the public may be more willing than before to allow the MPCA to implement controversial emission-reduction measures.

The Air Toxics Communications and Reduction Strategies Team will be responsible for sharing air toxics information with the public. In addition to designing strategies to do this, the team will develop strategies to get public input, including ideas for addressing the problem.

6.2.3 Communication Techniques

A variety of activities can be used to enlist citizen participation. Probably no one technique will work on its own, but using several techniques together will ensure that a government agency will hear from all potentially affected interests. A partial list of citizen-participation techniques that could be used in the air toxics effort and the strengths of each follows:

1. Open House: An open house provides an opportunity for the public to review displays, ask questions, express concerns, react to what is being proposed and make suggestions to the technical experts who are responsible for collecting air toxics data and for developing the emission-reduction plans.

2. Public Forum: A forum is designed to elicit different points of view and to shed light on a subject. A forum can play a constructive role in bringing out the views and perceptions of interested parties, and in exposing them to each others' views.

3. Producing and Releasing Environmental Materials to Communicate with the Public: Mass media coverage is a convenient way to reach many interests regarding the air toxic pollutant problem. The MPCA make use of advertisements to announce meetings, place and encourage feature articles, publish a project newsletter, develop slide shows and provide experts to appear on radio or TV to communicate ideas regarding the health hazard of air toxic pollutants and possible solutions.

6.2.4 Potentially Affected Interests

In February 1999, the Air Toxics Consent-Building Team came up with the following list of potentially affected interests. This preliminary list includes individuals, groups, institutions, other agencies and other officials who may either be impacted by decisions the MPCA makes regarding air toxics or have an interest in participating in discussions related to air toxics.

AAA (American Automobile Assn.)
American Lung Assn.
Health care community
Insurance companies
Ashland Refineries
Koch Refinery
Bulk terminals
Truckers
Gas stations
Minn. Street Rod Assn.
Public transit system
County associations
City associations
Republican Party
Minn. Chamber of Commerce
3M
Minn. Dept. of Transportation
Border Minnesota cities
Thousand Friends of Minnesota
Sierra Club
Minn. Center for Environmental Advocacy
Leslie Davis
Citizens for a Better Environment
Met Council
Mining industry
Minnesota Legislature
Governor
Newspapers
TV stations
TV climatologists
Minn. Department of Health
Minn. Dept. of Public Safety
Public Safety & Weights, Measure
Minn. Dept. of Agriculture
Farmers
Car dealers
Wisc. Dept. of Natural Resources
Utilities
Univ. of Minn. Automotive Dept.
Inner city residents
Radio talk show
Local government
Bicycle riders
Runners
School
Employers
U.S. Environmental Protection Agency
Telecommuting employees
Motorized recreational vehicle owners
Yard landscape maintenance
Neighborhood associations
Civic community organizers
Minnesota Taxpayers Association
People who heat with wood
Woodstove dealers
Local fire departments
Painting operations
Dry Cleaners Assn.
Democratic Party
Reform Party

7.0 POSSIBLE EMISSION-REDUCTION STRATEGIES

For this paper, we focused on finding primary pollutants of concern; characterizing the causes, effects and concentrations of those compounds; and recommending future technical activities. We also took a very preliminary look at toxics-reduction strategies.

In many ways, environmental solutions are as complex as the problems they are designed to solve. In order to come up with cost-effective strategies, we must first identify and understand why these toxics exist in our environment. Are the root causes for their existence social, economic or technological? In addition to looking at emissions, ambient concentrations and health risks, MPCA staff who examine new approaches are required to study economics, examine social factors and build relationships with those who need to be part of the solution. Future plans should also take into account the relative effectiveness of strategies that focus on pollution prevention, as opposed to mitigation. Human behavior is, however, notoriously difficult to change. Approaches that address pollution at early stages in the causal chain are more effective, although they may cause more apprehension as the focus shifts to behaviors and processes rather than cleanup and control. We want to present a "first-glance" look at some possible solutions to at least open a dialogue on solving some of the air toxics problems. It is important to define problems and work on solutions concurrently.

Below is an outline of possible emission-reduction strategies. This is not a comprehensive list, but a starting point to begin the thought process. The outline was broken down by source type.

Possible Emission-Reduction Strategies

A. General

1. Education/outreach
   - Cooperation with other governmental entities (Metropolitan Council, Minnesota Department of Transportation)
   - Environmental education (legislators, public, students)
2. Increased MPCA resources for toxics

B. Point Sources

1. Facility reporting, public risk notification (California Air Resources Board "Hot Spots" - program requiring stationary sources to report toxic emissions. Health risks are calculated for public notification. "Significant risk" facilities must reduce emissions.)
2. Promote process modifications
   - Raw material substitution
   - Environmentally friendly products (biodegradable, low toxic content)
   - Promote recycling to reduce disposal into environment
3. Improved control technology
4. Emissions trading

C. Area Sources

1. Volatile organic compounds (VOCs) content reduction (inks, solvents, coatings)
   - Water-based materials
2. Improved control technology
   - Stage I vapor control (fuel transfer from supply truck to storage tank)
   - Stage II vapor control (fuel transfer from pump to vehicle)
3. Improved residential/commercial energy efficiency

D. Mobile Sources

1. Vehicle miles traveled (VMT) reduction
   - Improve infrastructure for alternative transportation (bike lanes, light rail, buses) and promote alternatives to single occupant motor vehicle use
   - Encourage less transportation (telecommuting, "smart" development)
   - Tax shifts for energy efficiency (registration; fuel, BTU taxes; toll roads); offset by lowering other taxes
2. Alternative fuels
   - Cleaner gasoline (less sulfur, ethanol; reformulated gasoline)
   - Nontraditional fuel (methanol, ethanol, renewables)
3. Emissions command and control
   - Inspection/maintenance program
   - California-style emission standards (low- and zero-emission vehicles)
   - Corporate average fuel economy (CAFE) standards
4. Efficient development patterns (prevent sprawl)

We believe it is valuable to look further at the possible solutions. Table 7.1 includes some potential strategies listed above, a description of the source type the strategy is most suited to, partners to work with to implement the strategy, and possible barriers and challenges that may be faced.

Table 7.1 Emission-reduction strategies

Potential Strategy	Source Type	Time Frame	Partners	Barriers, Challenges
Cooperation with other entities	All	Short	Met Council, DOT, etc.	Must define problem and establish priorities
Increased MPCA toxics resources	All	Short (already started)		Funding availability
Reporting, public notification	Point	Intermediate	Large facilities	Industry cooperation
Process modifications	Point, area	Intermediate	Industry manufacturers	Cost, effectiveness of new materials
Improved control technology	Point, area	Short to intermediate		Installation costs
VOC-content reduction	Area	Intermediate	Solvent manufacturers, small businesses	Effectiveness of products, attitudes
Alternative transportation	Mobile	Intermediate to long	Met Council, DOT, citizens	Poor infrastructure, attitudes
Transportation reduction	Mobile	Intermediate to long	Employers, citizens	"Urban sprawl" individual driving habits
Taxes, fees	Mobile	Intermediate	Legislature	Resistance to new taxes, fees
Alternative fuels	Mobile	Intermediate to long	Fuel producers, automakers	Cheap gasoline, attitudes
Emissions control	Mobile	Intermediate	DOT	High cost to implement

REFERENCES

Agency for Toxic Substances and Disease Registry (ATSDR). 1990. *Toxicological Profile for Acrolein*. U. S. Public Health Service. U. S. Department of Health and Human Services, Atlanta, Georgia.

Agency for Toxic Substances and Disease Registry (ATSDR). 1998. *Toxicological Profile for Arsenic (Draft)*. U. S. Public Health Service. U. S. Department of Health and Human Services, Atlanta, Georgia.

Agency for Toxic Substances and Disease Registry (ATSDR). 1997. *Toxicological Profile for Benzene*. U. S. Public Health Service. U. S. Department of Health and Human Services, Atlanta, Georgia.

Agency for Toxic Substances and Disease Registry (ATSDR). 1992. *Toxicological Profile for 1,3-Butadiene*. U. S. Public Health Service. U. S. Department of Health and Human Services, Atlanta, Georgia.

Agency for Toxic Substances and Disease Registry (ATSDR). 1994. *Toxicological Profile for Carbon Tetrachloride*. U. S. Public Health Service. U. S. Department of Health and Human Services, Atlanta, Georgia.

Agency for Toxic Substances and Disease Registry (ATSDR). 1997. *Toxicological Profile for Chloroform*. U. S. Public Health Service. U. S. Department of Health and Human Services, Atlanta, Georgia.

Agency for Toxic Substances and Disease Registry (ATSDR). 1998. *Toxicological Profile for Chromium (Draft)*. U. S. Public Health Service. U. S. Department of Health and Human Services, Atlanta, Georgia

Agency for Toxic Substances and Disease Registry (ATSDR). 1992. *Toxicological Profile for 1,2-Dibromoethane*. U. S. Public Health Service. U. S. Department of Health and Human Services, Atlanta, Georgia.

Agency for Toxic Substances and Disease Registry (ATSDR). 1997. *Toxicological Profile for Formaldehyde (Draft)*. U. S. Public Health Service. U. S. Department of Health and Human Services, Atlanta, Georgia.

Agency for Toxic Substances and Disease Registry (ATSDR). 1997. *Toxicological Profile for Nickel*. U. S. Public Health Service. U. S. Department of Health and Human Services, Atlanta, Georgia.

Caldwell, J.C., Woodruff, T.J., Morello-Frosch, R., and Axelrad, D.A. 1998. Application of health information to hazardous air pollutants modeled in EPA's cumulative exposure project. *Toxicology and Industrial Health*, 14:429-454.

California Air Resources Board (CARB). 1997. *Toxic Air Contaminant Identification List Summaries*. Stationary Source Division, Sacramento, California.

California Environmental Protection Agency. 1999. *Air Toxics Hot Spots Program Risk Assessment Guidelines Part III: Technical Support Document for the Determination of Noncancer Chronic Reference Exposure Levels.* Office of Environmental Health Hazard Assessment, Air Toxicology and Epidemiology Section, Oakland, California.

ICF Kaiser, *Modeling Cumulative Outdoor Concentrations of Hazardous Air Pollutants.* Revised Final Report. Prepared by ICF Kaiser, Systems Applications International Division, February 1999.

ICF Kaiser, Extrapolation of Uncertainty of ASPEN Results (Revised). Technical Memorandum. Prepared by ICF Kaiser, Systems Applications International, November 30,1998.

Kao, Alan S. 1994. Formation and removal reactions of hazardous air pollutants. *Journal of Air and Waste Management.* 44:683-696.

Minnesota Department of Health. 1999. *Comparative Risks of Multiple Chemical Exposures: Interim Report for the Legislative Commission on Minnesota Resources.*

Minnesota Pollution Control Agency. 1999. *Toxic Air Pollutant Update: Report to the Environment & Natural Resources Policy Committee of the Minnesota Legislature.*

Oliaei, F. 1997. *Minnesota Air: Air Quality and Emissions Trends.* Minnesota Pollution Control Agency, September 1997.

Pratt, G.C., Gerbec, P.E., Livingston, S.K., Oliaei, F., Bollweg, G., Paterson, S., and D. Mackay. 1993. An indexing system for comparing toxic air pollutants based upon their potential environmental impacts. *Chemosphere.* 27:1359-1379.

Rosenbaum, A.S., Axelrad, D.A., Woodruff, T.J., Wei, Y., Ligocki, M.P., and Cohen, J.P. 1999. National estimates of outdoor air toxics concentrations. *Journal of the Air & Waste Management Association* (in press).

Rosenbaum, A.S., Ligocki, M.P., and Wei, Y. 1998. *Modeling Cumulative Outdoor Concentrations of Hazardous Air Pollutants*, Technical Report, San Rafael: Systems Applications International, Inc.

United States Environmental Protection Agency (U.S. EPA). 1998. *Carcinogenic Effects of Benzene: An Update.* Office of Research and Development, Washington, D.C. EPA 600/P-97/001F.

United States Environmental Protection Agency (U.S. EPA). 1997. *Health Effects Assessment Summary Tables.* Office of Emergency and Remedial Response, Washington, D.C. EPA 540/R-97-036.

United States Environmental Protection Agency (U.S. EPA). 1999. Integrated Risk Information System (IRIS).

United States Environmental Protection Agency (U.S. EPA). 1993. *Motor Vehicle-Related Air Toxics Study.* Office of Mobile Sources. Emissions Planning and Strategies Division. Ann Arbor, Michigan. EPA 420-R-93-005.

Woodruff, T.J., Axelrad, D.A., Caldwell, J.C., Morello-Frosch, R., and Rosenbaum, A. 1998. Public health implications of 1990 air toxics concentrations across the United States." *Environmental Health Perspectives*, 106:245-251.

APPENDIX A

Appendix A — Summaries of Ambient Data for Air Toxics at Minnesota Monitoring Sites, 1991-98

Table 1 Formaldehyde concentrations (μg/m³)

Site		1991	1992	1993	1994	1995	1996	1997	1998	All Years
Plymouth	Mean	.	.	.	.	.	0.91	1.37	.	1.24
	Median	.	.	.	.	.	0.88	1.11	.	1.01
	Maximum	.	.	.	.	.	2.11	5.48	.	5.48
	Total N						20	44		64
	Valid N						N=14	N=36		N=50
Koch420	Mean	0.72	0.98	0.85	0.71	1.23	1.57	1.12	1.70	1.10
	Median	0.54	0.79	0.74	0.54	0.95	1.32	0.80	1.32	0.85
	Maximum	3.43	3.46	2.57	2.10	4.50	5.29	3.73	4.65	5.29
	Total N	60	61	61	61	61	61	61	61	487
	Valid N	N=54	N=59	N=61	N=61	N=51	N=55	N=58	N=59	N=458
Koch423	Mean	0.35	0.82	1.12	0.57	1.08	1.49	1.48	1.50	1.10
	Median	0.22	0.65	0.52	0.43	0.77	1.19	1.26	1.31	0.85
	Maximum	2.03	3.75	7.81	1.56	4.29	4.05	3.84	4.18	7.81
	Total N	60	61	61	61	61	61	97	122	584
	Valid N	N=59	N=60	N=61	N=61	N=53	N=54	N=86	N=101	N=535
Koch426	Mean	0.77	0.89	0.78	0.71	1.25	1.55	.	.	0.98
	Median	0.53	0.82	0.69	0.56	0.87	1.22	.	.	0.78
	Maximum	3.50	3.19	2.14	2.91	4.27	4.86	.	.	4.86
	Total N	60	61	61	61	61	61			365
	Valid N	N=58	N=59	N=61	N=61	N=53	N=55			N=347
StPaulPark	Mean	.	.	1.16	0.95	1.36	1.93	1.51	2.01	1.49
	Median	.	.	0.95	0.75	1.17	1.55	1.23	1.95	1.20
	Maximum	.	.	7.74	2.71	3.37	5.61	4.56	4.82	7.74
	Total N			61	61	61	61	61	61	366
	Valid N			N=58	N=61	N=50	N=58	N=59	N=59	N=345
Ashland	Mean	.	.	.	.	2.41	2.03	1.81	1.91	2.00
	Median	.	.	.	.	2.05	1.56	1.53	1.78	1.65
	Maximum	.	.	.	.	5.93	6.87	4.78	4.67	6.87
	Total N					34	61	61	61	217
	Valid N					N=31	N=57	N=55	N=57	N=200
HolmanFld	Mean	0.94	1.04	1.07	1.04	2.04	2.25	2.03	1.38	1.53
	Median	0.65	0.80	0.91	0.77	1.48	1.88	1.95	1.37	1.26
	Maximum	4.49	3.92	5.33	4.05	6.28	5.09	4.29	2.97	6.28
	Total N	41	61	61	61	61	61	61	61	468
	Valid N	N=23	N=61	N=44	N=61	N=61	N=56	N=54	N=44	N=404
BushSt	Mean	.	.	.	.	.	.	.	4.43	4.43
	Median	.	.	.	.	.	.	.	3.05	3.05
	Maximum	.	.	.	.	.	.	.	20.99	20.99
	Total N								24	24
	Valid N								N=23	N=23

Table 1 (cont.) Formaldehyde concentrations (µg/m³)

Site		1991	1992	1993	1994	1995	1996	1997	1998	All Years
HardingHi	Mean	.	.	.	.	.	.	.	1.68	1.68
	Median	.	.	.	.	.	.	.	1.39	1.39
	Maximum	.	.	.	.	.	.	.	3.49	3.49
	Total N								16	16
	Valid N								N=15	N=15
MplsLibrary	Mean	1.71	1.76	1.53	1.50	2.65	2.85	2.52	2.77	2.18
	Median	1.06	1.40	1.49	1.34	2.24	2.50	2.23	2.65	1.87
	Maximum	13.38	5.35	3.54	3.54	7.23	5.83	7.52	6.45	13.38
	Total N	33	61	61	61	61	61	61	61	460
	Valid N	N=28	N=60	N=60	N=58	N=60	N=55	N=58	N=52	N=431
MhahaAcad	Mean	.	.	.	.	.	.	1.25	2.84	2.48
	Median	.	.	.	.	.	.	1.07	2.42	2.06
	Maximum	.	.	.	.	.	.	2.67	10.85	10.85
	Total N							17	46	63
	Valid N							N=13	N=44	N=57
I_Falls1240	Mean	.	.	.	7.07	0.87	1.00	.	0.83	0.99
	Median	.	.	.	7.07	0.88	0.77	.	0.58	0.78
	Maximum	.	.	.	7.07	1.40	3.73	.	2.62	7.07
	Total N				7	23	44		25	99
	Valid N				N=1	N=22	N=38		N=25	N=86
I_Falls1241	Mean	.	.	.	.	.	0.56	1.50	.	1.28
	Median	.	.	.	.	.	0.45	1.39	.	1.05
	Maximum	.	.	.	.	.	1.85	3.79	.	3.79
	Total N						17	44		61
	Valid N						N=13	N=44		N=57
Sandstone	Mean	.	.	.	.	.	0.38	1.38	.	1.17
	Median	.	.	.	.	.	0.40	1.06	.	0.89
	Maximum	.	.	.	.	.	0.61	3.60	.	3.60
	Total N						20	44		64
	Valid N						N=10	N=38		N=48
FergusFalls	Mean	.	.	.	.	.	.	1.34	1.76	1.66
	Median	.	.	.	.	.	.	0.99	1.61	1.42
	Maximum	.	.	.	.	.	.	3.24	3.53	3.53
	Total N							17	45	62
	Valid N							N=14	N=45	N=59
Alexandria	Mean	.	.	.	.	.	0.53	1.69	.	1.42
	Median	.	.	.	.	.	0.46	1.52	.	1.38
	Maximum	.	.	.	.	.	0.97	3.54	.	3.54
	Total N						20	44		64
	Valid N						N=13	N=43		N=56
Warroad	Mean	.	.	.	.	.	.	1.28	1.20	1.22
	Median	.	.	.	.	.	.	0.73	1.02	1.00
	Maximum	.	.	.	.	.	.	5.49	3.20	5.49
	Total N							17	45	62
	Valid N							N=15	N=44	N=59

Table 1 (cont.) Formaldehyde concentrations (µg/m^3)

Site		1991	1992	1993	1994	1995	1996	1997	1998	All Years
LittleFalls	Mean	.	.	.	.	.	0.48	1.33	.	1.11
	Median	.	.	.	.	.	0.32	1.19	.	0.98
	Maximum	.	.	.	.	.	1.45	2.90	.	2.90
	Total N						20	44		64
	Valid N						N=15	N=43		N=58
ElkRiver	Mean	.	.	.	.	.	.	0.90	1.62	1.43
	Median	.	.	.	.	.	.	0.82	1.61	1.23
	Maximum	.	.	.	.	.	.	2.06	4.18	4.18
	Total N							17	45	62
	Valid N							N=16	N=45	N=61
Pipestone	Mean	.	.	.	.	.	0.41	1.52	.	1.26
	Median	.	.	.	.	.	0.35	1.35	.	1.21
	Maximum	.	.	.	.	.	0.91	3.39	.	3.39
	Total N						20	44		64
	Valid N						N=13	N=42		N=55
GraniteFalls	Mean	.	.	.	.	.	.	1.00	2.29	1.98
	Median	.	.	.	.	.	.	0.90	1.87	1.47
	Maximum	.	.	.	.	.	.	1.90	20.20	20.20
	Total N							17	45	62
	Valid N							N=13	N=40	N=53
Rochester	Mean	.	.	.	.	.	.	0.92	1.51	1.36
	Median	.	.	.	.	.	.	0.84	1.49	1.30
	Maximum	.	.	.	.	.	.	1.89	2.86	2.86
	Total N							17	45	62
	Valid N							N=15	N=45	N=60
Zumbrota	Mean	.	.	.	.	.	0.37	1.35	.	1.16
	Median	.	.	.	.	.	0.28	1.22	.	1.04
	Maximum	.	.	.	.	.	0.95	3.21	.	3.21
	Total N						20	44		64
	Valid N						N=10	N=43		N=53
Hibbing	Mean	.	.	.	.	.	.	0.92	1.80	1.57
	Median	.	.	.	.	.	.	0.82	1.64	1.22
	Maximum	.	.	.	.	.	.	2.19	5.28	5.28
	Total N							17	45	62
	Valid N							N=16	N=45	N=61
Duluth7549	Mean	.	.	.	1.18	1.52	1.59	1.28	0.78	1.27
	Median	.	.	.	0.95	1.26	1.27	1.10	0.76	1.01
	Maximum	.	.	.	4.27	8.56	4.84	4.27	2.40	8.56
	Total N				61	61	61	61	61	305
	Valid N				N=61	N=61	N=56	N=59	N=57	N=294
Overall	Mean	0.78	1.10	1.08	0.96	1.64	1.64	1.52	1.81	1.44
	Median	0.50	0.90	0.85	0.72	1.20	1.28	1.28	1.49	1.13
	Maximum	13.38	5.35	7.81	7.07	8.56	6.87	7.52	20.99	20.99
	Total N	254	305	366	434	484	669	890	869	4271
	Valid N	N=222	N=299	N=345	N=425	N=442	N=572	N=820	N=800	N=3925

Table 2 Benzene concentrations (μg/m³)

Site		1991	1992	1993	1994	1995	1996	1997	1998	All Years
Plymouth	Mean	.	.	.	.	.	1.41	1.27	.	1.31
	Median	.	.	.	.	.	1.45	1.13	.	1.16
	Maximum	.	.	.	.	.	2.45	5.59	.	5.59
	Total N						20	44		64
	Valid N						N=15	N=40		N=55
Koch420	Mean	1.75	2.41	1.63	2.22	1.45	1.47	1.37	1.44	1.72
	Median	1.40	1.52	1.47	1.63	1.17	1.19	1.26	1.33	1.35
	Maximum	6.78	9.96	4.92	20.09	4.47	7.16	5.27	4.01	20.09
	Total N	60	61	61	61	61	61	61	61	487
	Valid N	N=54	N=58	N=45	N=57	N=53	N=55	N=59	N=58	N=439
Koch423	Mean	0.87	1.14	0.99	1.56	1.33	0.86	0.91	0.95	1.06
	Median	0.62	1.08	0.96	1.41	1.19	0.75	0.88	0.82	0.94
	Maximum	3.12	2.99	2.52	3.29	3.61	1.71	2.16	3.62	3.62
	Total N	60	61	61	61	61	61	97	122	584
	Valid N	N=59	N=53	N=46	N=59	N=48	N=56	N=68	N=100	N=489
Koch426	Mean	2.94	3.87	2.49	2.81	1.68	1.63	.	.	2.59
	Median	2.13	2.46	1.66	1.88	1.37	1.29	.	.	1.73
	Maximum	18.35	26.35	12.46	15.56	5.75	5.61	.	.	26.35
	Total N	60	61	61	61	61	61			365
	Valid N	N=58	N=60	N=49	N=59	N=55	N=56			N=337
StPaulPark	Mean	.	.	3.24	3.24	2.54	2.41	2.44	2.04	2.62
	Median	.	.	2.25	2.41	2.02	1.91	1.71	1.99	1.99
	Maximum	.	.	15.84	11.69	9.84	13.61	19.49	7.02	19.49
	Total N			61	61	61	61	61	61	366
	Valid N			N=42	N=54	N=52	N=56	N=56	N=59	N=319
Ashland	Mean	.	.	.	.	3.31	3.03	3.36	2.75	3.08
	Median	.	.	.	.	2.18	2.17	1.82	2.28	2.16
	Maximum	.	.	.	.	9.20	11.77	23.36	12.25	23.36
	Total N					34	61	61	61	217
	Valid N					N=27	N=53	N=56	N=58	N=194
HolmanFld	Mean	1.42	2.05	1.54	2.20	1.70	1.77	1.56	1.26	1.72
	Median	0.91	1.45	1.23	1.84	1.40	1.62	1.39	1.18	1.44
	Maximum	4.85	9.07	3.96	7.38	5.65	5.71	5.05	2.92	9.07
	Total N	41	61	61	61	61	61	61	61	468
	Valid N	N=23	N=31	N=34	N=60	N=55	N=55	N=54	N=41	N=353
BushSt	Mean	.	.	.	.	.	.	.	3.18	3.18
	Median	.	.	.	.	.	.	.	2.48	2.48
	Maximum	.	.	.	.	.	.	.	8.76	8.76
	Total N								24	24
	Valid N								N=23	N=23
HardingHi	Mean	.	.	.	.	.	.	.	2.74	2.74
	Median	.	.	.	.	.	.	.	2.23	2.23
	Maximum	.	.	.	.	.	.	.	5.71	5.71
	Total N								16	16
	Valid N								N=14	N=14

Table 2 (cont.) Benzene concentrations ($\mu g/m^3$)

Site		1991	1992	1993	1994	1995	1996	1997	1998	All Years
MplsLibrary	Mean	2.15	2.94	2.48	3.29	2.66	2.10	2.23	2.03	2.53
	Median	1.69	2.56	2.40	3.07	2.24	2.02	2.06	1.84	2.24
	Maximum	13.51	10.42	5.33	7.76	7.01	5.49	5.72	5.52	13.51
	Total N	33	61	61	61	61	61	61	61	460
	Valid N	N=28	N=57	N=49	N=60	N=53	N=56	N=52	N=45	N=400
MhahaAcad	Mean	.	.	.	.	.	.	1.71	1.34	1.44
	Median	.	.	.	.	.	.	1.31	1.14	1.20
	Maximum	.	.	.	.	.	.	4.72	2.79	4.72
	Total N							17	46	63
	Valid N							N=16	N=41	N=57
I_Falls1240	Mean	.	.	.	5.40	0.58	0.87	.	0.84	1.15
	Median	.	.	.	3.61	0.57	0.75	.	0.73	0.73
	Maximum	.	.	.	10.22	1.22	2.01	.	1.72	10.22
	Total N				7	23	44		25	99
	Valid N				N=7	N=20	N=39		N=25	N=91
I_Falls1241	Mean	.	.	.	.	.	1.97	1.13	.	1.37
	Median	.	.	.	.	.	1.66	0.88	.	0.98
	Maximum	.	.	.	.	.	5.40	6.44	.	6.44
	Total N						17	44		61
	Valid N						N=16	N=41		N=57
Sandstone	Mean	.	.	.	.	.	0.77	0.64	.	0.68
	Median	.	.	.	.	.	0.77	0.54	.	0.64
	Maximum	.	.	.	.	.	1.20	1.57	.	1.57
	Total N						20	44		64
	Valid N						N=15	N=36		N=51
FergusFalls	Mean	.	.	.	.	.	.	1.10	1.20	1.19
	Median	.	.	.	.	.	.	1.07	1.11	1.10
	Maximum	.	.	.	.	.	.	1.67	2.76	2.76
	Total N							17	45	62
	Valid N							N=6	N=42	N=48
Alexandria	Mean	.	.	.	.	.	1.49	1.12	.	1.22
	Median	.	.	.	.	.	1.39	0.94	.	1.02
	Maximum	.	.	.	.	.	3.00	2.42	.	3.00
	Total N						20	44		64
	Valid N						N=15	N=43		N=58
Warroad	Mean	.	.	.	.	.	.	0.70	0.61	0.64
	Median	.	.	.	.	.	.	0.75	0.52	0.62
	Maximum	.	.	.	.	.	.	0.97	1.95	1.95
	Total N							17	45	62
	Valid N							N=14	N=33	N=47
LittleFalls	Mean	.	.	.	.	.	1.10	0.84	.	0.90
	Median	.	.	.	.	.	1.01	0.73	.	0.78
	Maximum	.	.	.	.	.	2.24	1.80	.	2.24
	Total N						20	44		64
	Valid N						N=14	N=42		N=56

Table 2 (cont.) Benzene concentrations (µg/m³)

Site		1991	1992	1993	1994	1995	1996	1997	1998	All Years
ElkRiver	Mean	.	.	.	.	.	.	1.22	0.84	0.95
	Median	.	.	.	.	.	.	1.00	0.71	0.82
	Maximum	.	.	.	.	.	.	2.89	1.98	2.89
	Total N							17	45	62
	Valid N							N=16	N=42	N=58
Pipestone	Mean	.	.	.	.	.	0.94	0.77	.	0.82
	Median	.	.	.	.	.	0.91	0.72	.	0.76
	Maximum	.	.	.	.	.	1.64	1.97	.	1.97
	Total N						20	44		64
	Valid N						N=15	N=32		N=47
GraniteFalls	Mean	.	.	.	.	.	.	0.81	0.97	0.93
	Median	.	.	.	.	.	.	0.79	0.56	0.73
	Maximum	.	.	.	.	.	.	1.19	6.66	6.66
	Total N							17	45	62
	Valid N							N=13	N=32	N=45
Rochester	Mean	.	.	.	.	.	.	1.13	1.11	1.11
	Median	.	.	.	.	.	.	1.06	0.94	0.95
	Maximum	.	.	.	.	.	.	2.03	2.30	2.30
	Total N							17	45	62
	Valid N							N=14	N=45	N=59
Zumbrota	Mean	.	.	.	.	.	0.75	0.62	.	0.65
	Median	.	.	.	.	.	0.66	0.56	.	0.59
	Maximum	.	.	.	.	.	1.32	1.53	.	1.53
	Total N						20	44		64
	Valid N						N=11	N=43		N=54
Hibbing	Mean	.	.	.	.	.	.	1.19	0.95	1.02
	Median	.	.	.	.	.	.	0.99	0.84	0.87
	Maximum	.	.	.	.	.	.	2.93	2.32	2.93
	Total N							17	45	62
	Valid N							N=17	N=42	N=59
Duluth7549	Mean	.	.	.	2.42	1.98	1.71	1.66	1.39	1.74
	Median	.	.	.	1.98	1.58	1.43	1.56	1.21	1.50
	Maximum	.	.	.	5.14	4.43	3.74	5.91	3.04	5.91
	Total N				61	61	61	61	61	305
	Valid N				N=27	N=39	N=57	N=59	N=58	N=240
Overall	Mean	1.85	2.56	2.08	2.59	1.93	1.69	1.45	1.45	1.81
	Median	1.22	1.74	1.53	2.04	1.46	1.31	1.08	1.16	1.32
	Maximum	18.35	26.35	15.84	20.09	9.84	13.61	23.36	12.25	26.35
	Total N	254	305	366	434	484	669	890	869	4271
	Valid N	N=222	N=259	N=265	N=383	N=402	N=584	N=777	N=758	N=3650

Table 3 Carbon tetrachloride concentrations ($\mu g/m^3$)

Site		1991	1992	1993	1994	1995	1996	1997	1998	All Years
Plymouth	Mean	.	.	.	.	.	0.91	0.92	.	0.91
	Median	.	.	.	.	.	0.84	0.90	.	0.90
	Maximum	.	.	.	.	.	1.13	1.20	.	1.20
	Count						20	44		64
	Valid N						N=15	N=40		N=55
Koch420	Mean	0.41	0.57	0.56	0.77	0.64	0.66	0.91	0.76	0.67
	Median	0.42	0.60	0.57	0.75	0.73	0.69	0.89	0.79	0.70
	Maximum	0.80	1.19	0.82	1.26	1.03	1.02	1.09	0.99	1.26
	Count	60	61	61	61	61	61	61	61	487
	Valid N	N=54	N=58	N=45	N=57	N=53	N=55	N=59	N=58	N=439
Koch423	Mean	0.38	0.51	0.52	0.77	0.67	0.67	0.91	0.78	0.67
	Median	0.38	0.56	0.57	0.75	0.73	0.66	0.90	0.78	0.72
	Maximum	0.98	1.06	0.82	1.26	1.15	1.11	1.16	0.98	1.26
	Count	60	61	61	61	61	61	97	122	584
	Valid N	N=59	N=53	N=46	N=59	N=48	N=56	N=68	N=100	N=489
Koch426	Mean	0.40	0.55	0.56	0.78	0.69	0.67	.	.	0.61
	Median	0.42	0.58	0.57	0.75	0.75	0.70	.	.	0.63
	Maximum	0.73	1.33	1.07	1.20	1.19	1.09	.	.	1.33
	Count	60	61	61	61	61	61			365
	Valid N	N=58	N=60	N=49	N=59	N=55	N=56			N=337
StPaulPark	Mean	.	.	0.52	0.77	0.67	0.70	0.93	0.78	0.74
	Median	.	.	0.57	0.69	0.74	0.68	0.92	0.77	0.75
	Maximum	.	.	0.75	1.20	1.09	1.48	1.20	1.01	1.48
	Count			61	61	61	61	61	61	366
	Valid N			N=42	N=54	N=52	N=56	N=56	N=59	N=319
Ashland	Mean	.	.	.	.	0.53	0.70	0.93	0.76	0.76
	Median	.	.	.	.	0.49	0.71	0.92	0.78	0.80
	Maximum	.	.	.	.	1.16	1.15	1.23	0.98	1.23
	Count					34	61	61	61	217
	Valid N					N=27	N=53	N=56	N=58	N=194
HolmanFld	Mean	0.43	0.62	0.56	0.76	0.69	0.69	0.91	0.78	0.71
	Median	0.47	0.62	0.57	0.75	0.75	0.65	0.92	0.79	0.75
	Maximum	0.76	1.14	0.88	1.20	1.08	1.31	1.06	1.08	1.31
	Count	41	61	61	61	61	61	61	61	468
	Valid N	N=23	N=31	N=34	N=60	N=55	N=55	N=54	N=41	N=353
BushSt	Mean	.	.	.	.	.	.	.	0.72	0.72
	Median	.	.	.	.	.	.	.	0.74	0.74
	Maximum	.	.	.	.	.	.	.	0.87	0.87
	Count								24	24
	Valid N								N=23	N=23
HardingHi	Mean	.	.	.	.	.	.	.	0.78	0.78
	Median	.	.	.	.	.	.	.	0.81	0.81
	Maximum	.	.	.	.	.	.	.	0.95	0.95
	Count								16	16
	Valid N								N=14	N=14

Table 3 (cont.) Carbon tetrachloride concentrations (µg/m³)

Site		1991	1992	1993	1994	1995	1996	1997	1998	All Years
MplsLibrary	Mean	0.28	0.51	0.53	0.82	0.72	0.68	0.93	0.75	0.68
	Median	0.30	0.53	0.57	0.79	0.78	0.67	0.93	0.77	0.70
	Maximum	0.50	1.15	0.88	1.45	1.13	1.31	1.05	0.99	1.45
	Count	33	61	61	61	61	61	61	61	460
	Valid N	N=28	N=57	N=49	N=60	N=53	N=56	N=52	N=45	N=400
MhahaAcad	Mean	.	.	.	.	.	.	0.92	0.75	0.80
	Median	.	.	.	.	.	.	0.92	0.77	0.80
	Maximum	.	.	.	.	.	.	1.02	0.93	1.02
	Count							17	46	63
	Valid N							N=16	N=41	N=57
I_Falls1240	Mean	.	.	.	0.97	0.45	0.60	.	0.74	0.63
	Median	.	.	.	1.01	0.48	0.62	.	0.74	0.64
	Maximum	.	.	.	1.07	0.64	1.25	.	0.89	1.25
	Count				7	23	44		25	99
	Valid N				N=7	N=20	N=39		N=25	N=91
I_Falls1241	Mean	.	.	.	.	.	0.88	0.92	.	0.91
	Median	.	.	.	.	.	0.87	0.91	.	0.91
	Maximum	.	.	.	.	.	1.03	1.05	.	1.05
	Count						17	44		61
	Valid N						N=16	N=41		N=57
Sandstone	Mean	.	.	.	.	.	0.91	0.91	.	0.91
	Median	.	.	.	.	.	0.91	0.91	.	0.91
	Maximum	.	.	.	.	.	1.09	1.01	.	1.09
	Count						20	44		64
	Valid N						N=15	N=36		N=51
FergusFalls	Mean	.	.	.	.	.	.	0.96	0.75	0.78
	Median	.	.	.	.	.	.	0.95	0.78	0.79
	Maximum	.	.	.	.	.	.	1.13	0.98	1.13
	Count							17	45	62
	Valid N							N=6	N=42	N=48
Alexandria	Mean	.	.	.	.	.	0.90	0.92	.	0.92
	Median	.	.	.	.	.	0.88	0.91	.	0.91
	Maximum	.	.	.	.	.	1.12	1.20	.	1.20
	Count						20	44		64
	Valid N						N=15	N=43		N=58
Warroad	Mean	.	.	.	.	.	.	0.93	0.77	0.82
	Median	.	.	.	.	.	.	0.92	0.78	0.81
	Maximum	.	.	.	.	.	.	1.10	0.89	1.10
	Count							17	45	62
	Valid N							N=14	N=33	N=47
LittleFalls	Mean	.	.	.	.	.	0.90	0.91	.	0.91
	Median	.	.	.	.	.	0.87	0.90	.	0.89
	Maximum	.	.	.	.	.	1.15	1.02	.	1.15
	Count						20	44		64
	Valid N						N=14	N=42		N=56

Table 3 (cont.) Carbon tetrachloride concentrations (µg/m^3)

Site		1991	1992	1993	1994	1995	1996	1997	1998	All Years
ElkRiver	Mean	.	.	.	.	.	.	0.93	0.76	0.81
	Median	.	.	.	.	.	.	0.93	0.79	0.81
	Maximum	.	.	.	.	.	.	1.01	0.96	1.01
	Count							17	45	62
	Valid N							N=16	N=42	N=58
Pipestone	Mean	.	.	.	.	.	0.91	0.92	.	0.92
	Median	.	.	.	.	.	0.89	0.91	.	0.91
	Maximum	.	.	.	.	.	1.12	1.20	.	1.20
	Count						20	44		64
	Valid N						N=15	N=32		N=47
GraniteFalls	Mean	.	.	.	.	.	.	0.90	0.74	0.79
	Median	.	.	.	.	.	.	0.89	0.78	0.82
	Maximum	.	.	.	.	.	.	1.00	0.99	1.00
	Count							17	45	62
	Valid N							N=13	N=32	N=45
Rochester	Mean	.	.	.	.	.	.	0.94	0.77	0.81
	Median	.	.	.	.	.	.	0.95	0.81	0.82
	Maximum	.	.	.	.	.	.	1.04	0.95	1.04
	Count							17	45	62
	Valid N							N=14	N=45	N=59
Zumbrota	Mean	.	.	.	.	.	0.91	0.94	.	0.93
	Median	.	.	.	.	.	0.88	0.92	.	0.92
	Maximum	.	.	.	.	.	1.05	1.04	.	1.05
	Count						20	44		64
	Valid N						N=11	N=43		N=54
Hibbing	Mean	.	.	.	.	.	.	0.91	0.74	0.79
	Median	.	.	.	.	.	.	0.92	0.77	0.79
	Maximum	.	.	.	.	.	.	1.03	0.92	1.03
	Count							17	45	62
	Valid N							N=17	N=42	N=59
Duluth7549	Mean	.	.	.	0.83	0.68	0.67	0.90	0.76	0.77
	Median	.	.	.	0.75	0.72	0.67	0.91	0.78	0.80
	Maximum	.	.	.	1.26	1.06	1.13	1.03	1.06	1.26
	Count				61	61	61	61	61	305
	Valid N				N=27	N=39	N=57	N=59	N=58	N=240
All Sites	Mean	0.38	0.55	0.54	0.79	0.66	0.71	0.92	0.76	0.72
	Median	0.38	0.58	0.57	0.75	0.71	0.72	0.91	0.78	0.77
	Maximum	0.98	1.33	1.07	1.45	1.19	1.48	1.23	1.08	1.48
	Count	254	305	366	434	484	669	890	869	4271
	Valid N	N=222	N=259	N=265	N=383	N=402	N=584	N=777	N=758	N=3650

Table 4 Chloroform concentrations (µg/m^3)

Site		1991	1992	1993	1994	1995	1996	1997	1998	All Years
Plymouth	Mean	.	.	.	.	.	0.1266	0.1291	.	0.1285
	Median	.	.	.	.	.	0.1172	0.1123	.	0.1123
	Maximum	.	.	.	.	.	0.2246	0.4883	.	0.4883
	Count						20	44		64
	Valid N						N=15	N=40		N=55
Koch420	Mean	0.0659	0.1287	0.0846	0.0728	0.0696	0.1369	0.152	0.0842	0.1003
	Median	0.0586	0.1052	0.0488	0.0488	0.0684	0.1123	0.1221	0.0757	0.0879
	Maximum	0.3711	0.8007	0.3906	0.3906	0.4687	0.332	0.5517	0.4541	0.8007
	Count	60	61	61	61	61	61	61	61	487
	Valid N	N=54	N=58	N=45	N=57	N=53	N=55	N=59	N=58	N=439
Koch423	Mean	0.0555	0.0879	0.0637	0.0919	0.0631	0.108	0.1033	0.0801	0.0826
	Median	0.0537	0.0903	0.0488	0.0977	0.0464	0.0977	0.0928	0.0781	0.083
	Maximum	0.3027	0.2505	0.1465	0.3906	0.3467	0.6592	0.3369	0.4346	0.6592
	Count	60	61	61	61	61	61	97	122	584
	Valid N	N=59	N=53	N=46	N=59	N=48	N=56	N=68	N=100	N=489
Koch426	Mean	0.0875	0.2025	0.1176	0.1142	0.0692	0.1623	.	.	0.1265
	Median	0.0537	0.1357	0.0977	0.0977	0.0488	0.1196	.	.	0.0977
	Maximum	0.913	1.5517	0.83	0.4394	0.459	0.5078	.	.	1.5517
	Count	60	61	61	61	61	61			365
	Valid N	N=58	N=60	N=49	N=59	N=55	N=56			N=337
StPaulPark	Mean	.	.	0.0558	0.142	0.077	0.1471	0.1606	0.0892	0.1144
	Median	.	.	0.0488	0.0977	0.0757	0.1416	0.1318	0.0879	0.0977
	Maximum	.	.	0.1465	2.0995	0.2392	0.3369	0.5713	0.2588	2.0995
	Count			61	61	61	61	61	61	366
	Valid N			N=42	N=54	N=52	N=56	N=56	N=59	N=319
Ashland	Mean	.	.	.	.	0.0986	0.2088	0.1695	0.1168	0.1546
	Median	.	.	.	.	0.0928	0.1611	0.1489	0.0952	0.1172
	Maximum	.	.	.	.	0.3223	0.7373	0.4443	0.9912	0.9912
	Count					34	61	61	61	217
	Valid N					N=27	N=53	N=56	N=58	N=194
HolmanFld	Mean	0.0654	0.1647	0.0732	0.1359	0.1132	0.2083	0.1756	0.1047	0.138
	Median	0.0879	0.1411	0.0977	0.0977	0.0732	0.1758	0.1538	0.0928	0.1025
	Maximum	0.1611	0.791	0.1465	1.1718	0.6103	0.7373	0.498	0.332	1.1718
	Count	41	61	61	61	61	61	61	61	468
	Valid N	N=23	N=31	N=34	N=60	N=55	N=55	N=54	N=41	N=353
BushSt	Mean	.	.	.	.	.	.	.	0.1616	0.1616
	Median	.	.	.	.	.	.	.	0.1318	0.1318
	Maximum	.	.	.	.	.	.	.	0.5322	0.5322
	Count								24	24
	Valid N								N=23	N=23
HardingHi	Mean	.	.	.	.	.	.	.	0.1409	0.1409
	Median	.	.	.	.	.	.	.	0.1221	0.1221
	Maximum	.	.	.	.	.	.	.	0.293	0.293
	Count								16	16
	Valid N								N=14	N=14

Table 4 (cont.) Chloroform concentrations (µg/m³)

Site		1991	1992	1993	1994	1995	1996	1997	1998	All Years
MplsLibrary	Mean	0.0551	0.1597	0.0877	0.1497	0.1357	0.1977	0.1876	0.1187	0.1432
	Median	0.0586	0.1201	0.0977	0.1465	0.1221	0.1855	0.1855	0.1123	0.1269
	Maximum	0.1904	1.5717	0.1465	0.4394	1.123	0.913	0.4248	0.2734	1.5717
	Count	33	61	61	61	61	61	61	61	460
	Valid N	N=28	N=57	N=49	N=60	N=53	N=56	N=52	N=45	N=400
MhahaAcad	Mean	.	.	.	.	.	.	0.1187	0.0997	0.105
	Median	.	.	.	.	.	.	0.1025	0.0977	0.1025
	Maximum	.	.	.	.	.	.	0.293	0.2051	0.293
	Count							17	46	63
	Valid N							N=16	N=41	N=57
I_Falls1240	Mean	.	.	.	0.0767	0.6091	1.2592	.	1.2785	1.0307
	Median	.	.	.	0.0488	0.2319	0.5224	.	0.8886	0.4492
	Maximum	.	.	.	0.1465	2.7391	6.9138	.	4.8436	6.9138
	Count				7	23	44		25	99
	Valid N				N=7	N=20	N=39		N=25	N=91
I_Falls1241	Mean	.	.	.	.	.	0.1678	0.147	.	0.1528
	Median	.	.	.	.	.	0.144	0.1416	.	0.1416
	Maximum	.	.	.	.	.	0.5176	0.2539	.	0.5176
	Count						17	44		61
	Valid N						N=16	N=41		N=57
Sandstone	Mean	.	.	.	.	.	0.0954	0.1027	.	0.1005
	Median	.	.	.	.	.	0.0977	0.0952	.	0.0977
	Maximum	.	.	.	.	.	0.1465	0.2002	.	0.2002
	Count						20	44		64
	Valid N						N=15	N=36		N=51
FergusFalls	Mean	.	.	.	.	.	.	0.1066	0.0824	0.0854
	Median	.	.	.	.	.	.	0.0952	0.0806	0.0854
	Maximum	.	.	.	.	.	.	0.1562	0.21	0.21
	Count							17	45	62
	Valid N							N=6	N=42	N=48
Alexandria	Mean	.	.	.	.	.	0.1517	0.1752	.	0.1691
	Median	.	.	.	.	.	0.1318	0.1416	.	0.1343
	Maximum	.	.	.	.	.	0.4346	0.5029	.	0.5029
	Count						20	44		64
	Valid N						N=15	N=43		N=58
Warroad	Mean	.	.	.	.	.	.	0.1196	0.0948	0.1022
	Median	.	.	.	.	.	.	0.1025	0.0879	0.0928
	Maximum	.	.	.	.	.	.	0.2002	0.2832	0.2832
	Count							17	45	62
	Valid N							N=14	N=33	N=47
LittleFalls	Mean	.	.	.	.	.	0.1039	0.1121	.	0.11
	Median	.	.	.	.	.	0.1025	0.1025	.	0.1025
	Maximum	.	.	.	.	.	0.1465	0.2734	.	0.2734
	Count						20	44		64
	Valid N						N=14	N=42		N=56

Table 4 (cont.) Chloroform concentrations ($\mu g/m^3$)

Site		1991	1992	1993	1994	1995	1996	1997	1998	All Years
ElkRiver	Mean	.	.	.	.	.	.	0.1041	0.0606	0.0726
	Median	.	.	.	.	.	.	0.1001	0.0659	0.0684
	Maximum	.	.	.	.	.	.	0.21	0.1416	0.21
	Count							17	45	62
	Valid N							N=16	N=42	N=58
Pipestone	Mean	.	.	.	.	.	0.1178	0.1305	.	0.1264
	Median	.	.	.	.	.	0.1172	0.1001	.	0.1025
	Maximum	.	.	.	.	.	0.1953	0.3515	.	0.3515
	Count						20	44		64
	Valid N						N=15	N=32		N=47
GraniteFalls	Mean	.	.	.	.	.	.	0.0916	0.0809	0.084
	Median	.	.	.	.	.	.	0.0928	0.0806	0.0879
	Maximum	.	.	.	.	.	.	0.1172	0.1318	0.1318
	Count							17	45	62
	Valid N							N=13	N=32	N=45
Rochester	Mean	.	.	.	.	.	.	0.0893	0.0889	0.089
	Median	.	.	.	.	.	.	0.0879	0.083	0.0879
	Maximum	.	.	.	.	.	.	0.1611	0.21	0.21
	Count							17	45	62
	Valid N							N=14	N=45	N=59
Zumbrota	Mean	.	.	.	.	.	0.1127	0.1065	.	0.1078
	Median	.	.	.	.	.	0.1123	0.1025	.	0.105
	Maximum	.	.	.	.	.	0.1807	0.1953	.	0.1953
	Count						20	44		64
	Valid N						N=11	N=43		N=54
Hibbing	Mean	.	.	.	.	.	.	0.0885	0.0789	0.0817
	Median	.	.	.	.	.	.	0.0977	0.0781	0.083
	Maximum	.	.	.	.	.	.	0.1807	0.2051	0.2051
	Count							17	45	62
	Valid N							N=17	N=42	N=59
Duluth7549	Mean	.	.	.	0.1302	0.0709	0.1341	0.13	0.0737	0.1078
	Median	.	.	.	0.0977	0.0635	0.1318	0.1172	0.0732	0.0977
	Maximum	.	.	.	0.7812	0.1611	0.2832	0.2783	0.1904	0.7812
	Count				61	61	61	61	61	305
	Valid N				N=27	N=39	N=57	N=59	N=58	N=240
All Sites	Mean	0.0674	0.1486	0.0816	0.1179	0.1133	0.2295	0.1378	0.1314	0.1388
	Median	0.0586	0.1103	0.0488	0.0977	0.0757	0.1318	0.1123	0.0879	0.0977
	Maximum	0.913	1.5717	0.83	2.0995	2.7391	6.9138	0.5713	4.8436	6.9138
	Count	254	305	366	434	484	669	890	869	4271
	Valid N	N=222	N=259	N=265	N=383	N=402	N=584	N=777	N=758	N=3650

Table 5 Ethylene dibromide concentrations ($\mu g/m^3$)

Site		1991	1992	1993	1994	1995	1996	1997	1998	All Years
Plymouth	Mean	.	.	.	.	.	0.0666	0.0428	.	0.0493
	Median	.	.	.	.	.	0.0461	0.0307	.	0.0384
	Maximum	.	.	.	.	.	0.2382	0.1921	.	0.2382
	Count						20	44		64
	Valid N						N=15	N=40		N=55
Koch420	Mean	0.1709	0.0062	0.0017	0.0108	0.0023	0.0569	0.0728	0.0148	0.0426
	Median	0	0	0	0	0	0.0384	0.0461	0.0077	0
	Maximum	6.4925	0.1206	0.0768	0.2305	0.0461	0.315	0.5225	0.0692	6.4925
	Count	60	61	61	61	61	61	61	61	487
	Valid N	N=54	N=58	N=45	N=57	N=53	N=55	N=59	N=58	N=439
Koch423	Mean	0.4774	0.0179	0.0117	0.0117	0.0029	0.0431	0.0467	0.0164	0.0771
	Median	0	0	0	0	0	0.0307	0.0384	0.0154	0
	Maximum	14.6754	0.2705	0.0768	0.3842	0.0692	0.169	0.4072	0.0538	14.6754
	Count	60	61	61	61	61	61	97	122	584
	Valid N	N=59	N=53	N=46	N=59	N=48	N=56	N=68	N=100	N=489
Koch426	Mean	0.2149	0.025	0.0204	0.0456	0.0029	0.0724	.	.	0.0649
	Median	0	0.01	0	0	0	0.0538	.	.	0
	Maximum	4.1183	0.2497	0.1537	0.461	0.0615	0.2997	.	.	4.1183
	Count	60	61	61	61	61	61			365
	Valid N	N=58	N=60	N=49	N=59	N=55	N=56			N=337
StPaulPark	Mean	.	.	0.011	0.0071	0.0022	0.0449	0.0552	0.018	0.0239
	Median	.	.	0	0	0	0.0346	0.0384	0.0154	0.0077
	Maximum	.	.	0.1537	0.1537	0.0461	0.1537	0.4072	0.0538	0.4072
	Count			61	61	61	61	61	61	366
	Valid N			N=42	N=54	N=52	N=56	N=56	N=59	N=319
Ashland	Mean	.	.	.	.	0.0083	0.0504	0.0502	0.0143	0.0337
	Median	.	.	.	.	0	0.0384	0.0307	0.0154	0.0231
	Maximum	.	.	.	.	0.0999	0.2151	0.3995	0.0384	0.3995
	Count					34	61	61	61	217
	Valid N					N=27	N=53	N=56	N=58	N=194
HolmanFld	Mean	0.0418	0.0216	0.0136	0.0154	0.0027	0.0515	0.0521	0.0197	0.0272
	Median	0	0	0	0	0	0.0307	0.0307	0.0154	0
	Maximum	0.4994	0.2105	0.1537	0.2305	0.0538	0.3995	0.4994	0.1076	0.4994
	Count	41	61	61	61	61	61	61	61	468
	Valid N	N=23	N=31	N=34	N=60	N=55	N=55	N=54	N=41	N=353
BushSt	Mean	.	.	.	.	.	.	.	0.0207	0.0207
	Median	.	.	.	.	.	.	.	0.0077	0.0077
	Maximum	.	.	.	.	.	.	.	0.1998	0.1998
	Count								24	24
	Valid N								N=23	N=23
HardingHi	Mean	.	.	.	.	.	.	.	0.0154	0.0154
	Median	.	.	.	.	.	.	.	0.0077	0.0077
	Maximum	.	.	.	.	.	.	.	0.0768	0.0768
	Count								16	16
	Valid N								N=14	N=14

Table 5 (cont.) Ethylene dibromide concentrations ($\mu g/m^3$)

Site		1991	1992	1993	1994	1995	1996	1997	1998	All Years
MplsLibrary	Mean	0.0595	0.0137	0.0047	0.0243	0.0026	0.051	0.0368	0.015	0.0243
	Median	0	0	0	0	0	0.0346	0.0231	0.0154	0
	Maximum	1.1679	0.1913	0.1537	0.3842	0.0538	0.2766	0.1537	0.0845	1.1679
	Count	33	61	61	61	61	61	61	61	460
	Valid N	N=28	N=57	N=49	N=60	N=53	N=56	N=52	N=45	N=400
MhahaAcad	Mean	.	.	.	.	.	.	0.0485	0.0182	0.0267
	Median	.	.	.	.	.	.	0.0384	0.0154	0.0231
	Maximum	.	.	.	.	.	.	0.1153	0.0615	0.1153
	Count							17	46	63
	Valid N							N=16	N=41	N=57
I_Falls1240	Mean	.	.	.	0.0988	0.0058	0.0473	.	0.0166	0.0337
	Median	.	.	.	0	0	0.0384	.	0.0154	0.0154
	Maximum	.	.	.	0.3842	0.0538	0.2997	.	0.0538	0.3842
	Count				7	23	44		25	99
	Valid N				N=7	N=20	N=39		N=25	N=91
I_Falls1241	Mean	.	.	.	.	.	0.0648	0.0365	.	0.0445
	Median	.	.	.	.	.	0.0615	0.0307	.	0.0384
	Maximum	.	.	.	.	.	0.1614	0.1306	.	0.1614
	Count						17	44		61
	Valid N						N=16	N=41		N=57
Sandstone	Mean	.	.	.	.	.	0.0512	0.0785	.	0.0705
	Median	.	.	.	.	.	0.0307	0.0307	.	0.0307
	Maximum	.	.	.	.	.	0.1921	0.5378	.	0.5378
	Count						20	44		64
	Valid N						N=15	N=36		N=51
FergusFalls	Mean	.	.	.	.	.	.	0.0679	0.0185	0.0247
	Median	.	.	.	.	.	.	0.0692	0.0154	0.0231
	Maximum	.	.	.	.	.	.	0.1383	0.0461	0.1383
	Count							17	45	62
	Valid N							N=6	N=42	N=48
Alexandria	Mean	.	.	.	.	.	0.062	0.0531	.	0.0554
	Median	.	.	.	.	.	0.0538	0.0384	.	0.0384
	Maximum	.	.	.	.	.	0.1998	0.2228	.	0.2228
	Count						20	44		64
	Valid N						N=15	N=43		N=58
Warroad	Mean	.	.	.	.	.	.	0.028	0.0161	0.0196
	Median	.	.	.	.	.	.	0.0231	0.0154	0.0154
	Maximum	.	.	.	.	.	.	0.0538	0.0461	0.0538
	Count							17	45	62
	Valid N							N=14	N=33	N=47
LittleFalls	Mean	.	.	.	.	.	0.073	0.0688	.	0.0698
	Median	.	.	.	.	.	0.0845	0.0384	.	0.0384
	Maximum	.	.	.	.	.	0.2075	0.4533	.	0.4533
	Count						20	44		64
	Valid N						N=14	N=42		N=56

Table 5 (cont.) Ethylene dibromide concentrations (μg/m³)

Site		1991	1992	1993	1994	1995	1996	1997	1998	All Years
ElkRiver	Mean	.	.	.	.	.	.	0.0495	0.0172	0.0261
	Median	.	.	.	.	.	.	0.0346	0.0154	0.0192
	Maximum	.	.	.	.	.	.	0.1229	0.0461	0.1229
	Count							17	45	62
	Valid N							N=16	N=42	N=58
Pipestone	Mean	.	.	.	.	.	0.0825	0.0634	.	0.0695
	Median	.	.	.	.	.	0.0692	0.0461	.	0.0538
	Maximum	.	.	.	.	.	0.2151	0.1767	.	0.2151
	Count						20	44		64
	Valid N						N=15	N=32		N=47
GraniteFalls	Mean	.	.	.	.	.	.	0.0402	0.0178	0.0242
	Median	.	.	.	.	.	.	0.0384	0.0154	0.0154
	Maximum	.	.	.	.	.	.	0.0768	0.0538	0.0768
	Count							17	45	62
	Valid N							N=13	N=32	N=45
Rochester	Mean	.	.	.	.	.	.	0.0324	0.0166	0.0203
	Median	.	.	.	.	.	.	0.0269	0.0154	0.0154
	Maximum	.	.	.	.	.	.	0.1076	0.0461	0.1076
	Count							17	45	62
	Valid N							N=14	N=45	N=59
Zumbrota	Mean	.	.	.	.	.	0.0664	0.0499	.	0.0532
	Median	.	.	.	.	.	0.0538	0.0384	.	0.0384
	Maximum	.	.	.	.	.	0.2075	0.2151	.	0.2151
	Count						20	44		64
	Valid N						N=11	N=43		N=54
Hibbing	Mean	.	.	.	.	.	.	0.042	0.0165	0.0238
	Median	.	.	.	.	.	.	0.0384	0.0154	0.0154
	Maximum	.	.	.	.	.	.	0.1229	0.0692	0.1229
	Count							17	45	62
	Valid N							N=17	N=42	N=59
Duluth7549	Mean	.	.	.	0.0341	0.0018	0.0497	0.0412	0.0175	0.0303
	Median	.	.	.	0	0	0.0461	0.0384	0.0154	0.0154
	Maximum	.	.	.	0.461	0.0384	0.2305	0.1306	0.146	0.461
	Count				61	61	61	61	61	305
	Valid N				N=27	N=39	N=57	N=59	N=58	N=240
All Sites	Mean	0.2364	0.0165	0.0104	0.0219	0.0031	0.0546	0.0514	0.0168	0.0421
	Median	0	0	0	0	0	0.0384	0.0384	0.0154	0.0154
	Maximum	14.6754	0.2705	0.1537	0.461	0.0999	0.3995	0.5378	0.1998	14.6754
	Count	254	305	366	434	484	669	890	869	4271
	Valid N	N=222	N=259	N=265	N=383	N=402	N=584	N=777	N=758	N=3650

Table 6. Arsenic concentrations ($\mu g/m^3$)

Site		1996	1997	1998	All years
Plymouth	Mean	0.0021	0.0015	.	0.0017
	Median	0.0019	0.0016	.	0.0016
	Maximum	0.004	0.0058	.	0.0058
	Count	18	45		63
	Valid N	N=6	N=25		N=31
Bush St	Mean	0.0027	0.0025	0.0026	0.0025
	Median	0.0015	0.002	0.0021	0.002
	Maximum	0.011	0.0102	0.0098	0.011
	Count	18	61	61	140
	Valid N	N=9	N=41	N=42	N=92
Harding Hi	Mean	.	.	0.0029	0.0029
	Median	.	.	0.0017	0.0017
	Maximum	.	.	0.0063	0.0063
	Count			16	16
	Valid N			N=13	N=13
Mpls Library	Mean	0.0012	0.002	0.0015	0.0017
	Median	0.0013	0.0019	0.001	0.0013
	Maximum	0.0027	0.0057	0.0095	0.0095
	Count	18	61	61	140
	Valid N	N=9	N=41	N=39	N=89
MhahaAcad	Mean	.	0.0015	0.0014	0.0014
	Median	.	0.0014	0.0011	0.0012
	Maximum	.	0.0036	0.0039	0.0039
	Count		16	45	61
	Valid N		N=12	N=34	N=46
I_Falls1240	Mean	.	.	.	.
	Median	.	.	.	.
	Maximum	.	.	.	.
	Count	1			1
	Valid N	N=0			N=0
I_Falls1241	Mean	0.0005	0.0014	.	0.0012
	Median	0.0006	0.001	.	0.0008
	Maximum	0.0013	0.0044	.	0.0044
	Count	17	45		62
	Valid N	N=8	N=24		N=32
Sandstone	Mean	0.0012	0.0011	.	0.0011
	Median	0.0011	0.0008	.	0.0008
	Maximum	0.0027	0.0032	.	0.0032
	Count	18	45		63
	Valid N	N=6	N=22		N=28
FergusFalls	Mean	.	0.0016	0.0016	0.0016
	Median	.	0.0012	0.0012	0.0012
	Maximum	.	0.007	0.0047	0.007
	Count		16	45	61
	Valid N		N=11	N=28	N=39

Table 6 (cont.). Arsenic concentrations (μg/m³)

Site		1996	1997	1998	All years
Alexandria	Mean	0.0011	0.0011	.	0.0011
	Median	0.0009	0.0012	.	0.0011
	Maximum	0.0019	0.0026	.	0.0026
	Count	18	45		63
	Valid N	N=4	N=23		N=27
Moorhead	Mean	.	.	0.0025	0.0025
	Median	.	.	0.0025	0.0025
	Maximum	.	.	0.0043	0.0043
	Count			16	16
	Valid N			N=6	N=6
Bemidji	Mean	.	.	0.0012	0.0012
	Median	.	.	0.0016	0.0016
	Maximum	.	.	0.0019	0.0019
	Count			16	16
	Valid N			N=4	N=4
Warroad	Mean	.	0.0009	0.0009	0.0009
	Median	.	0.0009	0.0005	0.0007
	Maximum	.	0.0021	0.0046	0.0046
	Count		16	45	61
	Valid N		N=11	N=28	N=39
LittleFalls	Mean	0.0018	0.0012	.	0.0013
	Median	0.0009	0.001	.	0.001
	Maximum	0.0039	0.0044	.	0.0044
	Count	18	45		63
	Valid N	N=3	N=25		N=28
ElkRiver	Mean	.	0.0031	0.0025	0.0026
	Median	.	0.001	0.0018	0.0016
	Maximum	.	0.0149	0.0113	0.0149
	Count		16	45	61
	Valid N		N=6	N=34	N=40
St.Cloud	Mean	.	.	0.0011	0.0011
	Median	.	.	0.0014	0.0014
	Maximum	.	.	0.002	0.002
	Count			16	16
	Valid N			N=7	N=7
Pipestone	Mean	0.0003	0.0008	.	0.0007
	Median	0.0002	0.0007	.	0.0007
	Maximum	0.001	0.0019	.	0.0019
	Count	18	45		63
	Valid N	N=5	N=21		N=26
GraniteFalls	Mean	.	0.0008	0.0008	0.0008
	Median	.	0.0009	0.0007	0.0007
	Maximum	.	0.0015	0.0034	0.0034
	Count		16	45	61
	Valid N		N=7	N=28	N=35

Table 6 (cont.). Arsenic concentrations (μg/m³)

Site		1996	1997	1998	All years
Holloway	Mean	.	.	0.0004	0.0004
	Median	.	.	0.0004	0.0004
	Maximum	.	.	0.001	0.001
	Count			16	16
	Valid N			N=9	N=9
Rochester	Mean	.	0.0006	0.0011	0.001
	Median	.	0.0003	0.001	0.0007
	Maximum	.	0.0025	0.0035	0.0035
	Count		16	45	61
	Valid N		N=10	N=29	N=39
Winona	Mean	.	.	0.0023	0.0023
	Median	.	.	0.0023	0.0023
	Maximum	.	.	0.0048	0.0048
	Count			16	16
	Valid N			N=6	N=6
Zumbrota	Mean	0.0011	0.0012	.	0.0012
	Median	0.0005	0.0014	.	0.0011
	Maximum	0.0035	0.0036	.	0.0036
	Count	18	45		63
	Valid N	N=6	N=24		N=30
Hibbing	Mean	.	0.0016	0.0021	0.002
	Median	.	0.0021	0.0017	0.0017
	Maximum	.	0.004	0.008	0.008
	Count		16	45	61
	Valid N		N=9	N=31	N=40
Duluth	Mean	.	.	0.0011	0.0011
	Median	.	.	0.0008	0.0008
	Maximum	.	.	0.0044	0.0044
	Count			16	16
	Valid N			N=11	N=11
All Sites	Mean	0.0014	0.0015	0.0017	0.0016
	Median	0.0009	0.0011	0.0013	0.0012
	Maximum	0.011	0.0149	0.0113	0.0149
	Count	162	549	549	1260
	Valid N	N=56	N=312	N=349	N=717

Table 7 Total chromium concentrations (µg/m³)

Site		1996	1997	1998	All Years
Plymouth	Mean	0.0007	0.0012	.	0.001
	Median	0.0007	0.0012	.	0.0009
	Maximum	0.0022	0.0034	.	0.0034
	Count	18	45		63
	Valid N	N=12	N=32		N=44
BushSt	Mean	0.0012	0.002	0.0011	0.0015
	Median	0.0001	0.0016	0.001	0.0013
	Maximum	0.0051	0.0074	0.0041	0.0074
	Count	18	61	61	140
	Valid N	N=9	N=56	N=53	N=118
HardingHi	Mean	.	.	0.0014	0.0014
	Median	.	.	0.0013	0.0013
	Maximum	.	.	0.0036	0.0036
	Count			16	16
	Valid N			N=14	N=14
MplsLibrar	Mean	0.001	0.0017	0.0013	0.0015
	Median	0.0009	0.0013	0.0012	0.0012
	Maximum	0.0029	0.006	0.0062	0.0062
	Count	18	61	61	140
	Valid N	N=8	N=48	N=47	N=103
MhahaAcad	Mean	.	0.0018	0.0008	0.0011
	Median	.	0.0017	0.0005	0.0009
	Maximum	.	0.0045	0.0033	0.0045
	Count		16	45	61
	Valid N		N=11	N=35	N=46
I_Falls124	Mean	.	.	.	.
	Median	.	.	.	.
	Maximum	.	.	.	.
	Count	1			1
	Valid N	N=0			N=0
I_Falls124	Mean	0.0006	0.001	.	0.0009
	Median	0.0005	0.0009	.	0.0007
	Maximum	0.0025	0.0031	.	0.0031
	Count	17	45		62
	Valid N	N=9	N=34		N=43
Sandstone	Mean	0.0011	0.0011	.	0.0011
	Median	0.0008	0.0008	.	0.0008
	Maximum	0.0036	0.0047	.	0.0047
	Count	18	45		63
	Valid N	N=5	N=31		N=36
FergusFall	Mean	.	0.001	0.0012	0.0011
	Median	.	0.0011	0.0009	0.0009
	Maximum	.	0.0032	0.0043	0.0043
	Count		16	45	61
	Valid N		N=14	N=36	N=50

Table 7 (cont.) Total chromium concentrations (µg/m³)

Site		1996	1997	1998	All Years
Alexandria	Mean	0.0002	0.001	.	0.001
	Median	0.0002	0.0011	.	0.001
	Maximum	0.0008	0.005	.	0.005
	Count	18	45		63
	Valid N	N=2	N=24		N=26
Moorhead	Mean	.	.	0.0013	0.0013
	Median	.	.	0.0018	0.0018
	Maximum	.	.	0.003	0.003
	Count			16	16
	Valid N			N=10	N=10
Bemidji	Mean	.	.	0.0009	0.0009
	Median	.	.	0.0003	0.0003
	Maximum	.	.	0.0039	0.0039
	Count			16	16
	Valid N			N=10	N=10
Warroad	Mean	.	0.0003	0.0006	0.0005
	Median	.	0.0003	0.0006	0.0005
	Maximum	.	0.0013	0.0031	0.0031
	Count		16	45	61
	Valid N		N=12	N=33	N=45
LittleFall	Mean	0.0007	0.0012	.	0.0011
	Median	0.0007	0.0011	.	0.0011
	Maximum	0.0015	0.0033	.	0.0033
	Count	18	45		63
	Valid N	N=4	N=30		N=34
ElkRiver	Mean	.	0.0017	0.0009	0.001
	Median	.	0.0013	0.0008	0.0011
	Maximum	.	0.0047	0.0043	0.0047
	Count		16	45	61
	Valid N		N=8	N=38	N=46
St.Cloud	Mean	.	.	0.001	0.001
	Median	.	.	0.0007	0.0007
	Maximum	.	.	0.0026	0.0026
	Count			16	16
	Valid N			N=13	N=13
Pipestone	Mean	0.001	0.0012	.	0.0011
	Median	0.001	0.0007	.	0.0007
	Maximum	0.0015	0.0063	.	0.0063
	Count	18	45		63
	Valid N	N=4	N=21		N=25
GraniteFalls	Mean	.	0.0011	0.0005	0.0006
	Median	.	0.001	0.0005	0.0006
	Maximum	.	0.0026	0.0029	0.0029
	Count		16	45	61
	Valid N		N=11	N=33	N=44

Table 7 (cont.) Summary statistics for total chromium (µg/m³)

Site		1996	1997	1998	All Years
Holloway	Mean	.	.	0.0008	0.0008
	Median	.	.	0.0006	0.0006
	Maximum	.	.	0.0038	0.0038
	Count			16	16
	Valid N			N=11	N=11
Rochester	Mean	.	0.0005	0.0005	0.0005
	Median	.	0.0002	0.0007	0.0007
	Maximum	.	0.0026	0.0029	0.0029
	Count		16	45	61
	Valid N		N=11	N=30	N=41
Winona	Mean	.	.	0.0008	0.0008
	Median	.	.	0.0005	0.0005
	Maximum	.	.	0.003	0.003
	Count			16	16
	Valid N			N=9	N=9
Zumbrota	Mean	0.0013	0.001	.	0.001
	Median	0.0008	0.0009	.	0.0009
	Maximum	0.0031	0.0026	.	0.0031
	Count	18	45		63
	Valid N	N=5	N=27		N=32
Hibbing	Mean	.	0.0013	0.0008	0.0009
	Median	.	0.0017	0.0008	0.0009
	Maximum	.	0.0024	0.0036	0.0036
	Count		16	45	61
	Valid N		N=8	N=33	N=41
Duluth	Mean	.	.	0.001	0.001
	Median	.	.	0.001	0.001
	Maximum	.	.	0.0029	0.0029
	Count			16	16
	Valid N			N=14	N=14
All sites	Mean	0.0009	0.0013	0.0009	0.0011
	Median	0.0007	0.0011	0.0008	0.0009
	Maximum	0.0051	0.0074	0.0062	0.0074
	Count	162	549	549	1260
	Valid N	N=58	N=378	N=419	N=855

APPENDIX B

Appendix B — Features of Statistical Methods Used for Evaluation

Statistical software

All statistical analyses were done using either SPSS version 8.0 or SYSTAT version 8.0. Most of the statistical analyses presented in this document consist of descriptive statistics (mean, median, maximum, frequency distribution histograms, boxplots, etc.), although for some pollutants, analysis of variance, comparison of means, correlations, regression and time series analyses were conducted.

Sources of bias in the data

There have been multiple purposes behind the collection of air toxics data in Minnesota. Some sites were established to measure concentrations in the vicinity of point sources. Other sites were established to collect baseline data on air toxics concentrations in the Twin Cities metropolitan area. A third group of sites was established as part of a legislatively mandated statewide air toxics monitoring project. The objective of this project was to collect one-year snapshots of concentrations at sites throughout the state. The sites were randomly selected with weighting for geographic coverage and population density.

Given these multiple purposes, it is clear there are biases in the data that should be recognized in its interpretation. The biases include:

1. Changes in analytical techniques (*e.g.,* for formaldehyde) result in two different data populations. The two populations were combined for some analyses and separated for others. This issue is discussed in the sections on a pollutant-by-pollutant basis.
2. The uneven number of data points per location results in biases in frequency distributions and descriptive statistics. Although overall values are presented, it should be recognized that some sites are weighted more heavily than others because of these biases. The individual site and year values are also presented so the reader can make relevant comparisons. Another statistic that was considered for representing an overall statewide value was a mean of site means. This was not done because the monitoring locations tend to be biased toward locations where more people live. Thus, the monitoring locations are likely to be more representative of peoples' exposure than a mean of site means.
3. The uneven spatial distribution of sampling location also results in biases in the overall frequency distributions and descriptive statistics, with some geographic areas of the state being more heavily weighted than others. Again, the individual site and year values are also presented the reader can make relevant comparisons. At the conclusion of the five-year statewide air toxics monitoring program, the data from the sites included in that program will be analyzed separately in order to make specific conclusions about geographic and population-based concentrations.

Lower Detection Limits (LDLs)

We report LDLs that are determined as described below. Method detection limits are not reported because many of the analytes are not detected in a large fraction of the samples, making it difficult to calculate the method detection limit. This fact prohibits the determination of a method detection limit for those substances. Instrument detection limits are also available, but are not reported here.

VOCs and carbonyls: The LDL is determined by the following procedure. A standard is prepared one to five times the estimated LDL. A minimum of seven samples of this standard are processed through the entire analytical method. The resulting concentration data are input to the following equation:

$$LDL = t \times (SD), \text{ where}$$

t = the student's t-value appropriate for a 99% confidence level for the standard deviation with n-1 degrees of freedom, and
SD = the standard deviation of replicate analyses.

Metals (XRF): Using the XRF instrument, an element's peak is detected above background with 99% confidence if the peak counts are greater than three times the square root of the background counts:

$$LDL = (3 \times (Ib)^{1/2})/ Ip * 1/(T^{1/2}) * \text{concentration, where:}$$

Ib = background (cps, or counts per second),
Ip = peak (cps), and
T = time.

Protocol for treating values below detection

Although some measurements are below the level of reliable quantification, the information contained in the reading is valuable and should not be discarded. Likewise, it would represent a loss in information to assign some arbitrary value, such as one-half the detection limit. Therefore, all valid data, including values below detection, zeroes and negative values, are retained in the database used for statistical analysis.

The presence of a few negative or zero values is not a great concern in calculating descriptive statistics, such as means, medians, variances and quantiles. A few of these values will also not dramatically affect frequency distributions or tests of normality. A problem with negative values and zeroes occurs if, as is the case often in air monitoring, the data are approximately log-normally distributed and require a log transformation to obtain data that can be used with parametric statistics. If there are only a few negative or zero values, these can reasonably be substituted with a very small number. On the other hand, many zeroes and/or negative values are an indication that our analytical methodology is not sensitive enough and the variable should not be included in subsequent analyses that require a transformation for normality.

In the case of several metals, a large fraction of the measurements are below the LDL. In addition, since the reading from a blank filter is subtracted from each measurement, there are some negative values in the data. These negative values could be censored in some way, such as converting them to zero (or one-half the LDL). However this censoring would alter the frequency distribution. The best method for treating such data is a matter of debate in the scientific literature. We have chosen to retain all the raw values in the data for the statistical analyses reported here.

A blank subtraction is also done with the carbonyl data. With VOCs, there is presently no blank subtraction; however, was some blank subtraction was done early on, resulting in a few negative values. There are also several VOCs and carbonyls that are often below the LDL.

Decisions on the types of statistical analyses that are appropriate will be made on a chemical-by-chemical basis after looking at the descriptive statistics frequency distributions and other statistical analyses.

Frequency distributions and statistics for representing central tendency

Many air monitoring data, including many of the pollutants measured by the Minnesota air toxics monitoring network, are log-normally (rather than normally) distributed. This means there is a tail in the frequency distribution towards the high end values. In such cases, the bulk of the measurements often lie below the mean value, since the mean may tend upwards due to the presence of a few high measurements. The question then arises, "What is the most appropriate statistic to represent the central tendency of the data?" The median value represents the value with equal number of measurements above and below it, and is often reported for data that are not normally distributed. We report the median value in the detailed analyses of individual pollutants. When the data have a clear log-normal distribution, the median value is lower than the mean.

The mean value may also represent the central tendency of the data in a way that may be more appropriate for comparison with health benchmark numbers. Health benchmark values often are taken as some integrated representation of concentration over time. Mean values may better represent this integrated concentration than median values because the few high values that push the mean upwards in log-normally distributed data may be important in the toxicology of the pollutant. Due to this fact, we also report the mean values in this document.

Parametric versus nonparametric statistics

Since many of the pollutants are not normally distributed, the appropriateness of specific statistical techniques is often in question. In most cases, this issue was moot, since only descriptive statistics were used; however, in some cases, regression, ANOVA and other analyses that require an assumption of normally distributed data were used. In those cases, it was typically found that a transformation of the data (*e.g.*, log transformation) resulted in data that were approximately normally distributed, and parametric statistics were then used on the transformed data. In a few cases, the data could not be transformed to approximate normality, and in those cases, statistical analyses requiring an assumption of normality were not used.

APPENDIX C

Appendix C — Description of Source Categories: Mobile, Point and Area

Source category definitions are not consistent for all air toxics reports. The source categories for three relevant studies are discussed below. Source definitions become important when monitoring or modeling data indicate high concentrations of toxics in ambient air. Reduction strategies rely on emission inventories and other studies for data on source contributions. Unclear and inconsistent source category definitions can further complicate the search for solutions.

Minnesota Air Toxics Emission Inventory

The Minnesota Air Toxics Emission Inventory (toxics EI) divides sources into point, area and mobile sources. The toxics EI collects data for the point source inventory from two sources: the Minnesota Criteria Pollutant Emission Inventory (MCEI) and facility permits. Facilities must submit emissions estimates to the MCEI if they have a state or federal Part 70 permit or a registration permit. The toxics EI uses the volatile organic compound (VOC) and particulate matter less than 10 microns (PM_{10}) emissions from the MCEI to estimate emissions for some toxics. Toxics data included on permits are also used to build the inventory. Typically, point sources are large facilities or high emitters.

The area source category contains the following sources:

- architectural surface coating,
- autobody refinishing,
- chromium electroplating,
- commercial/consumer solvent products,
- dry cleaners,
- residential fossil fuel combustion,
- graphic arts,
- gasoline marketing,
- industrial surface coating,
- marine vessel loading,
- municipal solid waste landfills,
- pesticides – agricultural,
- publicly owned treatment works (POTW) facilities,
- solvent cleaning,
- traffic marking, and
- residential wood burning.

Some facilities that fall under these broad categories must submit emissions to the MCEI. In that case, the emissions are included under the point source portion of the inventory to avoid double counting. For example, emissions from large printing operations will likely be included in the point source inventory, while emissions from smaller facilities will be estimated on a county level and included in the graphic arts portion of the area source inventory. Other small sources, such as dry cleaners, are almost exclusively area sources.

The mobile source category includes on-road motor vehicles, locomotives, aircraft and "nonroad" vehicles. The last category includes construction equipment, lawn mowers and similar gasoline-powered machines.

Because the development of the Minnesota Air Toxics Emission Inventory is still in progress, only limited point source emissions were used in the data analysis in this report, not the entire point source inventory. The point source emission data were from two information sources: (1) the 1996 Minnesota Air Toxics Emission Inventory for metal mining/iron ores and electric services and (2) the 1996 Toxic Release Inventory (TRI).

After the 1996 toxics EI is completed, emissions from the remaining point sources, along with area and mobile sources, will be available.

The EPA Cumulative Exposure Project (CEP)

The preliminary CEP study released in December 1998 compiled toxics information for many sources. The CEP study was broken up into point, area and mobile sources. The point source category includes TRI point sources, refineries, municipal waste combustors, waste treatment, storage and disposal facilities (TSDF), and other facilities that emit more than 100 tons per year of a criteria pollutant. Facilities are required to report to the TRI if they meet three criteria: (1) 10 or more full-time employees; (2) the facility manufactures or processes more than 25,000 pounds (lb.) of listed chemicals or otherwise uses 10,000 lb. of a listed chemical and (3) the facility falls under Standard Industrial Classification (SIC) code 20-39.

The area source category includes other stationary sources not included in the point source inventory. The area sources include facilities that annually emit less than 100 tons of criteria pollutants, even if the facilities emit significant amounts of toxics. Emissions from the area source category are reported as county totals rather than individual facility emissions. The overall category is broken down into subgroups that include:

- stationary source fuel combustion – electric utilities, commercial and residential fossil fuel combustion;
- industrial processes – petroleum refining, chemical manufacturing, construction, mineral processes;
- solvent utilization – surface coating operations, degreasing, graphic arts, pesticides;
- storage and transport – gasoline service stations (stage I and II), gasoline storage tanks;
- waste disposal, treatment, and recovery facilities – wastewater treatment, on-site incineration;
- unpaved airstrips (for aircraft); and
- miscellaneous – forest and structure fires, agricultural production.

Similar sources may be included in both the point and area sections of the inventory. For example, electric utilities were not required to submit reports to the TRI until 1998, so a utility emitting 90 tons of criteria pollutants and five tons of toxics would be considered an area source and the emissions would be reported in the total county emissions. A utility emitting 110 tons of criteria pollutants and five tons of toxics would be part of the point source inventory since it crossed the 100-ton threshold.

The point and area source definitions in the CEP do not match exactly with the Minnesota toxics EI. Small electric utilities that emit less than 100 tons of criteria pollutants annually are defined as area sources in the CEP, as discussed above. The toxics EI includes them as point sources, as they probably are permitted by the MPCA and required to submit criteria emissions. Source contributions to toxics pollutants in Minnesota may vary depending on the study from which the data originate.

The mobile source category includes many of the same sources as the mobile source category for the Minnesota toxics EI: on–road motor vehicles, nonroad equipment, aircraft, locomotives and commercial marine vessels. All sources other than on-road vehicles are included in the broader nonroad category.

EPA Trends report

The data in the EPA Trends report are presented in a two-tier source category format. The first tier describes the general source category. "Metal processing" and "Industrial fuel combustion" are examples. The second tier divides those broader categories into more specific emission sources, such as "Nonferrous metals processing" (under metal processing) and "Internal combustion" (under industrial fuel combustion). The data for the Trends report are mostly state-reported data. The data under these tiers are broken down into point, area, and mobile sources according to state classifications.

Category	Subcategory	EPA Trends	MPCA Toxics EI	EPA CEP
Fuel Combustion - Electric Utility	Coal	P	P	P, A
Fuel Combustion - Electric Utility	Oil	P	P	P, A
Fuel Combustion - Electric Utility	Gas	P	P	P, A
Fuel Combustion - Electric Utility	Other		P	P, A
Fuel Combustion - Electric Utility	Internal Combustion	P	P	P, A
Fuel Combustion – Industrial	Coal	P	P	A
Fuel Combustion – Industrial	Oil	P, A	P	A
Fuel Combustion – Industrial	Gas	P, A	P	A
Fuel Combustion – Industrial	Other	P	P	A
Fuel Combustion – Industrial	Internal Combustion	P	P	A
Fuel Combustion – Other	Commercial/Institutional Coal	P	P	A
Fuel Combustion – Other	Commercial/Institutional Oil	P, A	P	A
Fuel Combustion – Other	Commercial/Institutional Gas	P, A	P	A
Fuel Combustion - Other	Misc. Fuel Comb. (Except Resid.)	P	P	A
Fuel Combustion - Other	Residential Wood	A	A	A
Fuel Combustion – Other	Residential Other	A		A

Category	Subcategory	EPA Trends	MPCA Toxics EI	EPA CEP
Chemical & Allied Product Mfg.	Inorganic Chemicals	P	P	P, A
Chemical & Allied Product Mfg.	Polymers & Resins	P	P	P, A
Chemical & Allied Product Mfg.	Agricultural Chemicals		P	P, A
Chemical & Allied Product Mfg.	Paints, Varnishes, Lacquers		P	P, A
Chemical & Allied Product Mfg.	Pharmaceuticals	A	P	P, A
Chemical & Allied Product Mfg.	Other Chemicals	P	P	P, A
Metals Processing	Nonferrous Metals Processing	P	P	P
Metals Processing	Ferrous Metals Processing	P	P	P
Metals Processing	Metals Processing NEC	P	P	P
Petroleum & Related Industries	Oil & Gas Production	A	P	P, A
Petroleum & Related Industries	Petroleum Refineries & Related Industries	P	P	P, A
Petroleum & Related Industries	Asphalt Manufacturing	P	P	P, A
Other Industrial Processes	Agriculture, Food, & Kindred Products	P	P	A
Other Industrial Processes	Textiles, Leather, & Apparel		P	P
Other Industrial Processes	Wood, Pulp & Paper, Publishing	P	P	P, A
Other Industrial Processes	Rubber & Miscellaneous Plastic	P	P	P, A
Other Industrial Processes	Mineral Products	P	P	
Other Industrial Processes	Machinery Products	P	P	P
Other Industrial Processes	Electronic Equipment		P	P
Other Industrial Processes	Transportation Equipment		P	P
Other Industrial Processes	Construction		P	
Other Industrial Processes	Misc. Industrial Processes	P	P	
Solvent Utilization	Degreasing	P, A	A	A
Solvent Utilization	Graphic Arts	P, A	P, A	A
Solvent Utilization	Dry Cleaning	A	A	A
Solvent Utilization	Surface Coating	P, A	A	A
Solvent Utilization	Other Industrial	A	A	A
Solvent Utilization	Non-industrial	A		A
Solvent Utilization	Solvent Utilization NEC			
Storage & Transport	Bulk Terminals & Plants	P, A		A
Storage & Transport	Petroleum & Petroleum Product	P		A
Storage & Transport	Petroleum & Petroleum Product	P		A
Storage & Transport	Service Stations: Stage I	A	A	A
Storage & Transport	Service Stations: Stage II	A	A	A
Storage & Transport	Service Stations: Breathing & Resting Losses	A		A
Storage & Transport	Organic Chemical Storage	P		A
Storage & Transport	Organic Chemical Transport	P		A
Storage & Transport	Inorganic Chemical Storage	P		A
Storage & Transport	Inorganic Chemical Transport	P		A
Storage & Transport	Bulk Materials Storage	P		A
Storage & Transport	Bulk Materials Transport	P		A
Waste Disposal & Recycling	Incineration	P, A	P	P, A

Category	Subcategory	EPA Trends	MPCA Toxics EI	EPA CEP
Waste Disposal & Recycling	Open Burning	A	P	P, A
Waste Disposal & Recycling	Publicly Owned Treatment Works (POTW)	P; A	A	P,A
Waste Disposal & Recycling	Industrial Waste Water			P, A
Waste Disposal & Recycling	Treatment, Storage, and Disposal Facilities (TSDF)	A	P	P
Waste Disposal & Recycling	Landfills		A	P, A
Waste Disposal & Recycling	Other			P, A
Highway Vehicles	Light-Duty Gas Vehicles & Motorcycles	A	M	M
Highway Vehicles	Light-Duty Gas Trucks	A	M	M
Highway Vehicles	Heavy-Duty Gas Vehicles	A	M	M
Highway Vehicles	Diesels	A	M	M
Off-Highway Vehicles	Nonroad Gasoline	A	M	M
Off-Highway Vehicles	Nonroad Diesel	A	M	M
Off-Highway Vehicles	Aircraft	A	M	M
Off-Highway Vehicles	Marine Vessels	A	M	M
Off-Highway Vehicles	Railroads	A	M	M
Natural Sources	Biogenic	A		
Natural Sources	Geogenic	A		
Natural Sources	Miscellaneous	A		
Miscellaneous	Agriculture & Forestry	A		A
Miscellaneous	Other Combustion	A		A
Miscellaneous	Catastrophic/Accidental Releases	A		
Miscellaneous	Repair Shops	A		
Miscellaneous	Health Services	A		
Miscellaneous	Cooling Towers	A		
Miscellaneous	Fugitive Dust	P, A		A
Miscellaneous	Aircraft Unpaved Airstrips	A		A

APPENDIX D

Appendix D — Chronic Inhalation Health Benchmark Tables

Table 1: Chronic Inhalation Health Benchmarks for Compounds of Concern Included in the Staff Paper

Chemical	CAS Number	Noncancer Health Benchmark (μg/m^3)	Noncancer Toxicity Endpoint/System	Noncancer Data Source*	Cancer Health Benchmark (μg/m^3)**	Cancer Unit Risk	Cancer Data Source*
ACROLEIN	107-02-8	0.02	upper respiratory	IRIS			
ARSENIC	7440-38-2	0.03	developmental, cardiovascular, nervous	OEHHA	0.002	4.3E-03	HRV
BENZENE	71-43-2	60	cardiovascular, developmental, immune, nervous	OEHHA	1.3 - 4.5	2.2E-06 - 7.83E-06	HRV
BENZO (a) PYRENE	50-32-8				0.011	0.9E-03	EPA
1,3-BUTADIENE	106-99-0	8	reproductive	OEHHA	0.04	2.8E-04	HRV
CARBON TETRACHLORIDE	56-23-5	40	alimentary, developmental, nervous	OEHHA	0.7	1.50E-05	IRIS
CHLOROFORM	67-66-3	300	alimentary, developmental, kidney	OEHHA	0.4	2.30E-05	IRIS
CHROMIC ACID MISTS	18540-29-9	0.008	upper respiratory	IRIS			
CHROMIUM VI PARTICULATES	18540-29-9	0.1	lower respiratory	IRIS			
CHROMIUM VI	18540-29-9				0.0008	1.2E-02	HRV
ETHYLENE DIBROMIDE (1,2-dibromoethane)	106-93-4	0.2	reproductive	HEAST	0.05	2.20E-04	HRV
FORMALDEHYDE	50-00-0	3	respiratory, eye	OEHHA	0.8	1.30E-05	HRV
NICKEL AND NICKEL COMPOUNDS	7440-02-0	0.05	respiratory, immune	OEHHA			
NICKEL REFINERY DUST	unknown				0.04	2.4E-04	HRV
NICKEL SUBSULFIDE	12035-72-2				0.02	4.8E-04	HRV

* EPA is a provisional EPA number from the Superfund Technical Support Center, December, 1998.
HRV is the Minnesota Department of Health, Draft Health Risk Values, September 1999
IRIS is the U.S. Environmental Protection Agency Integrated Risk Information System, IRIS2, October 1999.
HEAST is the U.S. Environmental Protection Agency Health Effects Assessment Summary Tables, 1997.
OEHHA is the California Office of Environmental Health Hazard Assessment. Cancer unit risks, April 1999; chronic reference exposure levels, September 1999.

**The cancer health benchmarks are based on the Minnesota Department of Health Tolerable Risk Level of $1x10^{-5}$. In other words, the cancer health benchmark = 1E-5/unit risk.

Table 2: Chronic Inhalation Health Benchmarks for Nonmetal Compounds Included in the Minnesota Statewide Air Toxics Monitoring Study

Chemical	CAS Number	Noncancer Health Benchmark (µg/m³)	Noncancer Toxicity Endpoint/System	Noncancer Data Source*	Cancer Health Benchmark (µg/m³)**	Cancer Unit Risk	Cancer Data Source*
1,1,1-TRICHLOROETHANE	71-55-6						
1,1,2,2-TETRACHLOROETHANE	79-34-5				0.2	5.80 E-05	IRIS
1,1,2-TRICHLOROETHANE	79-00-5				0.6	1.60E-05	IRIS
1,1,2-TRICHLORO-1,2,2-TRIFLUOROETHANE (CFC-113)	76-13-1	30000	whole body	HEAST			
1,1-DICHLOROETHANE	75-34-3	500	kidney	HEAST	6	1.60E-06	OEHHA
1,2-DICHLOROTETRAFLUOROETHANE (CFC-114)	76-14-2						
1,2,4-TRIMETHYLBENZENE	95-63-6						
1,2-DICHLOROETHANE	107-06-2	400	alimentary, nervous	OEHHA	0.4	2.60E-05	IRIS
1,2-DICHLOROETHYLENE	540-59-0						
1,2-DICHLOROPROPANE	78-87-5	4	upper respiratory	IRIS			
1,3,5-TRIMETHYLBENZENE	108-67-8						
1,3-DICHLOROPROPENE	542-75-6	20	upper respiratory	HRV	0.3	3.70E-05	HEAST
ACETALDEHYDE	75-07-0	9	upper respiratory	IRIS	5	2.20E-06	HRV
ACETONE	67-64-1						
BENZALDEHYDE	100-52-7						
BENZENE	71-43-2	60	cardiovascular, developmental, immune, nervous	OEHHA	1.3 - 4.5	2.2E-06 - 7.83E-06	HRV
BROMOMETHANE	74-83-9	5	upper respiratory	HRV			
BUTYRALDEHYDE	123-72-8						
CARBON TETRACHLORIDE	56-23-5	40	alimentary, developmental, nervous	OEHHA	0.7	1.50E-05	IRIS
CHLOROBENZENE	108-90-7	20	kidney, liver	HEAST			
CHLOROFORM	67-66-3	300	alimentary, developmental, kidney	OEHHA	0.4	2.30E-05	IRIS
CROTONALDEHYDE	4170-30-3						
M-DICHLOROBENZENE	541-73-1						
O-DICHLOROBENZENE	95-50-1	200	whole body	HEAST			
P-DICHLOROBENZENE	106-46-7	800	liver	IRIS			

Chemical	CAS Number	Noncancer Health Benchmark (µg/m³)	Noncancer Toxicity Endpoint/System	Noncancer Data Source*	Cancer Health Benchmark (µg/m³)**	Cancer Unit Risk	Cancer Data Source*
DICHLORODIFLUOROMETHANE (CFC-12)	75-71-8	200	liver	HEAST			
DICHLOROMETHANE	75-09-2	3000	liver	HEAST	20	4.70E-07	HRV
ETHYL BENZENE	100-41-4	1000	developmental	IRIS			
ETHYLENE DIBROMIDE (1,2-dibromoethane)	106-93-4	0.2	reproductive	HEAST	0.05	2.20E-04	HRV
FORMALDEHYDE	50-00-0	3	respiratory, eye	OEHHA	0.8	1.30E-05	HRV
HEXACHLORO-1,3-BUTADIENE	87-68-3	90	alimentary, kidney	OEHHA	0.5	2.20E-05	IRIS
PROPIONALDEHYDE	123-38-6						
STYRENE	100-42-5	200	nervous system	HRV			
TETRACHLOROETHYLENE	127-18-4						
TOLUENE	108-88-3	400	nervous, upper respiratory	HRV			
TRICHLOROETHENE	79-01-6	600	nervous, eye	OEHHA	5	2.00E-06	OEHHA
TRICHLOROFLUOROMETHANE (CFC-11)	75-69-4	700	kidney, lung	HEAST			
VINYL_CHLORIDE	75-01-4				0.1	8.40E-05	HEAST
VINYLIDINE_CHLORIDE	75-35-4						
XYLENE	108-38-3	700	nervous, respiratory	OEHHA			

* **HRV** is the Minnesota Department of Health, Draft Health Risk Values, September 1999
IRIS is the U.S. Environmental Protection Agency Integrated Risk Information System, IRIS2, October 1999.
HEAST is the U.S. Environmental Protection Agency Health Effects Assessment Summary Tables, 1997.
OEHHA is the California Office of Environmental Health Hazard Assessment. Cancer unit risks, April 1999; chronic reference exposure levels, September 1999.

**The cancer health benchmarks are based on the Minnesota Department of Health Tolerable Risk Level of $1x10^{-5}$. In other words, the cancer health benchmark = 1E-5/unit risk.

APPENDIX E

Appendix E. Summary Statistics for Monitored Organics.

		ACETALDE HYDE	ACETONE	BENZALDE HYDE	BENZENE	BROMO ETHANE	BUTYRALDE HYDE	C_13_DI CHLORO PROPENE	CARBON_ TETRACHLO RIDE	CFC_11	CFC_113	CFC_114	CFC_12	CHLOROB ENZENE	CHLORO FORM
Plymouth	Mean	0.9467	0.9536	0.2884	1.3091	0.1274	0.2542	0.0286	0.9142	2.0462	0.6794	0.0993	3.238	0.0958	0.1285
	Std Deviation	0.5042	0.3998	0.1509	0.7447	0.0928	0.1251	0.0295	0.0954	0.4502	0.1699	0.0656	0.5227	0.0592	0.0695
	Median	0.8901	1.0405	0.2561	1.1627	0.101	0.2477	0.0227	0.8996	1.899	0.6897	0.0839	3.2292	0.0875	0.1123
	Maximum	2.6738	1.6201	0.829	5.59	0.6019	0.7668	0.1135	1.1953	3.8879	1.1342	0.4824	4.4309	0.4007	0.4883
	Valid N	N=50	N=50	N=55	N=55	N=55	N=50	N=55	N=55	N=55	N=55	N=55	N=55	N=55	N=55
Koch420	Mean	0.9787	1.8752	0.1643	1.7227	0.059	0.3553	0.0182	0.6653	1.6131	0.785	0.1238	2.6806	0.0831	0.1003
	Std Deviation	0.5529	0.9033	0.1935	1.5812	0.0696	0.2296	0.0362	0.243	0.3918	0.5185	0.1133	0.5254	0.1918	0.0878
	Median	0.8973	1.7673	0.1302	1.3512	0.0505	0.2861	0	0.6983	1.6237	0.7281	0.0909	2.7792	0.0461	0.0879
	Maximum	4.0125	7.5492	1.671	20.092	0.5669	2.1116	0.2088	1.2582	2.8429	4.0542	0.4055	4.2875	2.3883	0.8007
	Valid N	N=223	N=223	N=225	N=439	N=22!	N=223	N=225	N=439	N=225	N=225	N=225	N=182	N=439	N=439
Koch423	Mean	0.9692	2.0068	0.1307	1.0594	0.0639	0.3485	0.0144	0.6724	1.7236	0.7111	0.1159	2.7722	0.0847	0.0826
	Std Deviation	0.4256	0.9719	0.1026	0.6334	0.0628	0.2093	0.0295	0.2482	0.4765	0.3817	0.1171	0.5418	0.1395	0.0599
	Median	0.9117	1.7768	0.1128	0.9391	0.0544	0.3097	0	0.7172	1.6911	0.6821	0.0839	2.8509	0.0507	0.083
	Maximum	3.5116	7.333	0.5382	3.6159	0.3999	1.1974	0.2088	1.2582	4.343	2.805	0.9787	4.3073	1.879	0.6592
	Valid N	N=294	N=294	N=272	N=489	N=27:	N=294	N=272	N=489	N=272	N=272	N=272	N=234	N=489	N=489
Koch426	Mean	1.1253	2.2213	0.113	2.5925	0.0293	0.4608	0.0146	0.6084	1.6383	0.6709	0.1886	2.355	0.1151	0.1265
	Std Deviation	0.5531	1.1306	0.1444	2.9138	0.0386	0.2021	0.0329	0.2574	0.4846	0.6421	0.1382	0.7157	0.4017	0.1588
	Median	1.0459	2.0738	0.0694	1.7281	0	0.4262	0	0.6291	1.6293	0.6668	0.1188	2.4652	0.0461	0.0977
	Maximum	2.7675	7.744	0.6163	26.3451	0.167	1.333	0.1634	1.3306	2.9665	5.1271	0.4264	4.6732	6.2218	1.5517
	Valid N	N=108	N=108	N=111	N=337	N=11'	N=108	N=111	N=337	N=111	N=111	N=111	N=66	N=337	N=337
StPaulPark	Mean	1.2796	2.2571	0.1647	2.6175	0.096	0.4391	0.0132	0.7366	1.6307	0.6787	0.1255	2.8927	0.0752	0.1144
	Std Deviation	0.6289	1.0679	0.1483	2.4015	0.118	0.2368	0.0251	0.2097	0.3881	0.4101	0.1233	0.671	0.0873	0.1411
	Median	1.1594	2.1355	0.1389	1.9932	0.0699	0.3967	0	0.7549	1.6518	0.6668	0.0909	2.9424	0.0599	0.0977
	Maximum	3.1387	7.7369	0.9028	19.4851	1.1998	1.3419	0.177	1.4847	3.534	2.621	0.7969	6.1765	0.829	2.0995
	Valid N	N=226	N=226	N=223	N=319	N=22:	N=226	N=223	N=319	N=223	N=223	N=223	N=179	N=319	N=319
Ashland	Mean	1.5366	2.1965	0.1626	3.0804	0.0722	0.4731	0.0196	0.7583	1.6679	0.6866	0.0953	2.7786	0.0766	0.1546
	Std Deviation	0.7744	1.0861	0.1285	2.8907	0.0604	0.2658	0.0434	0.2024	0.4253	0.3731	0.0901	0.6488	0.0612	0.1295
	Median	1.4198	1.9087	0.1454	2.1593	0.066	0.4099	0	0.799	1.6546	0.6821	0.0839	2.8435	0.0645	0.1172
	Maximum	4.9945	7.8723	0.6858	23.3597	0.4038	1.7223	0.4039	1.2331	3.843	2.5904	0.4194	6.7848	0.5434	0.9912
	Valid N	N=200	N=200	N=194	N=194	N=19	N=199	N=194	N=194	N=194	N=194	N=194	N=177	N=194	N=194
HolmanFld	Mean	1.2669	2.0094	0.2125	1.72	0.0615	0.4833	0.0132	0.7111	5.384	0.665	0.1442	2.914	0.0796	0.138
	Std Deviation	0.6617	0.9987	0.2367	1.1426	0.0671	0.2912	0.0296	0.2294	9.1526	0.5601	0.1223	0.8108	0.0998	0.1306
	Median	1.1459	1.9122	0.1693	1.4374	0.0582	0.4247	0	0.7549	2.4496	0.6668	0.0979	2.9399	0.0599	0.1025
	Maximum	3.6179	7.1976	1.4453	9.0682	0.563	2.0172	0.2133	1.3149	69.0277	6.7135	0.4404	6.587	0.898	1.1718
	Valid N	N=215	N=215	N=205	N=353	N=20!	N=215	N=205	N=353	N=205	N=205	N=205	N=160	N=353	N=353
BushSt	Mean	1.7878	2.183	0.2563	3.1846	0.156	0.5532	0.0191	0.7172	1.5465	0.6168	0.0046	2.8437	0.0861	0.1616
	Std Deviation	0.7873	0.8994	0.1434	2.054	0.4711	0.5169	0.0628	0.1271	0.231	0.0946	0.0175	0.5865	0.0738	0.1398
	Median	1.6846	1.9455	0.2344	2.4756	0.0505	0.2861	0	0.7424	1.5282	0.6131	0	2.9226	0.0553	0.1318
	Maximum	3.7405	4.6725	0.6727	8.7555	2.291	1.7489	0.2905	0.8682	1.9215	0.7894	0.0839	3.9512	0.2533	0.5322
	Valid N	N=23	N=23	N=23	N=23	N=23	N=23	N=23	N=23	N=23	N=23	N=23	N=23	N=23	N=23
HardingHi	Mean	.	.	.	2.7414	.	.	.	0.7819	.	.	.	.	0.0701	0.1409
	Std Deviation	.	.	.	1.2976	.	.	.	0.1002	.	.	.	.	0.036	0.0777
	Median	.	.	.	2.228	.	.	.	0.8053	.	.	.	.	0.0599	0.1221
	Maximum	.	.	.	5.7114	.	.	.	0.95	.	.	.	.	0.1243	0.293
	Valid N	N=0	N=0	N=0	N=14	N=0	N=0	N=0	N=14	N=0	N=0	N=0	N=0	N=14	N=14

Appendix E. Summary Statistics for Monitored Organics.

		ACETALDE HYDE	ACETONE	BENZALDE HYDE	BENZENE	BROMO ETHANE	BUTYRALDE HYDE	C_13_DI CHLORO PROPENE	CARBON_ TETRACHLO RIDE	CFC_11	CFC_113	CFC_114	CFC_12	CHLOROB ENZENE	CHLORO FORM
MplsLibrary	Mean	1.6856	2.0732	0.3215	2.5332	0.095	0.5962	0.0152	0.6784	2.9842	0.6913	0.1326	3.3118	0.0722	0.1432
	Std Deviation	0.6254	1.1244	0.3959	1.4362	0.2381	0.4537	0.0417	0.2659	2.8856	0.4031	0.1218	1.4112	0.0946	0.1234
	Median	1.6108	1.8909	0.2127	2.2392	0.0505	0.463	0	0.7015	2.3991	0.7127	0.0909	3.1105	0.0461	0.1269
	Maximum	4.0125	6.314	2.8299	13.5086	2.6094	3.4092	0.3812	1.447	27.2717	2.5367	0.4684	15.2757	0.6678	1.5717
	Valid N	N=225	N=225	N=206	N=400	N=20(	N=225	N=206	N=400	N=206	N=206	N=206	N=161	N=400	N=400
MhahaAcad	Mean	1.3827	1.8777	0.4901	1.4437	0.1092	0.3738	0.0186	0.8003	1.8045	0.6095	0.0683	2.9612	0.0893	0.105
	Std Deviation	0.6384	1.2143	0.3382	0.7631	0.2716	0.2522	0.0304	0.1239	1.4268	0.1262	0.0337	0.5253	0.0357	0.0508
	Median	1.3387	1.6106	0.3516	1.2042	0.0582	0.3067	0.0045	0.799	1.6069	0.5824	0.0769	3.0017	0.0829	0.1025
	Maximum	3.5747	7.9554	1.4931	4.7243	2.0696	1.4982	0.1634	1.0192	11.956	1.2262	0.1258	4.4111	0.2072	0.293
	Valid N	N=57	N=57	N=57	N=57	N=57	N=57	N=57	N=57	N=57	N=57	N=57	N=57	N=57	N=57
I_Falls1240	Mean	1.2832	2.4587	0.1793	1.1474	0.0345	0.3299	0.0097	0.6335	1.5341	1.3465	0.1044	4.6933	0.0426	1.0307
	Std Deviation	0.5782	1.0101	0.2266	1.5275	0.033	0.2774	0.0379	0.1976	0.5358	1.1061	0.1151	3.0239	0.05	1.3368
	Median	1.2576	2.2306	0.1128	0.7347	0.0349	0.2831	0	0.6354	1.5816	0.7319	0.0839	3.8622	0.0368	0.4492
	Maximum	3.6125	6.6869	1.3108	10.2217	0.1553	2.4006	0.2859	1.2457	4.0284	5.8551	0.3985	16.7049	0.2947	6.9138
	Valid N	N=85	N=85	N=84	N=91	N=84	N=85	N=84	N=91	N=84	N=84	N=84	N=73	N=91	N=91
I_Falls1241	Mean	0.6883	1.2368	0.2489	1.3657	0.1117	0.1736	0.0466	0.9067	2.855	1.275	0.1078	2.999	0.0802	0.1528
	Std Deviation	0.4315	0.3605	0.1265	1.1472	0.037	0.0948	0.1334	0.0774	5.4005	0.7915	0.047	0.5472	0.0312	0.0676
	Median	0.6811	1.2756	0.2127	0.9774	0.1165	0.1769	0.0182	0.9059	1.9664	0.8124	0.0979	3.0759	0.0783	0.1416
	Maximum	2.472	2.5655	0.6467	6.4365	0.1709	0.4394	0.9894	1.0506	42.5538	3.4104	0.2447	4.0798	0.1658	0.5176
	Valid N	N=57	N=57	N=57	N=57	N=57	N=57	N=57	N=57	N=57	N=57	N=57	N=57	N=57	N=57
Sandstone	Mean	0.6246	1.3861	0.3287	0.6811	0.1281	0.2176	0.0333	0.9122	1.9295	0.77	0.1029	2.9581	0.1019	0.1005
	Std Deviation	0.2968	0.5787	0.3586	0.327	0.1105	0.1132	0.0367	0.0612	0.6206	0.0904	0.0444	0.4226	0.1177	0.0357
	Median	0.6288	1.1759	0.1823	0.642	0.101	0.2109	0.0227	0.9059	1.7979	0.7817	0.0909	3.0561	0.0691	0.0977
	Maximum	1.1657	3.0857	1.6536	1.5652	0.5514	0.578	0.1452	1.0947	4.5959	0.912	0.2587	3.8869	0.5665	0.2002
	Valid N	N=48	N=48	N=51	N=51	N=51	N=48	N=51	N=51	N=51	N=51	N=51	N=51	N=51	N=51
FergusFalls	Mean	1.8061	1.6959	0.2279	1.1886	0.0616	0.2712	0.0118	0.775	2.0778	0.6462	0.0652	2.7261	0.0851	0.0854
	Std Deviation	1.269	0.7227	0.1405	0.4486	0.0247	0.1966	0.021	0.1287	1.6499	0.0946	0.0385	0.5569	0.0316	0.0508
	Median	1.1603	1.5559	0.2018	1.1036	0.0621	0.2271	0	0.7895	1.6378	0.6514	0.0769	2.8311	0.0829	0.0854
	Maximum	5.4071	3.6012	0.829	2.7567	0.1126	1.2092	0.0817	1.1261	11.4335	0.9733	0.1328	4.154	0.1612	0.21
	Valid N	N=59	N=59	N=48	N=48	N=48	N=59	N=48	N=48	N=48	N=48	N=48	N=48	N=48	N=48
Alexandria	Mean	0.8465	1.397	0.2526	1.2196	0.12	0.2986	0.0244	0.9186	1.9598	0.8038	0.1096	3.013	0.0903	0.1691
	Std Deviation	0.3473	0.4639	0.1436	0.5701	0.0801	0.1345	0.0451	0.0888	0.296	0.1351	0.0802	0.4999	0.0653	0.0961
	Median	0.845	1.3766	0.2192	1.0158	0.099	0.2684	0.0136	0.9059	1.8653	0.7894	0.0909	3.0784	0.0829	0.1343
	Maximum	1.9225	2.689	0.9505	2.9994	0.4077	0.6075	0.3177	1.2016	2.871	1.3795	0.4684	5.049	0.3868	0.5029
	Valid N	N=56	N=56	N=58	N=58	N=58	N=56	N=58	N=58	N=58	N=58	N=58	N=58	N=58	N=58
Warroad	Mean	0.5697	1.0795	0.1297	0.6401	0.059	0.1427	0.0056	0.8163	1.8606	0.7101	0.0754	2.9288	0.0763	0.1022
	Std Deviation	0.2385	0.406	0.0514	0.3213	0.0241	0.0754	0.011	0.1128	0.3539	0.1048	0.0287	0.3301	0.0391	0.0563
	Median	0.5459	1.0927	0.1215	0.6197	0.0621	0.1268	0	0.8053	1.7698	0.7051	0.0839	2.8979	0.0645	0.0928
	Maximum	1.6486	2.575	0.3342	1.9485	0.0971	0.407	0.0363	1.101	3.5621	1.0346	0.1188	3.5952	0.2349	0.2832
	Valid N	N=59	N=59	N=47	N=47	N=47	N=59	N=47	N=47	N=47	N=47	N=47	N=47	N=47	N=47
LittleFalls	Mean	0.5845	1.2736	0.2696	0.9027	0.108	0.2087	0.0335	0.9062	1.8737	1.3334	0.1086	3.0171	0.1266	0.11
	Std Deviation	0.3016	0.469	0.254	0.4502	0.0396	0.104	0.0364	0.0725	0.3802	3.6469	0.0411	0.6571	0.107	0.0378
	Median	0.5513	1.1711	0.1953	0.7794	0.101	0.1902	0.0272	0.8934	1.7782	0.7817	0.0979	3.0265	0.0967	0.1025
	Maximum	1.6216	2.6273	1.8316	2.2392	0.2213	0.5721	0.2224	1.145	3.6126	27.766	0.2447	6.7354	0.6493	0.2734
	Valid N	N=58	N=58	N=56	N=56	N=56	N=58	N=56	N=56	N=56	N=56	N=56	N=56	N=56	N=56

Appendix E. Summary Statistics for Monitored Organics.

		ACETALDEHYDE	ACETONE	BENZALDEHYDE	BENZENE	BROMOETHANE	BUTYRALDEHYDE	C_13_DICHLOROPROPENE	CARBON_TETRACHLORIDE	CFC_11	CFC_113	CFC_114	CFC_12	CHLOROBENZENE	CHLOROFORM
ElkRiver	Mean	0.9885	1.5957	0.1505	0.9464	0.0623	0.2317	0.0131	0.8076	1.5736	0.674	0.0688	2.7972	0.0918	0.0726
	Std Deviation	0.5484	0.6958	0.1119	0.5369	0.0228	0.1672	0.0265	0.1234	0.221	0.1094	0.0342	0.5033	0.0356	0.0402
	Median	0.8739	1.487	0.102	0.8209	0.0621	0.1887	0	0.8053	1.5928	0.6629	0.0804	2.9078	0.0898	0.0684
	Maximum	2.854	3.8292	0.612	2.8908	0.1476	0.8582	0.1225	1.0129	2.4047	1.1113	0.1188	4.1144	0.2164	0.21
	Valid N	N=61	N=61	N=58	N=58	N=58	N=61	N=58	N=58	N=58	N=58	N=58	N=58	N=58	N=58
Pipestone	Mean	0.7465	1.1301	0.4074	0.8214	0.1271	0.236	0.0397	0.9176	1.796	0.7056	0.1102	3.0017	0.1116	0.1264
	Std Deviation	0.3568	0.491	0.348	0.3525	0.0731	0.109	0.0539	0.0841	0.1431	0.1964	0.0912	0.4311	0.0748	0.066
	Median	0.7135	1.1497	0.3516	0.7634	0.101	0.23	0.0318	0.9059	1.7979	0.6974	0.0909	2.9968	0.0921	0.1025
	Maximum	1.6126	2.3802	2.3958	1.9709	0.365	0.6459	0.3404	1.2016	2.0844	1.1189	0.4684	4.2825	0.3915	0.3515
	Valid N	N=55	N=55	N=47	N=47	N=47	N=55	N=47	N=47	N=47	N=47	N=47	N=47	N=47	N=47
GraniteFalls	Mean	1.0011	1.568	0.1596	0.928	0.0737	0.2068	0.0127	0.7885	1.6735	0.6315	0.0701	2.8079	0.0824	0.084
	Std Deviation	0.4121	0.5991	0.0757	0.9938	0.0496	0.0926	0.023	0.1463	0.3096	0.0851	0.0388	0.4697	0.0299	0.0214
	Median	0.9495	1.5013	0.1389	0.7315	0.0699	0.1828	0	0.8241	1.6574	0.6284	0.0769	2.9325	0.0783	0.0879
	Maximum	2.7531	3.5656	0.3342	6.6601	0.3106	0.5869	0.1044	1.0003	2.6238	0.9963	0.1748	3.7485	0.1658	0.1318
	Valid N	N=53	N=53	N=45	N=45	N=45	N=53	N=45	N=45	N=45	N=45	N=45	N=45	N=45	N=45
Rochester	Mean	0.9116	1.1767	0.139	1.113	0.0631	0.2299	0.0165	0.8139	1.7126	0.6504	0.0633	2.9902	0.1163	0.089
	Std Deviation	0.3844	0.4439	0.0712	0.4609	0.0214	0.1376	0.0367	0.1232	0.4613	0.082	0.0366	0.5266	0.0498	0.0399
	Median	0.818	1.1355	0.1215	0.9519	0.0621	0.1961	0	0.8241	1.6743	0.6591	0.0699	3.0611	0.1151	0.0879
	Maximum	1.8126	2.5845	0.4905	2.2967	0.1126	0.7933	0.2179	1.038	4.3824	0.8583	0.1258	4.2331	0.2441	0.21
	Valid N	N=60	N=60	N=59	N=59	N=59	N=60	N=59	N=59	N=59	N=59	N=59	N=59	N=59	N=59
Zumbrota	Mean	0.63	0.9718	0.2908	0.649	0.1199	0.195	0.0229	0.9301	2.0351	0.8043	0.1178	3.0218	0.1377	0.1078
	Std Deviation	0.2989	0.5034	0.1677	0.3036	0.05	0.1022	0.0288	0.0609	0.5107	0.1554	0.0755	0.4178	0.0867	0.0319
	Median	0.6288	1.0143	0.2517	0.5861	0.1126	0.1917	0.0136	0.9248	1.8878	0.797	0.0979	3.0685	0.1151	0.105
	Maximum	1.6504	2.6914	0.8247	1.5269	0.2912	0.6134	0.118	1.0506	4.7307	1.6401	0.4055	3.6446	0.3592	0.1953
	Valid N	N=53	N=53	N=54	N=54	N=54	N=53	N=54	N=54	N=54	N=54	N=54	N=54	N=54	N=54
Hibbing	Mean	0.8857	2.0293	0.2533	1.0158	0.0578	0.2234	0.0158	0.7889	1.7238	0.6566	0.0774	2.8494	0.058	0.0817
	Std Deviation	0.4217	0.8473	0.2363	0.5101	0.0237	0.1237	0.0282	0.1272	0.2032	0.1012	0.0383	0.4521	0.0277	0.0399
	Median	0.8162	1.9312	0.1693	0.8656	0.0582	0.1858	0	0.7927	1.7024	0.6438	0.0839	2.9226	0.0507	0.083
	Maximum	2.2936	4.9956	1.1979	2.9323	0.0971	0.5043	0.1589	1.0318	2.2474	1.0269	0.1748	3.6496	0.1566	0.2051
	Valid N	N=61	N=61	N=59	N=59	N=59	N=61	N=59	N=59	N=59	N=59	N=59	N=59	N=59	N=59
Duluth7549	Mean	0.9251	1.4339	0.2134	1.7437	0.0589	0.2485	0.0182	0.7662	3.3677	14.322	0.1159	2.8388	0.07	0.1078
	Std Deviation	0.8313	0.9	0.2441	0.9061	0.0512	0.2021	0.0352	0.1935	3.092	31.0533	0.1121	0.6831	0.0605	0.0717
	Median	0.6901	1.2162	0.1736	1.5013	0.0544	0.2005	0	0.799	2.1968	1.1036	0.0909	2.8979	0.0691	0.0977
	Maximum	8.7583	6.9411	2.9818	5.9126	0.2835	1.3537	0.236	1.2582	23.2771	206.3479	0.5173	5.2963	0.4605	0.7812
	Valid N	N=233	N=233	N=213	N=240	N=21	N=233	N=213	N=240	N=213	N=213	N=213	N=182	N=240	N=240
All Sites	Mean	1.1272	1.8272	0.2094	1.8101	0.0766	0.3609	0.0179	0.7242	2.2924	1.9053	0.1133	2.9452	0.0845	0.1388
	Std Deviation	0.6864	0.9965	0.2284	1.7754	0.1136	0.2739	0.0401	0.2303	3.2177	9.8184	0.1049	0.9489	0.1616	0.2752
	Median	0.9838	1.6296	0.1563	1.3192	0.0621	0.289	0	0.7675	1.7586	0.6974	0.0909	2.9473	0.0599	0.0977
	Maximum	8.7583	7.9554	2.9818	26.3451	2.6094	3.4092	0.9894	1.4847	69.0277	206.3479	0.9787	16.7049	6.2218	6.9138
	Valid N	N=2619	N=2619	N=2507	N=3650	N=25	N=2618	N=2507	N=3650	N=250	N=250	N=250	N=218	N=3650	N=365

Appendix E. Summary Statistics for Monitored Organics.

		CROTON ALDEHYDE	11_DICHLORO ETHANE	12_DICHLORO ETHANE	12_DICHLORO ETHYLENE	12_DI CHLORO PROPANE	DICHLORO METHANE	ETHYLENE_ DIBROMIDE	ETHYL_ BENZENE	FORMALDE HYDE	HEXA CHLORO_13 BUTADIENE	M_DICHLORO BENZENE	M_P_ XYLENE
Plymouth	Mean	0.0076	0.0342	0.0688	0.0489	0.0466	0.6433	0.0493	0.5234	1.2436	0.2428	0.1982	1.68
	Std Deviation	0.0212	0.1406	0.073	0.1561	0.1639	0.5788	0.0476	0.3324	0.9674	0.323	0.1159	1.117
	Median	0	0	0.0607	0.0079	0	0.528	0.0384	0.4821	1.0125	0.16	0.1744	1.529
	Maximum	0.1061	0.8095	0.5142	0.9001	1.1923	3.0465	0.2382	2.1023	5.4784	1.8133	0.5591	6.85
	Valid N	N=50	N=55	N=55	N=55	N=55	N=55	N=55	N=55	N=50	N=55	N=55	N=55
Koch420	Mean	0.0761	0.0254	0.0561	0.0095	0.0094	0.2593	0.0426	0.6501	1.1035	0.1827	0.1836	1.768
	Std Deviation	0.185	0.0887	0.0853	0.0357	0.023	0.2051	0.3155	1.2362	0.8864	0.2859	0.3759	3.934
	Median	0	0	0.0405	0	0	0.2188	0	0.4083	0.851	0.1173	0.0902	1.175
	Maximum	1.1209	0.9592	1.1621	0.567	0.1571	1.2505	6.4925	21.0228	5.288	2.6667	3.944	58.725
	Valid N	N=223	N=439	N=439	N=439	N=225	N=439	N=439	N=439	N=458	N=225	N=439	N=282
Koch423	Mean	0.0824	0.0118	0.0606	0.01	0.0094	0.2922	0.0771	0.352	1.1006	0.1467	0.1329	0.951
	Std Deviation	0.208	0.0546	0.1855	0.0421	0.0426	0.8097	0.8517	0.328	0.9631	0.1349	0.2474	0.885
	Median	0	0	0.0445	0	0	0.2084	0	0.265	0.8474	0.128	0.0721	0.747
	Maximum	1.6226	0.7204	3.1542	0.567	0.6655	17.5778	14.6754	2.6713	7.8104	1.0773	3.3609	8.222
	Valid N	N=294	N=489	N=489	N=489	N=272	N=489	N=489	N=489	N=535	N=272	N=489	N=331
Koch426	Mean	0.1775	0.0455	0.0683	0.0182	0.0107	0.2698	0.0649	0.8645	0.981	0.168	0.2118	1.916
	Std Deviation	0.3374	0.1076	0.1049	0.122	0.0247	0.222	0.2767	1.214	0.7746	0.353	0.6864	2.172
	Median	0.0043	0	0.0405	0	0	0.2293	0	0.5256	0.7761	0	0.0601	1.303
	Maximum	1.5968	0.9099	1.2269	2.1807	0.1479	1.4107	4.1183	12.4777	4.8619	2.2507	8.5134	19.633
	Valid N	N=108	N=337	N=337	N=337	N=111	N=337	N=337	N=337	N=347	N=111	N=337	N=170
StPaulPark	Mean	0.0783	0.0203	0.0404	0.0104	0.0106	0.3867	0.0239	0.8618	1.4861	0.1501	0.1371	2.738
	Std Deviation	0.1844	0.0966	0.051	0.0429	0.0486	0.3224	0.0416	0.6437	1.0604	0.1762	0.1701	2.015
	Median	0	0	0.0121	0	0	0.3126	0.0077	0.7254	1.1986	0.1067	0.0902	2.215
	Maximum	0.9059	0.9835	0.2996	0.6503	0.6839	2.5463	0.4072	3.692	7.7368	1.184	1.3227	10.785
	Valid N	N=226	N=319	N=319	N=319	N=223	N=319	N=319	N=319	N=345	N=223	N=319	N=277
Ashland	Mean	0.0632	0.0241	0.0394	0.0134	0.0159	0.3714	0.0337	0.8135	1.9951	0.1741	0.129	2.727
	Std Deviation	0.1501	0.088	0.0482	0.0517	0.0709	0.3323	0.047	0.761	1.2228	0.2287	0.1274	1.74
	Median	0	0	0.0121	0	0	0.2987	0.0231	0.6124	1.6548	0.1173	0.1022	2.378
	Maximum	0.7482	0.68	0.2996	0.5987	0.9243	2.7095	0.3995	7.3884	6.8698	1.8027	0.7696	8.726
	Valid N	N=199	N=194	N=194	N=194	N=194	N=194	N=194	N=194	N=200	N=194	N=194	N=194
HolmanFld	Mean	0.0705	0.0103	0.0477	0.0153	0.0112	0.65	0.0272	0.8623	1.5258	0.1556	0.2579	2.445
	Std Deviation	0.1429	0.0435	0.0687	0.0323	0.0289	2.579	0.0623	0.9388	1.1272	0.2836	0.3413	2.494
	Median	0	0	0.0324	0	0	0.3474	0	0.5794	1.2575	0.096	0.1503	1.607
	Maximum	0.86	0.7124	0.6438	0.1931	0.208	46.2355	0.4994	8.6315	6.284	2.496	2.5252	17.578
	Valid N	N=215	N=353	N=353	N=353	N=205	N=353	N=353	N=353	N=404	N=205	N=353	N=265
BushSt	Mean	0.0027	0.0063	0.018	0.0029	0.004	0.5765	0.0207	1.6377	4.4301	0.1493	0.1404	5.658
	Std Deviation	0.0132	0.0143	0.0213	0.0115	0.012	0.411	0.0423	1.4644	4.6034	0.1029	0.1001	4.714
	Median	0	0	0.004	0	0	0.5662	0.0077	0.9512	3.0468	0.1173	0.1022	3.592
	Maximum	0.0631	0.0445	0.0688	0.0555	0.0555	1.8723	0.1998	5.4208	20.9949	0.48	0.4088	18.2
	Valid N	N=23	N=23	N=23	N=23	N=23	N=23	N=23	N=23	N=23	N=23	N=23	N=23
HardingHi	Mean	.	0.004	0.0237	0.0003	.	0.3781	0.0154	0.7325	1.6815	.	0.1271	.
	Std Deviation	.	0.0113	0.0233	0.0011	.	0.2172	0.0231	0.5162	0.8094	.	0.0815	.
	Median	.	0	0.0263	0	.	0.3404	0.0077	0.5755	1.3938	.	0.1202	.
	Maximum	.	0.0405	0.0648	0.004	.	0.7851	0.0768	1.7374	3.4914	.	0.2525	.
	Valid N	N=0	N=14	N=14	N=14	N=0	N=14	N=14	N=14	N=15	N=0	N=14	N=0

Appendix E. Summary Statistics for Monitored Organics.

Site	Statistic	CROTON ALDEHYDE	11_DICHLORO ETHANE	12_DICHLORO ETHANE	12_DICHLORO ETHYLENE	12_DI CHLORO PROPANE	DICHLORO METHANE	ETHYLENE_ DIBROMIDE	ETHYL_ BENZENE	FORMALDE HYDE	HEXA CHLORO_13 BUTADIENE	M_DICHLORO BENZENE	M_P_ XYLENE
MplsLibrary	Mean	0.0407	0.0211	0.0481	0.0183	0.0081	1.1795	0.0243	1.5179	2.1787	0.1487	0.5443	4.258
	Std Deviation	0.0947	0.1038	0.0917	0.063	0.0234	3.0323	0.0741	1.305	1.3792	0.2293	0.7206	2.852
	Median	0	0	0.0223	0	0	0.6235	0	1.1901	1.8666	0.096	0.2225	3.59
	Maximum	0.6565	1.4571	1.154	0.7851	0.2357	42.8035	1.1679	15.8714	13.3772	1.7707	4.7918	17.591
	Valid N	N=225	N=400	N=400	N=400	N=206	N=400	N=400	N=400	N=431	N=206	N=400	N=266
MhahaAcad	Mean	0.0197	0.008	0.0318	0.0025	0.0074	0.3902	0.0267	0.7612	2.4774	0.1929	0.1606	2.483
	Std Deviation	0.0477	0.0134	0.0362	0.0073	0.0124	0.306	0.0241	0.7144	1.9392	0.1541	0.1421	2.229
	Median	0	0	0.004	0	0	0.3474	0.0231	0.5082	2.0558	0.1493	0.1082	1.707
	Maximum	0.215	0.0688	0.1255	0.0357	0.0601	2.0808	0.1153	3.7181	10.8462	0.832	0.6794	11.61
	Valid N	N=57	N=57	N=57	N=57	N=57	N=57	N=57	N=57	N=57	N=57	N=57	N=57
I_Falls1240	Mean	0.1637	0.006	0.0281	0.009	0.0087	0.2446	0.0337	0.7806	0.986	0.1265	0.1345	2.213
	Std Deviation	0.1868	0.0123	0.0359	0.0298	0.0181	0.399	0.0627	1.7601	0.8971	0.1551	0.2472	5.057
	Median	0.0831	0	0.0121	0	0	0.1494	0.0154	0.2519	0.7841	0.096	0.0782	0.76
	Maximum	0.7453	0.0809	0.162	0.2379	0.1017	2.9874	0.3842	9.3387	7.0736	1.0027	1.7436	27.408
	Valid N	N=85	N=91	N=91	N=91	N=84	N=91	N=91	N=91	N=86	N=84	N=91	N=91
I_Falls1241	Mean	0.0479	0.0488	0.0671	0.0458	0.0837	0.2496	0.0445	0.5234	1.2839	0.2532	0.2383	1.709
	Std Deviation	0.0837	0.1495	0.0435	0.1365	0.2248	0.2936	0.0344	0.4062	0.8462	0.2028	0.1444	1.328
	Median	0	0	0.0688	0.0079	0.0092	0.2015	0.0384	0.404	1.0475	0.192	0.1864	1.29
	Maximum	0.4042	0.7731	0.162	0.7415	1.3494	2.1711	0.1614	2.5453	3.7935	1.088	0.6974	8.101
	Valid N	N=57	N=57	N=57	N=57	N=57	N=57	N=57	N=57	N=57	N=57	N=57	N=57
Sandstone	Mean	0.0922	0.044	0.0746	0.0203	0.0409	0.2998	0.0705	0.2071	1.1691	0.4001	0.3545	0.598
	Std Deviation	0.1629	0.1313	0.0738	0.0444	0.1293	0.2603	0.1071	0.139	0.8681	0.6251	0.4731	0.38
	Median	0	0	0.0607	0.004	0	0.2258	0.0307	0.1607	0.8928	0.16	0.1864	0.486
	Maximum	0.5991	0.6516	0.3766	0.226	0.7117	1.6535	0.5378	0.721	3.6019	2.7307	2.2726	1.746
	Valid N	N=48	N=51	N=51	N=51	N=51	N=51	N=51	N=51	N=48	N=51	N=51	N=51
FergusFalls	Mean	0.01	0.0063	0.0423	0.0118	0.0092	0.3064	0.0247	0.4252	1.6604	0.1867	0.1264	1.371
	Std Deviation	0.0287	0.0097	0.0365	0.0613	0.0178	0.6518	0.0241	0.3438	0.7989	0.1472	0.117	1.05
	Median	0	0	0.0547	0	0	0.1928	0.0231	0.3735	1.4184	0.1493	0.0902	1.242
	Maximum	0.1175	0.0445	0.1255	0.4243	0.0693	4.6513	0.1383	2.3629	3.5282	0.9173	0.7094	7.08
	Valid N	N=59	N=48	N=48	N=48	N=48	N=48	N=48	N=48	N=59	N=48	N=48	N=48
Alexandria	Mean	0.0366	0.1018	0.0969	0.0916	0.064	0.2996	0.0554	0.4418	1.418	0.2319	0.2037	1.365
	Std Deviation	0.0967	0.2389	0.1201	0.1991	0.2266	0.1541	0.0549	0.1884	0.8686	0.1731	0.1218	0.576
	Median	0	0	0.0749	0.0099	0	0.2727	0.0384	0.417	1.3803	0.1867	0.1653	1.323
	Maximum	0.5647	0.8581	0.5669	0.789	1.3818	0.7052	0.2228	1.0729	3.5393	0.9067	0.5171	3.353
	Valid N	N=56	N=58	N=58	N=58	N=58	N=58	N=58	N=58	N=56	N=58	N=58	N=58
Warroad	Mean	0.008	0.0065	0.0402	0.003	0.0105	0.1517	0.0196	0.1996	1.2181	0.1614	0.1314	0.603
	Std Deviation	0.0299	0.0158	0.0297	0.0106	0.0148	0.0843	0.0126	0.1224	0.8772	0.0822	0.0718	0.425
	Median	0	0	0.0486	0	0	0.1459	0.0154	0.1737	0.9972	0.128	0.1082	0.504
	Maximum	0.1863	0.0931	0.0891	0.0595	0.0508	0.4551	0.0538	0.6993	5.4894	0.416	0.3848	2.441
	Valid N	N=59	N=47	N=47	N=47	N=47	N=47	N=47	N=47	N=59	N=47	N=47	N=47
LittleFalls	Mean	0.0495	0.0507	0.0802	0.0527	0.0371	0.302	0.0698	0.319	1.1124	0.3086	0.2781	0.968
	Std Deviation	0.0979	0.1876	0.1042	0.1486	0.1052	0.227	0.0768	0.1331	0.6944	0.4122	0.346	0.437
	Median	0	0	0.0628	0.0079	0.0069	0.2327	0.0384	0.2802	0.9843	0.1813	0.1744	0.901
	Maximum	0.5533	1.0645	0.5547	0.793	0.7718	1.2992	0.4533	0.6819	2.8958	2.9013	2.459	2.298
	Valid N	N=58	N=56	N=56	N=56	N=56	N=56	N=56	N=56	N=58	N=56	N=56	N=56

Appendix E. Summary Statistics for Monitored Organics.

		CROTON ALDEHYDE	11_DICHLORO ETHANE	12_DICHLORO ETHANE	12_DICHLORO ETHYLENE	12_DI CHLORO PROPANE	DICHLORO METHANE	ETHYLENE_ DIBROMIDE	ETHYL_ BENZENE	FORMALDE HYDE	HEXA CHLORO_13 BUTADIENE	M_DICHLORO BENZENE	M_P_ XYLENE
ElkRiver	Mean	0.0281	0.008	0.0351	0.0043	0.0058	0.222	0.0261	0.3314	1.4339	0.1887	0.1436	1.038
	Std Deviation	0.071	0.0158	0.0341	0.0132	0.0112	0.2763	0.0259	0.2336	0.8292	0.1562	0.1401	0.752
	Median	0	0	0.0405	0	0	0.1754	0.0192	0.2693	1.233	0.1333	0.0902	0.836
	Maximum	0.3727	0.085	0.1093	0.0753	0.0462	2.1155	0.1229	1.2336	4.1779	0.8533	0.7094	3.527
	Valid N	N=61	N=58	N=58	N=58	N=58	N=58	N=58	N=58	N=61	N=58	N=58	N=58
Pipestone	Mean	0.0073	0.0622	0.0873	0.0943	0.0711	0.5906	0.0695	0.3434	1.2568	0.2776	0.2631	0.973
	Std Deviation	0.0289	0.1881	0.1143	0.2027	0.1294	0.8271	0.0499	0.185	0.8269	0.2199	0.1656	0.532
	Median	0	0	0.0607	0.0079	0.0092	0.2675	0.0538	0.2867	1.2109	0.1813	0.2044	0.786
	Maximum	0.1405	0.9066	0.5142	0.789	0.5915	3.7447	0.2151	0.9295	3.3931	0.9493	0.7696	2.606
	Valid N	N=55	N=47	N=47	N=47	N=47	N=47	N=47	N=47	N=55	N=47	N=47	N=47
GraniteFalls	Mean	0	0.0094	0.0385	0.0033	0.0113	0.1886	0.0242	0.2292	1.9754	0.1711	0.1377	0.643
	Std Deviation	0	0.0198	0.0317	0.0107	0.0169	0.1496	0.0197	0.1106	2.7445	0.0863	0.0921	0.363
	Median	0	0	0.0526	0	0	0.1494	0.0154	0.2085	1.4712	0.1387	0.0962	0.552
	Maximum	0	0.0931	0.0891	0.0674	0.0647	0.8233	0.0768	0.6298	20.1954	0.4053	0.4028	2.085
	Valid N	N=53	N=45	N=45	N=45	N=45	N=45	N=45	N=45	N=53	N=45	N=45	N=45
Rochester	Mean	0	0.0057	0.0387	0.0022	0.0059	0.2276	0.0203	0.392	1.3599	0.1674	0.1226	1.251
	Std Deviation	0	0.0099	0.0307	0.0073	0.0096	0.1065	0.0176	0.2187	0.6706	0.1281	0.1077	0.754
	Median	0	0	0.0526	0	0	0.2327	0.0154	0.3258	1.3036	0.1387	0.0902	0.99
	Maximum	0	0.0364	0.0891	0.0436	0.0323	0.5627	0.1076	1.0772	2.8638	0.9707	0.7094	3.709
	Valid N	N=60	N=59	N=59	N=59	N=59	N=59	N=59	N=59	N=60	N=59	N=59	N=59
Zumbrota	Mean	0.0616	0.0714	0.076	0.0681	0.0148	0.5495	0.0532	0.1969	1.1647	0.2489	0.228	0.564
	Std Deviation	0.1296	0.2178	0.0582	0.1676	0.0231	1.8048	0.0483	0.0729	0.7818	0.2415	0.1791	0.19
	Median	0	0	0.0709	0.0119	0	0.2623	0.0384	0.1803	1.0365	0.1813	0.1804	0.528
	Maximum	0.5045	1.2952	0.247	0.9595	0.0786	13.4503	0.2151	0.4778	3.2077	1.2053	0.992	1.36
	Valid N	N=53	N=54	N=54	N=54	N=54	N=54	N=54	N=54	N=53	N=54	N=54	N=54
Hibbing	Mean	0.0301	0.006	0.0399	0.0011	0.0076	0.2264	0.0238	0.357	1.5659	0.1741	0.1461	1.132
	Std Deviation	0.0617	0.0124	0.0319	0.0053	0.0161	0.1585	0.0235	0.2472	1.0302	0.1521	0.1446	0.818
	Median	0	0	0.0526	0	0	0.1911	0.0154	0.2736	1.217	0.128	0.0842	0.899
	Maximum	0.2494	0.0729	0.0972	0.0396	0.0647	0.9414	0.1229	1.3031	5.2843	0.9813	0.8177	4.344
	Valid N	N=61	N=59	N=59	N=59	N=59	N=59	N=59	N=59	N=61	N=59	N=59	N=59
Duluth7549	Mean	0.0735	0.0254	0.0382	0.0213	0.0162	1.0759	0.0303	0.9125	1.2704	0.1671	0.1479	2.787
	Std Deviation	0.1348	0.123	0.0453	0.0741	0.0546	1.7482	0.0498	1.0534	0.9543	0.1961	0.1492	2.518
	Median	0	0	0.0121	0	0	0.4498	0.0154	0.6559	1.0064	0.128	0.1142	2.241
	Maximum	0.8829	1.105	0.1984	0.7415	0.5915	11.5189	0.461	11.9882	8.5596	1.568	0.7996	31.1
	Valid N	N=233	N=240	N=240	N=240	N=213	N=240	N=240	N=240	N=294	N=213	N=240	N=240
All Sites	Mean	0.0641	0.0239	0.0521	0.0175	0.0167	0.491	0.0421	0.7445	1.4354	0.1798	0.2174	2.112
	Std Deviation	0.1596	0.0987	0.0974	0.0767	0.073	1.4642	0.344	0.9913	1.2141	0.243	0.4079	2.567
	Median	0	0	0.0405	0	0	0.2675	0.0154	0.4561	1.1335	0.128	0.1142	1.355
	Maximum	1.6226	1.4571	3.1542	2.1807	1.3818	46.2355	14.6754	21.0228	20.9949	2.9013	8.5134	58.725
	Valid N	N=2618	N=3650	N=3650	N=3650	N=2507	N=3650	N=3650	N=365(	N=3925	N=2507	N=3650	N=2890

Appendix E. Summary Statistics for Monitored Organics.

		M_XYLENE	O_DICHLORO BENZENE	O_XYLENE	P_DICHLORO BENZENE	PROPION ALDEHYDE	STYRENE	T_13_DI CHLORO PROPENE	111_TRI CHLORO ETHANE	112_TRI CHLORO ETHANE	1122_TETRA CHLORO ETHANE	TRICHLORO ETHENE	TETRA CHLORO ETHYLENE	124_TRI METHYL BENZENE
Plymouth	Mean	.	0.1796	0.6116	0.3995	0.1904	0.1273	0.0362	0.7245	0.0517	0.101	1.101	0.367	0.1119
	Std Deviation	.	0.1076	0.4021	0.2091	0.1206	0.0763	0.0553	0.2507	0.0565	0.0917	1.0121	0.2554	0.1489
	Median	.	0.1503	0.5386	0.3547	0.1734	0.1065	0.0182	0.6765	0.0371	0.0755	0.7328	0.2712	0.0737
	Maximum	.	0.5351	2.5366	1.1483	0.5155	0.3793	0.2905	1.555	0.3015	0.4807	4.9488	1.4173	0.8357
	Valid N	N=0	N=55	N=55	N=55	N=50	N=55	N=55	N=55	N=55	N=55	N=55	N=55	N=55
Koch420	Mean	2.234	0.1314	0.6598	0.2276	0.1753	0.0931	0.0258	0.9886	0.0288	0.0579	0.2157	0.2729	0.0842
	Std Deviation	2.085	0.1844	0.9843	0.268	0.1408	0.1307	0.0755	1.357	0.0655	0.1023	0.2303	0.4943	0.1318
	Median	1.694	0.0902	0.4344	0.1804	0.1544	0.0639	0	0.7147	0	0.0275	0.1345	0.1967	0.0541
	Maximum	12.127	1.8097	13.161	2.3147	0.9027	1.2828	0.8442	23.6846	0.487	0.9202	1.2152	8.6596	1.229
	Valid N	N=157	N=225	N=439	N=225	N=223	N=225	N=225	N=439	N=225	N=225	N=225	N=439	N=225
Koch423	Mean	1.124	0.1139	0.3447	0.1811	0.1704	0.0807	0.0197	0.9562	0.0143	0.0601	0.1963	0.2814	0.0676
	Std Deviation	0.991	0.1049	0.3229	0.1421	0.1032	0.0744	0.054	1.3313	0.0371	0.418	0.2206	0.574	0.0622
	Median	0.825	0.0992	0.2606	0.1563	0.1592	0.0703	0	0.6547	0	0.0206	0.1067	0.1899	0.059
	Maximum	7.193	0.5411	2.6496	0.7455	0.848	0.3836	0.5628	19.2762	0.3571	6.8671	1.243	10.1582	0.4965
	Valid N	N=158	N=272	N=489	N=272	N=294	N=272	N=272	N=489	N=272	N=272	N=272	N=489	N=272
Koch426	Mean	2.946	0.0953	0.8899	0.1566	0.2385	0.0675	0.0194	1.0274	0.0142	0.0592	0.1616	0.2796	0.0774
	Std Deviation	4.158	0.1542	1.2866	0.2001	0.1845	0.1093	0.049	0.7467	0.0333	0.1023	0.1777	0.3059	0.1627
	Median	1.889	0	0.5647	0.0962	0.1995	0	0	0.9275	0	0	0.0881	0.2102	0
	Maximum	35.415	0.6974	13.7964	0.8537	0.9359	0.4944	0.3132	7.2287	0.1531	0.5288	0.872	2.0886	1.0373
	Valid N	N=167	N=111	N=337	N=111	N=108	N=111	N=111	N=337	N=111	N=111	N=111	N=337	N=111
StPaulPark	Mean	3.249	0.1159	0.9645	0.2281	0.218	0.0821	0.0334	5.9669	0.0194	0.0515	0.2455	0.3899	0.0692
	Std Deviation	2.257	0.1174	0.7237	0.2055	0.1319	0.0832	0.0979	22.0648	0.0495	0.077	0.242	0.4384	0.0812
	Median	2.888	0.0962	0.7601	0.1924	0.1948	0.0682	0	0.6765	0	0.0275	0.1716	0.2712	0.0492
	Maximum	10.642	0.6493	3.7355	1.2506	0.6034	0.4603	0.8079	160.8984	0.3571	0.5425	2.0222	3.7771	0.5457
	Valid N	N=42	N=223	N=319	N=223	N=226	N=223	N=223	N=319	N=223	N=223	N=223	N=319	N=223
Ashland	Mean	.	0.1237	0.9374	0.2253	0.286	0.0877	0.0383	0.5812	0.02	0.0486	0.283	0.2781	0.0802
	Std Deviation	.	0.1199	0.6182	0.178	0.1967	0.085	0.1272	0.2608	0.0396	0.0693	0.3393	0.2071	0.1054
	Median	.	0.1022	0.7905	0.2014	0.2364	0.0724	0	0.5401	0	0.0275	0.1554	0.2306	0.0541
	Maximum	.	0.7455	3.2446	0.9499	1.392	0.5285	1.2708	2.4607	0.218	0.515	2.704	1.363	0.8308
	Valid N	N=0	N=194	N=194	N=194	N=200	N=194	N=194	N=193	N=194	N=194	N=194	N=194	N=194
HolmanFld	Mean	3.4	0.1224	0.9109	0.2944	0.2191	0.0867	0.0211	1.1864	0.0171	0.051	0.3853	0.5428	0.0717
	Std Deviation	3.891	0.1745	1.0275	0.3279	0.1447	0.1237	0.0834	1.1348	0.0393	0.108	0.4152	1.4132	0.1307
	Median	2.28	0.0902	0.5794	0.2345	0.1924	0.0639	0	0.873	0	0.0137	0.2597	0.3323	0.0442
	Maximum	28.052	1.6834	10.0102	2.0021	0.8385	1.1933	0.9123	9.8427	0.3479	0.879	3.4461	25.0802	1.1504
	Valid N	N=88	N=205	N=353	N=205	N=215	N=205	N=205	N=353	N=205	N=205	N=205	N=353	N=205
BushSt	Mean	.	0.1134	2.2855	0.355	0.2643	0.0804	0.0351	0.4417	0.0038	0.0358	0.4013	0.5245	0.0688
	Std Deviation	.	0.0794	2.0613	0.1986	0.1317	0.0563	0.1145	0.0974	0.0115	0.0511	0.2678	0.5251	0.0474
	Median	.	0.0842	1.3682	0.3247	0.2423	0.0597	0	0.4638	0	0.0069	0.4128	0.3187	0.0541
	Maximum	.	0.3547	6.8759	0.9319	0.5749	0.2514	0.4221	0.5947	0.0464	0.1991	1.1178	1.8648	0.2212
	Valid N	N=0	N=23	N=23	N=23	N=23	N=23	N=23	N=23	N=23	N=23	N=23	N=23	N=23
HardingHi	Mean	.	.	0.9019	.	.	.	.	0.4501	.	.	.	0.404	.
	Std Deviation	.	.	0.6051	.	.	.	.	0.0664	.	.	.	0.3296	.
	Median	.	.	0.7167	.	.	.	.	0.4583	.	.	.	0.356	.
	Maximum	.	.	2.0502	.	.	.	.	0.5947	.	.	.	1.1121	.
	Valid N	N=0	N=0	N=14	N=0	N=0	N=0	N=0	N=14	N=0	N=0	N=0	N=14	N=0

Appendix E. Summary Statistics for Monitored Organics.

		M_XYLENE	O_DICHLORO BENZENE	O_XYLENE	P_DICHLORO BENZENE	PROPION ALDEHYDE	STYRENE	T_13_DI CHLORO PROPENE	111_TRI CHLORO ETHANE	112_TRI CHLORO ETHANE	1122_TETRA CHLORO ETHANE	TRICHLORO ETHENE	TETRA CHLORO ETHYLENE	124_TRI METHYL BENZENE
MplsLibrary	Mean	5.484	0.1226	1.6454	0.4454	0.2803	0.0869	0.0255	2.26	0.0199	0.0572	1.0754	1.2158	0.0685
	Std Deviation	5.296	0.13	1.383	0.5484	0.1322	0.0922	0.0728	2.2988	0.0466	0.0781	1.4312	1.5225	0.1057
	Median	4.17	0.1022	1.3031	0.2946	0.2708	0.0724	0	1.6586	0	0.0343	0.5427	0.6713	0.0442
	Maximum	47.314	0.7215	16.9703	3.92	0.715	0.5114	0.6036	25.4251	0.4824	0.5082	8.8958	12.2807	0.8161
	Valid N	N=134	N=206	N=400	N=206	N=225	N=206	N=206	N=400	N=206	N=206	N=206	N=400	N=206
MhahaAcad	Mean	.	0.148	0.7355	0.679	0.2432	0.1049	0.0341	0.5645	0.0106	0.0395	0.2662	0.4296	0.0889
	Std Deviation	.	0.1143	0.5857	0.4685	0.1321	0.081	0.0721	0.1736	0.0153	0.0681	0.1718	0.3706	0.071
	Median	.	0.1142	0.5299	0.487	0.2328	0.081	0	0.5511	0	0.0275	0.2319	0.3458	0.0688
	Maximum	.	0.5892	3.236	2.0682	0.7435	0.4177	0.295	1.4022	0.0696	0.4876	1.1178	2.4344	0.3835
	Valid N	N=0	N=57	N=57	N=57	N=57	N=57	N=57	N=57	N=57	N=57	N=57	N=57	N=57
I_Falls1240	Mean	.	0.0842	0.6755	0.2484	0.2116	0.0597	0.012	0.6781	0.0245	0.0307	0.0936	0.3351	0.0583
	Std Deviation	.	0.1005	1.5284	0.3139	0.1586	0.0712	0.0482	0.7194	0.1002	0.0736	0.2575	0.5646	0.0715
	Median	.	0.0601	0.2519	0.1563	0.1782	0.0426	0	0.4692	0	0.0069	0.0394	0.1627	0.0442
	Maximum	.	0.5832	8.4265	1.8157	0.7744	0.4134	0.3313	5.1669	0.7653	0.515	2.268	4.0687	0.4621
	Valid N	N=0	N=84	N=91	N=84	N=85	N=84	N=84	N=91	N=84	N=84	N=84	N=91	N=84
I_Falls1241	Mean	.	0.2063	0.6369	0.3448	0.1152	0.1462	0.0711	0.8153	0.0526	0.0781	0.2933	0.4592	0.1167
	Std Deviation	.	0.1111	0.5083	0.1752	0.0817	0.0788	0.1992	0.5001	0.0579	0.0529	0.259	0.591	0.0935
	Median	.	0.1864	0.4734	0.2946	0.1093	0.1321	0.0318	0.6875	0.0371	0.0687	0.1855	0.2238	0.0885
	Maximum	.	0.5351	3.1795	0.8958	0.4347	0.3793	1.4841	3.4591	0.3386	0.2266	1.5166	3.1872	0.5014
	Valid N	N=0	N=57	N=57	N=57	N=57	N=57	N=57	N=57	N=57	N=57	N=57	N=57	N=57
Sandstone	Mean	.	0.3097	0.2409	0.4553	0.1336	0.2195	0.05	1.1934	0.0511	0.1415	0.5414	0.3348	0.1844
	Std Deviation	.	0.4178	0.1619	0.4968	0.085	0.2962	0.072	3.7324	0.0644	0.1942	0.7158	0.623	0.2881
	Median	.	0.1503	0.1868	0.2525	0.1449	0.1065	0.0227	0.5729	0.0371	0.0755	0.2876	0.1695	0.0737
	Maximum	.	1.8939	0.7732	2.2907	0.3611	1.3425	0.3268	27.2693	0.2783	0.9202	3.3811	4.3128	1.2585
	Valid N	N=0	N=51	N=51	N=51	N=48	N=51	N=51	N=51	N=51	N=51	N=51	N=51	N=51
FergusFalls	Mean	.	0.1286	0.4564	0.3156	0.1843	0.0912	0.0337	0.5021	0.0063	0.0256	0.2188	0.6785	0.086
	Std Deviation	.	0.1074	0.2663	0.1946	0.1067	0.0762	0.0709	0.0965	0.0131	0.0258	0.1638	0.5422	0.0679
	Median	.	0.1082	0.4061	0.2796	0.1568	0.0767	0	0.5129	0	0.0206	0.1878	0.5357	0.0688
	Maximum	.	0.6734	1.4507	1.1483	0.5297	0.4773	0.2996	0.7093	0.0557	0.1373	0.7374	2.5294	0.4228
	Valid N	N=0	N=48	N=48	N=48	N=59	N=48	N=48	N=48	N=48	N=48	N=48	N=48	N=48
Alexandria	Mean	.	0.1909	0.497	0.35	0.184	0.1353	0.0607	0.7475	0.0689	0.0945	0.5092	0.3442	0.1069
	Std Deviation	.	0.1061	0.2007	0.199	0.0931	0.0752	0.1366	0.2987	0.1097	0.0914	0.3954	0.38	0.0798
	Median	.	0.1533	0.4908	0.3036	0.1627	0.1087	0.0136	0.6575	0.0301	0.0687	0.3594	0.2407	0.086
	Maximum	.	0.4389	1.0729	1.3167	0.4038	0.3111	0.7126	1.5932	0.4638	0.515	1.7949	2.8481	0.4179
	Valid N	N=0	N=58	N=58	N=58	N=56	N=58	N=58	N=58	N=58	N=58	N=58	N=58	N=58
Warroad	Mean	.	0.1206	0.1938	0.1796	0.0791	0.0855	0.0234	0.558	0.0021	0.0386	0.7362	0.1776	0.0744
	Std Deviation	.	0.0562	0.1143	0.0712	0.0385	0.0398	0.0643	0.3662	0.0072	0.0549	0.7073	0.0774	0.0379
	Median	.	0.1082	0.1694	0.1683	0.0736	0.0767	0	0.5074	0	0.0275	0.4035	0.1492	0.059
	Maximum	.	0.3247	0.6081	0.4629	0.2352	0.2301	0.3903	2.9408	0.0417	0.3365	2.3886	0.495	0.1917
	Valid N	N=0	N=47	N=47	N=47	N=59	N=47	N=47	N=47	N=47	N=47	N=47	N=47	N=47
LittleFalls	Mean	.	0.2524	0.3744	0.3735	0.118	0.1789	0.0636	0.8184	0.0647	0.0873	1.4286	0.31	0.1422
	Std Deviation	.	0.3006	0.1747	0.3518	0.0837	0.2131	0.0906	0.3979	0.0949	0.0982	1.7461	0.3253	0.19
	Median	.	0.1653	0.3627	0.2706	0.1069	0.1172	0.0295	0.682	0.0371	0.0687	0.9392	0.2441	0.0836
	Maximum	.	2.1043	1.1076	2.5372	0.4228	1.4916	0.3676	2.417	0.5009	0.7004	12.2537	2.3124	1.3372
	Valid N	N=0	N=56	N=56	N=56	N=58	N=56	N=56	N=56	N=56	N=56	N=56	N=56	N=56

Appendix E. Summary Statistics for Monitored Organics.

		M_XYLENE	O_DICHLORO BENZENE	O_XYLENE	P_DICHLORO BENZENE	PROPION ALDEHYDE	STYRENE	T_13_DI CHLORO PROPENE	111_TRI CHLORO ETHANE	112_TRI CHLORO ETHANE	1122_TETRA CHLORO ETHANE	TRICHLORO ETHENE	TETRA CHLORO ETHYLENE	124_TRI METHYL BENZENE
ElkRiver	Mean	.	0.1407	0.3464	0.2085	0.1654	0.0997	0.0236	0.5142	0.009	0.0259	0.2703	0.195	0.087
	Std Deviation	.	0.1213	0.2413	0.155	0.0933	0.0859	0.0675	0.1075	0.0132	0.0267	0.1735	0.0889	0.072
	Median	.	0.0902	0.2758	0.1413	0.1473	0.0639	0	0.5074	0	0.0206	0.2435	0.1729	0.0615
	Maximum	.	0.6433	1.1293	0.8477	0.4846	0.456	0.4039	0.8839	0.0417	0.1167	1.1549	0.5086	0.3933
	Valid N	N=0	N=58	N=58	N=58	N=61	N=58	N=58	N=58	N=58	N=58	N=58	N=58	N=58
Pipestone	Mean	.	0.2361	0.3569	0.5644	0.1522	0.1674	0.0626	0.7015	0.0923	0.1042	1.4267	0.2847	0.1279
	Std Deviation	.	0.1434	0.1798	0.482	0.0899	0.1017	0.1024	0.3054	0.1038	0.0899	2.4873	0.1857	0.1013
	Median	.	0.1804	0.3127	0.487	0.1449	0.1279	0.0408	0.6493	0.0603	0.0687	0.4128	0.217	0.0836
	Maximum	.	0.7756	0.8166	3.3188	0.4133	0.5498	0.6763	1.7514	0.4313	0.467	12.6943	0.9155	0.4375
	Valid N	N=0	N=47	N=47	N=47	N=55	N=47	N=47	N=47	N=47	N=47	N=47	N=47	N=47
GraniteFalls	Mean	.	0.1335	0.2212	0.2211	0.1466	0.0946	0.0495	0.5112	0.0055	0.0305	0.1438	0.214	0.0789
	Std Deviation	.	0.0737	0.1079	0.1049	0.0622	0.0522	0.1408	0.0899	0.0099	0.0222	0.1396	0.1303	0.0398
	Median	.	0.1142	0.1955	0.1924	0.1402	0.081	0	0.5183	0	0.0275	0.0928	0.1831	0.0639
	Maximum	.	0.3367	0.6081	0.4629	0.3302	0.2387	0.8079	0.6656	0.0417	0.0824	0.5751	0.7188	0.1868
	Valid N	N=0	N=45	N=45	N=45	N=53	N=45	N=45	N=45	N=45	N=45	N=45	N=45	N=45
Rochester	Mean	.	0.1191	0.4249	0.1925	0.158	0.0844	0.0382	0.4982	0.0057	0.0235	0.1817	0.2873	0.0772
	Std Deviation	.	0.0786	0.2651	0.0987	0.0793	0.0557	0.0844	0.0967	0.0096	0.0224	0.1061	0.2162	0.059
	Median	.	0.0962	0.3388	0.1683	0.1413	0.0682	0	0.502	0	0.0206	0.167	0.2102	0.0639
	Maximum	.	0.511	1.3118	0.6794	0.4133	0.3622	0.4493	0.7202	0.0371	0.1305	0.4777	1.1257	0.4474
	Valid N	N=0	N=59	N=59	N=59	N=60	N=59	N=59	N=59	N=59	N=59	N=59	N=59	N=59
Zumbrota	Mean	.	0.2134	0.2483	0.4028	0.1917	0.1513	0.0414	0.9133	0.0463	0.0741	0.5537	0.2813	0.1147
	Std Deviation	.	0.1581	0.0904	0.2323	0.1546	0.112	0.0773	1.3746	0.0602	0.0535	0.4297	0.2012	0.1113
	Median	.	0.1683	0.2367	0.3487	0.1758	0.1193	0	0.6356	0.0325	0.0584	0.4476	0.2238	0.0836
	Maximum	.	0.8958	0.6776	1.1423	0.6152	0.635	0.4266	10.2082	0.4035	0.2403	1.9016	0.9901	0.5555
	Valid N	N=0	N=54	N=54	N=54	N=53	N=54	N=54	N=54	N=54	N=54	N=54	N=54	N=54
Hibbing	Mean	.	0.1306	0.3962	0.3509	0.1217	0.0926	0.026	0.4824	0.0057	0.0278	0.1131	0.2794	0.0802
	Std Deviation	.	0.1068	0.2886	0.3274	0.0735	0.0757	0.0767	0.0885	0.0098	0.0399	0.0855	0.2286	0.0701
	Median	.	0.0962	0.3127	0.2345	0.1188	0.0682	0	0.5074	0	0.0206	0.0788	0.2102	0.059
	Maximum	.	0.6734	1.7374	1.6594	0.4513	0.4773	0.4176	0.6493	0.0371	0.2541	0.4638	1.3562	0.4523
	Valid N	N=0	N=59	N=59	N=59	N=61	N=59	N=59	N=59	N=59	N=59	N=59	N=59	N=59
Duluth7549	Mean	.	0.1417	0.9367	0.2957	0.1478	0.1004	0.031	1.373	0.0231	0.0568	0.5144	0.4219	0.077
	Std Deviation	.	0.1315	1.1119	0.3382	0.1187	0.0932	0.0818	3.4306	0.0437	0.0732	1.9131	0.8568	0.0904
	Median	.	0.1142	0.7015	0.2405	0.1164	0.081	0	0.7475	0	0.0275	0.2505	0.2441	0.059
	Maximum	.	0.6794	15.3328	4.1304	0.8005	0.4816	0.6127	46.0053	0.269	0.3983	25.3098	9.6089	0.7227
	Valid N	N=0	N=213	N=240	N=213	N=233	N=213	N=213	N=239	N=213	N=213	N=213	N=240	N=213
All Sites	Mean	2.937	0.1379	0.7925	0.2901	0.1957	0.0977	0.0316	1.5089	0.024	0.0568	0.426	0.4401	0.0829
	Std Deviation	3.745	0.1538	1.0039	0.3164	0.1399	0.109	0.0893	6.8417	0.0549	0.16	0.9332	0.8444	0.112
	Median	1.872	0.1082	0.4995	0.2164	0.1663	0.0767	0	0.6711	0	0.0275	0.2087	0.2373	0.059
	Maximum	47.314	2.1043	16.9703	4.1304	1.392	1.4916	1.4841	160.8984	0.7653	6.8671	25.3098	25.0802	1.3372
	Valid N	N=746	N=2507	N=3650	N=2507	N=2619	N=2507	N=2507	N=3648	N=2507	N=2507	N=2507	N=3650	N=2507

Appendix E. Summary Statistics for Monitored Organics.

		135_TRI METHYL BENZENE	TOLUENE	VINYL_ CHLORIDE	VINYLIDINE_ CHLORIDE
Plymouth	Mean	0.031	2.7183	0	0.1463
	Std Deviation	0.0319	2.1278	0	0.1179
	Median	0.0246	2.2187	0	0.1031
	Maximum	0.1229	14.235	0	0.6423
	Valid N	N=55	N=55	N=55	N=55
Koch420	Mean	0.0197	3.0766	0.0143	0.0404
	Std Deviation	0.0392	3.6764	0.099	0.0835
	Median	0	2.3882	0	0
	Maximum	0.2261	62.4924	1.7689	0.7177
	Valid N	N=225	N=439	N=439	N=439
Koch423	Mean	0.0155	1.8347	0.0094	0.0353
	Std Deviation	0.0319	1.3405	0.0398	0.071
	Median	0	1.518	0	0
	Maximum	0.2261	10.0726	0.409	0.7097
	Valid N	N=272	N=489	N=489	N=489
Koch426	Mean	0.0158	4.1106	0.0188	0.0327
	Std Deviation	0.0357	4.8481	0.0678	0.0595
	Median	0	2.9348	0	0
	Maximum	0.177	50.1608	0.7669	0.4798
	Valid N	N=111	N=337	N=337	N=337
StPaulPark	Mean	0.0144	4.9463	0.0197	0.0588
	Std Deviation	0.0272	3.3582	0.0883	0.0998
	Median	0	4.185	0	0.0396
	Maximum	0.1917	28.5529	1.1247	0.7137
	Valid N	N=223	N=319	N=319	N=319
Ashland	Mean	0.0212	5.2041	0.0043	0.0794
	Std Deviation	0.047	3.43	0.0282	0.1164
	Median	0	4.4167	0	0.0555
	Maximum	0.4375	17.0263	0.2837	0.7256
	Valid N	N=194	N=194	N=194	N=194
HolmanFld	Mean	0.0143	4.9338	0.0181	0.0499
	Std Deviation	0.0321	4.4869	0.0633	0.0933
	Median	0	3.6162	0	0
	Maximum	0.2311	36.9244	0.7413	0.8049
	Valid N	N=205	N=353	N=353	N=353
BushSt	Mean	0.0207	10.1733	0.0028	0.0502
	Std Deviation	0.068	7.1808	0.0071	0.0859
	Median	0	6.7201	0	0.004
	Maximum	0.3146	25.8294	0.0281	0.2974
	Valid N	N=23	N=23	N=23	N=23
HardingHi	Mean	.	4.8087	0.0007	0.0076
	Std Deviation	.	3.5641	0.0027	0.0189
	Median	.	3.296	0	0
	Maximum	.	12.0578	0.0102	0.0595
	Valid N	N=0	N=14	N=14	N=14

Appendix E. Summary Statistics for Monitored Organics.

		135_TRI METHYL BENZENE	TOLUENE	VINYL_ CHLORIDE	VINYLIDINE_ CHLORIDE
MplsLibrary	Mean	0.0164	7.0691	0.0162	0.0573
	Std Deviation	0.0452	5.4494	0.0519	0.0972
	Median	0	6.0213	0	0
	Maximum	0.413	74.7355	0.4601	0.678
	Valid N	N=206	N=400	N=400	N=400
MhahaAcad	Mean	0.0201	3.3127	0.003	0.0512
	Std Deviation	0.0329	2.225	0.0054	0.0589
	Median	0.0049	2.6481	0	0.0436
	Maximum	0.177	10.988	0.0204	0.4124
	Valid N	N=57	N=57	N=57	N=57
I_Falls1240	Mean	0.0105	3.3246	0.0054	0.1585
	Std Deviation	0.0411	7.4948	0.0263	0.3321
	Median	0	1.4615	0	0.0595
	Maximum	0.3097	59.9837	0.2403	2.1887
	Valid N	N=84	N=91	N=91	N=91
I_Falls1241	Mean	0.0505	2.3442	0.0032	0.2004
	Std Deviation	0.1444	1.9572	0.0227	0.2209
	Median	0.0197	1.793	0	0.1229
	Maximum	1.0717	11.7828	0.1713	1.0428
	Valid N	N=57	N=57	N=57	N=57
Sandstone	Mean	0.0361	0.8167	0	0.17
	Std Deviation	0.0397	0.4305	0	0.3462
	Median	0.0246	0.6743	0	0.0793
	Maximum	0.1573	2.0115	0	2.4028
	Valid N	N=51	N=51	N=51	N=51
FergusFalls	Mean	0.0128	2.3902	0.0059	0.0393
	Std Deviation	0.0227	1.17	0.009	0.0271
	Median	0	2.2677	0	0.0396
	Maximum	0.0885	7.3341	0.0358	0.1031
	Valid N	N=48	N=48	N=48	N=48
Alexandria	Mean	0.0264	2.0818	0	0.1545
	Std Deviation	0.0489	0.9598	0	0.1435
	Median	0.0147	1.9569	0	0.111
	Maximum	0.3441	4.9308	0	0.6106
	Valid N	N=58	N=58	N=58	N=58
Warroad	Mean	0.0061	1.0653	0.0044	0.0409
	Std Deviation	0.012	0.7036	0.0068	0.0431
	Median	0	0.7986	0	0.0396
	Maximum	0.0393	4.2566	0.023	0.2934
	Valid N	N=47	N=47	N=47	N=47
LittleFalls	Mean	0.0363	1.6301	0.0025	0.1619
	Std Deviation	0.0395	0.8781	0.0135	0.1346
	Median	0.0295	1.3278	0	0.1189
	Maximum	0.2409	4.8103	0.0869	0.6106
	Valid N	N=56	N=56	N=56	N=56

Appendix E. Summary Statistics for Monitored Organics.

		135_TRI METHYL BENZENE	TOLUENE	VINYL_ CHLORIDE	VINYLIDINE_ CHLORIDE
ElkRiver	Mean	0.0142	1.7137	0.0045	0.0455
	Std Deviation	0.0287	1.1386	0.0065	0.0221
	Median	0	1.3674	0	0.0476
	Maximum	0.1327	5.6729	0.0256	0.0833
	Valid N	N=58	N=58	N=58	N=58
Pipestone	Mean	0.043	1.625	0	0.1382
	Std Deviation	0.0584	1.0173	0	0.126
	Median	0.0344	1.3146	0	0.0991
	Maximum	0.3687	5.8575	0	0.5947
	Valid N	N=47	N=47	N=47	N=47
GraniteFalls	Mean	0.0138	1.141	0.0034	0.0608
	Std Deviation	0.0249	0.4814	0.0074	0.0611
	Median	0	1.0171	0	0.0515
	Maximum	0.1131	2.844	0.0383	0.341
	Valid N	N=45	N=45	N=45	N=45
Rochester	Mean	0.0178	2.3048	0.0023	0.0426
	Std Deviation	0.0397	1.3417	0.0058	0.0338
	Median	0	1.9098	0	0.0436
	Maximum	0.236	7.0252	0.0332	0.1982
	Valid N	N=59	N=59	N=59	N=59
Zumbrota	Mean	0.0249	0.8807	0	0.1903
	Std Deviation	0.0312	0.36	0	0.1826
	Median	0.0147	0.8344	0	0.1249
	Maximum	0.1278	2.0605	0	0.9556
	Valid N	N=54	N=54	N=54	N=54
Hibbing	Mean	0.0171	2.0895	0.0052	0.0356
	Std Deviation	0.0305	1.6067	0.0083	0.0238
	Median	0	1.5595	0	0.0436
	Maximum	0.1721	10.5472	0.0307	0.0952
	Valid N	N=59	N=59	N=59	N=59
Duluth7549	Mean	0.0197	4.1699	0.0078	0.0907
	Std Deviation	0.0381	3.2343	0.0359	0.2232
	Median	0	3.5126	0	0.0595
	Maximum	0.2556	31.0767	0.3067	3.0768
	Valid N	N=213	N=240	N=240	N=240
All Sites	Mean	0.0193	3.786	0.0114	0.0652
	Std Deviation	0.0435	4.1032	0.0581	0.1309
	Median	0	2.6104	0	0.0396
	Maximum	1.0717	74.7355	1.7689	3.0768
	Valid N	N=2507	N=365C	N=3650	N=3650

APPENDIX F

Appendix F. Summary Statistics for Monitored Metals

Site		AG	AS	BA	BR	CA	CD	CL	CO	CR	CU	FE	GA
Plymouth	Mean	0.0022	0.0017	-0.0309	0.0023	0.3059	0.0025	0.0305	0.0004	0.0010	0.0289	0.1863	0.0005
	Std Deviation	0.0046	0.0013	0.0958	0.0014	0.4532	0.0045	0.1141	0.0005	0.0010	0.0328	0.1136	0.0009
	Median	0.0023	0.0016	-0.0463	0.0022	0.1630	0.0005	0.0022	0.0003	0.0009	0.0193	0.1832	0.0004
	Maximum	0.0124	0.0058	0.1733	0.0060	2.2127	0.0110	0.6729	0.0016	0.0034	0.1544	0.6088	0.0028
	Valid N	N=31	N=31	N=55	N=51	N=55	N=24	N=49	N=35	N=44	N=55	N=55	N=37
BushSt	Mean	0.0024	0.0025	-0.0149	0.0025	0.5204	0.0017	0.0253	0.0011	0.0015	0.0278	0.3771	0.0005
	Std Deviation	0.0042	0.0023	0.0933	0.0017	0.5951	0.0046	0.0947	0.0011	0.0016	0.0337	0.2556	0.0009
	Median	0.0016	0.0020	-0.0177	0.0023	0.3460	0.0002	0.0089	0.0009	0.0013	0.0175	0.3198	0.0004
	Maximum	0.0165	0.0110	0.2400	0.0083	3.7579	0.0254	0.9822	0.0049	0.0074	0.2580	1.3802	0.0030
	Valid N	N=81	N=92	N=130	N=128	N=130	N=69	N=121	N=94	N=118	N=130	N=130	N=93
HardingHi	Mean	0.0023	0.0029	-0.0163	0.0021	0.2671	0.0018	0.0360	0.0005	0.0014	0.0594	0.1976	0.0014
	Std Deviation	0.0055	0.0022	0.0644	0.0015	0.1892	0.0057	0.0540	0.0007	0.0011	0.0909	0.1113	0.0011
	Median	0.0016	0.0017	-0.0231	0.0017	0.2733	0.0003	0.0079	0.0004	0.0013	0.0228	0.1979	0.0012
	Maximum	0.0154	0.0063	0.1030	0.0060	0.6462	0.0130	0.1492	0.0026	0.0036	0.3717	0.4159	0.0034
	Valid N	N=9	N=13	N=16	N=16	N=16	N=6	N=14	N=12	N=14	N=16	N=16	N=8
MplsLibrary	Mean	0.0013	0.0017	0.0039	0.0039	0.5692	0.0025	0.0450	0.0009	0.0015	0.0242	0.3773	0.0005
	Std Deviation	0.0038	0.0017	0.0932	0.0023	0.5488	0.0039	0.1491	0.0009	0.0014	0.0144	0.2940	0.0010
	Median	0.0007	0.0013	-0.0018	0.0037	0.4387	0.0023	0.0135	0.0007	0.0012	0.0202	0.3167	0.0003
	Maximum	0.0145	0.0095	0.2944	0.0119	2.7065	0.0108	1.2390	3 .0035	0.0062	0.0695	1.9757	0.0036
	Valid N	N=66	N=89	N=122	N=122	N=122	N=56	N=122	N=102	N=103	N=122	N=122	N=84
MhahaAcad	Mean	0.0014	0.0014	-0.0114	0.0024	0.3429	0.0028	0.0077	0.0008	0.0011	0.0168	0.2147	0.0004
	Std Deviation	0.0037	0.0012	0.0939	0.0019	0.4078	0.0052	0.0089	0.0008	0.0012	0.0128	0.1846	0.0010
	Median	0.0004	0.0012	-0.0025	0.0023	0.2179	0.0012	0.0054	0.0008	0.0009	0.0144	0.1580	0.0002
	Maximum	0.0129	0.0039	0.2252	0.0079	1.7691	0.0171	0.0471	0.0033	0.0045	0.0452	0.9651	0.0033
	Valid N	N=25	N=46	N=56	N=56	N=56	N=32	N=51	N=43	N=46	N=56	N=56	N=39
I_Falls1241	Mean	0.0026	0.0012	-0.0099	0.0017	0.1018	0.0011	0.0183	0.0007	0.0009	0.0108	0.1371	0.0005
	Std Deviation	0.0051	0.0011	0.0990	0.0015	0.1071	0.0034	0.0930	0.0007	0.0009	0.0136	0.1424	0.0009
	Median	0.0018	0.0008	-0.0221	0.0013	0.0770	0.0005	0.0013	0.0005	0.0007	0.0084	0.1041	0.0004
	Maximum	0.0154	0.0044	0.2792	0.0079	0.5261	0.0099	0.6111	0.0032	0.0031	0.0876	0.8246	0.0029
	Valid N	N=35	N=32	N=58	N=55	N=58	N=32	N=43	N=33	N=43	N=58	N=58	N=41
Sandstone	Mean	0.0024	0.0011	-0.0164	0.0015	0.1067	0.0010	0.0015	0.0004	0.0011	0.0455	0.1244	0.0008
	Std Deviation	0.0054	0.0009	0.1165	0.0012	0.2072	0.0036	0.0037	0.0007	0.0014	0.0384	0.1204	0.0010
	Median	0.0023	0.0008	-0.0313	0.0009	0.0334	0.0003	0.0007	0.0002	0.0008	0.0325	0.0781	0.0007
	Maximum	0.0237	0.0032	0.3049	0.0042	1.0674	0.0099	0.0170	0.0024	0.0047	0.1459	0.6466	0.0033
	Valid N	N=30	N=28	N=59	N=53	N=59	N=30	N=45	N=37	N=36	N=59	N=59	N=44
FergusFalls	Mean	0.0030	0.0016	0.0041	0.0025	0.6609	0.0042	0.0118	0.0010	0.0011	0.0220	0.2483	0.0002

Appendix F. Summary Statistics for Monitored Metals

Site		AG	AS	BA	BR	CA	CD	CL	CO	CR	CU	FE	GA
	Std Deviation	0.0057	0.0018	0.0920	0.0027	0.7542	0.0051	0.0109	0.0011	0.0012	0.0182	0.2575	0.0009
	Median	0.0007	0.0012	-0.0054	0.0020	0.4942	0.0045	0.0086	0.0009	0.0009	0.0145	0.1816	0.0002
	Maximum	0.0169	0.0070	0.3000	0.0152	4.3037	0.0133	0.0514	0.0053	0.0043	0.0649	1.3964	0.0022
	Valid N	N=33	N=39	N=57	N=54	N=57	N=27	N=55	N=38	N=50	N=57	N=57	N=47
Alexandria	Mean	0.0005	0.0011	-0.0191	0.0025	0.2523	0.0011	0.0072	0.0004	0.0010	0.0084	0.1087	0.0008
	Std Deviation	0.0037	0.0007	0.0994	0.0017	0.2520	0.0037	0.0199	0.0006	0.0011	0.0082	0.0827	0.0008
	Median	0.0000	3 .0011	-0.0259	0.0025	0.1883	0.0000	3 .0018	0.0003	0.0010	0.0069	0.0890	0.0007
	Maximum	0.0088	0.0026	0.1757	0.0071	1.1741	0.0080	0.1117	0.0014	0.0050	0.0358	0.3600	0.0027
	Valid N	N=23	N=27	N=48	N=46	N=48	N=25	N=34	N=24	N=26	N=48	N=48	N=33
Moorhead	Mean	0.0019	0.0025	0.0252	0.0018	0.4856	0.0057	0.0205	0.0008	0.0013	0.0079	0.2540	0.0005
	Std Deviation	0.0037	0.0017	0.1092	0.0010	0.2907	0.0042	0.0257	0.0010	0.0015	0.0056	0.1101	0.0011
	Median	0.0024	0.0025	0.0093	0.0016	0.4183	0.0043	0.0060	0.0003	0.0018	0.0058	0.2330	0.0006
	Maximum	0.0062	0.0043	0.1928	0.0031	0.8378	0.0118	0.0884	0.0026	0.0030	0.0193	0.4519	0.0020
	Valid N	N=8	N=6	N=13	N=13	N=13	N=4	N=13	N=10	N=10	N=13	N=13	N=7
Bemidji	Mean	0.0014	0.0012	0.0188	0.0013	0.2313	0.0044	0.0092	0.0007	0.0009	0.0038	0.1384	0.0003
	Std Deviation	0.0041	0.0010	0.0669	0.0012	0.3419	0.0050	0.0085	0.0006	0.0013	0.0034	0.1391	0.0009
	Median	0.0010	0.0016	0.0136	0.0012	0.1130	0.0030	0.0090	0.0005	0.0003	0.0030	0.0889	0.0002
	Maximum	0.0075	0.0019	0.1304	0.0039	1.3065	0.0136	0.0274	0.0018	0.0039	0.0098	0.5725	0.0018
	Valid N	N=10	N=4	N=14	N=12	N=14	N=8	N=12	N=11	N=10	N=14	N=14	N=9
Warroad	Mean	0.0024	0.0009	-0.0267	0.0010	0.3802	0.0025	0.0077	0.0006	0.0005	0.0043	0.1438	0.0000
	Std Deviation	0.0045	0.0011	0.0905	0.0011	0.5195	0.0046	0.0119	0.0006	0.0009	0.0049	0.1395	0.0008
	Median	0.0014	0.0007	-0.0337	0.0008	0.2112	0.0019	0.0054	0.0005	0.0005	0.0027	0.0954	0.0000
	Maximum	0.0150	0.0046	0.1698	0.0041	3.3107	0.0131	0.0808	0.0024	0.0031	0.0279	0.7464	0.0016
	Valid N	N=36	N=39	N=57	N=54	N=57	N=33	N=55	N=38	N=45	N=57	N=57	N=39
LittleFalls	Mean	0.0012	0.0013	0.0020	0.0022	0.1591	0.0027	0.0027	0.0005	0.0011	0.0183	0.1735	0.0008
	Std Deviation	0.0051	0.0012	0.1258	0.0013	0.2444	0.0050	0.0049	0.0008	0.0010	0.0207	0.1642	0.0008
	Median	0.0000	2 .0010	0.0187	0.0023	0.0627	0.0020	0.0014	0.0003	0.0011	0.0097	0.1302	0.0008
	Maximum	0.0165	0.0044	0.2762	0.0057	1.4735	0.0172	0.0220	0.0038	0.0033	0.1032	0.9619	0.0028
	Valid N	N=27	N=28	N=49	N=45	N=49	N=20	N=38	N=34	N=34	N=49	N=49	N=33
ElkRiver	Mean	0.0020	0.0026	-0.0291	0.0018	0.2872	0.0026	0.0054	0.0007	0.0010	0.0211	0.2259	0.0004
	Std Deviation	0.0044	0.0031	0.0961	0.0013	0.4616	0.0052	0.0066	0.0010	0.0014	0.0206	0.2667	0.0010
	Median	0.0020	0.0016	-0.0250	0.0018	0.1438	0.0005	0.0039	0.0004	0.0011	0.0152	0.1297	0.0001
	Maximum	0.0117	0.0149	0.1683	0.0066	2.5566	0.0157	0.0392	0.0045	0.0047	0.1169	1.4467	0.0025
	Valid N	N=33	N=40	N=54	N=48	N=54	N=34	N=44	N=33	N=46	N=54	N=54	N=38
St.Cloud	Mean	0.0028	0.0011	-0.0255	0.0020	0.1177	0.0029	0.0157	0.0004	0.0010	0.0183	0.1381	0.0010
	Std Deviation	0.0059	0.0008	0.0852	0.0013	0.0978	0.0055	0.0336	0.0005	0.0009	0.0141	0.0750	0.0010

Appendix F. Summary Statistics for Monitored Metals

Site		AG	AS	BA	BR	CA	CD	CL	CO	CR	CU	FE	GA
	Median	0.0002	0.0014	-0.0223	0.0019	0.0965	0.0013	0.0022	0.0003	0.0007	0.0143	0.1143	0.0011
	Maximum	0.0131	0.0020	0.1253	0.0045	0.3868	0.0116	0.1244	0.0015	0.0026	0.0513	0.2896	0.0025
	Valid N	N=8	N=7	N=16	N=15	N=16	N=8	N=14	N=14	N=13	N=16	N=16	N=10
Pipestone	Mean	0.0038	0.0007	-0.0366	0.0020	0.3852	0.0034	0.0010	0.0006	0.0011	0.0219	0.1756	0.0009
	Std Deviation	0.0051	0.0006	0.0944	0.0013	0.4150	0.0041	0.0029	0.0007	0.0013	0.0318	0.1590	0.0009
	Median	0.0032	0.0007	-0.0300	0.0018	0.2616	0.0020	0.0005	0.0004	0.0007	0.0118	0.1221	0.0009
	Maximum	0.0154	0.0019	0.1533	0.0047	2.2350	0.0127	0.0107	0.0025	0.0063	0.2204	0.8241	0.0026
	Valid N	N=38	N=26	N=57	N=52	N=57	N=26	N=42	N=39	N=25	N=57	N=57	N=36
GraniteFalls	Mean	0.0015	0.0008	-0.0294	0.0016	0.3826	0.0028	0.0111	0.0007	0.0006	0.0379	0.1911	0.0002
	Std Deviation	0.0037	0.0009	0.0864	0.0012	0.4199	0.0046	0.0212	0.0007	0.0010	0.1281	0.2043	0.0009
	Median	0.0020	0.0007	-0.0156	0.0016	0.2691	0.0024	0.0025	0.0006	0.0006	0.0091	0.1057	0.0000
	Maximum	0.0116	0.0034	0.1839	0.0050	1.7434	0.0153	0.0830	0.0032	0.0029	0.8990	1.0597	0.0024
	Valid N	N=32	N=35	N=57	N=52	N=57	N=32	N=41	N=35	N=44	N=57	N=57	N=41
Holloway	Mean	0.0022	0.0004	0.0340	0.0026	0.3956	0.0017	0.0043	0.0003	0.0008	0.0330	0.1419	0.0009
	Std Deviation	0.0041	0.0004	0.0917	0.0056	0.5111	0.0046	0.0052	0.0006	0.0012	0.0294	0.1333	0.0014
	Median	0.0005	0.0004	0.0331	0.0014	0.1259	0.0000	1 .0023	0.0002	0.0006	0.0241	0.0825	0.0004
	Maximum	0.0100	0.0010	0.1896	0.0218	1.7473	0.0103	0.0177	0.0018	0.0038	0.0938	0.4508	0.0029
	Valid N	N=7	N=9	N=15	N=14	N=15	N=9	N=11	N=11	N=11	N=15	N=15	N=9
Rochester	Mean	0.0025	0.0010	-0.0111	0.0031	0.6306	0.0025	0.0055	0.0005	0.0005	0.0134	0.1533	0.0003
	Std Deviation	0.0043	0.0011	0.0714	0.0023	0.6777	0.0040	0.0100	0.0007	0.0010	0.0126	0.1138	0.0011
	Median	0.0016	0.0007	-0.0051	0.0026	0.3832	0.0017	0.0035	0.0005	0.0007	0.0100	0.1352	0.0001
	Maximum	0.0121	0.0035	0.1089	0.0117	2.5150	0.0121	0.0650	0.0027	0.0029	0.0742	0.5399	0.0043
	Valid N	N=36	N=39	N=51	N=51	N=51	N=23	N=44	N=30	N=41	N=51	N=51	N=34
Winona	Mean	0.0036	0.0023	-0.0297	0.0028	0.3408	0.0040	0.1978	0.0014	0.0008	0.0598	0.1648	0.0001
	Std Deviation	0.0043	0.0021	0.0810	0.0023	0.3906	0.0027	0.3590	0.0011	0.0014	0.0981	0.1705	0.0004
	Median	0.0033	0.0023	0.0009	0.0022	0.1395	0.0046	0.0072	0.0012	0.0005	0.0308	0.1042	0.0003
	Maximum	0.0099	0.0048	0.0586	0.0085	1.1661	0.0087	0.9371	0.0038	0.0030	0.3351	0.4875	0.0005
	Valid N	N=8	N=6	N=10	N=10	N=10	N=7	N=8	N=8	N=9	N=10	N=10	N=5
Zumbrota	Mean	0.0028	0.0012	-0.0087	0.0023	0.6311	0.0019	0.0015	0.0006	0.0010	0.0135	0.1259	0.0005
	Std Deviation	0.0047	0.0011	0.0934	0.0020	1.3644	0.0045	0.0044	0.0006	0.0010	0.0149	0.1282	0.0010
	Median	0.0009	0.0011	-0.0139	0.0019	0.2220	0.0003	0.0013	0.0005	0.0009	0.0094	0.0751	0.0003
	Maximum	0.0138	0.0036	0.1913	0.0128	8.9056	0.0133	0.0213	0.0018	0.0031	0.0779	0.6876	0.0031
	Valid N	N=31	N=30	N=48	N=47	N=48	N=25	N=33	N=29	N=32	N=48	N=48	N=35
Hibbing	Mean	0.0026	0.0020	0.0144	0.0017	0.0809	0.0012	0.0062	0.0010	0.0009	0.0109	0.3849	0.0002
	Std Deviation	0.0042	0.0017	0.0916	0.0021	0.1478	0.0029	0.0158	0.0014	0.0011	0.0116	0.3491	0.0010
	Median	0.0023	0.0017	0.0207	0.0014	0.0462	0.0005	0.0014	0.0007	0.0009	0.0076	0.2870	0.0000

Appendix F. Summary Statistics for Monitored Metals

Site		AG	AS	BA	BR	CA	CD	CL	CO	CR	CU	FE	GA
	Maximum	0.0113	0.0080	0.2003	0.0118	0.9811	0.0074	0.0832	0.0074	0.0036	0.0719	2.0565	0.0030
	Valid N	N=30	N=40	N=54	N=48	N=54	N=26	N=46	N=43	N=41	N=54	N=54	N=34
Duluth	Mean	0.0027	0.0011	-0.0321	0.0015	0.0478	0.0007	0.0178	0.0004	0.0010	0.0161	0.1576	0.0003
	Std Deviation	0.0044	0.0014	0.1169	0.0016	0.0727	0.0030	0.0322	0.0005	0.0011	0.0133	0.0972	0.0010
	Median	0.0019	0.0008	-0.0399	0.0012	0.0288	0.0003	0.0036	0.0002	0.0010	0.0119	0.1261	0.0003
	Maximum	0.0109	0.0044	0.2442	0.0055	0.2027	0.0053	0.0997	0.0012	0.0029	0.0494	0.3855	0.0021
	Valid N	N=8	N=11	N=16	N=13	N=16	N=5	N=16	N=10	N=14	N=16	N=16	N=13
All Sites	Mean	0.0022	0.0016	-0.0120	0.0023	0.3745	0.0023	0.0179	0.0007	0.0011	0.0220	0.2278	0.0005
	Std Deviation	0.0045	0.0017	0.0958	0.0020	0.5597	0.0044	0.0811	0.0009	0.0013	0.0400	0.2275	0.0010
	Median	0.0013	0.0012	-0.0126	0.0019	0.1893	0.0015	0.0042	0.0005	0.0009	0.0124	0.1662	0.0003
	Maximum	0.0237	0.0149	0.3049	0.0218	8.9056	0.0254	1.2390	3 .0074	0.0074	0.8990	2.0565	0.0043
	Valid N	N=645	N=717	N=1112	N=1055	N=1112	N=561	N=951	N=763	N=855	N=1112	N=1112	N=769

Appendix F. Summary Statistics for Monitored Metals

Site		HG	IN	K	LA	MN	MO	NI	P	PB	PD	RB	S
Plymouth	Mean	0.0000	0.0036	0.0850	0.0337	0.0055	-0.0021	0.0001	.	0.0049	0.0030	0.0005	0.9141
	Std Deviation	0.0000	0.0069	0.0596	0.0556	0.0055	0.0100	0.0009	.	0.0036	0.0036	0.0013	0.5270
	Median	0.0000	0.0029	0.0754	0.0223	0.0046	-0.0033	0.0000	.	0.0045	0.0023	0.0002	0.7800
	Maximum	0.0000	0.0220	0.3365	0.1792	0.0325	0.0203	0.0023	.	0.0146	0.0116	0.0037	2.7316
	Valid N	N=2	N=29	N=55	N=27	N=55	N=55	N=55	N=0	N=54	N=33	N=47	N=55
BushSt	Mean	0.0000	0.0045	0.1365	0.0294	0.0117	0.0008	0.0011	.	0.0093	0.0020	0.0008	0.9558
	Std Deviation	0.0000	0.0081	0.1373	0.0589	0.0095	0.0120	0.0013	.	0.0066	0.0033	0.0013	0.5586
	Median	0.0000	0.0022	0.0994	0.0208	0.0092	0.0005	0.0009	.	0.0079	0.0011	0.0007	0.8372
	Maximum	0.0000	0.0286	1.1681	0.2136	0.0500	0.0291	0.0088	.	0.0372	0.0170	0.0047	3.1685
	Valid N	N=2	N=67	N=130	N=62	N=130	N=130	N=130	N=0	N=129	N=70	N=116	N=130
HardingHi	Mean	0.0000	0.0012	0.0671	0.0851	0.0067	-0.0125	0.0013	.	0.0074	0.0021	0.0000	0.7265
	Std Deviation	0.0000	0.0041	0.0347	0.0570	0.0045	0.0108	0.0007	.	0.0078	0.0009	0.0012	0.5036
	Median	0.0000	0.0016	0.0582	0.0875	0.0062	-0.0123	0.0015	.	0.0052	0.0019	0.0000	4 .6078
	Maximum	0.0000	0.0049	0.1294	0.1793	0.0180	0.0057	0.0025	.	0.0275	0.0034	0.0019	2.1399
	Valid N	N=3	N=4	N=16	N=9	N=16	N=16	N=16	N=0	N=16	N=5	N=12	N=16
MplsLibrary	Mean	0.0000	0.0052	0.1459	0.0388	0.0105	-0.0005	0.0019	.	0.0066	0.0023	0.0007	1.1079
	Std Deviation	0.0000	0.0094	0.1352	0.0508	0.0087	0.0123	0.0034	.	0.0055	0.0034	0.0013	0.6402
	Median	0.0000	0.0025	0.1112	0.0317	0.0084	-0.0007	0.0008	.	0.0060	0.0014	0.0004	1.0011
	Maximum	0.0000	0.0357	0.9459	0.1540	0.0401	0.0257	0.0198	.	0.0439	0.0135	0.0050	3.4394
	Valid N	N=5	N=70	N=122	N=67	N=122	N=122	N=121	N=0	N=120	N=68	N=107	N=122
MhahaAcad	Mean	0.0000	0.0040	0.1032	0.0218	0.0071	-0.0029	0.0007	.	0.0056	0.0025	0.0003	0.8963
	Std Deviation	0.0000	0.0092	0.0909	0.0515	0.0069	0.0131	0.0008	.	0.0045	0.0030	0.0013	0.4972
	Median	0.0000	0.0012	0.0713	0.0083	0.0050	-0.0030	0.0007	.	0.0049	0.0026	0.0002	0.8782
	Maximum	0.0000	0.0292	0.4573	0.1493	0.0343	0.0313	0.0031	.	0.0172	0.0103	0.0037	2.4425
	Valid N	N=4	N=35	N=56	N=29	N=56	N=56	N=55	N=0	N=56	N=30	N=47	N=56
I_Falls1241	Mean	0.0000	0.0064	0.0596	0.0274	0.0024	0.0001	0.0002	.	0.0030	0.0016	0.0006	0.7406
	Std Deviation	0.0000	0.0057	0.0357	0.0558	0.0026	0.0106	0.0007	.	0.0026	0.0027	0.0013	0.4989
	Median	0.0000	0.0066	0.0536	0.0198	0.0022	0.0019	0.0002	.	0.0023	0.0016	0.0003	0.6069
	Maximum	0.0000	0.0210	0.2027	0.1589	0.0093	0.0196	0.0014	.	0.0103	0.0082	0.0041	2.3147
	Valid N	N=7	N=31	N=58	N=31	N=58	N=58	N=58	N=0	N=52	N=34	N=48	N=58
Sandstone	Mean	0.0000	0.0065	0.0613	0.0323	0.0034	0.0004	0.0001	.	0.0024	0.0020	0.0004	0.6188
	Std Deviation	.	0.0069	0.0551	0.0528	0.0048	0.0109	0.0007	.	0.0029	0.0030	0.0012	0.4305
	Median	0.0000	0.0055	0.0436	0.0225	0.0023	0.0004	0.0000	.	0.0024	0.0010	0.0001	0.5386
	Maximum	0.0000	0.0215	0.3334	0.1799	0.0315	0.0285	0.0020	.	0.0107	0.0101	0.0030	2.4567
	Valid N	N=1	N=31	N=59	N=33	N=59	N=59	N=58	N=0	N=55	N=30	N=52	N=59
FergusFalls	Mean	0.0000	0.0037	0.1209	0.0310	0.0102	0.0020	0.0001	.	0.0052	0.0023	0.0010	0.7505

Appendix F. Summary Statistics for Monitored Metals

Site		HG	IN	K	LA	MN	MO	NI	P	PB	PD	RB	S
	Std Deviation	0.0000	0.0056	0.1038	0.0562	0.0117	0.0140	0.0008	.	0.0054	0.0031	0.0015	0.4237
	Median	0.0000	0.0025	0.0942	0.0254	0.0067	0.0036	0.0002	.	0.0049	0.0013	0.0010	0.7159
	Maximum	0.0000	0.0181	0.5400	0.1482	0.0640	0.0325	0.0024	.	0.0262	0.0093	0.0041	2.5916
	Valid N	N=2	N=24	N=57	N=23	N=57	N=57	N=56	N=0	N=56	N=29	N=49	N=57
Alexandria	Mean	0.0000	0.0046	0.0602	0.0248	0.0043	-0.0026	0.0002	.	0.0031	0.0015	0.0003	0.7078
	Std Deviation	0.0000	0.0062	0.0380	0.0443	0.0042	0.0118	0.0009	.	0.0035	0.0024	0.0010	0.3941
	Median	0.0000	0.0059	0.0504	0.0124	0.0034	-0.0029	0.0002	.	0.0030	0.0015	0.0003	0.6595
	Maximum	0.0000	0.0142	0.1718	0.0992	0.0189	0.0258	0.0026	.	0.0155	0.0072	0.0027	1.9924
	Valid N	N=5	N=25	N=48	N=17	N=48	N=48	N=48	N=0	N=47	N=22	N=46	N=48
Moorhead	Mean	.	0.0041	0.0874	0.0683	0.0079	-0.0107	0.0007	.	0.0025	0.0025	0.0008	0.5390
	Std Deviation	.	0.0072	0.0385	0.0612	0.0047	0.0108	0.0007	.	0.0019	0.0038	0.0017	0.2338
	Median	.	0.0004	0.0767	0.0670	0.0082	-0.0122	0.0008	.	0.0022	0.0010	0.0002	0.5053
	Maximum	.	0.0144	0.1647	0.1443	0.0147	0.0071	0.0019	.	0.0072	0.0097	0.0047	1.1723
	Valid N	N=0	N=5	N=13	N=6	N=13	N=13	N=13	N=0	N=12	N=8	N=11	N=13
Bemidji	Mean	0.0000	0.0082	0.0566	0.0679	0.0034	-0.0073	0.0006	.	0.0020	0.0045	0.0002	0.3820
	Std Deviation	0.0000	0.0063	0.0521	0.0700	0.0042	0.0067	0.0007	.	0.0028	0.0039	0.0008	0.2214
	Median	0.0000	0.0075	0.0431	0.0758	0.0025	-0.0096	0.0006	.	0.0012	0.0029	0.0003	0.3419
	Maximum	0.0000	0.0164	0.2052	0.1316	0.0146	0.0087	0.0020	.	0.0075	0.0096	0.0012	0.9695
	Valid N	N=2	N=10	N=14	N=4	N=14	N=14	N=14	N=0	N=13	N=6	N=11	N=14
Warroad	Mean	1 .0000	0.0030	0.0920	0.0394	0.0047	-0.0036	0.0005	.	0.0017	0.0017	0.0004	0.5218
	Std Deviation	0.0000	0.0070	0.0755	0.0559	0.0052	0.0147	0.0007	.	0.0025	0.0028	0.0012	0.3235
	Median	3 .0000	0.0017	0.0770	0.0252	0.0032	-0.0020	0.0005	.	0.0016	0.0008	0.0003	0.4832
	Maximum	0.0000	0.0189	0.3554	0.1813	0.0258	0.0180	0.0026	.	0.0098	0.0103	0.0030	1.4213
	Valid N	N=8	N=25	N=57	N=27	N=57	N=57	N=55	N=0	N=53	N=30	N=52	N=57
LittleFalls	Mean	0.0000	0.0049	0.0840	0.0250	0.0053	-0.0014	0.0004	.	0.0035	0.0015	0.0007	0.7615
	Std Deviation	0.0000	0.0083	0.0707	0.0450	0.0074	0.0107	0.0007	.	0.0025	0.0033	0.0013	0.4337
	Median	0.0000	0.0047	0.0670	0.0278	0.0027	-0.0034	0.0005	.	0.0036	0.0003	0.0005	0.6410
	Maximum	0.0000	0.0310	0.4533	0.1261	0.0473	0.0273	0.0017	.	0.0078	0.0106	0.0032	2.0505
	Valid N	N=4	N=31	N=49	N=24	N=49	N=49	N=49	N=0	N=49	N=23	N=40	N=49
ElkRiver	Mean	0.0000	0.0014	0.1038	0.0387	0.0087	0.0000	0.0007	.	0.0038	0.0023	0.0010	0.7536
	Std Deviation	0.0000	0.0061	0.1048	0.0589	0.0129	0.0112	0.0008	.	0.0035	0.0030	0.0016	0.3649
	Median	0.0000	0.0007	0.0707	0.0324	0.0042	0.0035	0.0007	.	0.0037	0.0018	0.0008	0.7214
	Maximum	0.0000	0.0194	0.5132	0.1746	0.0705	0.0198	0.0022	.	0.0147	0.0084	0.0055	1.6983
	Valid N	N=11	N=26	N=54	N=25	N=54	N=54	N=53	N=0	N=54	N=31	N=47	N=54
St.Cloud	Mean	0.0000	0.0098	0.0552	0.0104	0.0039	-0.0055	0.0007	.	0.0032	0.0015	0.0007	0.5144
	Std Deviation	0.0000	0.0048	0.0294	0.0339	0.0023	0.0086	0.0007	.	0.0039	0.0034	0.0014	0.3404

Appendix F. Summary Statistics for Monitored Metals

Site		HG	IN	K	LA	MN	MO	NI	P	PB	PD	RB	S
	Median	0.0000	0.0098	0.0524	0.0021	0.0044	-0.0040	0.0009	.	0.0024	0.0003	0.0006	0.3959
	Maximum	0.0000	0.0175	0.1115	0.0673	0.0092	0.0069	0.0017	.	0.0122	0.0080	0.0035	1.2720
	Valid N	N=2	N=6	N=16	N=6	N=16	N=16	N=16	N=0	N=16	N=9	N=14	N=16
Pipestone	Mean	0.0000	0.0029	0.0740	0.0190	0.0094	0.0022	0.0002	0.0000	0 .0038	0.0022	0.0002	0.8340
	Std Deviation	0.0000	0.0059	0.0634	0.0531	0.0108	0.0115	0.0008	.	0.0028	0.0032	0.0011	0.4271
	Median	0.0000	0.0033	0.0612	0.0154	0.0067	0.0015	0.0000	0.0000	0 .0035	0.0016	0.0001	0.8331
	Maximum	0.0000	0.0142	0.3819	0.2360	0.0504	0.0295	0.0019	0.0000	0 .0099	0.0112	0.0032	2.1288
	Valid N	N=5	N=26	N=57	N=30	N=57	N=57	N=57	N=1	N=56	N=30	N=54	N=57
GraniteFalls	Mean	0.0000	0.0045	0.0899	0.0339	0.0072	-0.0015	0.0002	.	0.0030	0.0012	0.0004	0.9979
	Std Deviation	0.0000	0.0066	0.0765	0.0462	0.0072	0.0197	0.0008	.	0.0027	0.0016	0.0014	0.5081
	Median	0.0000	0.0038	0.0677	0.0229	0.0045	-0.0010	0.0002	.	0.0032	0.0009	0.0002	0.8888
	Maximum	0.0000	0.0185	0.3646	0.1431	0.0310	0.0958	0.0020	.	0.0090	0.0044	0.0041	2.4390
	Valid N	N=7	N=31	N=57	N=24	N=57	N=57	N=56	N=0	N=56	N=23	N=51	N=57
Holloway	Mean	0.0000	0.0082	0.0548	0.0497	0.0073	-0.0134	0.0003	.	0.0044	0.0028	0.0007	0.4233
	Std Deviation	.	0.0123	0.0517	0.0198	0.0078	0.0081	0.0008	.	0.0073	0.0020	0.0012	0.2913
	Median	0.0000	0.0039	0.0388	0.0495	0.0057	-0.0125	0.0005	.	0.0033	0.0024	0.0005	0.3073
	Maximum	0.0000	0.0250	0.1757	0.0718	0.0286	0.0008	0.0019	.	0.0293	0.0056	0.0022	1.0336
	Valid N	N=1	N=6	N=15	N=5	N=15	N=15	N=15	N=0	N=15	N=5	N=12	N=15
Rochester	Mean	0.0000	0.0024	0.1067	0.0632	0.0051	0.0001	0.0004	.	0.0040	0.0030	0.0005	0.8902
	Std Deviation	0.0000	0.0066	0.0833	0.0737	0.0047	0.0138	0.0007	.	0.0044	0.0036	0.0012	0.4405
	Median	0.0000	0.0002	0.0829	0.0845	0.0046	0.0009	0.0005	.	0.0037	0.0030	0.0004	0.7721
	Maximum	0.0000	0.0178	0.3812	0.2098	0.0214	0.0353	0.0017	.	0.0211	0.0154	0.0027	1.9827
	Valid N	N=5	N=28	N=51	N=27	N=51	N=51	N=50	N=0	N=51	N=27	N=45	N=51
Winona	Mean	0.0000	0.0069	0.0628	0.0692	0.0071	-0.0069	0.0004	.	0.0052	0.0012	0.0000	1 .6544
	Std Deviation	0.0000	0.0079	0.0559	0.0610	0.0081	.0137	0.0008	. .	0.0089	0.0023	0.0006	0.3598
	Median	0.0000	0.0069	0.0420	0.0775	0.0034	-0.0080	0.0003	.	0.0023	0.0000	4 -.000	2 .5512
	Maximum	0.0000	0.0189	0.1601	0.1968	0.0264	0.0226	0.0019	.	0.0285	0.0046	0.0012	1.4593
	Valid N	N=2	N=6	N=10	N=9	N=10	N=10	N=10	N=0	N=10	N=7	N=9	N=10
Zumbrota	Mean	0.0000	0.0072	0.1096	0.0405	0.0041	0.0000	0.0002	.	0.0037	0.0022	0.0007	0.8962
	Std Deviation	0.0000	0.0093	0.1653	0.0638	0.0053	0.0104	0.0007	.	0.0027	0.0037	0.0011	0.5383
	Median	0.0000	0.0062	0.0632	0.0304	0.0030	-0.0005	0.0001	.	0.0039	0.0015	0.0006	0.8344
	Maximum	0.0000	0.0340	1.0659	0.2004	0.0272	0.0219	0.0022	.	0.0119	0.0093	0.0040	3.1819
	Valid N	N=5	N=23	N=48	N=31	N=48	N=48	N=48	N=0	N=45	N=20	N=44	N=48
Hibbing	Mean	0.0000	0.0038	0.0583	0.0488	0.0084	0.0014	0.0003	.	0.0047	0.0028	0.0001	0.6669
	Std Deviation	.	0.0059	0.0703	0.0604	0.0106	0.0133	0.0009	.	0.0109	0.0029	0.0010	0.4121
	Median	2 .0000	0.0022	0.0479	0.0411	0.0057	0.0028	0.0003	.	0.0021	0.0021	0.0000	1 .6071

Appendix F. Summary Statistics for Monitored Metals

Site		HG	IN	K	LA	MN	MO	NI	P	PB	PD	RB	S
	Maximum	0.0000	0.0144	0.5206	0.2094	0.0626	0.0286	0.0025	.	0.0675	0.0093	0.0031	2.0459
	Valid N	N=1	N=25	N=54	N=29	N=54	N=54	N=53	N=0	N=52	N=30	N=46	N=54
Duluth	Mean	0.0000	0.0056	0.0253	0.0587	0.0024	-0.0114	0.0008	.	0.0022	0.0014	0.0007	0.4177
	Std Deviation	.	0.0088	0.0129	0.0568	0.0021	0.0090	0.0010	.	0.0023	0.0031	0.0011	0.2116
	Median	0.0000	0.0048	0.0263	0.0410	0.0023	-0.0114	0.0010	.	0.0015	0.0021	0.0005	0.4004
	Maximum	0.0000	0.0218	0.0537	0.1579	0.0072	0.0050	0.0024	.	0.0076	0.0067	0.0027	0.8476
	Valid N	N=1	N=10	N=16	N=8	N=16	N=16	N=16	N=0	N=14	N=9	N=16	N=16
All Sites	Mean	0.0000	0.0046	0.0960	0.0366	0.0072	-0.0012	0.0006	0.0000	0 .0047	0.0022	0.0005	0.8134
	Std Deviation	0.0000	0.0076	0.0996	0.0563	0.0084	0.0127	0.0015	.	0.0054	0.0031	0.0013	0.5075
	Median	0.0000	0.0031	0.0685	0.0280	0.0048	-0.0011	0.0004	0.0000	0 .0037	0.0015	0.0003	0.7135
	Maximum	0.0000	0.0357	1.1681	0.2360	0.0705	0.0958	0.0198	0.0000	0 .0675	0.0170	0.0055	3.4394
	Valid N	N=85	N=574	N=1112	N=553	N=1112	N=1112	N=1102	N=1	N=1081	N=579	N=976	N=1112

Appendix F. Summary Statistics for Monitored Metals

Site		SB	SE	SN	SR	TI	V	Y	ZN	ZR	PM_10
Plymouth	Mean	0.0165	0.0003	0.0127	0.0013	0.0118	.	0.0002	0.0125	0.0002	15.1400
	Std Deviation	0.0205	0.0006	0.0130	0.0021	0.0091	.	0.0020	0.0074	0.0040	7.1900
	Median	0.0128	0.0002	0.0124	0.0011	0.0101	.	0.0000	0.0118	0.0001	14.4000
	Maximum	0.0738	0.0018	0.0476	0.0071	0.0436	.	0.0042	0.0310	0.0099	35.5000
	Valid N	N=33	N=38	N=31	N=55	N=55	N=0	N=46	N=55	N=55	N=55
BushSt	Mean	0.0092	0.0007	0.0105	0.0023	0.0277	0.0057	0.0005	0.0327	0.0018	21.5500
	Std Deviation	0.0153	0.0008	0.0099	0.0029	0.0242	0.0059	0.0027	0.0293	0.0047	10.4800
	Median	0.0086	0.0006	0.0105	0.0022	0.0190	0.0057	-0.0001	0.0246	0.0013	19.5000
	Maximum	0.0657	0.0030	0.0433	0.0226	0.1347	0.0099	0.0101	0.1871	0.0166	56.9000
	Valid N	N=67	N=89	N=88	N=130	N=130	N=2	N=113	N=130	N=130	N=130
HardingHi	Mean	0.0137	0.0006	0.0106	0.0012	0.0085	.	0.0028	0.0297	0.0050	14.5200
	Std Deviation	0.0151	0.0008	0.0111	0.0021	0.0062	.	0.0024	0.0242	0.0029	7.4500
	Median	0.0166	0.0004	0.0073	0.0015	0.0068	.	0.0030	0.0194	0.0040	14.3500
	Maximum	0.0381	0.0017	0.0277	0.0039	0.0254	.	0.0071	0.1012	0.0101	29.5000
	Valid N	N=10	N=9	N=8	N=16	N=16	N=0	N=16	N=16	N=16	N=16
MplsLibrary	Mean	0.0113	0.0008	0.0090	0.0025	0.0247	0.0119	0.0003	0.0210	0.0027	22.0000
	Std Deviation	0.0144	0.0007	0.0114	0.0028	0.0254	0.0107	0.0023	0.0103	0.0046	10.1400
	Median	0.0093	0.0007	0.0074	0.0023	0.0194	0.0084	-0.0003	0.0198	0.0020	20.2000
	Maximum	0.0489	0.0034	0.0610	0.0178	0.1810	0.0311	0.0065	0.0659	0.0184	67.6000
	Valid N	N=70	N=75	N=74	N=122	N=122	N=9	N=99	N=122	N=122	N=122
MhahaAcad	Mean	0.0079	0.0007	0.0118	0.0013	0.0129	.	0.0005	0.0159	0.0016	18.1000
	Std Deviation	0.0147	0.0008	0.0105	0.0023	0.0170	.	0.0023	0.0083	0.0048	8.4400
	Median	0.0046	0.0005	0.0097	0.0012	0.0068	.	0.0000	0.0156	0.0014	17.9000
	Maximum	0.0514	0.0030	0.0353	0.0057	0.1010	.	0.0062	0.0362	0.0151	40.4000
	Valid N	N=29	N=32	N=26	N=56	N=56	N=0	N=51	N=56	N=56	N=56
I_Falls1241	Mean	0.0132	0.0003	0.0072	0.0010	0.0066	.	-0.0002	0.0068	0.0001	9.4600
	Std Deviation	0.0145	0.0007	0.0075	0.0021	0.0065	.	0.0014	0.0049	0.0040	4.4800
	Median	0.0124	0.0001	0.0074	0.0010	0.0053	.	-0.0002	0.0056	0.0005	8.7500
	Maximum	0.0456	0.0021	0.0239	0.0073	0.0288	.	0.0025	0.0208	0.0091	22.3000
	Valid N	N=26	N=29	N=32	N=58	N=58	N=0	N=41	N=58	N=58	N=58
Sandstone	Mean	0.0098	0.0004	0.0046	0.0013	0.0082	.	0.0002	0.0072	0.0000	1 9.58
	Std Deviation	0.0140	0.0007	0.0066	0.0017	0.0103	.	0.0017	0.0068	0.0031	5.6900
	Median	0.0038	0.0004	0.0033	0.0012	0.0057	.	0.0002	0.0054	0.0000	1 8.10
	Maximum	0.0545	0.0027	0.0238	0.0054	0.0503	.	0.0037	0.0289	0.0072	28.4000
	Valid N	N=32	N=37	N=31	N=59	N=59	N=0	N=51	N=59	N=59	N=59
FergusFalls	Mean	0.0057	0.0008	0.0063	0.0023	0.0168	.	-0.0002	0.0182	0.0004	17.9700

Appendix F. Summary Statistics for Monitored Metals

Site		SB	SE	SN	SR	TI	V	Y	ZN	ZR	PM_10
	Std Deviation	0.0119	0.0009	0.0089	0.0026	0.0222	.	0.0020	0.0178	0.0042	10.0800
	Median	0.0046	0.0007	0.0058	0.0019	0.0117	.	-0.0005	0.0127	0.0000	16.2000
	Maximum	0.0344	0.0032	0.0267	0.0136	0.1024	.	0.0059	0.0847	0.0125	55.4000
	Valid N	N=32	N=36	N=42	N=57	N=57	N=0	N=46	N=57	N=57	N=57
Alexandria	Mean	0.0067	0.0005	0.0056	0.0011	0.0070	.	0.0000	0.0082	0.0000	5 10.81
	Std Deviation	0.0110	0.0008	0.0077	0.0020	0.0076	.	0.0018	0.0053	0.0036	4.7500
	Median	0.0074	0.0006	0.0035	0.0012	0.0055	.	0.0001	0.0075	-0.0010	0 10.70
	Maximum	0.0386	0.0019	0.0270	0.0054	0.0290	.	0.0032	0.0201	0.0079	21.2000
	Valid N	N=23	N=33	N=26	N=48	N=48	N=0	N=36	N=48	N=48	N=49
Moorhead	Mean	0.0176	0.0002	0.0046	0.0015	0.0135	.	0.0034	0.0210	0.0069	14.2000
	Std Deviation	0.0125	0.0007	0.0066	0.0025	0.0077	.	0.0023	0.0072	0.0042	4.1700
	Median	0.0190	0.0000	0.0071	0.0015	0.0117	.	0.0037	0.0210	0.0066	13.6000
	Maximum	0.0294	0.0012	0.0141	0.0046	0.0306	.	0.0069	0.0372	0.0133	25.6000
	Valid N	N=3	N=7	N=9	N=13	N=13	N=0	N=13	N=13	N=13	N=13
Bemidji	Mean	0.0040	0.0003	0.0043	0.0011	0.0073	.	0.0029	0.0107	0.0060	10.2600
	Std Deviation	0.0102	0.0004	0.0061	0.0030	0.0084	.	0.0034	0.0051	0.0042	5.2100
	Median	0.0021	0.0002	0.0025	0.0017	0.0059	.	0.0037	0.0092	0.0053	8.1500
	Maximum	0.0199	0.0009	0.0134	0.0068	0.0325	.	0.0066	0.0226	0.0144	24.1000
	Valid N	N=8	N=5	N=10	N=14	N=14	N=0	N=14	N=14	N=14	N=14
Warroad	Mean	0.0152	0.0005	0.0095	0.0010	0.0096	.	0.0005	0.0075	0.0013	11.6900
	Std Deviation	0.0223	0.0006	0.0114	0.0023	0.0127	.	0.0022	0.0058	0.0053	6.6600
	Median	0.0072	0.0004	0.0078	0.0010	0.0063	.	0.0001	0.0066	0.0007	11.6000
	Maximum	0.0778	0.0022	0.0396	0.0065	0.0603	.	0.0052	0.0264	0.0140	39.8000
	Valid N	N=23	N=36	N=36	N=57	N=57	N=0	N=50	N=57	N=57	N=57
LittleFalls	Mean	0.0052	0.0003	0.0067	0.0008	0.0111	.	-0.0002	0.0115	0.0001	13.1700
	Std Deviation	0.0114	0.0006	0.0101	0.0018	0.0132	.	0.0021	0.0069	0.0034	7.5200
	Median	0.0020	0.0001	0.0054	0.0009	0.0073	.	-0.0004	0.0113	0.0000	11.4000
	Maximum	0.0342	0.0019	0.0304	0.0047	0.0705	.	0.0053	0.0380	0.0076	42.7000
	Valid N	N=23	N=28	N=27	N=49	N=49	N=0	N=47	N=49	N=49	N=49
ElkRiver	Mean	0.0069	0.0007	0.0075	0.0013	0.0132	.	0.0010	0.0167	0.0020	16.8200
	Std Deviation	0.0127	0.0008	0.0116	0.0022	0.0195	.	0.0022	0.0076	0.0056	8.4200
	Median	0.0065	0.0004	0.0040	0.0012	0.0073	.	0.0007	0.0175	0.0012	15.3000
	Maximum	0.0365	0.0031	0.0373	0.0060	0.0925	.	0.0064	0.0343	0.0164	41.4000
	Valid N	N=33	N=39	N=29	N=54	N=54	N=0	N=40	N=54	N=54	N=54
St.Cloud	Mean	0.0037	0.0006	0.0103	0.0010	0.0077	.	0.0034	0.0179	0.0044	9.9900
	Std Deviation	0.0120	0.0009	0.0137	0.0018	0.0067	.	0.0024	0.0079	0.0030	5.2900

Appendix F. Summary Statistics for Monitored Metals

Site		SB	SE	SN	SR	TI	V	Y	ZN	ZR	PM_10
	Median	0.0074	0.0003	0.0040	0.0005	0.0052	.	0.0036	0.0183	0.0044	9.6500
	Maximum	0.0248	0.0022	0.0356	0.0048	0.0262	.	0.0081	0.0328	0.0089	21.8000
	Valid N	N=9	N=9	N=13	N=16	N=16	N=0	N=16	N=16	N=16	N=16
Pipestone	Mean	0.0158	0.0006	0.0102	0.0019	0.0108	.	-0.0001	0.0122	0.0000	12.8000
	Std Deviation	0.0148	0.0009	0.0116	0.0022	0.0108	.	0.0015	0.0114	0.0032	6.1400
	Median	0.0124	0.0005	0.0094	0.0017	0.0083	.	-0.0003	0.0105	0.0001	13.7000
	Maximum	0.0493	0.0028	0.0365	0.0086	0.0523	.	0.0033	0.0769	0.0088	36.9000
	Valid N	N=30	N=45	N=33	N=57	N=57	N=0	N=43	N=57	N=57	N=57
GraniteFalls	Mean	0.0118	0.0009	0.0076	0.0010	0.0100	.	0.0006	0.0099	0.0012	15.5900
	Std Deviation	0.0183	0.0010	0.0112	0.0021	0.0117	.	0.0024	0.0053	0.0053	7.1200
	Median	0.0051	0.0007	0.0057	0.0009	0.0067	.	0.0004	0.0096	0.0007	16.0000
	Maximum	0.0578	0.0033	0.0388	0.0063	0.0523	.	0.0068	0.0209	0.0145	35.1000
	Valid N	N=26	N=39	N=32	N=57	N=57	N=0	N=51	N=57	N=57	N=57
Holloway	Mean	0.0151	0.0006	0.0104	0.0012	0.0067	.	0.0027	0.0126	0.0056	11.8000
	Std Deviation	0.0163	0.0008	0.0121	0.0026	0.0069	.	0.0029	0.0047	0.0031	8.3700
	Median	0.0226	0.0004	0.0087	0.0015	0.0032	.	0.0036	0.0126	0.0049	10.1000
	Maximum	0.0361	0.0017	0.0381	0.0055	0.0233	.	0.0080	0.0192	0.0116	27.1000
	Valid N	N=11	N=7	N=9	N=15	N=15	N=0	N=15	N=15	N=15	N=15
Rochester	Mean	0.0058	0.0008	0.0067	0.0016	0.0099	.	0.0002	0.0150	0.0002	17.4700
	Std Deviation	0.0135	0.0008	0.0082	0.0023	0.0106	.	0.0025	0.0089	0.0045	9.5600
	Median	0.0044	0.0007	0.0070	0.0019	0.0080	.	-0.0009	0.0134	0.0002	15.5000
	Maximum	0.0424	0.0030	0.0248	0.0069	0.0408	.	0.0079	0.0557	0.0123	61.6000
	Valid N	N=33	N=38	N=35	N=51	N=51	N=0	N=42	N=51	N=51	N=51
Winona	Mean	0.0132	0.0007	0.0132	0.0013	0.0084	.	0.0026	0.0309	0.0066	14.4100
	Std Deviation	0.0142	0.0011	0.0090	0.0022	0.0087	.	0.0015	0.0273	0.0028	8.8000
	Median	0.0062	0.0002	0.0124	0.0006	0.0057	.	0.0030	0.0224	0.0069	12.3500
	Maximum	0.0361	0.0031	0.0233	0.0063	0.0285	.	0.0046	0.0950	0.0101	28.9000
	Valid N	N=6	N=9	N=4	N=10	N=10	N=0	N=10	N=10	N=10	N=10
Zumbrota	Mean	0.0105	0.0008	0.0080	0.0011	0.0091	.	-0.0002	0.0109	0.0000	14.4500
	Std Deviation	0.0126	0.0009	0.0118	0.0019	0.0136	.	0.0019	0.0060	0.0035	6.4300
	Median	0.0087	0.0004	0.0042	0.0008	0.0065	.	-0.0004	0.0096	0.0001	13.0500
	Maximum	0.0435	0.0035	0.0416	0.0055	0.0740	.	0.0042	0.0258	0.0081	31.2000
	Valid N	N=24	N=30	N=30	N=48	N=48	N=0	N=39	N=48	N=48	N=48
Hibbing	Mean	0.0029	0.0007	0.0054	0.0011	0.0067	.	0.0013	0.0103	0.0017	11.1600
	Std Deviation	0.0129	0.0007	0.0107	0.0025	0.0152	.	0.0032	0.0081	0.0049	6.7400
	Median	0.0000	8 .0004	0.0009	0.0008	0.0037	.	0.0005	0.0093	0.0011	9.5500

Appendix F. Summary Statistics for Monitored Metals

Site		SB	SE	SN	SR	TI	V	Y	ZN	ZR	PM_10
	Maximum	0.0465	0.0023	0.0400	0.0089	0.1093	.	0.0109	0.0445	0.0143	38.6000
	Valid N	N=35	N=38	N=35	N=54	N=54	N=0	N=44	N=54	N=54	N=54
Duluth	Mean	0.0142	0.0003	0.0120	0.0005	0.0030	.	0.0033	0.0086	0.0067	7.4100
	Std Deviation	0.0112	0.0007	0.0122	0.0021	0.0048	.	0.0026	0.0050	0.0041	3.0300
	Median	0.0179	0.0001	0.0118	0.0007	0.0027	.	0.0033	0.0072	0.0054	6.7500
	Maximum	0.0288	0.0015	0.0374	0.0045	0.0098	.	0.0079	0.0231	0.0148	13.4000
	Valid N	N=11	N=9	N=8	N=16	N=16	N=0	N=16	N=16	N=16	N=16
All Sites	Mean	0.0098	0.0006	0.0084	0.0015	0.0137	0.0108	0.0006	0.0157	0.0014	15.4400
	Std Deviation	0.0150	0.0008	0.0104	0.0024	0.0179	0.0101	0.0024	0.0155	0.0046	9.0200
	Median	0.0068	0.0004	0.0069	0.0014	0.0084	0.0084	0.0001	0.0123	0.0012	13.8000
	Maximum	0.0778	0.0035	0.0610	0.0226	0.1810	0.0311	0.0109	0.1871	0.0184	67.6000
	Valid N	N=597	N=717	N=668	N=1112	N=1112	N=11	N=939	N=1112	N=1112	N=1113

APPENDIX G

Appendix G. Description of Ambient Air Toxic Monitoring and Analysis Procedures

The MPCA collects ambient air toxic samples every six days over a 24-hour period. The standard operating procedure is to retrieve the samples from the sites within 24 hours of collection and return them to the MPCA Air Monitoring Lab in St. Paul. Analysis is performed for 35 volatile organic compounds (VOCs), seven carbonyl compounds and 33 particulate elements. The MPCA began VOC and carbonyl analysis in 1991. Particulate element analysis began in September 1996.

Volatile Organic Compounds

VOC samples are collected in summa canisters. Canisters are deployed to the field, where the site operator attaches them to a Xontech instrument. When the sample has been collected, the canisters are returned to the lab, where they are mounted on a Varian Saturn Gas Chromatograph/Mass Spectrometer and analyzed. After the analysis is completed, the canisters are moved to the cleaning station. At the cleaning station, the canisters are cleaned and evacuated to a negative pressure. The canisters are then taken back out to the field.

Carbonyls

Carbonyl samples are chemically trapped on a silica gel cartridge that contains 2,4-dinitrophenylhydrazine (DNPH). Cartridges are cleaned and impregnated with DNPH. The cartridges are deployed to the field along with the VOC canisters and inserted into the Xontech instrument, which draws ambient air through the cartridges. After samples have been collected, the cartridges are returned to the MPCA Air Monitoring Lab and kept refrigerated until they are analyzed. The cartridges are extracted with acetonitrile (CH_3CN), and then injected into a Dionex High Performance Liquid Chromatography instrument.

PM_{10}, Particulate Elements (Metals)

Particulate matter less than 10 microns in diameter is collected on quartz filters and analyzed using gravimetric analyses. Filters are weighed before deployment to obtain a tare weight value. Filters are deployed to the field and inserted into the particulate monitor. Exposed filters are returned to the lab, where they are reweighed. Final concentration values are then calculated, using the tare and exposed weights.

After filters have been weighed for the final time, they are manually cut with a die and placed in a petri dish to create a sample for the TN Spectrace X-Ray Fluorescence (XRF) instrument. Filters are then processed with the XRF instrument.

APPENDIX H

Appendix H. Specific Locations of Ambient Monitors

MPCA air toxic monitoring sites

Site	Name	Start Date	End Date	Address	City	Latitude	Longitude
260	Plymouth	6. Sept 96	25. Sep 97	Plymouth Municipal Water Plant	Plymouth	45.03271	93.422
420	Koch420	6. Jan 91	Active	12821 Pine Bend Trail	Pine Bend	44.76328	93.03221
423	Koch423	6. Jan 91	Active	120th St. E.	Rosemount	44.7753	93.06303
426	Koch426	6. Jan 91	29. Dec 96	NE of Refinery	Pine Bend		
436	St. Paul Park	1. Jan 93	Active	649 5th St.	St. Paul Park	44.8475	92.99548
438	Ashland	14. Jun 95	Active	4th Avenue & 2nd Street	New Port	44.85756	93.00337
816	Holman Field	6. Jan 91	Active	Holman Field Airport	St. Paul		
820	Bush Street	18. Sep 96	Active	1038 Ross Ave	St. Paul	44.9656	93.05636
871	Harding High	2. Oct 98	Active	Harding High School, 1540 E. 6th St.	St. Paul	44.95935	93.03567
945	Mpls Library	29. Jan 91	Active	300 Nicollet Mall	Minneapolis	44.98045	93.27011
958	Minnehaha Academy	25. Sep 97	20. Oct 98	4200 W. River Parkway	Minneapolis	44.92636	93.20465
1240	International Falls	4. Aug 94 6. Sep 95 4. Jul 98	18. Aug 94 18. Sep 96 25. Nov 98	2 Second Ave. (Customs Building)	International Falls		
1241	International Falls	24. Sep 96	25. Sep 97		International Falls	48.60081	93.4145
1400	Sandstone	6. Sep 96	25. Sep 97	Northwoods Audobon Nature Center	Sandstone	46.12151	92.99995
2005	Fergus Falls	25. Sep 97	26. Sep 98	112 W. Washington	Fergus Falls	46.28162	96.0740[illegible]
2010	Alexandria	6. Sep 96	25. Sep 97	Douglas County Courthouse, 305 8th Ave. W.	Alexandria	45.88331	95.38006
2103	Moorhead	2. Oct 98	Active	Moorhead Senior High School, 1304 N. 15th Ave.	Moorhead	46.87207	96.74351
2302	Bemidji	2. Oct 98	Active	Kitchigami Regional Library, 509 America Ave.	Bemidji	47.47335	94.88447
2401	Warroad	25. Sep 97	26. Sep 98	Warroad Middle School	Warroad	48.91192	95.32831
3049	Little Falls	6. Sep 96	25. Sep 97	Little Falls High School, 1001 5th Ave.S.E.	Little Falls	45.97116	94.3472
3050	Elk River	25. Sep 97	26. Sep 98	13065 Orono Parkway	Elk River	45.30348	93.59969
3052	St. Cloud	2. Oct 98	Active	Talahi Community School, 1321 Michigan Ave. N.	St. Cloud		
4002	Pipestone	6. Sep 96	25. Sep 97	Pipestone Central School, 400 2nd Ave. S.W.	Pipestone	43.99745	96.31979
4003	Granite Falls	25. Sep 97	26. Sep 98	108 Baldwin	Granite Falls	44.81013	95.53567
4500	Holloway	2. Oct 98	Active	Schlueter Residence, Route 1, Box 3	Holloway		
5008	Rochester	25. Sep 97	26. Sep 98	Ben Franklin School, 1801 9th Ave. S.E.	Rochester	43.99492	92.44994
5210	Winona	2. Oct 98	Active	Winona Middle School, 166 W. Broadway	Winona		
5356	Zumbrota	6. Sep 96	25. Sep 97	14999 420th St.	Zumbrota	44.39765	92.8312
7014	Hibbing	25. Sep 97	26. Sep 98	23rd Street & 12th Avenue	Hibbing	47.42398	92.9269
7549	Duluth	2. Jan 94	Active	1532 W. Michigan Ave.	Duluth	46.77107	92.11712

APPENDIX I

Appendix I. U.S. EPA Cumulative Exposure Project (CEP) modeled concentrations in census tracts with monitoring sites. The CEP modeling data (1990 emissions) is for purposes of comparison with monitoring data (see Appendices J, K L).

			acrylic_acid	Propoxur	chloroprene	trimethylpentane(2,2,4)	butadiene(1,3)	hexane	polycyclic_organic_matter	PCDD/PCDFs
Site No.	**Site Name**	TRACT-KEY	ACRYLIC_AC	PROPOXUR	CHLOROPREN	TRIMETHYLP	BUTADIENE(	HEXANE	POLYCYCLIC	PCDD/PCDFS
260	**Plymouth**	27053026509	0.0000E+00	0.0000E+00	4.1498E-04	7.4096E-01	1.3657E-01	6.6856E-01	2.1963E-01	2.0000E-08
420	**Koch420**	27037061002	9.5500E-06	0.0000E+00	5.4484E-04	3.3918E-01	3.5131E-02	1.3428E+00	1.0916E-01	2.0000E-08
423	**Koch423**	27037061002	9.5500E-06	0.0000E+00	5.4484E-04	3.3918E-01	3.5131E-02	1.3428E+00	1.0916E-01	2.0000E-08
426	**Koch426**	27037061002	9.5500E-06	0.0000E+00	5.4484E-04	3.3918E-01	3.5131E-02	1.3428E+00	1.0916E-01	2.0000E-08
436	**StPaulPark**	27163071301	5.2420E-05	0.0000E+00	2.6628E-03	1.0189E+00	8.2317E-02	6.7895E+00	1.9450E-01	2.0000E-08
438	**Ashland**	27163071003	3.9170E-05	0.0000E+00	1.0246E-03	1.0519E+00	7.0895E-02	4.4031E+00	1.9042E-01	2.0000E-08
816	**HolmanFld**	27123036100	1.9690E-05	0.0000E+00	6.0790E-04	1.3579E+00	2.1547E-01	1.5588E+00	3.6329E-01	2.0000E-08
820	**BushSt**	27123031700	1.6200E-05	0.0000E+00	5.0584E-04	1.1863E+00	1.9744E-01	1.2302E+00	3.0778E-01	2.0000E-08
871	**HardingHi**	27123034602	1.7680E-05	0.0000E+00	5.3797E-04	1.4372E+00	4.3520E-01	1.6325E+00	3.7038E-01	2.0000E-08
945	**MplsLibrary**	27053004500	9.7600E-06	0.0000E+00	3.0157E-03	1.7370E+00	2.8182E-01	1.6330E+00	4.4381E-01	2.0000E-08
958	**MhahaAcad**	27053010500	1.2850E-05	0.0000E+00	6.9738E-04	1.4757E+00	3.1858E-01	1.3173E+00	3.6651E-01	2.0000E-08
1240	**I_Falls1240**	27071990200	0.0000E+00	0.0000E+00	0.0000E+00	3.2088E-01	1.1688E-01	3.7414E-01	1.0578E-01	2.0000E-08
1241	**I_Falls1241**	27071990200	0.0000E+00	0.0000E+00	0.0000E+00	3.2088E-01	1.1688E-01	3.7414E-01	1.0578E-01	2.0000E-08
1400	**Sandstone**	27115950500	0.0000E+00	0.0000E+00	0.0000E+00	3.4589E-02	5.8715E-03	3.1271E-02	1.0625E-02	2.0000E-08
2005	**FergusFalls**	27111961000	0.0000E+00	0.0000E+00	0.0000E+00	3.7531E-01	1.0679E-01	3.5482E-01	1.9988E-01	2.0000E-08
2010	**Alexandria**	27041950700	0.0000E+00	0.0000E+00	0.0000E+00	5.0455E-01	6.3727E-02	1.4104E+00	2.7761E-01	2.0000E-08
2401	**Warroad**	27135970100	0.0000E+00	0.0000E+00	3.6870E-05	2.4131E-02	5.2456E-03	3.1322E-02	8.0360E-03	2.0000E-08
3049	**LittleFalls**	27097980600	0.0000E+00	0.0000E+00	0.0000E+00	2.6123E-01	7.6528E-02	2.4392E-01	7.8321E-02	2.0000E-08
3050	**ElkRiver**	27141030500	0.0000E+00	0.0000E+00	3.0860E-05	2.2369E-01	3.1665E-02	1.8399E-01	6.8896E-02	2.0000E-08
4002	**Pipestone**	27117960300	0.0000E+00	0.0000E+00	0.0000E+00	2.2465E-01	4.1948E-02	2.4631E-01	4.5553E-02	2.0000E-08
4003	**GraniteFalls**	27023950300	0.0000E+00	0.0000E+00	0.0000E+00	4.6207E-02	7.6721E-03	4.0916E-02	1.1393E-02	2.0000E-08
5008	**Rochester**	27109001000	0.0000E+00	0.0000E+00	5.9120E-05	1.2267E+00	2.1489E-01	4.8292E-01	3.8374E-01	2.0000E-08
5356	**Zumbrota**	27049980500	1.0220E-05	0.0000E+00	2.7081E-04	7.3387E-02	7.9192E-03	1.5363E-01	3.5566E-02	2.0000E-08
7014	**Hibbing**	27137012300	0.0000E+00	0.0000E+00	1.0516E-02	1.0496E+00	2.1018E-01	4.6990E-01	2.2272E-01	2.0000E-08
7549	**Duluth7549**	27137002500	0.0000E+00	0.0000E+00	1.9565E-03	7.0929E-01	1.6199E-01	4.3002E-01	1.6727E-01	2.0000E-08

Appendix I. U.S. EPA Cumulative Exposure Project (CEP) modeled concentrations in census tracts with monitoring sites. The CEP modeling data (1990 emissions) is for purposes of comparison with monitoring data (see Appendices J, K L).

		propionaldehyde_total	chlordane	hexachlorobenzene	hexachlorobutadiene	Lindane	methyl_bromide	methyl_iodide	methyl_hydrazine	pentachlorophenol
Site No.	Site Name	PROPIONALD	CHLORDANE	HEXACHLORO	HEXACHLORO	LINDANE	METHYL_BRO	METHYL_IOD	METHYL_HYD	PENTACHLOR
260	**Plymouth**	1.8608E-01	9.8900E-06	9.3200E-05	1.8100E-03	2.5000E-04	4.5488E-02	1.1600E-02	0.0000E+00	1.8710E-05
420	**Koch420**	1.2290E-01	9.8900E-06	9.3200E-05	1.8100E-03	2.5000E-04	3.9807E-02	1.1600E-02	0.0000E+00	1.8270E-05
423	**Koch423**	1.2290E-01	9.8900E-06	9.3200E-05	1.8100E-03	2.5000E-04	3.9807E-02	1.1600E-02	0.0000E+00	1.8270E-05
426	**Koch426**	1.2290E-01	9.8900E-06	9.3200E-05	1.8100E-03	2.5000E-04	3.9807E-02	1.1600E-02	0.0000E+00	1.8270E-05
436	**StPaulPark**	2.6771E-01	9.8900E-06	9.3200E-05	1.8100E-03	2.5000E-04	4.0192E-02	1.1600E-02	0.0000E+00	2.0320E-05
438	**Ashland**	2.4868E-01	9.8900E-06	9.3200E-05	1.8100E-03	2.5000E-04	4.0251E-02	1.1600E-02	0.0000E+00	2.5700E-05
816	**HolmanFld**	2.2747E-01	9.8900E-06	9.3200E-05	1.8100E-03	2.5000E-04	4.0944E-02	1.1600E-02	0.0000E+00	4.1700E-05
820	**BushSt**	2.1543E-01	9.8900E-06	9.3200E-05	1.8100E-03	2.5000E-04	4.0683E-02	1.1600E-02	0.0000E+00	5.1760E-05
871	**HardingHi**	2.5508E-01	9.8900E-06	9.3200E-05	1.8100E-03	2.5000E-04	4.0621E-02	1.1600E-02	0.0000E+00	4.8520E-05
945	**MplsLibrary**	2.6505E-01	9.8900E-06	9.3200E-05	1.8100E-03	2.5000E-04	5.0413E-02	1.1600E-02	0.0000E+00	4.3850E-05
958	**MhahaAcad**	2.7382E-01	9.8900E-06	9.3200E-05	1.8100E-03	2.5000E-04	4.2100E-02	1.1600E-02	0.0000E+00	6.2700E-05
1240	**I_Falls1240**	2.7448E-02	9.8900E-06	9.3200E-05	1.8100E-03	2.5000E-04	3.9000E-02	1.1600E-02	0.0000E+00	0.0000E+00
1241	**I_Falls1241**	2.7448E-02	9.8900E-06	9.3200E-05	1.8100E-03	2.5000E-04	3.9000E-02	1.1600E-02	0.0000E+00	0.0000E+00
1400	**Sandstone**	9.5177E-03	9.8900E-06	9.3200E-05	1.8100E-03	2.5000E-04	3.9000E-02	1.1600E-02	0.0000E+00	0.0000E+00
2005	**FergusFalls**	3.2884E-02	9.8900E-06	9.3200E-05	1.8100E-03	2.5000E-04	3.9000E-02	1.1600E-02	0.0000E+00	0.0000E+00
2010	**Alexandria**	5.7536E-02	9.8900E-06	9.3200E-05	1.8100E-03	2.5000E-04	3.9000E-02	1.1600E-02	0.0000E+00	0.0000E+00
2401	**Warroad**	7.4304E-03	9.8900E-06	9.3200E-05	1.8100E-03	2.5000E-04	3.9000E-02	1.1600E-02	0.0000E+00	0.0000E+00
3049	**LittleFalls**	2.7121E-02	9.8900E-06	9.3200E-05	1.8100E-03	2.5000E-04	3.9000E-02	1.1600E-02	0.0000E+00	0.0000E+00
3050	**ElkRiver**	5.9440E-02	9.8900E-06	9.3200E-05	1.8100E-03	2.5000E-04	3.9875E-02	1.1600E-02	0.0000E+00	1.6910E-05
4002	**Pipestone**	2.7097E-02	9.8900E-06	9.3200E-05	1.8100E-03	2.5000E-04	3.9000E-02	1.1600E-02	0.0000E+00	0.0000E+00
4003	**GraniteFalls**	1.3259E-02	9.8900E-06	9.3200E-05	1.8100E-03	2.5000E-04	3.9000E-02	1.1600E-02	0.0000E+00	0.0000E+00
5008	**Rochester**	6.7510E-02	9.8900E-06	9.3200E-05	1.8100E-03	2.5000E-04	3.9000E-02	1.1600E-02	0.0000E+00	0.0000E+00
5356	**Zumbrota**	2.6584E-02	9.8900E-06	9.3200E-05	1.8100E-03	2.5000E-04	3.9000E-02	1.1600E-02	0.0000E+00	0.0000E+00
7014	**Hibbing**	4.6093E-02	9.8900E-06	9.3200E-05	1.8100E-03	2.5000E-04	3.9000E-02	1.1600E-02	0.0000E+00	0.0000E+00
7549	**Duluth7549**	6.7705E-02	9.8900E-06	9.3200E-05	1.8100E-03	2.5000E-04	3.9000E-02	1.1600E-02	0.0000E+00	0.0000E+00

Appendix I. U.S. EPA Cumulative Exposure Project (CEP) modeled concentrations in census tracts with monitoring sites. The CEP modeling data (1990 emissions) is for purposes of comparison with monitoring data (see Appendices J, K L).

Site No.	Site Name	ethylene_dibromide ETHYLENE_D	maleic_anhydride MALEIC_ANH	propylene_dichloride PROPYLENE_	dichloropropene(1,3) DICHLOROPR	bromoform BROMOFORM	ethylene_oxide ETHYLENE_O	chloroform CHLOROFORM	p-dichlorobenzene P-DICHLORO	phosgene_total PHOSGENE_T
260	**Plymouth**	7.6900E-03	1.4507E-04	2.5120E-05	3.1364E-02	2.2258E-02	9.9818E-04	8.6976E-02	5.3576E-02	6.6828E-02
420	**Koch420**	7.6900E-03	1.3467E-04	3.1170E-05	1.7891E-02	2.2126E-02	5.9374E-04	8.5198E-02	2.8605E-02	6.6015E-02
423	**Koch423**	7.6900E-03	1.3467E-04	3.1170E-05	1.7891E-02	2.2126E-02	5.9374E-04	8.5198E-02	2.8605E-02	6.6015E-02
426	**Koch426**	7.6900E-03	1.3467E-04	3.1170E-05	1.7891E-02	2.2126E-02	5.9374E-04	8.5198E-02	2.8605E-02	6.6015E-02
436	**StPaulPark**	7.6900E-03	5.7337E-04	1.4410E-04	2.3044E-02	2.3186E-02	8.4923E-04	8.6410E-02	4.4358E-02	6.6284E-02
438	**Ashland**	7.6900E-03	2.5249E-04	5.8490E-05	2.4277E-02	2.4269E-02	8.1219E-04	8.7313E-02	4.4979E-02	6.6349E-02
816	**HolmanFld**	7.6900E-03	2.0500E-04	3.6790E-05	5.4476E-02	3.6950E-02	1.7034E-03	9.9050E-02	1.2220E-01	6.6942E-02
820	**BushSt**	7.6900E-03	1.7089E-04	3.1670E-05	5.4543E-02	4.7046E-02	1.7015E-03	1.0636E-01	1.5382E-01	6.6885E-02
871	**HardingHi**	7.6900E-03	1.7444E-04	3.3470E-05	4.2249E-02	1.1267E-01	1.3331E-03	1.5150E-01	3.2834E-01	6.6996E-02
945	**MplsLibrary**	7.6900E-03	8.7622E-04	1.6280E-04	6.1813E-02	2.5180E-02	2.0383E-03	9.1703E-02	1.0857E-01	6.8492E-02
958	**MhahaAcad**	7.6900E-03	3.1246E-04	4.0620E-05	4.4185E-02	7.5102E-02	1.3983E-03	1.2514E-01	2.2214E-01	6.7144E-02
1240	**I_Falls1240**	7.6900E-03	0.0000E+00	0.0000E+00	1.5722E-02	2.0700E-02	4.7384E-04	2.8344E-01	1.9411E-02	6.0760E-02
1241	**I_Falls1241**	7.6900E-03	0.0000E+00	0.0000E+00	1.5722E-02	2.0700E-02	4.7384E-04	2.8344E-01	1.9411E-02	6.0760E-02
1400	**Sandstone**	7.6900E-03	0.0000E+00	0.0000E+00	8.8439E-04	2.0713E-02	2.7640E-05	8.3076E-02	1.3436E-03	6.0768E-02
2005	**FergusFalls**	7.6900E-03	0.0000E+00	0.0000E+00	1.6392E-02	2.0724E-02	4.9432E-04	8.5854E-02	2.2281E-02	6.0817E-02
2010	**Alexandria**	7.6900E-03	0.0000E+00	0.0000E+00	1.2352E-02	2.0739E-02	3.7298E-04	8.3995E-02	1.6670E-02	6.0931E-02
2401	**Warroad**	7.6900E-03	7.2800E-06	2.4200E-06	8.3673E-04	2.0700E-02	2.7740E-05	8.3059E-02	1.1000E-03	6.0763E-02
3049	**LittleFalls**	7.6900E-03	0.0000E+00	0.0000E+00	1.0769E-02	2.0723E-02	3.2700E-04	8.3846E-02	1.4638E-02	6.1148E-02
3050	**ElkRiver**	7.6900E-03	2.3820E-05	2.0700E-06	1.0006E-02	2.0719E-02	3.2280E-04	8.3708E-02	1.5385E-02	6.4998E-02
4002	**Pipestone**	7.6900E-03	0.0000E+00	0.0000E+00	1.0000E-02	2.0720E-02	3.0189E-04	8.4005E-02	1.4808E-02	6.1296E-02
4003	**GraniteFalls**	7.6900E-03	0.0000E+00	0.0000E+00	1.2790E-03	2.0703E-02	3.9420E-05	8.3151E-02	2.1836E-03	6.0798E-02
5008	**Rochester**	7.6900E-03	1.1670E-05	3.2200E-06	2.8677E-02	2.0964E-02	8.7000E-04	8.5161E-02	3.3842E-02	6.1573E-02
5356	**Zumbrota**	7.6900E-03	5.4950E-05	1.7410E-05	2.4019E-03	2.0808E-02	9.3900E-05	8.3298E-02	4.7848E-03	6.1532E-02
7014	**Hibbing**	7.6900E-03	2.0753E-03	5.5832E-04	2.1907E-02	2.1288E-02	1.1500E-03	8.3912E-02	5.3545E-02	6.0902E-02
7549	**Duluth7549**	7.6900E-03	3.9068E-04	1.0737E-04	1.6790E-02	2.4108E-02	6.0349E-04	9.5198E-02	3.7763E-02	6.1025E-02

Appendix I. U.S. EPA Cumulative Exposure Project (CEP) modeled concentrations in census tracts with monitoring sites. The CEP modeling data (1990 emissions) is for purposes of comparison with monitoring data (see Appendices J, K L).

		acrolein_total	diethanolamine	methylene_diphenyl_diisocyanate	ethyl_acrylate	propylene_oxide	vinyl_acetate	biphenyl	carbonyl_sulfide	ethylene_glycol
Site No.	Site Name	ACROLEIN_T	DIETHANOLA	METHYLENE_	ETHYL_ACRY	PROPYLENE_	VINYL_ACET	BIPHENYL	CARBONYL_S	ETHYLENE_G
260	**Plymouth**	2.3621E-01	8.4920E-05	1.0921E-04	1.5593E-04	6.1500E-06	7.0950E-04	3.6000E-07	1.2301E+00	3.1455E-01
420	**Koch420**	7.8343E-02	3.6200E-06	7.2220E-05	4.5783E-04	7.7100E-06	9.1410E-04	1.3600E-06	1.2301E+00	1.8859E-01
423	**Koch423**	7.8343E-02	3.6200E-06	7.2220E-05	4.5783E-04	7.7100E-06	9.1410E-04	1.3600E-06	1.2301E+00	1.8859E-01
426	**Koch426**	7.8343E-02	3.6200E-06	7.2220E-05	4.5783E-04	7.7100E-06	9.1410E-04	1.3600E-06	1.2301E+00	1.8859E-01
436	**StPaulPark**	1.1970E-01	5.6000E-06	6.2250E-05	2.3685E-03	3.5850E-05	4.3570E-03	8.3600E-06	1.2303E+00	2.3573E-01
438	**Ashland**	1.1292E-01	6.1900E-06	5.8630E-05	1.4313E-03	1.4500E-05	1.7158E-03	1.8900E-06	1.2301E+00	2.3332E-01
816	**HolmanFld**	2.2883E-01	1.1570E-05	8.7290E-05	7.5896E-04	9.0900E-06	1.0421E-03	3.1900E-06	1.2301E+00	5.7474E-01
820	**BushSt**	2.4317E-01	9.5000E-06	6.5790E-05	6.2872E-04	7.8100E-06	8.7756E-04	1.2100E-06	1.2301E+00	5.3028E-01
871	**HardingHi**	4.9994E-01	9.2200E-06	6.8600E-05	6.8050E-04	8.2700E-06	9.3146E-04	2.6900E-06	1.2303E+00	4.6976E-01
945	**MplsLibrary**	2.7766E-01	2.2640E-05	1.2155E-04	1.3449E-03	4.0480E-05	4.9255E-03	1.2200E-06	1.2303E+00	6.3918E-01
958	**MhahaAcad**	4.5893E-01	1.2180E-05	1.4075E-04	6.0426E-04	1.0030E-05	1.1765E-03	1.0300E-06	1.2302E+00	4.2689E-01
1240	**I_Falls1240**	3.6173E-02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	6.0000E-08	1.2300E+00	1.6298E-01
1241	**I_Falls1241**	3.6173E-02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	6.0000E-08	1.2300E+00	1.6298E-01
1400	**Sandstone**	6.0079E-03	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	1.2300E+00	8.3257E-03
2005	**FergusFalls**	4.2487E-02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	4.0000E-08	1.2300E+00	1.4635E-01
2010	**Alexandria**	3.2393E-02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	3.2000E-07	1.2300E+00	1.1162E-01
2401	**Warroad**	5.1615E-03	0.0000E+00	0.0000E+00	1.4350E-05	5.3000E-07	6.5310E-05	9.1000E-07	1.2300E+00	6.8217E-03
3049	**LittleFalls**	3.4416E-02	0.0000E+00	1.7780E-05	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	1.2300E+00	1.0206E-01
3050	**ElkRiver**	5.0627E-02	1.7550E-05	1.7910E-05	1.1970E-05	4.4000E-07	5.4500E-05	7.0000E-08	1.2300E+00	9.5181E-02
4002	**Pipestone**	2.4697E-02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	1.2300E+00	9.6882E-02
4003	**GraniteFalls**	8.7536E-03	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	1.2300E+00	1.3774E-02
5008	**Rochester**	1.0171E-01	0.0000E+00	0.0000E+00	2.1330E-05	7.9000E-07	9.7070E-05	9.0000E-08	1.2300E+00	2.1761E-01
5356	**Zumbrota**	1.7056E-02	0.0000E+00	7.4900E-06	3.7911E-04	4.1300E-06	4.7340E-04	8.0000E-08	1.2300E+00	2.7781E-02
7014	**Hibbing**	8.6190E-02	0.0000E+00	0.0000E+00	3.7505E-03	1.3877E-04	1.7072E-02	5.0000E-08	1.2309E+00	1.9089E-01
7549	**Duluth7549**	1.4554E-01	0.0000E+00	2.3200E-06	7.0875E-04	2.7736E-04	3.2256E-03	5.0000E-08	1.2302E+00	1.5086E-01

Appendix I. U.S. EPA Cumulative Exposure Project (CEP) modeled concentrations in census tracts with monitoring sites. The CEP modeling data (1990 emissions) is for purposes of comparison with monitoring data (see Appendices J, K L).

		glycol_ethers	methyl_tert-butyl_ether	cumene	ethyl_chloride	beryllium_total	cadmium_total	hydrochloric_acid	hydrofluoric_acid	arsenic_total
Site No.	**Site Name**	GLYCOL_ETH	METHYL_TER	CUMENE	ETHYL_CHLO	BERYLLIUM_	CADMIUM_TO	HYDROCHLOR	HYDROFLUOR	ARSENIC_TO
260	**Plymouth**	6.1315E-01	4.0326E-01	2.0855E-02	1.0264E-03	3.1600E-06	1.7503E-04	1.0562E+00	8.3511E-03	3.5904E-04
420	**Koch420**	6.5071E-01	7.4105E-01	1.0449E-02	7.5331E-04	4.7400E-06	1.1403E-04	4.6638E-01	4.7043E-03	2.5401E-04
423	**Koch423**	6.5071E-01	7.4105E-01	1.0449E-02	7.5331E-04	4.7400E-06	1.1403E-04	4.6638E-01	4.7043E-03	2.5401E-04
426	**Koch426**	6.5071E-01	7.4105E-01	1.0449E-02	7.5331E-04	4.7400E-06	1.1403E-04	4.6638E-01	4.7043E-03	2.5401E-04
436	**StPaulPark**	9.4383E-01	1.8424E+00	2.0956E-02	2.6442E-03	8.9500E-06	1.7694E-04	1.3481E+00	9.8888E-03	4.1658E-04
438	**Ashland**	5.5760E-01	1.4445E+00	2.0542E-02	1.2970E-03	7.3700E-06	2.0587E-04	7.5888E-01	8.4115E-03	4.3945E-04
816	**HolmanFld**	2.8254E+00	8.3976E-01	3.7189E-02	1.5841E-03	8.5100E-06	4.8386E-04	1.6994E+00	1.9767E-02	2.1240E-03
820	**BushSt**	9.8966E-01	6.6421E-01	4.0917E-02	1.5506E-03	9.0600E-06	4.5281E-04	1.7652E+00	1.5863E-02	1.0416E-03
871	**HardingHi**	1.7794E+00	9.5026E-01	9.4095E-02	1.3504E-03	8.5700E-06	4.3893E-04	1.3871E+00	1.2797E-02	2.1478E-03
945	**MplsLibrary**	4.8076E+00	1.2600E+00	3.6904E-02	3.7914E-03	1.0160E-05	3.5044E-04	2.0344E+00	1.6910E-02	1.3737E-03
958	**MhahaAcad**	1.2818E+00	8.7761E-01	5.0961E-02	1.4812E-03	1.1870E-05	2.8322E-04	1.4569E+00	1.1772E-02	8.6752E-04
1240	**I_Falls1240**	2.0091E-01	1.5332E-01	5.3136E-02	3.0253E-04	2.9100E-06	8.5050E-05	9.1644E-01	3.4936E-03	8.3210E-05
1241	**I_Falls1241**	2.0091E-01	1.5332E-01	5.3136E-02	3.0253E-04	2.9100E-06	8.5050E-05	9.1644E-01	3.4936E-03	8.3210E-05
1400	**Sandstone**	7.0907E-03	1.9422E-02	3.7753E-03	1.4710E-05	5.0000E-08	4.2100E-06	2.4156E-02	1.7009E-04	8.7300E-06
2005	**FergusFalls**	1.4147E-01	2.2391E-01	4.0121E-02	6.2198E-04	4.6400E-06	3.4233E-04	1.0763E+00	1.5269E-02	1.7138E-04
2010	**Alexandria**	1.8937E-01	6.1295E-01	2.2986E-02	2.1235E-04	1.8600E-06	2.5734E-04	5.1862E-01	2.4106E-03	8.7480E-05
2401	**Warroad**	9.4110E-03	1.8793E-02	2.4821E-03	5.1440E-05	1.3000E-07	4.1900E-06	2.1888E-02	1.7031E-04	8.1600E-06
3049	**LittleFalls**	2.1590E-01	1.1546E-01	3.1861E-02	1.8185E-04	1.2600E-06	5.1630E-05	3.0438E-01	2.8017E-03	6.9610E-05
3050	**ElkRiver**	1.5202E-01	1.1400E-01	1.3610E-02	1.8295E-04	6.9000E-07	3.4460E-05	2.5937E-01	2.3963E-03	9.3570E-05
4002	**Pipestone**	3.6829E-01	2.5842E-01	9.4824E-03	2.1750E-04	1.4000E-06	5.9810E-05	3.6180E-01	2.6031E-03	5.9760E-05
4003	**GraniteFalls**	1.7028E-02	4.0410E-02	2.2276E-03	3.1970E-05	5.2700E-06	3.2820E-05	8.9534E-02	1.8223E-03	1.0233E-04
5008	**Rochester**	2.5050E-01	4.9063E-01	2.1575E-02	4.8397E-04	1.5700E-06	1.7837E-04	1.0743E+00	5.0419E-03	1.4542E-04
5356	**Zumbrota**	6.5537E-02	6.4756E-02	3.0368E-03	3.2489E-04	7.6000E-07	2.3490E-05	1.0444E-01	1.0619E-03	3.2930E-05
7014	**Hibbing**	3.4916E-01	4.0428E-01	3.4444E-02	8.9836E-03	5.1050E-05	7.3700E-05	2.4243E-01	8.0863E-02	2.6970E-03
7549	**Duluth7549**	1.1514E-01	2.9489E-01	3.2222E-02	1.7784E-03	1.2850E-05	3.6120E-05	4.9003E-01	1.4427E-02	1.6071E-04

Appendix I. U.S. EPA Cumulative Exposure Project (CEP) modeled concentrations in census tracts with monitoring sites. The CEP modeling data (1990 emissions) is for purposes of comparison with monitoring data (see Appendices J, K L).

		cobalt_total	chromium_total	mercury_compounds	manganese_total	nickel_total	lead_total	antimony_total	selenium_total	acetaldehyde_total
Site No.	**Site Name**	COBALT_TOT	CHROMIUM_T	MERCURY_CO	MANGANESE_	NICKEL_TOT	LEAD_TOTAL	ANTIMONY_T	SELENIUM_T	ACETALDEHY
260	**Plymouth**	1.7663E-04	1.3327E-03	1.8404E-03	3.6047E-03	2.7954E-03	5.1917E-03	1.5688E-04	4.0927E-04	8.3467E-01
420	**Koch420**	9.0130E-05	2.8506E-03	1.6527E-03	2.2085E-03	4.5768E-03	6.1321E-03	2.4962E-04	2.9149E-04	4.6999E-01
423	**Koch423**	9.0130E-05	2.8506E-03	1.6527E-03	2.2085E-03	4.5768E-03	6.1321E-03	2.4962E-04	2.9149E-04	4.6999E-01
426	**Koch426**	9.0130E-05	2.8506E-03	1.6527E-03	2.2085E-03	4.5768E-03	6.1321E-03	2.4962E-04	2.9149E-04	4.6999E-01
436	**StPaulPark**	1.1158E-04	3.2505E-03	1.7191E-03	3.3506E-03	9.4615E-03	8.2688E-03	7.4230E-04	4.6404E-04	8.9614E-01
438	**Ashland**	1.0857E-04	3.0448E-03	1.7097E-03	3.1900E-03	7.5824E-03	8.5060E-03	6.0361E-04	3.9074E-04	8.5342E-01
816	**HolmanFld**	2.8281E-04	6.5529E-03	2.0542E-03	6.4330E-03	7.9579E-03	1.1918E-02	4.3718E-04	7.1266E-04	9.9242E-01
820	**BushSt**	2.9480E-04	3.5740E-03	2.0693E-03	6.0208E-03	8.2188E-03	1.0226E-02	4.1636E-04	6.2214E-04	9.7026E-01
871	**HardingHi**	2.6227E-04	5.5649E-03	2.0260E-03	1.0289E-02	8.8849E-03	1.3135E-02	4.6212E-04	6.3269E-04	1.3004E+00
945	**MplsLibrary**	3.3403E-04	3.6473E-03	2.1664E-03	6.7484E-03	9.8107E-03	9.6969E-03	4.3991E-04	1.7119E-03	1.2005E+00
958	**MhahaAcad**	2.4507E-04	3.9793E-03	1.9750E-03	8.7395E-03	1.1593E-02	9.7914E-03	4.8859E-04	6.0938E-04	1.3699E+00
1240	**I_Falls1240**	1.0607E-04	1.8245E-04	1.6752E-03	4.2794E-03	1.2590E-03	2.7076E-03	5.4540E-05	1.0319E-04	1.3869E-01
1241	**I_Falls1241**	1.0607E-04	1.8245E-04	1.6752E-03	4.2794E-03	1.2590E-03	2.7076E-03	5.4540E-05	1.0319E-04	1.3869E-01
1400	**Sandstone**	6.0800E-06	4.2120E-05	1.5016E-03	5.4893E-04	5.5510E-05	2.4354E-04	2.3200E-06	8.3200E-06	4.1327E-02
2005	**FergusFalls**	3.2925E-04	4.5806E-04	2.3149E-03	3.8565E-03	1.6983E-03	5.9106E-03	1.4073E-04	1.4650E-04	1.6584E-01
2010	**Alexandria**	2.0796E-04	1.9406E-04	1.7686E-03	1.3764E-03	1.5588E-03	3.1260E-03	2.2001E-04	1.4268E-04	2.1127E-01
2401	**Warroad**	4.8700E-06	2.3650E-05	1.4990E-03	1.1964E-03	1.0373E-04	1.9477E-04	1.1920E-05	7.7400E-06	2.9407E-02
3049	**LittleFalls**	6.5430E-05	1.3081E-04	1.6147E-03	2.2566E-03	8.4094E-04	2.0423E-03	3.7130E-05	6.6710E-05	1.3641E-01
3050	**ElkRiver**	4.1720E-05	1.7941E-04	1.5808E-03	1.2708E-03	4.9240E-04	1.1992E-03	2.1620E-05	9.4190E-05	2.5337E-01
4002	**Pipestone**	6.2560E-05	1.0762E-04	1.6097E-03	8.9774E-04	1.1924E-03	1.3413E-03	7.2480E-05	9.2100E-05	1.2093E-01
4003	**GraniteFalls**	3.0790E-05	1.0887E-04	1.5135E-03	4.0428E-04	3.1392E-04	2.2208E-03	4.6559E-04	6.8310E-05	5.5707E-02
5008	**Rochester**	2.0486E-04	4.2888E-04	2.1088E-03	2.6765E-03	1.3281E-03	4.3185E-03	1.7507E-04	4.2183E-04	3.8992E-01
5356	**Zumbrota**	2.2960E-05	3.2628E-04	1.5369E-03	4.3320E-04	9.6061E-04	1.1153E-03	7.5600E-05	3.8880E-05	1.0323E-01
7014	**Hibbing**	1.5208E-04	5.9967E-04	1.6821E-03	4.3798E-03	4.2813E-03	7.8555E-03	2.3244E-04	4.1629E-03	2.9536E-01
7549	**Duluth7549**	5.7110E-05	2.6105E-04	1.5870E-03	3.4809E-03	4.1492E-03	2.2919E-03	1.5462E-04	1.2076E-04	4.1436E-01

Appendix I. U.S. EPA Cumulative Exposure Project (CEP) modeled concentrations in census tracts with monitoring sites. The CEP modeling data (1990 emissions) is for purposes of comparison with monitoring data (see Appendices J, K L).

		calcium_cyanamide	dioxane(1,4)	hexachloroethane	acetonitrile	aniline	toluene_diisocyanate(2,4)	bis(2-ethylhexyl)phthalate	cyanide_compounds	acrylonitrile
Site No.	**Site Name**	CALCIUM_CY	DIOXANE(1,	HEXACHLORO	ACETONITRI	ANILINE	TOLUENE_DI	BIS(2-ETHY	CYANIDE_CO	ACRYLONITR
260	**Plymouth**	0.0000E+00	1.4934E-03	4.8400E-03	1.1680E-05	0.0000E+00	2.4500E-06	1.4122E-03	7.4772E-02	3.8453E-04
420	**Koch420**	0.0000E+00	7.2844E-04	4.8400E-03	9.5000E-06	0.0000E+00	1.0020E-05	1.4166E-03	2.9513E-02	4.4192E-04
423	**Koch423**	0.0000E+00	7.2844E-04	4.8400E-03	9.5000E-06	0.0000E+00	1.0020E-05	1.4166E-03	2.9513E-02	4.4192E-04
426	**Koch426**	0.0000E+00	7.2844E-04	4.8400E-03	9.5000E-06	0.0000E+00	1.0020E-05	1.4166E-03	2.9513E-02	4.4192E-04
436	**StPaulPark**	0.0000E+00	6.3106E-04	4.8400E-03	2.9310E-05	3.0000E-08	6.0710E-05	1.4261E-03	5.5589E-02	2.2090E-03
438	**Ashland**	0.0000E+00	7.0127E-04	4.8400E-03	5.8120E-05	1.1000E-07	1.0925E-04	1.4308E-03	5.3478E-02	1.6007E-03
816	**HolmanFld**	0.0000E+00	9.2195E-04	4.8400E-03	1.4737E-04	1.0000E-08	2.7640E-05	1.4394E-03	1.3625E-01	1.3146E-03
820	**BushSt**	0.0000E+00	1.0880E-03	4.8400E-03	1.2053E-04	1.0000E-08	2.1150E-05	1.4363E-03	1.2282E-01	1.0303E-03
871	**HardingHi**	0.0000E+00	1.0135E-03	4.8400E-03	1.4988E-04	1.0000E-08	2.3680E-05	1.4346E-03	1.4631E-01	1.2089E-03
945	**MplsLibrary**	0.0000E+00	1.8633E-03	4.8400E-03	2.1170E-05	0.0000E+00	2.2830E-05	1.4430E-03	1.7525E-01	2.0873E-03
958	**MhahaAcad**	0.0000E+00	1.5680E-03	4.8400E-03	1.7210E-05	1.0000E-08	1.5430E-05	1.4279E-03	1.3931E-01	6.3799E-04
1240	**I_Falls1240**	0.0000E+00	0.0000E+00	4.8400E-03	0.0000E+00	0.0000E+00	0.0000E+00	1.4000E-03	2.3247E-02	0.0000E+00
1241	**I_Falls1241**	0.0000E+00	0.0000E+00	4.8400E-03	0.0000E+00	0.0000E+00	0.0000E+00	1.4000E-03	2.3247E-02	0.0000E+00
1400	**Sandstone**	0.0000E+00	0.0000E+00	4.8400E-03	0.0000E+00	0.0000E+00	0.0000E+00	1.4000E-03	2.9975E-03	0.0000E+00
2005	**FergusFalls**	0.0000E+00	0.0000E+00	4.8400E-03	0.0000E+00	0.0000E+00	0.0000E+00	1.4002E-03	3.2180E-02	0.0000E+00
2010	**Alexandria**	0.0000E+00	0.0000E+00	4.8400E-03	0.0000E+00	0.0000E+00	0.0000E+00	1.4000E-03	2.2169E-02	0.0000E+00
2401	**Warroad**	0.0000E+00	0.0000E+00	4.8400E-03	0.0000E+00	0.0000E+00	0.0000E+00	1.4000E-03	2.0306E-03	2.8670E-05
3049	**LittleFalls**	0.0000E+00	0.0000E+00	4.8400E-03	0.0000E+00	0.0000E+00	0.0000E+00	1.4004E-03	2.1951E-02	0.0000E+00
3050	**ElkRiver**	0.0000E+00	6.2071E-04	4.8400E-03	0.0000E+00	0.0000E+00	1.6000E-07	1.4063E-03	2.1200E-02	2.4490E-05
4002	**Pipestone**	0.0000E+00	0.0000E+00	4.8400E-03	0.0000E+00	0.0000E+00	0.0000E+00	1.4000E-03	2.0378E-02	0.0000E+00
4003	**GraniteFalls**	0.0000E+00	0.0000E+00	4.8400E-03	0.0000E+00	0.0000E+00	0.0000E+00	1.4022E-03	4.4110E-03	0.0000E+00
5008	**Rochester**	0.0000E+00	0.0000E+00	4.8400E-03	0.0000E+00	0.0000E+00	0.0000E+00	1.4011E-03	1.3270E-01	3.8110E-05
5356	**Zumbrota**	0.0000E+00	0.0000E+00	4.8400E-03	0.0000E+00	0.0000E+00	9.8100E-06	1.4006E-03	6.4918E-03	2.0675E-04
7014	**Hibbing**	0.0000E+00	0.0000E+00	4.8400E-03	0.0000E+00	0.0000E+00	0.0000E+00	1.4014E-03	1.1007E-01	6.6173E-03
7549	**Duluth7549**	0.0000E+00	0.0000E+00	4.8400E-03	0.0000E+00	0.0000E+00	0.0000E+00	1.4016E-03	7.3240E-02	1.2726E-03

Appendix I. U.S. EPA Cumulative Exposure Project (CEP) modeled concentrations in census tracts with monitoring sites. The CEP modeling data (1990 emissions) is for purposes of comparison with monitoring data (see Appendices J, K L).

Site No.	Site Name	carbon_disulfide CARBON_DIS	ethylene_dichloride ETHYLENE_D	methyl_methacrylate METHYL_MET	-dibutylphthalate DIBUTYLPHT	trichloroethane(1,1,2) TRICHLOROE	methyl_isobutyl_ketone METHYL_ISO	phthalic_anhydride PHTHALIC_A	methanol METHANOL	styrene STYRENE
260	**Plymouth**	4.8066E-02	6.1517E-02	2.7657E-04	1.5212E-03	4.0604E-04	1.5028E-01	7.1105E-04	7.0268E-01	4.5411E-02
420	**Koch420**	4.7877E-02	6.2075E-02	2.1230E-04	1.2476E-03	2.6774E-03	2.6549E-01	5.3923E-04	4.4759E-01	1.2625E-02
423	**Koch423**	4.7877E-02	6.2075E-02	2.1230E-04	1.2476E-03	2.6774E-03	2.6549E-01	5.3923E-04	4.4759E-01	1.2625E-02
426	**Koch426**	4.7877E-02	6.2075E-02	2.1230E-04	1.2476E-03	2.6774E-03	2.6549E-01	5.3923E-04	4.4759E-01	1.2625E-02
436	**StPaulPark**	4.8973E-02	6.7431E-02	1.2667E-03	1.3347E-03	1.4071E-02	3.1506E-01	1.9235E-03	8.4856E-01	3.3392E-02
438	**Ashland**	4.8766E-02	6.5059E-02	6.0714E-04	1.3447E-03	1.3315E-02	1.7470E-01	9.7429E-04	7.6773E-01	2.8866E-02
816	**HolmanFld**	4.9685E-02	6.2760E-02	2.3955E-04	1.7880E-03	5.9989E-03	7.1395E-01	1.0124E-03	1.1188E+00	7.7188E-02
820	**BushSt**	4.9096E-02	6.2419E-02	2.0143E-04	1.8162E-03	4.9859E-03	2.7154E-01	8.9578E-04	1.1163E+00	6.4700E-02
871	**HardingHi**	4.8934E-02	6.2549E-02	2.2239E-04	1.6354E-03	5.2956E-03	5.6890E-01	8.6079E-04	9.6884E-01	7.6103E-02
945	**MplsLibrary**	5.1166E-02	6.6247E-02	8.4000E-04	1.9602E-03	3.2789E-03	1.3098E+00	3.4365E-03	1.3826E+00	1.3871E-01
958	**MhahaAcad**	4.8927E-02	6.2530E-02	1.9538E-04	1.6683E-03	3.9103E-03	3.8000E-01	1.3953E-03	1.0540E+00	8.9306E-02
1240	**I_Falls1240**	4.6700E-02	6.0700E-02	0.0000E+00	1.2062E-03	1.6756E-04	9.7747E-02	4.4270E-05	5.1591E-01	1.3257E-02
1241	**I_Falls1241**	4.6700E-02	6.0700E-02	0.0000E+00	1.2062E-03	1.6756E-04	9.7747E-02	4.4270E-05	5.1591E-01	1.3257E-02
1400	**Sandstone**	4.6700E-02	6.0700E-02	0.0000E+00	1.0142E-03	1.1990E-05	1.2676E-03	3.0500E-06	1.9259E-02	1.3996E-03
2005	**FergusFalls**	4.6723E-02	6.0700E-02	0.0000E+00	1.2389E-03	1.1802E-04	2.6739E-02	5.1300E-05	3.1328E-01	1.8390E-02
2010	**Alexandria**	4.6700E-02	6.0700E-02	0.0000E+00	1.1782E-03	1.2055E-04	3.5865E-02	3.8270E-05	3.0697E-01	1.2407E-02
2401	**Warroad**	4.6712E-02	6.0776E-02	2.1500E-06	1.0107E-03	4.1300E-06	4.8913E-02	2.9800E-05	1.5317E-02	8.9973E-04
3049	**LittleFalls**	4.6740E-02	6.0700E-02	5.4498E-03	1.1567E-03	9.8900E-05	1.2453E-01	3.3650E-05	2.0050E-01	1.2111E+00
3050	**ElkRiver**	4.7355E-02	6.0765E-02	3.4100E-05	1.1653E-03	9.2860E-05	3.9343E-02	1.6520E-04	2.1496E-01	8.7856E-03
4002	**Pipestone**	4.6700E-02	6.0700E-02	0.0000E+00	1.1589E-03	7.7320E-05	1.8441E-01	3.4100E-05	2.3111E-01	1.2977E-01
4003	**GraniteFalls**	4.6920E-02	6.0700E-02	0.0000E+00	1.0239E-03	1.3170E-05	3.2273E-03	5.1300E-06	3.3713E-02	1.7932E-03
5008	**Rochester**	4.6823E-02	6.0801E-02	1.2570E-05	1.3492E-03	2.5129E-04	4.4030E-02	1.1155E-04	4.5693E-01	7.2119E-02
5356	**Zumbrota**	4.6846E-02	6.1666E-02	6.5590E-05	1.0407E-03	2.7325E-03	3.2602E-02	2.0683E-04	8.6968E-02	2.0542E-03
7014	**Hibbing**	4.9631E-02	7.8276E-02	2.7303E-03	1.3094E-03	2.0840E-04	4.2963E-02	6.4149E-03	4.2267E-01	8.5426E-02
7549	**Duluth7549**	4.7397E-02	6.4080E-02	3.4493E-04	1.2530E-03	1.7139E-04	1.0912E-02	1.2751E-03	3.5635E-01	4.1556E-02

Appendix I. U.S. EPA Cumulative Exposure Project (CEP) modeled concentrations in census tracts with monitoring sites. The CEP modeling data (1990 emissions) is for purposes of comparison with monitoring data (see Appendices J, K L).

		vinylidene_chloride	polychlorinated_biphenyls	chlorobenzene	carbon_tetrachloride	methyl_chloride	methylene_chloride	methyl_chloroform	tetrachloroethylene	trichloroethylene
Site No.	**Site Name**	VINYLIDENE	POLYCHLORI	CHLOROBENZ	CARBON_TET	METHYL_CHL	METHYLENE_	METHYL_CHL	TETRACHLOR	TRICHLOROE
260	**Plymouth**	1.5600E-06	3.7752E-04	1.7575E-02	8.8248E-01	1.2454E+00	4.4798E-01	2.9359E+00	5.6482E-01	4.8260E-01
420	**Koch420**	1.3300E-06	3.7717E-04	1.0851E-02	8.8237E-01	1.2429E+00	3.3773E-01	2.4330E+00	4.9751E-01	3.8649E-01
423	**Koch423**	1.3300E-06	3.7717E-04	1.0851E-02	8.8237E-01	1.2429E+00	3.3773E-01	2.4330E+00	4.9751E-01	3.8649E-01
426	**Koch426**	1.3300E-06	3.7717E-04	1.0851E-02	8.8237E-01	1.2429E+00	3.3773E-01	2.4330E+00	4.9751E-01	3.8649E-01
436	**StPaulPark**	1.6300E-06	3.7836E-04	1.7869E-02	8.8370E-01	1.2458E+00	4.9907E-01	3.3074E+00	5.1529E-01	6.3826E-01
438	**Ashland**	9.1000E-07	3.7722E-04	1.5440E-02	8.8429E-01	1.2459E+00	3.5939E-01	2.3943E+00	4.6416E-01	3.5836E-01
816	**HolmanFld**	1.3100E-06	3.7758E-04	3.1697E-02	8.9484E-01	1.2485E+00	7.5158E-01	5.1722E+00	7.1014E-01	1.0298E+00
820	**BushSt**	1.1300E-06	3.7760E-04	3.2953E-02	9.0319E-01	1.2490E+00	4.9763E-01	3.3679E+00	5.5397E-01	5.0802E-01
871	**HardingHi**	1.1300E-06	3.7747E-04	3.5931E-02	9.5772E-01	1.2473E+00	7.9358E-01	4.6719E+00	6.2504E-01	8.9365E-01
945	**MplsLibrary**	5.1400E-06	3.7790E-04	3.8636E-02	8.8558E-01	1.2494E+00	2.0707E+00	1.4463E+01	3.3562E+00	4.0155E+00
958	**MhahaAcad**	2.6100E-06	3.7763E-04	3.1959E-02	9.2652E-01	1.2469E+00	6.4315E-01	4.0745E+00	7.5832E-01	7.7709E-01
1240	**I_Falls1240**	0.0000E+00	3.7717E-04	7.9550E-03	8.8102E-01	1.2778E+00	1.8044E-01	1.4476E+00	1.9588E-01	1.2032E-01
1241	**I_Falls1241**	0.0000E+00	3.7717E-04	7.9550E-03	8.8102E-01	1.2778E+00	1.8044E-01	1.4476E+00	1.9588E-01	1.2032E-01
1400	**Sandstone**	0.0000E+00	3.7701E-04	4.6894E-04	8.8101E-01	1.2425E+00	1.5512E-01	1.1293E+00	1.4445E-01	8.3608E-02
2005	**FergusFalls**	3.6050E-05	3.7766E-04	8.2394E-03	8.8106E-01	1.2674E+00	1.8846E-01	1.4869E+00	2.2783E-01	1.3120E-01
2010	**Alexandria**	6.5800E-06	3.7739E-04	6.2483E-03	8.8104E-01	1.2541E+00	2.1460E-01	1.6155E+00	3.8832E-01	1.8746E-01
2401	**Warroad**	0.0000E+00	3.7701E-04	5.1363E-04	8.8101E-01	1.2416E+00	1.6335E-01	1.1332E+00	1.4759E-01	8.7083E-02
3049	**LittleFalls**	0.0000E+00	3.7710E-04	5.4673E-03	8.8103E-01	1.2616E+00	1.9483E-01	2.2689E+00	1.9481E-01	1.4764E-01
3050	**ElkRiver**	7.9000E-07	3.7741E-04	5.4600E-03	8.8106E-01	1.2475E+00	2.2183E-01	1.6559E+00	2.4823E-01	1.9645E-01
4002	**Pipestone**	0.0000E+00	3.7712E-04	5.0277E-03	8.8103E-01	1.2452E+00	3.9262E-01	1.8606E+00	2.2683E-01	1.9956E-01
4003	**GraniteFalls**	0.0000E+00	3.7702E-04	6.6957E-04	8.8101E-01	1.2412E+00	1.5912E-01	1.1534E+00	1.4982E-01	9.3431E-02
5008	**Rochester**	4.2100E-06	3.7837E-04	1.4627E-02	8.8126E-01	1.2480E+00	2.5417E-01	1.9910E+00	6.4350E-01	2.3862E-01
5356	**Zumbrota**	9.6000E-07	3.7779E-04	1.9846E-03	8.8116E-01	1.2413E+00	1.6851E-01	1.2122E+00	1.6528E-01	1.0628E-01
7014	**Hibbing**	0.0000E+00	3.7703E-04	3.2153E-02	8.8359E-01	1.2592E+00	2.2484E-01	1.7884E+00	4.3386E-01	1.9662E-01
7549	**Duluth7549**	8.2000E-07	3.7745E-04	1.3045E-02	8.8425E-01	1.2570E+00	1.8355E-01	1.4357E+00	2.5413E-01	1.0984E-01

Appendix I. U.S. EPA Cumulative Exposure Project (CEP) modeled concentrations in census tracts with monitoring sites. The CEP modeling data (1990 emissions) is for purposes of comparison with monitoring data (see Appendices J, K L).

		vinyl_chloride	benzene	ethylbenzene	naphthalene	phenol	cresol_total	formaldehyde_total	MEK_total	toluene	xylene
Site No.	**Site Name**	VINYL_CHLO	BENZENE	ETHYLBENZE	NAPHTHALEN	PHENOL	CRESOL_TOT	FORMALDEHY	MEK_TOTAL	TOLUENE	XYLENE
260	**Plymouth**	3.0819E-03	1.6603E+00	3.7906E-01	1.3391E-01	8.1853E-02	5.9340E-02	1.5233E+00	6.3510E-01	3.2539E+00	2.7471E+00
420	**Koch420**	1.6763E-03	1.4471E+00	1.9967E-01	5.2645E-02	3.4334E-02	3.2364E-02	1.1994E+00	6.9677E-01	2.3329E+00	2.1804E+00
423	**Koch423**	1.6763E-03	1.4471E+00	1.9967E-01	5.2645E-02	3.4334E-02	3.2364E-02	1.1994E+00	6.9677E-01	2.3329E+00	2.1804E+00
426	**Koch426**	1.6763E-03	1.4471E+00	1.9967E-01	5.2645E-02	3.4334E-02	3.2364E-02	1.1994E+00	6.9677E-01	2.3329E+00	2.1804E+00
436	**StPaulPark**	4.2899E-03	3.4294E+00	5.9309E-01	9.6859E-02	7.0274E-02	5.3960E-02	1.6832E+00	1.1324E+00	5.4524E+00	4.6192E+00
438	**Ashland**	2.6646E-03	2.6548E+00	5.8092E-01	9.3980E-02	6.8665E-02	5.1611E-02	1.1348E+00	9.1237E-01	4.3776E+00	3.2529E+00
816	**HolmanFld**	4.8478E-03	2.6486E+00	8.4065E-01	2.1671E-01	1.4750E-01	1.0019E-01	1.7179E+00	1.9717E+00	7.5691E+00	6.9639E+00
820	**BushSt**	4.9454E-03	2.3478E+00	6.9452E-01	1.8950E-01	1.7250E-01	9.3543E-02	1.6430E+00	1.2408E+00	6.7171E+00	4.3573E+00
871	**HardingHi**	4.0361E-03	2.9349E+00	1.0086E+00	2.3531E-01	1.7116E-01	1.2905E-01	2.7809E+00	1.8481E+00	8.7367E+00	7.1182E+00
945	**MplsLibrary**	8.1687E-03	3.3062E+00	8.6066E-01	2.7550E-01	1.7120E-01	1.2007E-01	2.0339E+00	4.2820E+00	1.2654E+01	1.4615E+01
958	**MhahaAcad**	4.2470E-03	2.8597E+00	9.3151E-01	2.4022E-01	1.3774E-01	9.5124E-02	2.6380E+00	1.2281E+00	6.6019E+00	6.4560E+00
1240	**I_Falls1240**	1.2489E-03	1.2072E+00	1.8988E-01	7.0854E-02	2.1246E-01	1.0679E-01	5.2260E-01	3.2396E-01	1.4407E+00	1.2023E+00
1241	**I_Falls1241**	1.2489E-03	1.2072E+00	1.8988E-01	7.0854E-02	2.1246E-01	1.0679E-01	5.2260E-01	3.2396E-01	1.4407E+00	1.2023E+00
1400	**Sandstone**	6.0750E-05	5.4885E-01	1.7538E-02	6.7651E-03	1.4568E-02	5.1618E-03	2.8978E-01	2.4681E-02	1.1462E-01	2.4029E-01
2005	**FergusFalls**	2.5674E-03	1.2214E+00	1.9751E-01	7.4021E-02	1.6230E-01	8.5823E-02	5.4918E-01	1.9279E-01	1.3825E+00	1.0767E+00
2010	**Alexandria**	8.7630E-04	1.4651E+00	2.4328E-01	4.9573E-02	1.2816E-01	4.6694E-02	5.0396E-01	2.3533E-01	1.7629E+00	1.4367E+00
2401	**Warroad**	1.0111E-04	5.4500E-01	1.5352E-02	4.7632E-03	9.7961E-03	4.0392E-03	2.8679E-01	3.9213E-02	1.3153E-01	2.7217E-01
3049	**LittleFalls**	7.5060E-04	9.9331E-01	1.4576E-01	5.3844E-02	1.2659E-01	6.4145E-02	4.8242E-01	2.8202E-01	1.4877E+00	1.3986E+00
3050	**ElkRiver**	6.6024E-04	8.4804E-01	1.1533E-01	4.0318E-02	5.1070E-02	3.2442E-02	5.6014E-01	1.9816E-01	9.0525E-01	8.7576E-01
4002	**Pipestone**	8.9795E-04	9.2707E-01	9.8264E-02	3.4900E-02	3.9912E-02	2.4187E-02	4.1650E-01	3.7695E-01	1.3740E+00	1.6456E+00
4003	**GraniteFalls**	1.3197E-04	5.6776E-01	2.0113E-02	7.7155E-03	8.9882E-03	4.5763E-03	3.0049E-01	3.0924E-02	1.6593E-01	2.8061E-01
5008	**Rochester**	1.8501E-03	2.1280E+00	5.1170E-01	1.8348E-01	1.3413E-01	8.5939E-02	1.0942E+00	2.7370E-01	3.7468E+00	2.8011E+00
5356	**Zumbrota**	5.4066E-04	6.2288E-01	3.6719E-02	1.1421E-02	1.0791E-02	8.7673E-03	3.6434E-01	8.7239E-02	4.0938E-01	5.5597E-01
7014	**Hibbing**	1.1417E-02	2.0311E+00	4.5681E-01	1.6033E-01	1.8944E-01	1.0541E-01	9.3076E-01	3.1667E-01	3.4752E+00	2.3413E+00
7549	**Duluth7549**	2.4042E-03	1.6535E+00	3.2238E-01	1.1827E-01	1.4229E-01	7.2967E-02	1.0745E+00	1.6197E-01	2.2651E+00	1.6376E+00

APPENDIX J

Appendix J. MPCA-measured air concentrations compared to EPA Cumulative Exposure Project modeled values for organic substances
(%difference = [modeled - monitored]/monitored * 100)
(difference = modeled - monitored)

Monitoring Site			propionaldehyde_total				hexachlorobutadiene				propylene_dichloride			
Site No.	Site Name	Census Tract #	modelled	monitored	%diff	difference	modelled	monitored	%diff	difference	modelled	monitored	%diff	difference
260	Plymouth	27053026509	0.1861	0.1904	-2.27	-0.0043	0.0018	0.2428	-99.25	-0.2410	0.0000	0.0466	-99.95	-0.0466
420	Koch420	27037061002	0.1229	0.1753	-29.89	-0.0524	0.0018	0.1827	-99.01	-0.1809	0.0000	0.0094	-99.67	-0.0094
423	Koch423	27037061002	0.1229	0.1704	-27.87	-0.0475	0.0018	0.1467	-98.77	-0.1449	0.0000	0.0094	-99.67	-0.0094
426	Koch426	27037061002	0.1229	0.2385	-48.47	-0.1156	0.0018	0.1680	-98.92	-0.1662	0.0000	0.0107	-99.71	-0.0107
436	StPaulPark	27163071301	0.2677	0.2180	22.80	0.0497	0.0018	0.1501	-98.79	-0.1483	0.0001	0.0106	-98.64	-0.0105
438	Ashland	27163071003	0.2487	0.2860	-13.05	-0.0373	0.0018	0.1741	-98.96	-0.1723	0.0001	0.0159	-99.63	-0.0158
816	HolmanFld	27123036100	0.2275	0.2191	3.82	0.0084	0.0018	0.1556	-98.84	-0.1538	0.0000	0.0112	-99.67	-0.0112
820	BushSt	27123031700	0.2154	0.2643	-18.49	-0.0489	0.0018	0.1493	-98.79	-0.1475	0.0000	0.0040	-99.21	-0.0040
871	HardingHi	27123034602	0.2551				0.0018				0.0000			
945	MplsLibrary	27053004500	0.2651	0.2803	-5.44	-0.0152	0.0018	0.1487	-98.78	-0.1469	0.0002	0.0081	-97.99	-0.0079
958	MhahaAcad	27053010500	0.2738	0.2432	12.59	0.0306	0.0018	0.1929	-99.06	-0.1911	0.0000	0.0074	-99.45	-0.0074
1240	I_Falls1240	27071990200	0.0274	0.2116	-87.03	-0.1842	0.0018	0.1265	-98.57	-0.1247	0.0000	0.0087	-100.00	-0.0087
1241	I_Falls1241	27071990200	0.0274	0.1152	-76.17	-0.0878	0.0018	0.2532	-99.29	-0.2514	0.0000	0.0837	-100.00	-0.0837
1400	Sandstone	27115950500	0.0095	0.1336	-92.88	-0.1241	0.0018	0.4001	-99.55	-0.3983	0.0000	0.0409	-100.00	-0.0409
2005	FergusFalls	27111961000	0.0329	0.1843	-82.16	-0.1514	0.0018	0.1867	-99.03	-0.1849	0.0000	0.0092	-100.00	-0.0092
2010	Alexandria	27041950700	0.0575	0.1840	-68.73	-0.1265	0.0018	0.2319	-99.22	-0.2301	0.0000	0.0640	-100.00	-0.0640
2401	Warroad	27135970100	0.0074	0.0791	-90.61	-0.0717	0.0018	0.1614	-98.88	-0.1596	0.0000	0.0105	-99.98	-0.0105
3049	LittleFalls	27097980600	0.0271	0.1180	-77.02	-0.0909	0.0018	0.3086	-99.41	-0.3068	0.0000	0.0371	-100.00	-0.0371
3050	ElkRiver	27141030500	0.0594	0.1654	-64.06	-0.1060	0.0018	0.1887	-99.04	-0.1869	0.0000	0.0058	-99.96	-0.0058
4002	Pipestone	27117960300	0.0271	0.1522	-82.20	-0.1251	0.0018	0.2776	-99.35	-0.2758	0.0000	0.0711	-100.00	-0.0711
4003	GraniteFalls	27023950300	0.0133	0.1466	-90.96	-0.1333	0.0018	0.1711	-98.94	-0.1693	0.0000	0.0113	-100.00	-0.0113
5008	Rochester	27109001000	0.0675	0.1580	-57.27	-0.0905	0.0018	0.1674	-98.92	-0.1656	0.0000	0.0059	-99.95	-0.0059
5356	Zumbrota	27049980500	0.0266	0.1917	-86.13	-0.1651	0.0018	0.2489	-99.27	-0.2471	0.0000	0.0148	-99.88	-0.0148
7014	Hibbing	27137012300	0.0461	0.1217	-62.13	-0.0756	0.0018	0.1741	-98.96	-0.1723	0.0006	0.0076	-92.65	-0.0070
7549	Duluth7549	27137002500	0.0677	0.1478	-54.19	-0.0801	0.0018	0.1671	-98.92	-0.1653	0.0001	0.0162	-99.34	-0.0161
Average over all sites			0.1122	0.1831	-49.07	-0.0769	0.0018	0.1989	-99.02	-0.1971	0.0001	0.0217	-99.39	-0.0216

Appendix J. MPCA-measured air concentrations compared to EPA Cumulative Exposure Project modeled values for organic substances
(%difference = [modeled - monitored]/monitored * 100)
(difference = modeled - monitored)

Monitoring Site			dichloropropene(1,3)				chloroform				p-dichlorobenzene			
Site No.	Site Name	Census Tract #	modelled	monitored	%diff	difference	modelled	monitored	%diff	difference	modelled	monitored	%diff	difference
260	Plymouth	27053026509	0.0314	0.0286	9.66	0.0028	0.0870	0.1285	-32.31	-0.0415	0.0536	0.3995	-86.59	-0.3459
420	Koch420	27037061002	0.0179	0.0182	-1.70	-0.0003	0.0852	0.1003	-15.06	-0.0151	0.0286	0.2276	-87.43	-0.1990
423	Koch423	27037061002	0.0179	0.0144	24.25	0.0035	0.0852	0.0826	3.14	0.0026	0.0286	0.1811	-84.20	-0.1525
426	Koch426	27037061002	0.0179	0.0146	22.54	0.0033	0.0852	0.1265	-32.65	-0.0413	0.0286	0.1566	-81.73	-0.1280
436	StPaulPark	27163071301	0.0230	0.0132	74.58	0.0098	0.0864	0.1144	-24.47	-0.0280	0.0444	0.2281	-80.55	-0.1837
438	Ashland	27163071003	0.0243	0.0196	23.86	0.0047	0.0873	0.1546	-43.52	-0.0673	0.0450	0.2253	-80.04	-0.1803
816	HolmanFld	27123036100	0.0545	0.0132	312.70	0.0413	0.0991	0.1380	-28.22	-0.0389	0.1222	0.2944	-58.49	-0.1722
820	BushSt	27123031700	0.0545	0.0191	185.56	0.0354	0.1064	0.1616	-34.18	-0.0552	0.1538	0.3550	-56.67	-0.2012
871	HardingHi	27123034602	0.0422				0.1515	0.1409	7.52	0.0106	0.3283			
945	MplsLibrary	27053004500	0.0618	0.0152	306.66	0.0466	0.0917	0.1432	-35.96	-0.0515	0.1086	0.4454	-75.62	-0.3368
958	MhahaAcad	27053010500	0.0442	0.0186	137.55	0.0256	0.1251	0.1050	19.18	0.0201	0.2221	0.6790	-67.28	-0.4569
1240	I_Falls1240	27071990200	0.0157	0.0097	62.08	0.0060	0.2834	1.0307	-72.50	-0.7473	0.0194	0.2484	-92.19	-0.2290
1241	I_Falls1241	27071990200	0.0157	0.0466	-66.26	-0.0309	0.2834	0.1528	85.50	0.1306	0.0194	0.3448	-94.37	-0.3254
1400	Sandstone	27115950500	0.0009	0.0333	-97.34	-0.0324	0.0831	0.1005	-17.34	-0.0174	0.0013	0.4553	-99.70	-0.4540
2005	FergusFalls	27111961000	0.0164	0.0118	38.91	0.0046	0.0859	0.0854	0.53	0.0005	0.0223	0.3156	-92.94	-0.2933
2010	Alexandria	27041950700	0.0124	0.0244	-49.38	-0.0120	0.0840	0.1691	-50.33	-0.0851	0.0167	0.3500	-95.24	-0.3333
2401	Warroad	27135970100	0.0008	0.0056	-85.06	-0.0048	0.0831	0.1022	-18.73	-0.0191	0.0011	0.1796	-99.39	-0.1785
3049	LittleFalls	27097980600	0.0108	0.0335	-67.85	-0.0227	0.0838	0.1100	-23.78	-0.0262	0.0146	0.3735	-96.08	-0.3589
3050	ElkRiver	27141030500	0.0100	0.0131	-23.62	-0.0031	0.0837	0.0726	15.30	0.0111	0.0154	0.2085	-92.62	-0.1931
4002	Pipestone	27117960300	0.0100	0.0397	-74.81	-0.0297	0.0840	0.1264	-33.54	-0.0424	0.0148	0.5644	-97.38	-0.5496
4003	GraniteFalls	27023950300	0.0013	0.0127	-89.93	-0.0114	0.0832	0.0840	-1.01	-0.0008	0.0022	0.2211	-99.01	-0.2189
5008	Rochester	27109001000	0.0287	0.0165	73.80	0.0122	0.0852	0.0890	-4.31	-0.0038	0.0338	0.1925	-82.42	-0.1587
5356	Zumbrota	27049980500	0.0024	0.0229	-89.51	-0.0205	0.0833	0.1078	-22.73	-0.0245	0.0048	0.4028	-98.81	-0.3980
7014	Hibbing	27137012300	0.0219	0.0158	38.65	0.0061	0.0839	0.0817	2.71	0.0022	0.0535	0.3509	-84.74	-0.2974
7549	Duluth7549	27137002500	0.0168	0.0182	-7.75	-0.0014	0.0952	0.1078	-11.69	-0.0126	0.0378	0.2957	-87.23	-0.2579
Average over all sites			0.0221	0.0199	27.40	0.0014	0.1070	0.1526	-14.74	-0.0456	0.0568	0.3206	-86.28	-0.2751

Appendix J. MPCA-measured air concentrations compared to EPA Cumulative Exposure Project modeled values for organic substances
(%difference = [modeled - monitored]/monitored * 100)
(difference = modeled - monitored)

Monitoring Site			acetaldehyde_total				ethylene_dichloride				trichloroethane(1,1,2)			
Site No.	Site Name	Census Tract #	modelled	monitored	%diff	difference	modelled	monitored	%diff	difference	modelled	monitored	%diff	difference
260	Plymouth	27053026509	0.8347	0.9467	-11.83	-0.1120	0.0615	0.0493	24.78	0.0122	0.0004	0.0517	-99.21	-0.0513
420	Koch420	27037061002	0.4700	0.9787	-51.98	-0.5087	0.0621	0.0426	45.72	0.0195	0.0027	0.0288	-90.70	-0.0261
423	Koch423	27037061002	0.4700	0.9692	-51.51	-0.4992	0.0621	0.0771	-19.49	-0.0150	0.0027	0.0143	-81.28	-0.0116
426	Koch426	27037061002	0.4700	1.1253	-58.23	-0.6553	0.0621	0.0649	-4.35	-0.0028	0.0027	0.0142	-81.15	-0.0115
436	StPaulPark	27163071301	0.8961	1.2796	-29.97	-0.3835	0.0674	0.0239	182.14	0.0435	0.0141	0.0194	-27.47	-0.0053
438	Ashland	27163071003	0.8534	1.5366	-44.46	-0.6832	0.0651	0.0337	93.05	0.0314	0.0133	0.0200	-33.43	-0.0067
816	HolmanFld	27123036100	0.9924	1.2669	-21.67	-0.2745	0.0628	0.0272	130.74	0.0356	0.0060	0.0171	-64.92	-0.0111
820	BushSt	27123031700	0.9703	1.7878	-45.73	-0.8175	0.0624	0.0207	201.54	0.0417	0.0050	0.0038	31.21	0.0012
871	HardingHi	27123034602	1.3004				0.0625	0.0154	306.16	0.0471	0.0053			
945	MplsLibrary	27053004500	1.2005	1.6856	-28.78	-0.4851	0.0662	0.0243	172.62	0.0419	0.0033	0.0199	-83.52	-0.0166
958	MhahaAcad	27053010500	1.3699	1.3827	-0.92	-0.0128	0.0625	0.0267	134.20	0.0358	0.0039	0.0106	-63.11	-0.0067
1240	I_Falls1240	27071990200	0.1387	1.2832	-89.19	-1.1445	0.0607	0.0337	80.12	0.0270	0.0002	0.0245	-99.32	-0.0243
1241	I_Falls1241	27071990200	0.1387	0.6883	-79.85	-0.5496	0.0607	0.0445	36.40	0.0162	0.0002	0.0526	-99.68	-0.0524
1400	Sandstone	27115950500	0.0413	0.6246	-93.38	-0.5833	0.0607	0.0705	-13.90	-0.0098	0.0000	0.0511	-99.98	-0.0511
2005	FergusFalls	27111961000	0.1658	1.8061	-90.82	-1.6403	0.0607	0.0247	145.75	0.0360	0.0001	0.0063	-98.13	-0.0062
2010	Alexandria	27041950700	0.2113	0.8465	-75.04	-0.6352	0.0607	0.0554	9.57	0.0053	0.0001	0.0689	-99.83	-0.0688
2401	Warroad	27135970100	0.0294	0.5697	-94.84	-0.5403	0.0608	0.0196	210.08	0.0412	0.0000	0.0021	-99.80	-0.0021
3049	LittleFalls	27097980600	0.1364	0.5845	-76.66	-0.4481	0.0607	0.0698	-13.04	-0.0091	0.0001	0.0647	-99.85	-0.0646
3050	ElkRiver	27141030500	0.2534	0.9885	-74.37	-0.7351	0.0608	0.0261	132.82	0.0347	0.0001	0.0090	-98.97	-0.0089
4002	Pipestone	27117960300	0.1209	0.7465	-83.80	-0.6256	0.0607	0.0695	-12.66	-0.0088	0.0001	0.0923	-99.92	-0.0922
4003	GraniteFalls	27023950300	0.0557	1.0011	-94.44	-0.9454	0.0607	0.0242	150.83	0.0365	0.0000	0.0055	-99.76	-0.0055
5008	Rochester	27109001000	0.3899	0.9116	-57.23	-0.5217	0.0608	0.0203	199.51	0.0405	0.0003	0.0057	-95.59	-0.0054
5356	Zumbrota	27049980500	0.1032	0.6300	-83.61	-0.5268	0.0617	0.0532	15.91	0.0085	0.0027	0.0463	-94.10	-0.0436
7014	Hibbing	27137012300	0.2954	0.8857	-66.65	-0.5903	0.0783	0.0238	228.89	0.0545	0.0002	0.0057	-96.34	-0.0055
7549	Duluth7549	27137002500	0.4144	0.9251	-55.21	-0.5107	0.0641	0.0303	111.49	0.0338	0.0002	0.0231	-99.26	-0.0229
	Average over all sites		0.4929	1.0604	-60.84	-0.6012	0.0627	0.0389	101.95	0.0239	0.0025	0.0274	-82.25	-0.0250

Appendix J. MPCA-measured air concentrations compared to EPA Cumulative Exposure Project modeled values for organic substances
(%difference = [modeled - monitored]/monitored * 100)
(difference = modeled - monitored)

Monitoring Site			styrene				vinylidene_chloride				chlorobenzene			
Site No.	Site Name	Census Tract #	modelled	monitored	%diff	difference	modelled	monitored	%diff	difference	modelled	monitored	%diff	difference
260	Plymouth	27053026509	0.0454	0.1273	-64.33	-0.0819	0.0000	0.1463	-100.00	-0.1463	0.0176	0.0286	-38.55	-0.0110
420	Koch420	27037061002	0.0126	0.0931	-86.44	-0.0805	0.0000	0.0404	-100.00	-0.0404	0.0109	0.0182	-40.38	-0.0073
423	Koch423	27037061002	0.0126	0.0807	-84.36	-0.0681	0.0000	0.0353	-100.00	-0.0353	0.0109	0.0144	-24.65	-0.0035
426	Koch426	27037061002	0.0126	0.0675	-81.30	-0.0549	0.0000	0.0327	-100.00	-0.0327	0.0109	0.0146	-25.68	-0.0037
436	StPaulPark	27163071301	0.0334	0.0821	-59.33	-0.0487	0.0000	0.0588	-100.00	-0.0588	0.0179	0.0132	35.37	0.0047
438	Ashland	27163071003	0.0289	0.0877	-67.08	-0.0588	0.0000	0.0794	-100.00	-0.0794	0.0154	0.0196	-21.22	-0.0042
816	HolmanFld	27123036100	0.0772	0.0867	-10.97	-0.0095	0.0000	0.0499	-100.00	-0.0499	0.0317	0.0132	140.13	0.0185
820	BushSt	27123031700	0.0647	0.0804	-19.53	-0.0157	0.0000	0.0502	-100.00	-0.0502	0.0330	0.0191	72.53	0.0139
871	HardingHi	27123034602	0.0761				0.0000	0.0076	-99.99	-0.0076	0.0359			
945	MplsLibrary	27053004500	0.1387	0.0869	59.62	0.0518	0.0000	0.0573	-99.99	-0.0573	0.0386	0.0152	154.18	0.0234
958	MhahaAcad	27053010500	0.0893	0.1049	-14.87	-0.0156	0.0000	0.0512	-99.99	-0.0512	0.0320	0.0186	71.82	0.0134
1240	I_Falls1240	27071990200	0.0133	0.0597	-77.79	-0.0464	0.0000	0.1585	-100.00	-0.1585	0.0080	0.0097	-17.99	-0.0017
1241	I_Falls1241	27071990200	0.0133	0.1462	-90.93	-0.1329	0.0000	0.2004	-100.00	-0.2004	0.0080	0.0466	-82.93	-0.0386
1400	Sandstone	27115950500	0.0014	0.2195	-99.36	-0.2181	0.0000	0.1700	-100.00	-0.1700	0.0005	0.0333	-98.59	-0.0328
2005	FergusFalls	27111961000	0.0184	0.0912	-79.84	-0.0728	0.0000	0.0393	-99.91	-0.0393	0.0082	0.0118	-30.17	-0.0036
2010	Alexandria	27041950700	0.0124	0.1353	-90.83	-0.1229	0.0000	0.1545	-100.00	-0.1545	0.0062	0.0244	-74.39	-0.0182
2401	Warroad	27135970100	0.0009	0.0855	-98.95	-0.0846	0.0000	0.0409	-100.00	-0.0409	0.0005	0.0056	-90.83	-0.0051
3049	LittleFalls	27097980600	1.2111	0.1789	576.95	1.0322	0.0000	0.1619	-100.00	-0.1619	0.0055	0.0335	-83.68	-0.0280
3050	ElkRiver	27141030500	0.0088	0.0997	-91.19	-0.0909	0.0000	0.0455	-100.00	-0.0455	0.0055	0.0131	-58.32	-0.0076
4002	Pipestone	27117960300	0.1298	0.1674	-22.48	-0.0376	0.0000	0.1382	-100.00	-0.1382	0.0050	0.0397	-87.34	-0.0347
4003	GraniteFalls	27023950300	0.0018	0.0946	-98.10	-0.0928	0.0000	0.0608	-100.00	-0.0608	0.0007	0.0127	-94.73	-0.0120
5008	Rochester	27109001000	0.0721	0.0844	-14.55	-0.0123	0.0000	0.0426	-99.99	-0.0426	0.0146	0.0165	-11.35	-0.0019
5356	Zumbrota	27049980500	0.0021	0.1513	-98.64	-0.1492	0.0000	0.1903	-100.00	-0.1903	0.0020	0.0229	-91.33	-0.0209
7014	Hibbing	27137012300	0.0854	0.0926	-7.75	-0.0072	0.0000	0.0356	-100.00	-0.0356	0.0322	0.0158	103.50	0.0164
7549	Duluth7549	27137002500	0.0416	0.1004	-58.61	-0.0588	0.0000	0.0907	-100.00	-0.0907	0.0130	0.0182	-28.32	-0.0052
Average over all sites			0.0881	0.1085	-32.53	-0.0198	0.0000	0.0855	-99.99	-0.0855	0.0146	0.0199	-17.62	-0.0063

Appendix J. MPCA-measured air concentrations compared to EPA Cumulative Exposure Project modeled values for organic substances
(%difference = [modeled - monitored]/monitored * 100)
(difference = modeled - monitored)

Monitoring Site			carbon_tetrachloride				methylene_chloride				tetrachloroethylene			
Site No.	Site Name	Census Tract #	modelled	monitored	%diff	difference	modelled	monitored	%diff	difference	modelled	monitored	%diff	difference
260	Plymouth	27053026509	0.8825	0.9142	-3.47	-0.0317	0.4480	0.6433	-30.36	-0.1953	0.5648	0.3670	53.90	0.1978
420	Koch420	27037061002	0.8824	0.6653	32.63	0.2171	0.3377	0.2593	30.25	0.0784	0.4975	0.2729	82.30	0.2246
423	Koch423	27037061002	0.8824	0.6724	31.23	0.2100	0.3377	0.2922	15.58	0.0455	0.4975	0.2814	76.80	0.2161
426	Koch426	27037061002	0.8824	0.6084	45.03	0.2740	0.3377	0.2698	25.18	0.0679	0.4975	0.2796	77.94	0.2179
436	StPaulPark	27163071301	0.8837	0.7366	19.97	0.1471	0.4991	0.3867	29.06	0.1124	0.5153	0.3899	32.16	0.1254
438	Ashland	27163071003	0.8843	0.7583	16.62	0.1260	0.3594	0.3714	-3.23	-0.0120	0.4642	0.2781	66.91	0.1861
816	HolmanFld	27123036100	0.8948	0.7111	25.84	0.1837	0.7516	0.6500	15.63	0.1016	0.7101	0.5428	30.83	0.1673
820	BushSt	27123031700	0.9032	0.7172	25.93	0.1860	0.4976	0.5765	-13.68	-0.0789	0.5540	0.5245	5.62	0.0295
871	HardingHi	27123034602	0.9577	0.7819	22.49	0.1758	0.7936	0.3781	109.89	0.4155	0.6250	0.4040	54.71	0.2210
945	MplsLibrary	27053004500	0.8856	0.6784	30.54	0.2072	2.0707	1.1795	75.56	0.8912	3.3562	1.2158	176.05	2.1404
958	MhahaAcad	27053010500	0.9265	0.8003	15.77	0.1262	0.6432	0.3902	64.83	0.2530	0.7583	0.4296	76.52	0.3287
1240	I_Falls1240	27071990200	0.8810	0.6335	39.07	0.2475	0.1804	0.2446	-26.23	-0.0642	0.1959	0.3351	-41.55	-0.1392
1241	I_Falls1241	27071990200	0.8810	0.9067	-2.83	-0.0257	0.1804	0.2496	-27.71	-0.0692	0.1959	0.4592	-57.34	-0.2633
1400	Sandstone	27115950500	0.8810	0.9122	-3.42	-0.0312	0.1551	0.2998	-48.26	-0.1447	0.1445	0.3348	-56.85	-0.1903
2005	FergusFalls	27111961000	0.8811	0.7750	13.68	0.1061	0.1885	0.3064	-38.49	-0.1179	0.2278	0.6785	-66.42	-0.4507
2010	Alexandria	27041950700	0.8810	0.9186	-4.09	-0.0376	0.2146	0.2996	-28.37	-0.0850	0.3883	0.3442	12.82	0.0441
2401	Warroad	27135970100	0.8810	0.8163	7.93	0.0647	0.1634	0.1517	7.68	0.0117	0.1476	0.1776	-16.90	-0.0300
3049	LittleFalls	27097980600	0.8810	0.9062	-2.78	-0.0252	0.1948	0.3020	-35.49	-0.1072	0.1948	0.3100	-37.16	-0.1152
3050	ElkRiver	27141030500	0.8811	0.8076	9.10	0.0735	0.2218	0.2220	-0.08	-0.0002	0.2482	0.1950	27.30	0.0532
4002	Pipestone	27117960300	0.8810	0.9176	-3.99	-0.0366	0.3926	0.5906	-33.52	-0.1980	0.2268	0.2847	-20.33	-0.0579
4003	GraniteFalls	27023950300	0.8810	0.7885	11.73	0.0925	0.1591	0.1886	-15.63	-0.0295	0.1498	0.2140	-29.99	-0.0642
5008	Rochester	27109001000	0.8813	0.8139	8.28	0.0674	0.2542	0.2276	11.67	0.0266	0.6435	0.2873	123.98	0.3562
5356	Zumbrota	27049980500	0.8812	0.9301	-5.26	-0.0489	0.1685	0.5495	-69.33	-0.3810	0.1653	0.2813	-41.24	-0.1160
7014	Hibbing	27137012300	0.8836	0.7889	12.00	0.0947	0.2248	0.2264	-0.69	-0.0016	0.4339	0.2794	55.28	0.1545
7549	Duluth7549	27137002500	0.8842	0.7662	15.41	0.1180	0.1836	1.0759	-82.94	-0.8923	0.2541	0.4219	-39.77	-0.1678
Average over all sites			0.8882	0.7890	14.30	0.0992	0.3983	0.4133	-2.75	-0.0149	0.5063	0.3835	21.82	0.1227

Appendix J. MPCA-measured air concentrations compared to EPA Cumulative Exposure Project modeled values for organic substances

(%difference = [modeled - monitored]/monitored * 100)
(difference = modeled - monitored)

Monitoring Site			trichloroethylene				vinyl_chloride				benzene			
Site No.	Site Name	Census Tract #	modelled	monitored	%diff	difference	modelled	monitored	%diff	difference	modelled	monitored	%diff	difference
260	Plymouth	27053026509	0.4826	1.1010	-56.17	-0.6184	0.0031	0.0000		0.0031	1.6603	1.3090	26.84	0.3513
420	Koch420	27037061002	0.3865	0.2157	79.18	0.1708	0.0017	0.0143	-88.28	-0.0126	1.4471	1.7230	-16.01	-0.2759
423	Koch423	27037061002	0.3865	0.1963	96.89	0.1902	0.0017	0.0094	-82.17	-0.0077	1.4471	1.0590	36.65	0.3881
426	Koch426	27037061002	0.3865	0.1616	139.16	0.2249	0.0017	0.0188	-91.08	-0.0171	1.4471	2.5930	-44.19	-1.1459
436	StPaulPark	27163071301	0.6383	0.2455	159.98	0.3928	0.0043	0.0197	-78.22	-0.0154	3.4294	2.6180	30.99	0.8114
438	Ashland	27163071003	0.3584	0.2830	26.63	0.0754	0.0027	0.0043	-38.03	-0.0016	2.6548	3.0840	-13.92	-0.4292
816	HolmanFld	27123036100	1.0298	0.3853	167.26	0.6445	0.0048	0.0181	-73.22	-0.0133	2.6486	1.7200	53.99	0.9286
820	BushSt	27123031700	0.5080	0.4013	26.59	0.1067	0.0049	0.0028	76.62	0.0021	2.3478	3.1850	-26.29	-0.8372
871	HardingHi	27123034602	0.8937				0.0040	0.0007	476.58	0.0033	2.9349	2.7410	7.08	0.1939
945	MplsLibrary	27053004500	4.0155	1.0754	273.39	2.9401	0.0082	0.0162	-49.58	-0.0080	3.3062	2.5330	30.53	0.7732
958	MhahaAcad	27053010500	0.7771	0.2662	191.92	0.5109	0.0042	0.0030	41.57	0.0012	2.8597	1.4440	98.04	1.4157
1240	I_Falls1240	27071990200	0.1203	0.0936	28.55	0.0267	0.0012	0.0054	-76.87	-0.0042	1.2072	1.1470	5.25	0.0602
1241	I_Falls1241	27071990200	0.1203	0.2933	-58.98	-0.1730	0.0012	0.0032	-60.97	-0.0020	1.2072	1.3660	-11.63	-0.1588
1400	Sandstone	27115950500	0.0836	0.5414	-84.56	-0.4578	0.0001	0.0000		0.0001	0.5488	0.6810	-19.41	-0.1322
2005	FergusFalls	27111961000	0.1312	0.2188	-40.03	-0.0876	0.0026	0.0059	-56.49	-0.0033	1.2214	1.1890	2.73	0.0324
2010	Alexandria	27041950700	0.1875	0.5092	-63.19	-0.3217	0.0009	0.0000		0.0009	1.4651	1.2200	20.09	0.2451
2401	Warroad	27135970100	0.0871	0.7362	-88.17	-0.6491	0.0001	0.0044	-97.70	-0.0043	0.5450	0.6400	-14.84	-0.0950
3049	LittleFalls	27097980600	0.1476	1.4286	-89.67	-1.2810	0.0008	0.0025	-69.98	-0.0017	0.9933	0.9030	10.00	0.0903
3050	ElkRiver	27141030500	0.1964	0.2703	-27.32	-0.0739	0.0007	0.0045	-85.33	-0.0038	0.8480	0.9460	-10.35	-0.0980
4002	Pipestone	27117960300	0.1996	1.4267	-86.01	-1.2271	0.0009	0.0000		0.0009	0.9271	0.8210	12.92	0.1061
4003	GraniteFalls	27023950300	0.0934	0.1438	-35.03	-0.0504	0.0001	0.0034	-96.12	-0.0033	0.5678	0.9280	-38.82	-0.3602
5008	Rochester	27109001000	0.2386	0.1817	31.32	0.0569	0.0019	0.0023	-19.56	-0.0004	2.1280	1.1130	91.20	1.0150
5356	Zumbrota	27049980500	0.1063	0.5537	-80.81	-0.4474	0.0005	0.0000		0.0005	0.6229	0.6490	-4.03	-0.0261
7014	Hibbing	27137012300	0.1966	0.1131	73.84	0.0835	0.0114	0.0052	119.56	0.0062	2.0311	1.0160	99.91	1.0151
7549	Duluth7549	27137002500	0.1098	0.5144	-78.65	-0.4046	0.0024	0.0078	-69.18	-0.0054	1.6535	1.7440	-5.19	-0.0905
	Average over all sites		0.4752	0.4732	21.09	-0.0154	0.0026	0.0061	-20.92	-0.0034	1.6860	1.5349	12.86	0.1511

Appendix J. MPCA-measured air concentrations compared to EPA Cumulative Exposure Project modeled values for organic substances
(%difference = [modeled - monitored]/monitored * 100)
(difference = modeled - monitored)

Monitoring Site			ethylbenzene				formaldehyde_total				toluene			
Site No.	Site Name	Census Tract #	modelled	monitored	%diff	difference	modelled	monitored	%diff	difference	modelled	monitored	%diff	difference
260	Plymouth	27053026509	0.3791	0.5234	-27.58	-0.1443	1.5233	1.2430	22.55	0.2803	3.2539	2.7183	19.70	0.5356
420	Koch420	27037061002	0.1997	0.6501	-69.29	-0.4504	1.1994	1.4090	-14.88	-0.2097	2.3329	3.0766	-24.17	-0.7437
423	Koch423	27037061002	0.1997	0.3520	-43.28	-0.1523	1.1994	1.3849	-13.40	-0.1856	2.3329	1.8347	27.15	0.4982
426	Koch426	27037061002	0.1997	0.8645	-76.90	-0.6648	1.1994	1.4039	-14.57	-0.2046	2.3329	4.1106	-43.25	-1.7777
436	StPaulPark	27163071301	0.5931	0.8618	-31.18	-0.2687	1.6832	1.7165	-1.94	-0.0333	5.4524	4.9463	10.23	0.5061
438	Ashland	27163071003	0.5809	0.8135	-28.59	-0.2326	1.1348	1.9950	-43.12	-0.8602	4.3776	5.2041	-15.88	-0.8265
816	HolmanFld	27123036100	0.8407	0.8623	-2.51	-0.0216	1.7179	1.9586	-12.29	-0.2407	7.5691	4.9338	53.41	2.6353
820	BushSt	27123031700	0.6945	1.6377	-57.59	-0.9432	1.6430	4.4300	-62.91	-2.7870	6.7171	10.1733	-33.97	-3.4562
871	HardingHi	27123034602	1.0086	0.7325	37.69	0.2761	2.7809	1.6820	65.33	1.0989	8.7367	4.8087	81.69	3.9280
945	MplsLibrary	27053004500	0.8607	1.5179	-43.30	-0.6572	2.0339	2.6953	-24.54	-0.6613	12.6538	7.0691	79.00	5.5847
958	MhahaAcad	27053010500	0.9315	0.7612	22.37	0.1703	2.6380	2.4770	6.50	0.1610	6.6019	3.3127	99.29	3.2892
1240	I_Falls1240	27071990200	0.1899	0.7806	-75.68	-0.5907	0.5226	0.9142	-42.83	-0.3916	1.4407	3.3246	-56.67	-1.8839
1241	I_Falls1241	27071990200	0.1899	0.5234	-63.72	-0.3335	0.5226	1.2840	-59.30	-0.7614	1.4407	2.3442	-38.54	-0.9035
1400	Sandstone	27115950500	0.0175	0.2071	-91.53	-0.1896	0.2898	1.1690	-75.21	-0.8792	0.1146	0.8167	-85.97	-0.7021
2005	FergusFalls	27111961000	0.1975	0.4252	-53.55	-0.2277	0.5492	1.6600	-66.92	-1.1108	1.3825	2.3902	-42.16	-1.0077
2010	Alexandria	27041950700	0.2433	0.4418	-44.93	-0.1985	0.5040	1.4180	-64.46	-0.9140	1.7629	2.0818	-15.32	-0.3189
2401	Warroad	27135970100	0.0154	0.1996	-92.31	-0.1842	0.2868	1.2180	-76.45	-0.9312	0.1315	1.0653	-87.65	-0.9338
3049	LittleFalls	27097980600	0.1458	0.3190	-54.31	-0.1732	0.4824	1.1120	-56.62	-0.6296	1.4877	1.6301	-8.73	-0.1424
3050	ElkRiver	27141030500	0.1153	0.3314	-65.20	-0.2161	0.5601	1.4340	-60.94	-0.8739	0.9052	1.7137	-47.18	-0.8085
4002	Pipestone	27117960300	0.0983	0.3434	-71.38	-0.2451	0.4165	1.2570	-66.87	-0.8405	1.3740	1.6250	-15.45	-0.2510
4003	GraniteFalls	27023950300	0.0201	0.2292	-91.22	-0.2091	0.3005	1.9750	-84.79	-1.6745	0.1659	1.1410	-85.46	-0.9751
5008	Rochester	27109001000	0.5117	0.3920	30.53	0.1197	1.0942	1.3600	-19.55	-0.2658	3.7468	2.3048	62.56	1.4420
5356	Zumbrota	27049980500	0.0367	0.1969	-81.35	-0.1602	0.3643	1.1650	-68.73	-0.8007	0.4094	0.8807	-53.52	-0.4713
7014	Hibbing	27137012300	0.4568	0.3570	27.96	0.0998	0.9308	1.5660	-40.56	-0.6352	3.4752	2.0895	66.32	1.3857
7549	Duluth7549	27137002500	0.3224	0.9125	-64.67	-0.5901	1.0745	1.2957	-17.07	-0.2212	2.2651	4.1699	-45.68	-1.9048
	Average over all sites		0.3619	0.6094	-44.46	-0.2475	1.0661	1.6489	-35.74	-0.5829	3.2985	3.1906	-8.01	0.1079

Appendix J. MPCA-measured air concentrations compared to EPA Cumulative Exposure Project modeled values for organic substances
(%difference = [modeled - monitored]/monitored * 100)
(difference = modeled - monitored)

Monitoring Site			xylene				ethylene_dibromide			
Site No.	Site Name	Census Tract #	modelled	monitored	%diff	difference	modelled	monitored	%diff	difference
260	Plymouth	27053026509	2.7471	2.2910	19.91	0.4561	0.0077	0.0493	-84.40	-0.0416
420	Koch420	27037061002	2.1804	2.5950	-15.98	-0.4146	0.0077	0.0426	-81.95	-0.0349
423	Koch423	27037061002	2.1804	1.3520	61.27	0.8284	0.0077	0.0771	-90.03	-0.0694
426	Koch426	27037061002	2.1804	3.3160	-34.25	-1.1356	0.0077	0.0649	-88.15	-0.0572
436	StPaulPark	27163071301	4.6192	3.7700	22.52	0.8492	0.0077	0.0239	-67.82	-0.0162
438	Ashland	27163071003	3.2529	3.6640	-11.22	-0.4111	0.0077	0.0337	-77.18	-0.0260
816	HolmanFld	27123036100	6.9639	3.5940	93.76	3.3699	0.0077	0.0272	-71.73	-0.0195
820	BushSt	27123031700	4.3573	7.9430	-45.14	-3.5857	0.0077	0.0207	-62.85	-0.0130
871	HardingHi	27123034602	7.1182	0.9020	689.16	6.2162	0.0077	0.0154	-50.06	-0.0077
945	MplsLibrary	27053004500	14.6153	6.3140	131.48	8.3013	0.0077	0.0243	-68.35	-0.0166
958	MhahaAcad	27053010500	6.4560	3.2190	100.56	3.2370	0.0077	0.0267	-71.20	-0.0190
1240	I_Falls1240	27071990200	1.2023	2.8890	-58.38	-1.6867	0.0077	0.0337	-77.18	-0.0260
1241	I_Falls1241	27071990200	1.2023	2.3460	-48.75	-1.1437	0.0077	0.0445	-82.72	-0.0368
1400	Sandstone	27115950500	0.2403	0.8390	-71.36	-0.5987	0.0077	0.0705	-89.09	-0.0628
2005	FergusFalls	27111961000	1.0767	1.8270	-41.06	-0.7503	0.0077	0.0247	-68.87	-0.0170
2010	Alexandria	27041950700	1.4367	1.8620	-22.84	-0.4253	0.0077	0.0554	-86.12	-0.0477
2401	Warroad	27135970100	0.2722	0.7970	-65.85	-0.5248	0.0077	0.0196	-60.77	-0.0119
3049	LittleFalls	27097980600	1.3986	1.3430	4.14	0.0556	0.0077	0.0698	-88.98	-0.0621
3050	ElkRiver	27141030500	0.8758	1.3840	-36.72	-0.5082	0.0077	0.0261	-70.54	-0.0184
4002	Pipestone	27117960300	1.6456	1.3300	23.73	0.3156	0.0077	0.0695	-88.94	-0.0618
4003	GraniteFalls	27023950300	0.2806	0.8640	-67.52	-0.5834	0.0077	0.0242	-68.22	-0.0165
5008	Rochester	27109001000	2.8011	1.6760	67.13	1.1251	0.0077	0.0203	-62.12	-0.0126
5356	Zumbrota	27049980500	0.5560	0.8130	-31.61	-0.2570	0.0077	0.0532	-85.55	-0.0455
7014	Hibbing	27137012300	2.3413	1.5290	53.13	0.8123	0.0077	0.0238	-67.69	-0.0161
7549	Duluth7549	27137002500	1.6376	3.7240	-56.02	-2.0864	0.0077	0.0303	-74.62	-0.0226
	Average over all sites		2.9455	2.4873	26.40	0.4582	0.0077	0.0389	-75.40	-0.0312

APPENDIX K

Appendix K. **MPCA-measured air concentrations compared to U.S. EPA Cumulative Exposure Project modeled values for metals (%difference = [modeled - monitored]/monitored * 100) (difference = modeled - monitored)**

			CADMIUM_TO cadmium_total				ARSENIC_TO arsenic_total				COBALT_TOT cobalt_total			
Site No.	Site Name	TRACT-KEY	modelled	monitored	% diff	difference	modelled	monitored	% diff	difference	modelled	monitored	% diff	difference
260	**Plymouth**	27053026509	0.0002	0.0025	-93.00	-0.0023	0.0004	0.0017	-78.88	-0.0013	0.0002	0.0004	-55.84	-0.0002
420	**Koch420**	27037061002	0.0001				0.0003				0.0001			
423	**Koch423**	27037061002	0.0001				0.0003				0.0001			
426	**Koch426**	27037061002	0.0001				0.0003				0.0001			
436	**StPaulPark**	27163071301	0.0002				0.0004				0.0001			
438	**Ashland**	27163071003	0.0002				0.0004				0.0001			
816	**HolmanFld**	27123036100	0.0005				0.0021				0.0003			
820	**BushSt**	27123031700	0.0005	0.0017	-73.36	-0.0012	0.0010	0.0025	-58.34	-0.0015	0.0003	0.0011	-73.20	-0.0008
871	**HardingHi**	27123034602	0.0004	0.0018	-75.62	-0.0014	0.0021	0.0029	-25.94	-0.0008	0.0003	0.0005	-47.55	-0.0002
945	**MplsLibrary**	27053004500	0.0004	0.0025	-85.98	-0.0021	0.0014	0.0017	-19.20	-0.0003	0.0003	0.0009	-62.89	-0.0006
958	**MhahaAcad**	27053010500	0.0003	0.0028	-89.89	-0.0025	0.0009	0.0014	-38.03	-0.0005	0.0002	0.0008	-69.37	-0.0006
1240	**I_Falls1240**	27071990200	0.0001				0.0001				0.0001			
1241	**I_Falls1241**	27071990200	0.0001	0.0011	-92.27	-0.0010	0.0001	0.0012	-93.07	-0.0011	0.0001	0.0007	-84.85	-0.0006
1400	**Sandstone**	27115950500	0.0000	0.0010	-99.58	-0.0010	0.0000	0.0011	-99.21	-0.0011	0.0000	0.0004	-98.48	-0.0004
2005	**FergusFalls**	27111961000	0.0003	0.0042	-91.85	-0.0039	0.0002	0.0016	-89.29	-0.0014	0.0003	0.0010	-67.08	-0.0007
2010	**Alexandria**	27041950700	0.0003	0.0011	-76.61	-0.0008	0.0001	0.0011	-92.05	-0.0010	0.0002	0.0004	-48.01	-0.0002
2401	**Warroad**	27135970100	0.0000	0.0025	-99.83	-0.0025	0.0000	0.0009	-99.09	-0.0009	0.0000	0.0006	-99.19	-0.0006
3049	**LittleFalls**	27097980600	0.0001	0.0027	-98.09	-0.0026	0.0001	0.0013	-94.65	-0.0012	0.0001	0.0005	-86.91	-0.0004
3050	**ElkRiver**	27141030500	0.0000	0.0026	-98.67	-0.0026	0.0001	0.0026	-96.40	-0.0025	0.0000	0.0007	-94.04	-0.0007
4002	**Pipestone**	27117960300	0.0001	0.0034	-98.24	-0.0033	0.0001	0.0007	-91.46	-0.0006	0.0001	0.0006	-89.57	-0.0005
4003	**GraniteFalls**	27023950300	0.0000	0.0028	-98.83	-0.0028	0.0001	0.0008	-87.21	-0.0007	0.0000	0.0007	-95.60	-0.0007
5008	**Rochester**	27109001000	0.0002	0.0025	-92.87	-0.0023	0.0001	0.0001	45.42	0.0000	0.0002	0.0005	-59.03	-0.0003
5356	**Zumbrota**	27049980500	0.0000	0.0019	-98.76	-0.0019	0.0000	0.0012	-97.26	-0.0012	0.0000	0.0006	-96.17	-0.0006
7014	**Hibbing**	27137012300	0.0001	0.0012	-93.86	-0.0011	0.0027	0.0020	34.85	0.0007	0.0002	0.0010	-84.79	-0.0008
7549	**Duluth7549**	27137002500	0.0000	0.0007	-94.84	-0.0007	0.0002	0.0011	-85.39	-0.0009	0.0001	0.0004	-85.72	-0.0003
	Average over all sites		0.0002	0.0022	-91.79	-0.0020	0.0005	0.0014	-64.73	-0.0009	0.0001	0.0007	-77.68	-0.0005

Appendix K. MPCA-measured air concentrations compared to U.S. EPA Cumulative Exposure Project modeled values for metals
(%difference = [modeled - monitored]/monitored * 100)
(difference = modeled - monitored)

		CHROMIUM_T chromium_total				MANGANESE_ manganese_total				NICKEL_TOT nickel_total			
Site No.	Site Name	modelled	monitored	% diff	difference	modelled	monitored	% diff	difference	modelled	monitored	% diff	difference
260	Plymouth	0.0013	0.0010	33.27	0.0003	0.0036	0.0055	-34.46	-0.0019	0.0028	0.0001	2695.39	0.0027
420	Koch420	0.0029				0.0022				0.0046			
423	Koch423	0.0029				0.0022				0.0046			
426	Koch426	0.0029				0.0022				0.0046			
436	StPaulPark	0.0033				0.0034				0.0095			
438	Ashland	0.0030				0.0032				0.0076			
816	HolmanFld	0.0066				0.0064				0.0080			
820	BushSt	0.0036	0.0015	138.26	0.0021	0.0060	0.0117	-48.54	-0.0057	0.0082	0.0011	647.16	0.0071
871	HardingHi	0.0056	0.0014	297.50	0.0042	0.0103	0.0067	53.56	0.0036	0.0089	0.0013	583.45	0.0076
945	MplsLibrary	0.0036	0.0015	143.15	0.0021	0.0067	0.0105	-35.73	-0.0038	0.0098	0.0019	416.35	0.0079
958	MhahaAcad	0.0040	0.0011	261.75	0.0029	0.0087	0.0071	23.09	0.0016	0.0116	0.0007	1556.17	0.0109
1240	I_Falls1240	0.0002				0.0043				0.0013			
1241	I_Falls1241	0.0002	0.0009	-79.73	-0.0007	0.0043	0.0024	78.31	0.0019	0.0013	0.0002	529.50	0.0011
1400	Sandstone	0.0000	0.0011	-96.17	-0.0011	0.0005	0.0034	-83.86	-0.0029	0.0001	0.0001	-44.49	0.0000
2005	FergusFalls	0.0005	0.0011	-58.36	-0.0006	0.0039	0.0102	-62.19	-0.0063	0.0017	0.0001	1598.26	0.0016
2010	Alexandria	0.0002	0.0010	-80.59	-0.0008	0.0014	0.0043	-67.99	-0.0029	0.0016	0.0002	679.39	0.0014
2401	Warroad	0.0000	0.0005	-95.27	-0.0005	0.0012	0.0047	-74.55	-0.0035	0.0001	0.0005	-79.25	-0.0004
3049	LittleFalls	0.0001	0.0011	-88.11	-0.0010	0.0023	0.0053	-57.42	-0.0030	0.0008	0.0004	110.24	0.0004
3050	ElkRiver	0.0002	0.0010	-82.06	-0.0008	0.0013	0.0087	-85.39	-0.0074	0.0005	0.0007	-29.66	-0.0002
4002	Pipestone	0.0001	0.0011	-90.22	-0.0010	0.0009	0.0094	-90.45	-0.0085	0.0012	0.0002	496.20	0.0010
4003	GraniteFalls	0.0001	0.0006	-81.86	-0.0005	0.0004	0.0072	-94.39	-0.0068	0.0003	0.0002	56.96	0.0001
5008	Rochester	0.0004	0.0005	-14.22	-0.0001	0.0027	0.0051	-47.52	-0.0024	0.0013	0.0004	232.03	0.0009
5356	Zumbrota	0.0003	0.0010	-67.37	-0.0007	0.0004	0.0041	-89.43	-0.0037	0.0010	0.0002	380.31	0.0008
7014	Hibbing	0.0006	0.0009	-33.37	-0.0003	0.0044	0.0084	-47.86	-0.0040	0.0043	0.0003	1327.11	0.0040
7549	Duluth7549	0.0003	0.0010	-73.90	-0.0007	0.0035	0.0024	45.04	0.0011	0.0041	0.0008	418.66	0.0033
	Average over a	0.0017	0.0010	-3.74	0.0002	0.0035	0.0065	-39.99	-0.0030	0.0040	0.0005	642.99	0.0028

Appendix K. MPCA-measured air concentrations compared to U.S. EPA Cumulative Exposure Project modeled values for metals
(%difference = [modeled - monitored]/monitored * 100)
(difference = modeled - monitored)

		LEAD_TOTAL lead_total				SELENIUM_T selenium_total			
Site No.	Site Name	modelled	monitored	% diff	difference	modelled	monitored	% diff	difference
260	Plymouth	0.0052	0.0049	5.95	0.0003	0.0004	0.0003	36.42	0.0001
420	Koch420	0.0061				0.0003			
423	Koch423	0.0061				0.0003			
426	Koch426	0.0061				0.0003			
436	StPaulPark	0.0083				0.0005			
438	Ashland	0.0085				0.0004			
816	HolmanFld	0.0119				0.0007			
820	BushSt	0.0102	0.0093	9.96	0.0009	0.0006	0.0007	-11.12	-0.0001
871	HardingHi	0.0131	0.0074	77.49	0.0057	0.0006	0.0006	5.45	0.0000
945	MplsLibrary	0.0097	0.0066	46.92	0.0031	0.0017	0.0008	113.99	0.0009
958	MhahaAcad	0.0098	0.0056	74.85	0.0042	0.0006	0.0007	-12.95	-0.0001
1240	I_Falls1240	0.0027				0.0001			
1241	I_Falls1241	0.0027	0.0030	-9.75	-0.0003	0.0001	0.0003	-65.60	-0.0002
1400	Sandstone	0.0002	0.0024	-89.85	-0.0022	0.0000	0.0004	-97.92	-0.0004
2005	FergusFalls	0.0059	0.0052	13.66	0.0007	0.0001	0.0008	-81.69	-0.0007
2010	Alexandria	0.0031	0.0031	0.84	0.0000	0.0001	0.0005	-71.46	-0.0004
2401	Warroad	0.0002	0.0017	-88.54	-0.0015	0.0000	0.0005	-98.45	-0.0005
3049	LittleFalls	0.0020	0.0035	-41.65	-0.0015	0.0001	0.0003	-77.76	-0.0002
3050	ElkRiver	0.0012	0.0038	-68.44	-0.0026	0.0001	0.0007	-86.54	-0.0006
4002	Pipestone	0.0013	0.0038	-64.70	-0.0025	0.0001	0.0006	-84.65	-0.0005
4003	GraniteFalls	0.0022	0.0030	-25.97	-0.0008	0.0001	0.0009	-92.41	-0.0008
5008	Rochester	0.0043	0.0040	7.96	0.0003	0.0004	0.0008	-47.27	-0.0004
5356	Zumbrota	0.0011	0.0037	-69.86	-0.0026	0.0000	0.0008	-95.14	-0.0008
7014	Hibbing	0.0079	0.0047	67.14	0.0032	0.0042	0.0007	494.69	0.0035
7549	Duluth7549	0.0023	0.0022	4.17	0.0001	0.0001	0.0003	-59.75	-0.0002
	Average over a	0.0053	0.0043	-8.32	0.0003	0.0005	0.0006	-18.45	-0.0001

APPENDIX L

Appendix L. Summary of MPCA-measured air Concentrations compared to EPA Cumulative Exposure Project modeled values

average across all sites

Substance	monitored value (ug/m3)	modeled value (ug/m3)	percent difference ([(model-monitor)/ monitor]*100)	
vinylidene_chloride	0.0855	0.0000	-100.0	monitored values
propylene_dichloride	0.0217	0.0001	-99.4	are higher
hexachlorobutadiene	0.1989	0.0018	-99.0	
cadmium_total	0.0022	0.0002	-91.9	
p-dichlorobenzene	0.3206	0.0568	-86.3	
trichloroethane(1,1,2)	0.0274	0.0025	-82.3	
cobalt_total	0.0007	0.0001	-77.7	
ethylene_dibromide	0.0389	0.0077	-75.4	
arsenic_total	0.0014	0.0005	-64.7	
acetaldehyde_total	1.0604	0.4929	-60.8	
propionaldehyde_total	0.1831	0.1122	-49.1	
ethylbenzene	0.6094	0.3619	-44.5	
manganese_total	0.0065	0.0035	-40.0	
formaldehyde_total	1.6489	1.0661	-35.7	
styrene	0.1085	0.0881	-32.5	
vinyl_chloride	0.0061	0.0026	-20.9	
selenium_total	0.0006	0.0005	-18.5	
chlorobenzene	0.0199	0.0146	-17.6	
chloroform	0.1526	0.1070	-14.7	
lead_total	0.0043	0.0053	-8.3	
toluene	3.1906	3.2985	-8.0	
chromium_total	0.0010	0.0017	-3.7	
methylene_chloride	0.4133	0.3983	-2.7	
benzene	1.5349	1.6860	12.9	
carbon_tetrachloride	0.7890	0.8882	14.3	
trichloroethylene	0.4732	0.4752	21.1	
tetrachloroethylene	0.3835	0.5063	21.8	
xylene	2.4873	2.9455	26.4	
dichloropropene(1,3)	0.0199	0.0221	27.4	
ethylene_dichloride	0.0389	0.0627	102.0	modeled values
nickel_total	0.0005	0.0040	643.0	are higher

APPENDIX M

Appendix M.1. Estimated lifetime cancer risks of mean VOC and carbonyl ambient air concentrations at monitoring sites. (Lifetime cancer risk per 100,000 exposed individuals)

Site	ACETALDEHYDE	ACETONE	BENZALDEHYDE	BENZENE	BROMOETHANE	BUTYRALDEHYDE	C_13_DICHLOROPROPENE	CARBON_TETRACHLORIDE	CFC_11
Plymouth	1.8934E-01			1.0070E+00			9.5333E-02	1.3060E+00	
Koch420	1.9574E-01			1.3252E+00			6.0667E-02	9.5043E-01	
Koch423	1.9384E-01			8.1492E-01			4.8000E-02	9.6057E-01	
Koch426	2.2506E-01			1.9942E+00			4.8667E-02	8.6914E-01	
StPaulPark	2.5592E-01			2.0135E+00			4.4000E-02	1.0523E+00	
Ashland	3.0732E-01			2.3695E+00			6.5333E-02	1.0833E+00	
HolmanFld	2.5338E-01			1.3231E+00			4.4000E-02	1.0159E+00	
BushSt	3.5756E-01			2.4497E+00			6.3667E-02	1.0246E+00	
HardingHi				2.1088E+00				1.1170E+00	
MplsLibrary	3.3712E-01			1.9486E+00			5.0667E-02	9.6914E-01	
MhahaAcad	2.7654E-01			1.1105E+00			6.2000E-02	1.1433E+00	
I_Falls1240	2.5664E-01			8.8262E-01			3.2333E-02	9.0500E-01	
I_Falls1241	1.3766E-01			1.0505E+00			1.5533E-01	1.2953E+00	
Sandstone	1.2492E-01			5.2392E-01			1.1100E-01	1.3031E+00	
FergusFalls	3.6122E-01			9.1431E-01			3.9333E-02	1.1071E+00	
Alexandria	1.6930E-01			9.3815E-01			8.1333E-02	1.3123E+00	
Warroad	1.1394E-01			4.9238E-01			1.8667E-02	1.1661E+00	
LittleFalls	1.1690E-01			6.9438E-01			1.1167E-01	1.2946E+00	
ElkRiver	1.9770E-01			7.2800E-01			4.3667E-02	1.1537E+00	
Pipestone	1.4930E-01			6.3185E-01			1.3233E-01	1.3109E+00	
GraniteFalls	2.0022E-01			7.1385E-01			4.2333E-02	1.1264E+00	
Rochester	1.8232E-01			8.5615E-01			5.5000E-02	1.1627E+00	
Zumbrota	1.2600E-01			4.9923E-01			7.6333E-02	1.3287E+00	
Hibbing	1.7714E-01			7.8138E-01			5.2667E-02	1.1270E+00	
Duluth7549	1.8502E-01			1.3413E+00			6.0667E-02	1.0946E+00	
max	3.6122E-01	0.0000E+00	0.0000E+00	2.4497E+00	0.0000E+00	0.0000E+00	1.5533E-01	1.3287E+00	0.0000E+00

Appendix M.1. Estimated lifetime cancer risks of mean VOC and carbonyl ambient air concentrations at monitoring sites. (Lifetime cancer risk per 100,000 exposed individuals)

Site	CFC_113	CFC_114	CFC_12	CHLOROBENZENE	CHLOROFORM	CROTONALDEHYDE	11_DICHLOROETHANE	12_DICHLOROETHANE	12_DICHLOROETHYLENE
Plymouth					3.2125E-01		5.4720E-03	1.7200E-01	
Koch420					2.5075E-01		4.0640E-03	1.4025E-01	
Koch423					2.0650E-01		1.8880E-03	1.5150E-01	
Koch426					3.1625E-01		7.2800E-03	1.7075E-01	
StPaulPark					2.8600E-01		3.2480E-03	1.0100E-01	
Ashland					3.8650E-01		3.8560E-03	9.8500E-02	
HolmanFld					3.4500E-01		1.6480E-03	1.1925E-01	
BushSt					4.0400E-01		1.0080E-03	4.5000E-02	
HardingHi					3.5225E-01		6.4000E-04	5.9250E-02	
MplsLibrary					3.5800E-01		3.3760E-03	1.2025E-01	
MhahaAcad					2.6250E-01		1.2800E-03	7.9500E-02	
I_Falls1240					2.5768E+00		9.6000E-04	7.0250E-02	
I_Falls1241					3.8200E-01		7.8080E-03	1.6775E-01	
Sandstone					2.5125E-01		7.0400E-03	1.8650E-01	
FergusFalls					2.1350E-01		1.0080E-03	1.0575E-01	
Alexandria					4.2275E-01		1.6288E-02	2.4225E-01	
Warroad					2.5550E-01		1.0400E-03	1.0050E-01	
LittleFalls					2.7500E-01		8.1120E-03	2.0050E-01	
ElkRiver					1.8150E-01		1.2800E-03	8.7750E-02	
Pipestone					3.1600E-01		9.9520E-03	2.1825E-01	
GraniteFalls					2.1000E-01		1.5040E-03	9.6250E-02	
Rochester					2.2250E-01		9.1200E-04	9.6750E-02	
Zumbrota					2.6950E-01		1.1424E-02	1.9000E-01	
Hibbing					2.0425E-01		9.6000E-04	9.9750E-02	
Duluth7549					2.6950E-01		4.0640E-03	9.5500E-02	
max	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	2.5768E+00	0.0000E+00	1.6288E-02	2.4225E-01	0.0000E+00

Appendix M.1. Estimated lifetime cancer risks of mean VOC and carbonyl ambient air concentrations at monitoring sites. (Lifetime cancer risk per 100,000 exposed individuals)

Site	12_DICHLOROPROPAN	DICHLOROMETHANE	ETHYLENE_DIBROMIDE	ETHYL_BENZENE	FORMALDEHYDE	HEXACHLORO_13_BUTADIENE	M_DICHLOROBENZENE
Plymouth		3.2165E-02	9.8600E-01		1.5545E+00	4.8560E-01	
Koch420		1.2965E-02	8.5200E-01		1.3794E+00	3.6540E-01	
Koch423		1.4610E-02	1.5420E+00		1.3758E+00	2.9340E-01	
Koch426		1.3490E-02	1.2980E+00		1.2263E+00	3.3600E-01	
StPaulPark		1.9335E-02	4.7800E-01		1.8576E+00	3.0020E-01	
Ashland		1.8570E-02	6.7400E-01		2.4939E+00	3.4820E-01	
HolmanFld		3.2500E-02	5.4400E-01		1.9073E+00	3.1120E-01	
BushSt		2.8825E-02	4.1400E-01		5.5376E+00	2.9860E-01	
HardingHi		1.8905E-02	3.0800E-01		2.1019E+00		
MplsLibrary		5.8975E-02	4.8600E-01		2.7234E+00	2.9740E-01	
MhahaAcad		1.9510E-02	5.3400E-01		3.0968E+00	3.8580E-01	
I_Falls1240		1.2230E-02	6.7400E-01		1.2325E+00	2.5300E-01	
I_Falls1241		1.2480E-02	8.9000E-01		1.6049E+00	5.0640E-01	
Sandstone		1.4990E-02	1.4100E+00		1.4614E+00	8.0020E-01	
FergusFalls		1.5320E-02	4.9400E-01		2.0755E+00	3.7340E-01	
Alexandria		1.4980E-02	1.1080E+00		1.7725E+00	4.6380E-01	
Warroad		7.5850E-03	3.9200E-01		1.5226E+00	3.2280E-01	
LittleFalls		1.5100E-02	1.3960E+00		1.3905E+00	6.1720E-01	
ElkRiver		1.1100E-02	5.2200E-01		1.7924E+00	3.7740E-01	
Pipestone		2.9530E-02	1.3900E+00		1.5710E+00	5.5520E-01	
GraniteFalls		9.4300E-03	4.8400E-01		2.4693E+00	3.4220E-01	
Rochester		1.1380E-02	4.0600E-01		1.6999E+00	3.3480E-01	
Zumbrota		2.7475E-02	1.0640E+00		1.4559E+00	4.9780E-01	
Hibbing		1.1320E-02	4.7600E-01		1.9574E+00	3.4820E-01	
Duluth7549		5.3795E-02	6.0600E-01		1.5880E+00	3.3420E-01	
max	0.0000E+00	5.8975E-02	1.5420E+00	0.0000E+00	5.5376E+00	8.0020E-01	0.0000E+00

Appendix M.1. Estimated lifetime cancer risks of mean VOC and carbonyl ambient air concentrations at monitoring sites. (Lifetime cancer risk per 100,000 exposed individuals)

Site	M_P_XYLENE	M_XYLENE	O_DICHLOROBENZENE	O_XYLENE	P_DICHLOROBENZENE	PROPIONALDEHYDE	STYRENE	T_13_DICHLOROPROPENE
Plymouth								1.2067E-01
Koch420								8.6000E-02
Koch423								6.5667E-02
Koch426								6.4667E-02
StPaulPark								1.1133E-01
Ashland								1.2767E-01
HolmanFld								7.0333E-02
BushSt								1.1700E-01
HardingHi								
MplsLibrary								8.5000E-02
MhahaAcad								1.1367E-01
I_Falls1240								4.0000E-02
I_Falls1241								2.3700E-01
Sandstone								1.6667E-01
FergusFalls								1.1233E-01
Alexandria								2.0233E-01
Warroad								7.8000E-02
LittleFalls								2.1200E-01
ElkRiver								7.8667E-02
Pipestone								2.0867E-01
GraniteFalls								1.6500E-01
Rochester								1.2733E-01
Zumbrota								1.3800E-01
Hibbing								8.6667E-02
Duluth7549								1.0333E-01
max	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	2.3700E-01

Appendix M.1. Estimated lifetime cancer risks of mean VOC and carbonyl ambient air concentrations at monitoring sites. (Lifetime cancer risk per 100,000 exposed individuals)

Site	111_TRICHLOROETHANE	112_TRICHLOROETHANE	1122_TETRACHLOROETHANE	TRICHLOROETHENE	TETRACHLOROETHYLENE	124_TRIMETHYLBENZENE
Plymouth		8.6167E-02	5.0500E-01	2.2020E-01		
Koch420		4.8000E-02	2.8950E-01	4.3140E-02		
Koch423		2.3833E-02	3.0050E-01	3.9260E-02		
Koch426		2.3667E-02	2.9600E-01	3.2320E-02		
StPaulPark		3.2333E-02	2.5750E-01	4.9100E-02		
Ashland		3.3333E-02	2.4300E-01	5.6600E-02		
HolmanFld		2.8500E-02	2.5500E-01	7.7060E-02		
BushSt		6.3333E-03	1.7900E-01	8.0260E-02		
HardingHi						
MplsLibrary		3.3167E-02	2.8600E-01	2.1508E-01		
MhahaAcad		1.7667E-02	1.9750E-01	5.3240E-02		
I_Falls1240		4.0833E-02	1.5350E-01	1.8720E-02		
I_Falls1241		8.7667E-02	3.9050E-01	5.8660E-02		
Sandstone		8.5167E-02	7.0750E-01	1.0828E-01		
FergusFalls		1.0500E-02	1.2800E-01	4.3760E-02		
Alexandria		1.1483E-01	4.7250E-01	1.0184E-01		
Warroad		3.5000E-03	1.9300E-01	1.4724E-01		
LittleFalls		1.0783E-01	4.3650E-01	2.8572E-01		
ElkRiver		1.5000E-02	1.2950E-01	5.4060E-02		
Pipestone		1.5383E-01	5.2100E-01	2.8534E-01		
GraniteFalls		9.1667E-03	1.5250E-01	2.8760E-02		
Rochester		9.5000E-03	1.1750E-01	3.6340E-02		
Zumbrota		7.7167E-02	3.7050E-01	1.1074E-01		
Hibbing		9.5000E-03	1.3900E-01	2.2620E-02		
Duluth7549		3.8500E-02	2.8400E-01	1.0288E-01		
max	0.0000E+00	1.5383E-01	7.0750E-01	2.8572E-01	0.0000E+00	0.0000E+00

Appendix M.1. Estimated lifetime cancer risks of mean VOC and carbonyl ambient air concentrations at monitoring sites. (Lifetime cancer risk per 100,000 exposed individuals)

Site	135_TRIMETHYLBENZENE	TOLUENE	VINYL_CHLORIDE	VINYLIDINE_CHLORIDE	Total Cancer Risk
Plymouth			0.0000E+00		7.09
Koch420			1.4300E-01		6.15
Koch423			9.4000E-02		6.13
Koch426			1.8800E-01		7.11
StPaulPark			1.9700E-01		7.06
Ashland			4.3000E-02		8.35
HolmanFld			1.8100E-01		6.51
BushSt			2.8000E-02		11.04
HardingHi			7.0000E-03		6.07
MplsLibrary			1.6200E-01		8.13
MhahaAcad			3.0000E-02		7.38
I_Falls1240			5.4000E-02		7.20
I_Falls1241			3.2000E-02		7.02
Sandstone			0.0000E+00		7.26
FergusFalls			5.9000E-02		6.05
Alexandria			0.0000E+00		7.43
Warroad			4.4000E-02		4.86
LittleFalls			2.5000E-02		7.19
ElkRiver			4.5000E-02		5.42
Pipestone			0.0000E+00		7.48
GraniteFalls			3.4000E-02		6.08
Rochester			2.3000E-02		5.34
Zumbrota			0.0000E+00		6.24
Hibbing			5.2000E-02		5.55
Duluth7549			7.8000E-02		6.24
max	0.0000E+00	0.0000E+00	1.9700E-01	0.0000E+00	

Appendix M.2. Hazard indices of mean VOC and carbonyl ambient air concentrations at monitoring sites.

Site	ACETALDEHYDE	ACETONE	BENZALDEHYDE	BENZENE	BROMOETHANE	BUTYRALDEHYDE	C_13_DICHLOROPROPENE	CARBON_TETRACHLORIDE	CFC_11
Plymouth	1.0519E-01			2.1818E-02	2.5480E-02		1.4300E-03	2.2855E-02	2.9231E-03
Koch420	1.0874E-01			2.8712E-02	1.1800E-02		9.1000E-04	1.6633E-02	2.3044E-03
Koch423	1.0769E-01			1.7657E-02	1.2780E-02		7.2000E-04	1.6810E-02	2.4623E-03
Koch426	1.2503E-01			4.3208E-02	5.8600E-03		7.3000E-04	1.5210E-02	2.3404E-03
StPaulPark	1.4218E-01			4.3625E-02	1.9200E-02		6.6000E-04	1.8415E-02	2.3296E-03
Ashland	1.7073E-01			5.1340E-02	1.4440E-02		9.8000E-04	1.8958E-02	2.3827E-03
HolmanFld	1.4077E-01			2.8667E-02	1.2300E-02		6.6000E-04	1.7778E-02	7.6914E-03
BushSt	1.9864E-01			5.3077E-02	3.1200E-02		9.5500E-04	1.7930E-02	2.2093E-03
HardingHi				4.5690E-02				1.9548E-02	
MplsLibrary	1.8729E-01			4.2220E-02	1.9000E-02		7.6000E-04	1.6960E-02	4.2631E-03
MhahaAcad	1.5363E-01			2.4062E-02	2.1840E-02		9.3000E-04	2.0008E-02	2.5779E-03
I_Falls1240	1.4258E-01			1.9123E-02	6.9000E-03		4.8500E-04	1.5838E-02	2.1916E-03
I_Falls1241	7.6478E-02			2.2762E-02	2.2340E-02		2.3300E-03	2.2668E-02	4.0786E-03
Sandstone	6.9400E-02			1.1352E-02	2.5620E-02		1.6650E-03	2.2805E-02	2.7564E-03
FergusFalls	2.0068E-01			1.9810E-02	1.2320E-02		5.9000E-04	1.9375E-02	2.9683E-03
Alexandria	9.4056E-02			2.0327E-02	2.4000E-02		1.2200E-03	2.2965E-02	2.7997E-03
Warroad	6.3300E-02			1.0668E-02	1.1800E-02		2.8000E-04	2.0408E-02	2.6580E-03
LittleFalls	6.4944E-02			1.5045E-02	2.1600E-02		1.6750E-03	2.2655E-02	2.6767E-03
ElkRiver	1.0983E-01			1.5773E-02	1.2460E-02		6.5500E-04	2.0190E-02	2.2480E-03
Pipestone	8.2944E-02			1.3690E-02	2.5420E-02		1.9850E-03	2.2940E-02	2.5657E-03
GraniteFalls	1.1123E-01			1.5467E-02	1.4740E-02		6.3500E-04	1.9713E-02	2.3907E-03
Rochester	1.0129E-01			1.8550E-02	1.2620E-02		8.2500E-04	2.0348E-02	2.4466E-03
Zumbrota	7.0000E-02			1.0817E-02	2.3980E-02		1.1450E-03	2.3253E-02	2.9073E-03
Hibbing	9.8411E-02			1.6930E-02	1.1560E-02		7.9000E-04	1.9723E-02	2.4626E-03
Duluth7549	1.0279E-01			2.9062E-02	1.1780E-02		9.1000E-04	1.9155E-02	4.8110E-03
max	2.0068E-01	0.0000E+00	0.0000E+00	5.3077E-02	3.1200E-02	0.0000E+00	2.3300E-03	2.3253E-02	7.6914E-03

Appendix M.2. Hazard indices of mean VOC and carbonyl ambient air concentrations at monitoring sites.

Site	CFC_113	CFC_114	CFC_12	CHLOROBENZENE	CHLOROFORM	CROTONALDEHYDE	11_DICHLOROETHANE	12_DICHLOROETHANE	12_DICHLOROETHYLENE
Plymouth	2.2647E-05		1.6190E-02	4.7900E-03	4.2833E-04		6.8400E-05		
Koch420	2.6167E-05		1.3403E-02	4.1550E-03	3.3433E-04		5.0800E-05		
Koch423	2.3703E-05		1.3861E-02	4.2350E-03	2.7533E-04		2.3600E-05		
Koch426	2.2363E-05		1.1775E-02	5.7550E-03	4.2167E-04		9.1000E-05		
StPaulPark	2.2623E-05		1.4464E-02	3.7600E-03	3.8133E-04		4.0600E-05		
Ashland	2.2887E-05		1.3893E-02	3.8300E-03	5.1533E-04		4.8200E-05		
HolmanFld	2.2167E-05		1.4570E-02	3.9800E-03	4.6000E-04		2.0600E-05		
BushSt	2.0560E-05		1.4219E-02	4.3050E-03	5.3867E-04		1.2600E-05		
HardingHi				3.5050E-03	4.6967E-04		8.0000E-06		
MplsLibrary	2.3043E-05		1.6559E-02	3.6100E-03	4.7733E-04		4.2200E-05		
MhahaAcad	2.0317E-05		1.4806E-02	4.4650E-03	3.5000E-04		1.6000E-05		
I_Falls1240	4.4883E-05		2.3467E-02	2.1300E-03	3.4357E-03		1.2000E-05		
I_Falls1241	4.2500E-05		1.4995E-02	4.0100E-03	5.0933E-04		9.7600E-05		
Sandstone	2.5667E-05		1.4791E-02	5.0950E-03	3.3500E-04		8.8000E-05		
FergusFalls	2.1540E-05		1.3631E-02	4.2550E-03	2.8467E-04		1.2600E-05		
Alexandria	2.6793E-05		1.5065E-02	4.5150E-03	5.6367E-04		2.0360E-04		
Warroad	2.3670E-05		1.4644E-02	3.8150E-03	3.4067E-04		1.3000E-05		
LittleFalls	4.4447E-05		1.5086E-02	6.3300E-03	3.6667E-04		1.0140E-04		
ElkRiver	2.2467E-05		1.3986E-02	4.5900E-03	2.4200E-04		1.6000E-05		
Pipestone	2.3520E-05		1.5009E-02	5.5800E-03	4.2133E-04		1.2440E-04		
GraniteFalls	2.1050E-05		1.4040E-02	4.1200E-03	2.8000E-04		1.8800E-05		
Rochester	2.1680E-05		1.4951E-02	5.8150E-03	2.9667E-04		1.1400E-05		
Zumbrota	2.6810E-05		1.5109E-02	6.8850E-03	3.5933E-04		1.4280E-04		
Hibbing	2.1887E-05		1.4247E-02	2.9000E-03	2.7233E-04		1.2000E-05		
Duluth7549	4.7740E-04		1.4194E-02	3.5000E-03	3.5933E-04		5.0800E-05		
max	4.7740E-04	0.0000E+00	2.3467E-02	6.8850E-03	3.4357E-03	0.0000E+00	2.0360E-04	0.0000E+00	0.0000E+00

Appendix M.2. Hazard indices of mean VOC and carbonyl ambient air concentrations at monitoring sites.

Site	12_DICHLOROPROPAN	DICHLOROMETHANE	ETHYLENE_DIBROMIDE	ETHYL_BENZENE	FORMALDEHYDE	HEXACHLORO_13_BUTADIENE	M_DICHLOROBENZENE
Plymouth	1.1650E-02	2.1443E-04	2.4650E-01	5.2340E-04	4.1453E-01		
Koch420	2.3500E-03	8.6433E-05	2.1300E-01	6.5010E-04	3.6783E-01		
Koch423	2.3500E-03	9.7400E-05	3.8550E-01	3.5200E-04	3.6687E-01		
Koch426	2.6750E-03	8.9933E-05	3.2450E-01	8.6450E-04	3.2700E-01		
StPaulPark	2.6500E-03	1.2890E-04	1.1950E-01	8.6180E-04	4.9537E-01		
Ashland	3.9750E-03	1.2380E-04	1.6850E-01	8.1350E-04	6.6503E-01		
HolmanFld	2.8000E-03	2.1667E-04	1.3600E-01	8.6230E-04	5.0860E-01		
BushSt	1.0000E-03	1.9217E-04	1.0350E-01	1.6377E-03	1.4767E+00		
HardingHi		1.2603E-04	7.7000E-02	7.3250E-04	5.6050E-01		
MplsLibrary	2.0250E-03	3.9317E-04	1.2150E-01	1.5179E-03	7.2623E-01		
MhahaAcad	1.8500E-03	1.3007E-04	1.3350E-01	7.6120E-04	8.2580E-01		
I_Falls1240	2.1750E-03	8.1533E-05	1.6850E-01	7.8060E-04	3.2867E-01		
I_Falls1241	2.0925E-02	8.3200E-05	2.2250E-01	5.2340E-04	4.2797E-01		
Sandstone	1.0225E-02	9.9933E-05	3.5250E-01	2.0710E-04	3.8970E-01		
FergusFalls	2.3000E-03	1.0213E-04	1.2350E-01	4.2520E-04	5.5347E-01		
Alexandria	1.6000E-02	9.9867E-05	2.7700E-01	4.4180E-04	4.7267E-01		
Warroad	2.6250E-03	5.0567E-05	9.8000E-02	1.9960E-04	4.0603E-01		
LittleFalls	9.2750E-03	1.0067E-04	3.4900E-01	3.1900E-04	3.7080E-01		
ElkRiver	1.4500E-03	7.4000E-05	1.3050E-01	3.3140E-04	4.7797E-01		
Pipestone	1.7775E-02	1.9687E-04	3.4750E-01	3.4340E-04	4.1893E-01		
GraniteFalls	2.8250E-03	6.2867E-05	1.2100E-01	2.2920E-04	6.5847E-01		
Rochester	1.4750E-03	7.5867E-05	1.0150E-01	3.9200E-04	4.5330E-01		
Zumbrota	3.7000E-03	1.8317E-04	2.6600E-01	1.9690E-04	3.8823E-01		
Hibbing	1.9000E-03	7.5467E-05	1.1900E-01	3.5700E-04	5.2197E-01		
Duluth7549	4.0500E-03	3.5863E-04	1.5150E-01	9.1250E-04	4.2347E-01		
max	2.0925E-02	3.9317E-04	3.8550E-01	1.6377E-03	1.4767E+00	0.0000E+00	0.0000E+00

Appendix M.2. Hazard indices of mean VOC and carbonyl ambient air concentrations at monitoring sites.

Site	M_P_XYLENE	M_XYLENE	O_DICHLOROBENZENE	O_XYLENE	P_DICHLOROBENZENE	PROPIONALDEHYDE	STYRENE	T_13_DICHLOROPROPENE
Plymouth	2.4000E-03		8.9800E-04	8.7371E-04	4.9938E-04		6.3650E-04	1.8100E-03
Koch420	2.5257E-03		6.5700E-04	9.4257E-04	2.8450E-04		4.6550E-04	1.2900E-03
Koch423	1.3586E-03		5.6950E-04	4.9243E-04	2.2638E-04		4.0350E-04	9.8500E-04
Koch426	2.7371E-03		4.7650E-04	1.2713E-03	1.9575E-04		3.3750E-04	9.7000E-04
StPaulPark	3.9114E-03		5.7950E-04	1.3779E-03	2.8513E-04		4.1050E-04	1.6700E-03
Ashland	3.8957E-03		6.1850E-04	1.3391E-03	2.8163E-04		4.3850E-04	1.9150E-03
HolmanFld	3.4929E-03		6.1200E-04	1.3013E-03	3.6800E-04		4.3350E-04	1.0550E-03
BushSt	8.0829E-03		5.6700E-04	3.2650E-03	4.4375E-04		4.0200E-04	1.7550E-03
HardingHi				1.2884E-03				
MplsLibrary	6.0829E-03		6.1300E-04	2.3506E-03	5.5675E-04		4.3450E-04	1.2750E-03
MhahaAcad	3.5471E-03		7.4000E-04	1.0507E-03	8.4875E-04		5.2450E-04	1.7050E-03
I_Falls1240	3.1614E-03		4.2100E-04	9.6500E-04	3.1050E-04		2.9850E-04	6.0000E-04
I_Falls1241	2.4414E-03		1.0315E-03	9.0986E-04	4.3100E-04		7.3100E-04	3.5550E-03
Sandstone	8.5429E-04		1.5485E-03	3.4414E-04	5.6913E-04		1.0975E-03	2.5000E-03
FergusFalls	1.9586E-03		6.4300E-04	6.5200E-04	3.9450E-04		4.5600E-04	1.6850E-03
Alexandria	1.9500E-03		9.5450E-04	7.1000E-04	4.3750E-04		6.7650E-04	3.0350E-03
Warroad	8.6143E-04		6.0300E-04	2.7686E-04	2.2450E-04		4.2750E-04	1.1700E-03
LittleFalls	1.3829E-03		1.2620E-03	5.3486E-04	4.6688E-04		8.9450E-04	3.1800E-03
ElkRiver	1.4829E-03		7.0350E-04	4.9486E-04	2.6063E-04		4.9850E-04	1.1800E-03
Pipestone	1.3900E-03		1.1805E-03	5.0986E-04	7.0550E-04		8.3700E-04	3.1300E-03
GraniteFalls	9.1857E-04		6.6750E-04	3.1600E-04	2.7638E-04		4.7300E-04	2.4750E-03
Rochester	1.7871E-03		5.9550E-04	6.0700E-04	2.4063E-04		4.2200E-04	1.9100E-03
Zumbrota	8.0571E-04		1.0670E-03	3.5471E-04	5.0350E-04		7.5650E-04	2.0700E-03
Hibbing	1.6171E-03		6.5300E-04	5.6600E-04	4.3863E-04		4.6300E-04	1.3000E-03
Duluth7549	3.9814E-03		7.0850E-04	1.3381E-03	3.6963E-04		5.0200E-04	1.5500E-03
max	8.0829E-03	0.0000E+00	1.5485E-03	3.2650E-03	8.4875E-04	0.0000E+00	1.0975E-03	3.5550E-03

Appendix M.2. Hazard indices of mean VOC and carbonyl ambient air concentrations at monitoring sites.

Site	111_TRICHLOROETHANE	112_TRICHLOROETHANE	1122_TETRACHLOROETHANE	TRICHLOROETHENE	TETRACHLOROETHYLENE	124_TRIMETHYLBENZENE
Plymouth				1.8350E-03		
Koch420				3.5950E-04		
Koch423				3.2717E-04		
Koch426				2.6933E-04		
StPaulPark				4.0917E-04		
Ashland				4.7167E-04		
HolmanFld				6.4217E-04		
BushSt				6.6883E-04		
HardingHi						
MplsLibrary				1.7923E-03		
MhahaAcad				4.4367E-04		
I_Falls1240				1.5600E-04		
I_Falls1241				4.8883E-04		
Sandstone				9.0233E-04		
FergusFalls				3.6467E-04		
Alexandria				8.4867E-04		
Warroad				1.2270E-03		
LittleFalls				2.3810E-03		
ElkRiver				4.5050E-04		
Pipestone				2.3778E-03		
GraniteFalls				2.3967E-04		
Rochester				3.0283E-04		
Zumbrota				9.2283E-04		
Hibbing				1.8850E-04		
Duluth7549				8.5733E-04		
max	0.0000E+00	0.0000E+00	0.0000E+00	2.3810E-03	0.0000E+00	0.0000E+00

Appendix M.2. Hazard indices of mean VOC and carbonyl ambient air concentrations at monitoring sites.

Site	135_TRIMETHYLBENZENE	TOLUENE	VINYL_CHLORIDE	VINYLIDINE_CHLORIDE	Total Noncancer Risk
Plymouth		6.7958E-03			0.89
Koch420		7.6915E-03			0.79
Koch423		4.5868E-03			0.94
Koch426		1.0277E-02			0.88
StPaulPark		1.2366E-02			0.88
Ashland		1.3010E-02			1.14
HolmanFld		1.2335E-02			0.90
BushSt		2.5433E-02			1.95
HardingHi		1.2022E-02			0.72
MplsLibrary		1.7673E-02			1.17
MhahaAcad		8.2818E-03			1.22
I_Falls1240		8.3115E-03			0.73
I_Falls1241		5.8605E-03			0.86
Sandstone		2.0418E-03			0.92
FergusFalls		5.9755E-03			0.97
Alexandria		5.2045E-03			0.97
Warroad		2.6633E-03			0.64
LittleFalls		4.0753E-03			0.89
ElkRiver		4.2843E-03			0.80
Pipestone		4.0625E-03			0.97
GraniteFalls		2.8525E-03			0.97
Rochester		5.7620E-03			0.75
Zumbrota		2.2018E-03			0.82
Hibbing		5.2238E-03			0.82
Duluth7549		1.0425E-02			0.79
max	0.0000E+00	2.5433E-02	0.0000E+00	0.0000E+00	

APPENDIX N

APPENDIX N – Summary of the MPCA's Mercury Initiative

Air Pollution Causes Mercury Contamination of Fish

Mercury, a pollutant toxic to the nervous system, can concentrate in fish to the point that eating the fish is hazardous. Mercury contamination of fish is a problem in Minnesota and many other states. Given Minnesota's lakes and the widespread interest in fishing and the importance of fish-eating wildlife, such as loons, mink and otter, it makes sense that Minnesota has one of the best fish-contamination monitoring programs in the country. Managed by the Minnesota Department of Natural Resources, more than 700 lakes have been tested in the program. The Minnesota Department of Health has issued advice to limit consumption of fish on more than 90 percent of the tested lakes.

Virtually all of the mercury found in fish is delivered to the lake from the atmosphere. About three-quarters of the mercury in the atmosphere is a result of man-made air pollution. Reducing mercury contamination is a high priority in Minnesota, and several programs are in place to reduce the use and emission of mercury, including a comprehensive reduction effort that is discussed in the following section.

The Mercury Contamination Reduction Initiative

In early 1997, the MPCA began the Mercury Contamination Reduction Initiative, aimed at reducing mercury contamination of fish in Minnesota lakes. A major part of this effort was receiving advice and comments from the public regarding the goals of the initiative. The MPCA established a Mercury Advisory Council that includes representatives from government, business, and citizen and environmental groups. The advisory council met almost monthly from May 1997 to December 1998.

The advisory council's chartered goal was to devise a package of recommendations to reduce mercury contamination in the environment. In December 1998, the advisory council agreed to adopt a goal of reducing mercury releases to Minnesota's air and water by 70 percent (compared to 1990 levels) by the year 2005. This goal was established in statute in the 1999 legislative session.

The recommendations which the council voted to forward to the MPCA included:

- encouraging voluntary commitments on the part of sources of mercury emissions (*e.g,*. power plants, taconite facilities, sewage sludge incinerators) to reduce or work toward reducing mercury emissions.
- a package of seven strategies which the state will advance at the national level to encourage states and the federal government to act in concert to reduce national mercury releases.
- a package of strategies to persuade consumers to reduce their purchases and use of mercury-containing products and encourage counties to collect more mercury-containing waste in their household hazardous waste pickups.
- pursuing continued research on mercury sources, transport, and impacts on human health and wildlife.

Mercury Emission Inventory for Minnesota

It is important to understand the sources of mercury to the atmosphere in order to reduce air pollution, mercury deposition to lakes, and fish contamination. To that end, the MPCA staff have revised estimated emissions of mercury to the air for 1990 and 1995 (Table 1). Table 1 is subdivided into three main categories of emissions: (1) emissions that are incidental to energy production (the release of trace amounts in fossil fuels), (2) emissions that largely result from the purposeful use of mercury (volatilization during product disposal and incineration) and (3) emissions incidental to other activities (*e.g.*, processing natural resources, such as wood and iron ore). Category 3 is distinct from category 1 (even though they are both incidental emissions) in that once mercury is released during production of a material such as iron, that iron can be recycled without releasing additional mercury.

Table 1 Inventory of mercury emissions, in pounds, in Minnesota, 1990-95 (The data are subject to change as better information is received.)

	confidence level	1990 (best)	1990 Min.	1990 Max.	1995 (best)	1995 Min.	1995 Max.
Incidental to Energy Production							
coal (total) (1)	medium	1,526	1,145	1,908	1,462	1,096	1,827
electric utility coal	medium	1,416	1,062	1,770	1,332	999	1,665
commercial/industrial coal	medium	110	83	138	130	97	162
residential coal		0	0	1	0	0	1
Petroleum Sector (including refining and combustion of products) (2)	low	250	125	250	250	125	250
wood (3)	medium	13	9	16	10	8	13
natural gas (4)	low	0.2	0.1	0.5	0.28	0	1
Subtotal incidental with energy production		1,792	1,281	2,179	1,725	1,230	2,095
% of total state emissions		21%			37%		
Largely Resulting from the Purposeful Use of Mercury							
Latex Paint Volatilization (5)	low	500	250	1,000	10	5	20
Municipal Solid Waste Combustion (6)	high	1,806	1,626	1,987	634	570	697
On-site Household waste incineration (7)	low	666	333	1,332	270	135	540
Medical Waste Combustion (8)	high	516	464	568	36	32	40
Sewage sludge Incineration (0.6 metro sludge (70% control in 05) + Seneca) (9)	med.	247	185	309	160	120	200
Fluorescent Lamp Breakage (10)	low	330	165	660	83	41	165
Class IV incinerators --1,000 closed by 1/96 (11)	low	55	28	110	28	14	56
Crematories (12)	low	24	12	49	35	18	71
General Laboratory Use (13)	low	44	22	88	44	22	88
Dental Preparations (14)	low	24	12	48	12	6	24
Hazardous Waste incineration (15)	medium	5	4	6	5	4	6
Landfill volatilization (16)	low	13	6	25	3	2	7
Recycling mercury from Products within MN (17)	medium	4	3	4	35	26	44
Smelters that recycle cars and appliances (18)	medium	166	125	208	166	125	208
Volatilization from Dissipative Use (19)	low	2	1	4	2	1	4
Fungicide Volatilization (20)	low	86	43	172	25	13	50
Volatilization from spills and land dumping (21)	low	55	27	109	48	24	96
Volatilization during SW collection & processing (22)	low	1,304	652	2,607	432	216	864
Volatilization: land application of compost (23)	low	2	1	3	1	0	1
Volatilization: land application of sludge (24)	low	4	2	7	2	1	3
Subtotal associated with purposeful use of mercury		5,852	3,960	9,297	2,031	1,375	3,184
% of total state emissions		69%			44%		
Emissions Incidental to other Activities:							
Taconite Processing (25)	medium	797	598	797	828	621	828
Pulp and Paper Manufacturing (26)	low	4	2	7	4	2	7
Soil Roasting (27)	low	13	7	27	13	7	27
Subtotal emissions incidental to other activities		814	606	831	845	629	862
% of total state emissions		10%	10%	7%	18%	19%	14%
GRAND TOTAL =		8,457	5,847	12,307	4,600	3,235	6,140

Abbreviations: NA = Not Applicable; NQ = Not Quantified
Confidence intervals: High +/- 10%; Medium +/- 25%; Low +/- 50% (except when best estimate cannot be exceeded)

Notes about sources emissions listed in Table 1

(1) Based on data submitted by facilities with stack tests (NSP, MP) and extrapolated to other coal combustors.

(2) Based on a preliminary analysis of crude oils delivered to Minnesota refineries. The fate of the mercury in the refinery and various products is being investigated.

(3) From Pang, S.M. 1997. Mercury in wood and wood fuels. Thesis. Master of Science. University of Minnesota.

(4) Assumes the EPRI emission factor of 0.0008 lb/trillion Btu.

(5) Nationally, 24.2 tons of mercury were added to paint in 1990 (2% = 968 lb). Half is assumed to volatilize the first year. (Minnesota's economy is about 2% of the U.S. economy.) The addition of mercury to paint was discontinued by 1992.

(6) Based on stack tests.

(7) Quantity is based on Office of Environmental Assistance estimates. Municipal solid waste (MSW) is assumed to be 3.7 ppm in 1990 and 1.5 ppm in 1995.

(8) Based on stack tests.

(9) Based on sludge analyses and the analysis published by S. Balogh and L. Liang, 1995. Mercury pathways in municipal wastewater treatment plants. Water, Air, and Soil Pollution. 80:1181-1190.

(10) Based on the proportion not recycled and industry figures on mg/lamp, assuming 25% is volatilized.

(11) All of these small incinerators associated with grocery stores, etc. (about 1,000) closed by January 1996. It is assumed that they mostly burned cardboard with mercury at 0.2 ppm.

(12) Assumes that each person has four amalgam fillings containing 0.5 gram of mercury each.

(13) Estimate in the U.S. Environmental Protection Agency (EPA) Mercury Report to Congress.

(14) Estimate in the U.S. Environmental Protection Agency (EPA) Mercury Report to Congress.

(15) Estimate from Minnesota's only hazardous waste incinerator, 3M Chemolite.

(16) 0.1% of landfilled municipal solid waste (MSW) is assumed to volatilize to the air per year (based on studies of MSW emissions in Florida by S. E. Lindberg and J. L. Price, 1998).

(17) Products within Minnesota estimate from Brian Golob, personal communication.

(18) Automobile Shredder Residue Report. MPCA, 1995. The largest scrap metal smelter in Minnesota is North Star Steel; it is assumed that 50% of mercury is emitted, and that the number of mercury switches declines with time.

(19) Mercury that dissipates into the environment (excluding fungicides): ritual uses, pharmaceuticals, etc.).

(20) Estimate of volatilization from fungicides applied to golf courses.

(21) Estimate assumes that 8% of mercury removed from service each year is spilled on the ground and that 5% of that amount volatilizes.

(22) Assumes that the 5% of the mercury in solid waste is volatilized during collection, transportation and mechanical processing. Includes demolition, industrial and municipal solid waste (MSW) landfills, MSW and medical waste incineration, MSW compost, backyard burn barrels and steel-recycling facilities. Fluorescent lamps calculated separately.

(23) Assumes that 1.0% of mercury applied to the surface of the land volatilizes within a year.

(24) Assumes that 1.0% of mercury applied to the surface of the land volatilizes within a year.

(25) From Engesser *et al.* 1997. Mercury Emissions from Taconite Pellet Production. University Minnesota report to the MPCA.

(26) From voluntary reports to the MPCA.

(27) An average of 83,000 tons per year of surface soil are heated annually in Minnesota to remove organic contaminants. A background concentration of 0.08 ppm of mercury is assumed.

Trends in Mercury Emissions

It is clear that air emissions declined greatly (by about 45 percent) from 1990 to 1995, from about 8,500 pounds (lb) to 4,500 lb (Table 1). Virtually all of the decline can be attributed to emissions associated with the purposeful use of mercury. The major reductions were the elimination of mercury additives to latex paint (estimated reductions of about 500 lb) source reduction and control at municipal waste incinerators (1,200 lb) and on-site incinerators (about 500 lb), and reductions from medical waste incinerators (about 500 lb). Reductions occurred at larger incinerators due to both lower levels of mercury in waste (mercury in municipal solid waste declined from about 4 ppm in 1990 to about 1.5 ppm in 1995) and control technology (*e.g.*, the Hennepin Energy Resource Company municipal waste combustor and the Mayo Clinic medical waste incinerator installed activated carbon injection systems). Further reductions in mercury use and additional emissions control will likely result in lower emissions from waste incineration, from 878 lb emitted in 1995, declining to projections of about 380 lb in 2000 and 280 lb in 2005. In addition, MPCA staff calculate that about 550 fewer pounds of mercury were emitted to the air in 1995 simply because there was less mercury in products to volatilize when these products were disposed of or accidentally spilled.

Mercury Deposition Monitoring

The MPCA participates in the National Atmospheric Deposition Program (NADP) to monitor mercury deposition in rain and snow. In 1996, four sites were established across Minnesota: Lamberton in southwestern Minnesota, Camp Ripley in central Minnesota, Marcell in north-central Minnesota and Ely in northeastern Minnesota. Each site is also a NADP acid-deposition monitoring site. Total mercury and acid rain parameters (major cations and anions) are monitored weekly, while methyl mercury is analyzed using four-week composite samples.

The MPCA also has obtained data on historical mercury deposition rates through sediment cores from more than 50 lakes. As sediments accumulate over time, they act as a natural archiving system for the history of contamination. By obtaining a three- to four-foot-long core of the sediment from a lake, and slicing it into thin layers for analysis, the history of the mercury contamination of that lake can be reconstructed with about a five-year resolution. From these reconstructions, the degree and timing of changes in atmospheric deposition can be calculated, including the natural level of contamination. Comparing cores from Minnesota lakes to remote Alaskan lakes also indicates the amount of contamination that has resulted from sources in the Minnesota region versus the amount of mercury that contaminates the entire globe. Results from the coring program show that, (1) of the mercury deposited in northeastern Minnesota, 30% is natural, 30% is global pollution and 40% is regional, and (2) in some parts of Minnesota, the regional pollution peaked in the 1970s and has declined since then due to less emission of mercury (Engstrom and Swain, 1997).

How Mercury in Products Gets to the Atmosphere — Development of a Conversion Factor

Mercury has been used in many products for many reasons. Some uses, such as pharmaceuticals and fungicides, dissipate the mercury into the environment as it is used. Such uses have a relatively short life span, and then more mercury is purchased for that use. In contrast, mercury is used in some electrical switches that have an indefinite life span (40 years or longer), and the mercury may be encapsulated until the switch is decommissioned due to equipment changes. Most of these mercury uses, such as in appliance and automobile switches and in medical equipment (*e.g.*, manometers), probably have life spans between 10 and 30 years.

Table 2 represents an attempt to track the fate of mercury in products from purchase to disposal and estimates the quantity of mercury released to air, land and water during storage and use. One of the primary motivating factors for the creation of Table 2 was the need to understand the relative importance of reducing mercury use in products as compared to the direct release of mercury to air and water from point sources, such as coal-fired power plant stacks. Evaluation of the connection between mercury use and release indicates that, for every 100 lb of mercury contained in products disposed of in 1995, 15 lb were released to the atmosphere. The remainder either was recycled, or is associated with land (via a landfill or landspreading). The 15 percent figure can be used as a conversion factor between mercury used in products and mercury emitted to the atmosphere. Assessment of the cost of reducing mercury releases by reducing use in products versus controlling emissions from coal-fired utilities or taconite plants showed that, in general, the cost per pound to reduce emissions is lowest by reducing mercury use in products and by reducing improper disposal.

For instance, in 1995 (Table 2) of the 60 to 100 tons of mercury in use in Minnesota, about 4 tons (7,777 lb) were discarded in about 2.5 million tons of solid waste. About 44 percent of this waste (containing about 3,420 lb of mercury) went to landfills, of which MPCA staff estimate 5 percent (171 lb of mercury) was lost to the atmosphere before the waste was dumped out of the truck at the landfill (during waste collection, transportation and mechanical processing). An additional 0.1 percent, or 3.3 lb of mercury, is estimated to be volatilized to the air at the landfill. A greater proportion (53 percent) of solid waste went to combustors in 1995, where 634 lb of mercury were emitted to the air. No matter how mercury-containing products are disposed of, some mercury makes its way to the atmosphere.

Once all possible fates of mercury-containing-products are estimated, one can add all sources of mercury to air, land and surface water. For 1995, MPCA staff estimate that, of the approximately 11,000 lb of mercury removed from service that year, 15 percent (1,655 lb) made its way to the atmosphere, 76 percent (about 8,400 lb) is on the land or in landfills, 9 percent was recycled, and only 17 lb per year — 0.1 percent — were discharged to surface water.

Table 2. Fate of mercury used in products in Minnesota, 1995

Mercury not Recycled and not Disposed to Waste Streams

Mercury not Recycled and not Disposed to Waste Streams

Estimated lb/year	% to environmental compartment	Fate	% of total Hg per yr.
26 2 3	85% land 5% air (11) 10% water	Dissipative use (ritual, meds, paint fungicides)	0.25% 30 lb. (10)
570 30 0	95% land 5% air (11) 0% water	Accidental release to air, land, & water during storage & use (spills)	5% 600 lb. (10)
342 18 9	95% land 5% air (11) 0% water	Un-permitted Disposal (primarily land dumping)	3% 360 lb. (10)

12,000 lb. purchased ← 1,000 lb. recycled

Estimate of total Hg in use (7)

60 to 100 tons of mercury with a 10 to 30 yr average life span,

implying that 3.3% to 10.0% is removed per year, or

2.0 to 10 tons per year, or

4,000 to 20,000 pounds of mercury is removed from use each year.

→ lb lost to air from recycling (2): 35

Mercury Disposed in Solid or Liquid Waste Streams

Mercury Disposed to Waste Streams

Solid Waste tons/yr	Hg (ppm)	lb Hg	Solid	% of waste stream		lb. Hg to Air (1) during processing	lb. to air	lb. to surface water	lb. to land	secondary release from land to: air (8)	leachate (9)
2,592,393	1.5	7,777	MSW	44%	MSW Landfills	171	0	0	3,251	3.3	0.1
				53%	MSW Incineration	206	634	0	3,282	3.3	0.0
				1%	Compost (land applied)	4	0	0	74	0.7	0.0
				2%	Backyard burn barrels (13)	8	74	0	74	0.7	0.0
1,700,000	0.1	340	Construction & Demo	100%	Demolition Landfills	17	0	0	323	0.3	1.6
				50%	Autoclave	4	0.075	?	71	0.1	0.4
15,000	5	150	Medical (5)	50%	Medical Waste Incineration	4	33.75	0	38	0.0	0.0
1,000,000	0.1	200	Industrial	100%	Industrial Landfill	10	0	0	190	0.2	1.0
50,000	1.75	175	Scrap Metal Recycling (6)	100%	Smelter	9	166.3	0	0	0.0	0.0
Liquid mil gal/day	Hg(ppt)	lb Hg	liquid								
510	170	264	POTWs → sludge	36%	Land Application (3)	0	0	0	96.0	1.0	0.0
				64%	Sludge Incineration	0	170	0.0	0.0	0.0	0.0
		17%	→ water	100%	discharged to water (4)	0	0	10.6	0.0	0.0	0.0
0.68	5,000	10.4	Septage (12)	83%	land applied	0	0		8.6	0.1	0.0
65	5	1.0	Industrial Discharge	100%	discharged to water	0	0	1.0	0.0	0.0	0.0
					Subtotals	432	1,078	12	7,407	10	3

Summary: Fate of Mercury in 1995

to air	=	1,604 pounds/year	15%
to land	=	8,319 pounds/year	76%
to surface water	=	12 pounds/year	0.1%
recycled	=	1,000 pounds/year	9%
TOTAL	=	10,935 pounds/year	100%

Notes:

1. Pounds of Hg in this waste stream that is lost to air during collection, transportation & mechanical processing, assuming that 5% is lost during those processes.
2. The Mercury Report to Congress estimates 7.4 tons per year lost to air from recycling, while USBM data indicate about 220 tons per year, about 3.5 percent.
3. Total sludge land spread in Minnesota in 1995 was 46,668 dry tons with an average mercury content of 1.83 ppm, or 171 lb. (R. Wirth, pers. com.).
4. This calculation assumes that 4% of the mercury entering a POTW is discharged to surface water, and that the rest associates with sludge (Balogh and Liang 1995, Water, Air and Soil Pollution 80: 1181-1190).
5. About 7,500 tons/year medical waste is incinerated at the two large facilities (6,900 t/yr) and 20 small units (600 t/yr)(P. Torkelson, pers. com.). The amount accepted by autoclaves is unknown.
6. Automobile shredder Residue Report. MPCA. 1995. The largest scrap metal smelter in MN is North Star Steel; it is assumed that 50% of Hg is emitted, and that the rest is emitted when the fly ash is refined for its zinc content in another state. After 1995, Nor Star Steel asked suppliers to remove mercury switches before delivering scrap.
7. Based on pro-rated estimates of U.S. installed base, not counting chlor-alkali plants (S.M. Jasinski, 1995. The materials flow of mercury in the United States. Resources, Conservation and Recycling 15:145-179.)
8. The following rates are assumed for air emissions from land: 1%/yr from surface application; 0.1%/yr from other landfilled material (0.1% is based on studies of MSW emissions in Florida by S.E. Lindberg and J.L. Price, 1998).
9. Leachate (assumed to be 0.002%/yr, based on concentration x leachate volume), is either land applied (through spray irrigation) or transported to a POTW. Median concentration is 0.7 ppb (Land Treatment of Landfill Landfill Leachate, MPCA, 1993, pg. 27).
10. Based on the mean quantity of mercury estimated to be removed from the installed base per year (in this case, the mean of 4,000 and 20,000 pounds per year or 12,000 pounds).
11. Consistent with Note number 1, 5% of these materials is assumed to become volatilized within a year of disposal. There may be continuing release in subsequent years, which is not accounted for in this estimate.
12. Concentration from document provided by Joe Carruth.
13. It is assumed that half of the mercury burned in a back yard burn barrel is volatilized immediately, and half is buried in the land.

APPENDIX O

Appendix O — Team Participants and Authorship of Sections

Technical Team		Consent-Building Team	
Cynthia Hollerbach	Chris Nelson	Sherryl Livingston (coordinator)	John Seltz
Margaret McCourtney	Mary Jean Fenske (coordinator)	Dale Thompson	Mary Jean Fenske
Kari Palmer	Greg Pratt	Leo Raudys	Dave Kelso
Fardin Oliaei	Gretchen Rohweder	Becky Helgesen	
Chun Yi Wu			
Product Review: Helen Goeden, Dept. of Health Rep.		Product review: Dick Cordes, Mike Mondloch	

The primary authors of the various sections of this paper are listed below:

Executive Summary (M. J. Fenske)

1.0 What is the purpose of this paper? (M. J. Fenske)

2.0 What are the primary pollutants of concern? (G. Pratt, M. J. Fenske)

- 2.1 Which pollutants exceed health benchmarks?
  - What information indicates pollutant is a concern? (G. Pratt)
  - What are the health effects of pollutant? (C. Hollerbach)
  - How are people exposed to pollutant? (C. Hollerbach)
  - What happens to pollutant in the atmosphere? (C. Hollerbach)
  - Which sources emit pollutant? (C. Y. Wu)
  - Pollutant summary (G. Pratt)
- 2.2 Priority Persistent, Bioaccumulative Toxics (PBTs) (F. Oliaei)

3.0 What are the primary sources of the pollutants of concern?

- 3.1 What are point, area and mobile sources? (C. Nelson)
- 3.2 What sources are primary contributors to multiple pollutants? (C. Y. Wu)

4.0 Which geographic areas are affected? (G. Pratt)

5.0 How serious is the air toxics threat?

- 5.1 Contributions to increased excess cancer risk (C. Hollerbach)
- 5.2 How do air issues rank with the general public? (S. Livingston)
- 5.3 What efforts are taking place at the national level to reduce air toxics? (M. J. Fenske)

6.0 What future activities are recommended?

- 6.1 Air Toxics Technical Team (M. J. Fenske)
- 6.2 Air Toxics Communication and Reduction Strategies Team (S. Livingston)

7.0 What are possible emission reduction strategies? (C. Nelson)

REFERENCES

APPENDICES