Environmental Information Report:
An Assessment of Stresses Facing Minnesota's Environment

2003

An Environmental Outcomes Division Report to the Minnesota Pollution Control Agency

Minnesota Pollution Control Agency

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Appendices (contained in a separate document)

Acknowledgments

This report was prepared by Todd Biewen, Dave Christopherson, Tom Clark, Chris Nelson, Kari Palmer, Mike Trojan and Chris Zadak of the MPCA Environmental Outcomes Division, with additional support from Mike Sandusky, Gaylen Reetz, and Paul Hoff.

I. Introduction

This is the first edition of the Environmental Outcomes Division's Environmental Information Report (EIR). The report contains assessments of a wide variety of environmental stresses facing Minnesota, and identifies and compares their causes. Current environmental programs are taken into account; the analysis examines the health and ecological stresses that remain. Finally, the EIR provides an assessment of our confidence in these measurements, as well as an indication of current trends of the various stressors and sources that contribute to environmental risks.

The primary audience of the report is agency decision-makers, although we envision that it will have application to external audiences such as the legislature and citizens. The EIR was prepared in part to help fulfill the mission of the Environmental Outcomes (EO) Division and to meet a need envisioned by other divisions. The purpose of the EO Division is to monitor and evaluate the physical, chemical and biological conditions of Minnesota's environment; to identify environmental threats and impacts to human and ecosystem health; and to report results to agency leadership, staff, stakeholders, and citizens. Since this is the first report of its type, it should be looked at as a baseline against which future environmental change may be assessed.

A core team of staff from the Environmental Outcomes Division developed the EIR, with support from division leadership, supervisors, managers and the division director. The EIR team met frequently between October 2000 and January 2002. We gathered and evaluated existing environmental data and information from MPCA programs; assessed status and trends of environmental impacts, stressors and sources; and identified gaps in information that need to be filled. Six categories of information were examined: environmental stressors; environmental risk; resource conditions; statutory obligations and responsibilities; socioeconomic and future trends; and public and stakeholder expectations (see Figure 1).

We considered many approaches to presenting environmental data and information. The format we selected consisted of a matrix approach organized by environmental impacts, stressors and sources. The matrix format uses symbols (circles, squares, and arrows) to graphically indicate the respective magnitude of the contribution, confidence level, and trend of each stressor and source. We also assessed the adequacy of monitoring of these stresses and sources and our confidence level in our decisions. Impact overviews, public/stakeholder information, and socioeconomic and future trends were also compiled and summarized as a part of each environmental matrix. We developed six environmental matrices and a program matrix, and sought MPCA staff input on each using a combination of group and one-on-one meetings.

For five of the environmental matrices (human health cancer, human health chronic, human health acute, aquatic organisms and terrestrial organisms), a panel of 10 to 15 technical experts was convened to share information and score the comparative contribution of environmental stressors. The group of experts also scored their confidence level for evaluating the comparative contribution and adequacy of monitoring of each stressor.

Modification of the list of stressors, sources and specific pollutants was considered in general discussions with each panel prior to the scoring. Some changes were made based on panelists' comments before scoring began. After the meetings, the EIR team attempted to reconcile those results that appeared contradictory when viewed across the matrices. We also sought feedback from the panelists on the final draft matrices. Finally, we sought and received input on the final draft from the Minnesota Departments of Natural Resources, Health and Agriculture.

The EIR team developed support documentation for evaluating stressors, sources and the rationale for each (see appendices). We also independently completed a matrix for "quality of life" impacts, i.e., diminished aesthetics and reduced access to resources.

Our attempt to summarize both internal and external agency environmental efforts is included in the "program matrix." This matrix addresses statutory obligations and responsibilities and existing program coverage for the stressor sources we identified. In compiling this matrix we sought input and verification from staff in each program area.

The EIR concludes with a section describing potential uses of the report, including sample queries of the database and example questions that decision-makers might ask about the information contained in the report.

It should be noted that in addition to the specific input provided by staff, we also received many general comments regarding the overall approach taken with this report. These comments ranged from enthusiastic support to serious concern. A primary concern for some was the validity of making comparisons with incomplete information. Some also were troubled by trying to compare stressors with different endpoints. We acknowledge these concerns, but are confident that this first-time effort has resulted in a high-quality report that can be an important tool to inform agency decision-making.

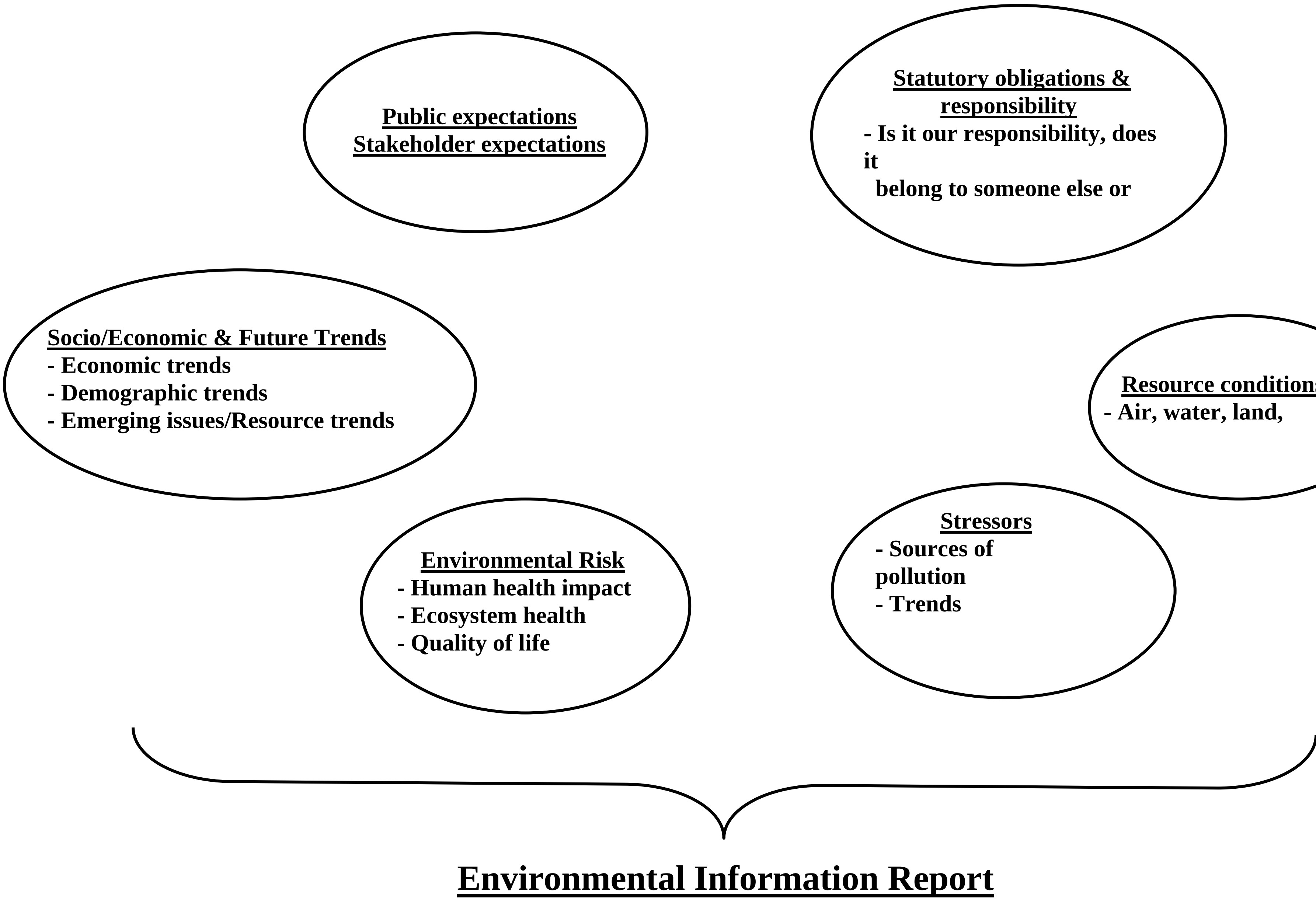

Figure 1: Information Categories for the Environmental Information Report

II. Environmental Matrices

This section provides information on human health, ecosystems and quality of life in a matrix format. *Comparison of information for stressors and sources should only be made within a single matrix and not across matrices.*

Explanation of terms and guide to symbols

***Adequacy of ambient monitoring**:* Effectiveness of monitoring efforts to determine ambient levels and trends (not necessarily actual impacts) of an environmental stressor. Recognizing that a complete monitoring network is not possible, there are four monitoring levels for the EIR:

□□□ = no monitoring exists;
■□□ = extent and quality of monitoring very limited; barely a presence;
■■□ = adequate monitoring of hotspots, but no widespread network; and
■■■ = reasonable monitoring network.

The following factors were used to rank the effectiveness of an ambient monitoring program to determine status, compliance, or trend(s) of a stressor or indicator:

- pollutant coverage;
- geographic coverage;
- adequacy to assess exposure; and
- meets established QA/QC (i.e., MPCA, EPA) requirements or protocols.

Confidence level: Degree of assurance or certainty of our knowledge of comparative contribution of a stressor or source. Recognizing that complete confidence is not possible, there are four confidence levels for the EIR:

□□□ = very unsure; near zero level of confidence;
■□□ = somewhat speculative; many assumptions at play;
■■□ = moderately confident, although holes in understanding exist; and
■■■ = reasonable level of confidence.

The following factors were used in assigning a confidence level to a stressor or source:

- availability of data from sources, emissions, discharges, etc.;
- ability to quantify over time; and
- degree of confidence in risk information.

Geographic extent: Area or region where the overall comparative contribution to the risk posed by a stressor is significant. Factors used in assigning geographic extent include: urban, agricultural, geographic region of the state, etc.

Overall comparative contribution: A qualitative ranking of the contribution—in terms of risk rather than total mass—of a stressor to the impact in question. The measurement is one of residual risk—risk that remains given the environmental programs currently in place. The three rankings used for the matrices are:

○ = low overall comparative contribution;

◒ = medium overall comparative contribution; and

● = high overall comparative contribution.

Pollutant: Predominant chemicals, groups of chemicals, or substances within a stressor.

Source: An activity or category of activities that contributes to concentrations of a pollutant in the environment.

Comparative contribution of a source: A qualitative ranking of the contribution of a source to a stressor. The same symbols used for the stressors are used with the sources.

Source trend: A qualitative assessment of the trend of a source's contribution to a stressor. Source trends were assigned using best professional judgment of the EIR team members, in consultation with other experts who assisted in producing this report. Trends should therefore not be viewed as scientifically rigorous assessments. The symbols used to indicate trends are:

↑ = upward trend;

↓ = downward trend;

⟷ = no trend; and

↑↓ = upward and downward trend (some contributing pollutants are up and others are down; we don't have adequate information to make an assessment).

Stressor: A pollutant or human activity that contributes to an impact in the environment. The stressors considered in this report are generally those for which the MPCA currently has a role or may have a role in the future. With this report intended mainly for internal MPCA decisionmakers, several key stressors under other departments' jurisdiction, such as exotic species or indoor air quality, were not included.

Stressor trend: A qualitative assessment of the trend for a stressor. Stressor trends were assigned using best professional judgment of the EIR team members, in consultation with other experts who assisted in producing this report. Trends should therefore not be viewed as scientifically rigorous assessments.

The same symbols used for the sources are used with the stressors.

Human Health Impacts: *Cancer impacts*

<u>Overview of impact</u>: Preventing exposure to cancer-causing substances is an important focus of various MPCA pollution control programs. The risk of cancer from environmental pollutants is a function of the cancer potency of a given pollutant and the exposure to that pollutant. Exposure to pollutants occurs through inhalation, ingestion, and dermal contact. Typically the time between exposure to cancer-causing substances and onset of cancer is many years.

Nearly 50% of Minnesotans contract some form of cancer during their lifetime, with diet/obesity and smoking comprising the majority of the causes of cancer incidences and deaths (MDH, 1999). Cancer accounts for about 24% of all US and Minnesota deaths (which is topped only by major cardiovascular diseases—about 36% in Minnesota). "Pollution" is roughly estimated to be responsible for about 2% of the total US cancer deaths (Harvard Report on Cancer Prevention, 1996). The comparisons shown in the matrix below are only among the stressors listed; not to other non-environmental sources of cancer. For this matrix "environmental" was defined as anthropogenic sources of chemicals or other stressors. This did not include exposures resulting from the use of consumer products, occupational exposures, or indoor sources. Chemical exposures to naturally occurring chemicals were not included. The factors considered in the comparisons included the estimated number of incidences of cancer for each stressor.

<u>Public/Stakeholder information</u>: Concern over "chemicals in the environment" generally ranks "medium-high" in Minnesotans' list of concerns (see Appendix E, Public/Stakeholder Information). A 1999 national public health survey showed that 39% of respondents believed that environmental factors play an important role in causing childhood cancer (though not as strongly linked to environmental factors as childhood asthma (54% saying that environmental factors play a role) and sinus and allergy problems (also 54%)). Given these studies, it seems likely that many people believe that pollution-related cancers are more prevalent than the 2% figure estimated by Harvard.

<u>Socioeconomic & future trends</u>: Cancer stressors that may affect large populations are particles in air, toxic chemicals in air, toxic chemicals in food, and excess UV radiation. Of these, the air stressors, particles and toxic chemicals, have a high potential to worsen because of trends we are seeing in Minnesota. One trend relates to the **presence** of the stressors in the environment. Important sources of these air stressors include industrial activity, energy production from coal, and on-road vehicle and off-road equipment use. Each of these activities has increased and will likely continue to increase. Technology improvements, alternative fuel development, and control strategies may lessen the impact of particles and toxics by reducing them at their source. A second trend relates to **exposure:** Two-thirds of Minnesotans now live and work in urban and suburban areas. Taken together, these trends suggest there is an increasing population breathing air that contains particles and toxic chemicals that have the potential to cause cancer.

Human Health Impacts: Cancer impacts

Stressors	Overall comparative contribution* / Confidence level / Geographic extent	Stressor Trend	Adequacy of ambient monitoring	Source	Comparative contribution of sources / Confidence level	Source trends	Specific pollutants	Rationale/Comments
Particles in air	● ■□□ Urban	↔	■■□	Coal-fired power plants	● ■■□	↑↓	Fine particles (PM2.5) Diesel particles Nanoparticles Air toxics attached to particles (PAHs, PBTs, semivolatiles) Metals PM10 Asbestos	• Large portion of population exposed; cancer risk for ambient exposure levels not well understood. • Pathway is inhalation. • Lung cancer is the primary concern. • Toxicity may come from particles or attached chemicals; we have good data on the former, poor on the latter. • There is limited PM2.5 data. Stressor trend is based on PM10 data. Primary health concern is with PM2.5 and nanoparticles. • Many listed sources do not emit particles. Instead they emit compounds which form particles downwind of the emission point. These compounds are known as particle precursors (e.g., agricultural practices and wastewater emit NH3, not particles). • Fossil fuel combustion emits particles and precursors. • It is unknown if cancer effects are primarily linked to mass of particulate or to another parameter such as number of particles. It is difficult to assess trends because, for example, while the mass of particles has remained steady or even decreased, the trend for number of particles is unknown.
				On-road vehicles	● ■□□	↑↓		
				Off-road equipment	● ■□□	↑↓		
				Area source combustion	◒ ■□□	↑↓		
				Agriculture	◒ ■□□	↑↓		
				Municipal and industrial wastewater	○ ■□□	↑↓		
				Fugitive dust	○ ■□□	↑↓		
				Industry	○ ■□□	↑↓		
Toxic volatile organic chemicals in air	◒ ■■□ Urban; localized	↑↓	■■■	On-road vehicles	● ■■■	↑↓	Benzene Formaldehyde 1,3-Butadiene Acetaldehyde	• Large portion of population exposed. A few chemicals are above health benchmarks. A few chemicals may be approaching health benchmarks. • Pathway is inhalation. • Cancers vary with chemical (e.g., benzene causes leukemia). Cancer risks from exposures to multiple chemicals not well understood. • Pollutants and pollutant sources are ubiquitous; not all are listed. • Highest exposures likely to occur in microenvironments (e.g., gas stations).
				Off-road equipment	◒ ■■□	↑↓		
				Residential fuel combustion	◒ ■□□	↔		
				Industry	◒ ■■■	↑↓		

*Compared only among the pollutants listed; not to other sources of cancer.

Stressors	Overall comparative contribution* / Confidence level / Geographic extent	Stressor Trend	Adequacy of ambient monitoring	Source	Comparative contribution of sources / Confidence level	Source trends	Specific pollutants	Rationale/Comments
Toxic chemicals in food	◒ ■□□ Statewide	↑↓	■□□	Residential fuel combustion	● ■□□	↔	Dioxins and furans Hormones PAHs Pesticides Metals Phthalates PCBs PBBs Alkyl phenols Hexachloro-benzene Octachlorostyrene Polychlorinated naphthalenes	• Overall comparative contribution due to increasing toxicological evidence of food chain effects. Laboratory tests indicate that effects of high doses of these chemicals may be very serious. • Cancers vary with chemical (e.g. PCBs are suspected to cause many forms of cancer, including liver and skin cancer). • Pathway is ingestion. • Food chain effects typically are passed from the contaminant source through other media. For example, many chemicals released to air are deposited to soil and surface waters. • Most pollutants of concern are classified as Persistent Bioaccumulative Toxics. • Chlorinated insecticides are the pesticides of greatest concern because they accumulate in the food chain. Their use has decreased and many have been banned in the United States. • Residential fuel combustion includes wood burning; pollutants of concern are PAHs and dioxins.
				Pesticide use	● ■■□	↓		
				On-road vehicles	◒ ■□□	↑↓		
				Off-road equipment	◒ ■□□	↑↓		
				Unpermitted waste disposal	◒ ■□□	↓		
				Mining	◒ ■□□	↔		
				Municipal and Industrial Wastewater	◒ ■□□	↔		
				Coal-fired power plants	◒ ■□□	↔		
				Waste incineration	◒ ■□□	↑↓		
				Industry	◒ ■□□	↓		
				Permitted waste disposal	◒ ■□□	↑↓		
Excess UV radiation from stratospheric ozone depletion	◒ ■■□ Statewide	↔	■■■	Refrigerants	◒ ■□□	↑↓	Chlorofluoro-carbons Hydrochloro-fluorocarbons 1,1,1-Trichloroethane Methyl Bromide	• Large portion of population exposed. • Pathway is exposure to sunlight. • Skin cancer is the primary concern. Severity varies from basal cell to squamous to melanoma. • Ozone depleting chemical emissions are reported by many industries; for other sources we have little information. • Chlorofluorocarbons have been banned. Brominated compounds
				Fire extinguishers	○ ■□□	↑↓		

				Unpermitted waste disposal	○ ■□□	↑↓		
				Industry	○ ■■□	↑↓		

*Compared only among the pollutants listed; not to other sources of cancer.

Human Health Impacts: Cancer impacts (cont'd)

Stressors	Overall comparative contribution* / Confidence level / Geographic extent	Stressor Trend	Adequacy of ambient monitoring	Source	Comparative contribution of sources / Confidence level	Source trends	Specific pollutants	Rationale/Comments
Toxic chemicals in water	○ ■■□ Urban; agricultural	↑↓	■■□	Pesticide use	● ■■□	↔	VOCs PAHs Pesticides Phthalates Metals	• Relatively small number of people exposed to pollutants at levels of concern. Most Minnesotans use public water supplies, which are routinely tested for VOCs, some metals, and some pesticides. Intervention (blending, treatment, drilling new wells) ensures low exposure from public supplies. Private water supplies are generally not tested and people using these supplies may be at greater risk than people using public water supplies. • Pathway is ingestion. • Cancers vary with chemical (e.g. benzene causes leukemia). Trihalomethanes (associated with chlorine disinfection) may contribute to some cases of bladder cancer. • Most pollutants are persistent. • Occurrence and health effects of numerous chemicals are unknown (e.g. prescription drugs and over-the-counter drugs). Some of these chemicals have recently been discovered in surface and ground water.
				Unpermitted waste disposal	◒ ■■□	↓		
				Tanks	◒ ■■■	↓		
				Land-applied municipal and industrial byproducts	○ ■■□	↑		
				Municipal and industrial wastewater	○ ■■□	↔		
				Spills	○ ■■□	↔		
Toxic chemicals in soil	○ ■□□ Localized	↔	■□□	Pesticide use	● ■■□	↔	Dioxins Metals PCBs Pesticides VOCs PAHs	• Likelihood of exposure at levels of concern is low. Long term exposure is unlikely. • Pathways are skin contact and ingestion. • Cancers vary with chemical (e.g. PCBs are suspected to cause many forms of cancer, including liver and skin cancer). Children are at greatest risk because they have greater contact with and ingestion of soil for their size than adults. • Most pollutants are persistent. • Industry impacts soil through air deposition.
				Industry	◒ ■□□	↔		
				Land-applied industrial and municipal byproducts	○ ■■□	↑		
				Unpermitted waste disposal	○ ■■□	↓		

				Spills	○ ■■□	↔		

*Compared only among the pollutants listed; not to other sources of cancer.

Human Health Impacts: *Noncancer acute impacts*

Overview of impact: The scope of this section is human health impacts in which the exposure is of a short duration (i.e., from instantaneous to hours on up to days). Examples of acute effects include asthma attacks, heat stress, and headaches. It is important to point out, however, that the lines of distinction between acute and chronic in the field of environmental risk assessment are unclear. Also, the actual health impacts in some cases of acute exposure may not show up for many years. Noncancer acute impacts are an issue for all media—air, surface water, ground water and soils—and the exposure pathways include inhalation, ingestion, and dermal contact. The factors considered in the comparisons of stressors below included the estimated extent of exposure in the state as well as the severity of the impact(s).

It is difficult to put environmental-related acute health impacts into context with other health impacts (acute or otherwise), mainly because of incomplete knowledge on cause and effect and the limited nature of disease and death statistics. The leading causes of death in Minnesota according to 1999 MDH statistics are: major cardiovascular diseases (36% of all deaths), cancer (24%), "violent" deaths (6%), chronic lower respiratory disease (5%), diseases of the nervous system (5%), and accidents (5%).

Public/Stakeholder information: Because the range of stressors for acute effects is so varied, it is hard to make specific conclusions about public/stakeholder views. However, a 1996 joint U of M-MPCA survey showed that the public cited "protecting human health" and "protecting future generations" as their first and second reasons, respectively, for why their most important environmental issue concerns them (and in this survey their top issues in order were polluted lakes, general water pollution, and motor vehicle pollution). Concerning specific environmental-related health threats, a 1999 national public health survey showed that the highest percentage of respondents believed that environmental factors play a more important role in causing childhood asthma (as well as sinus and allergy problems) than other diseases.

Socioeconomic & future trends: Two primary socioeconomic trends in Minnesota may have implications for noncancer acute impacts on human health. First, Minnesota's human population is expanding and migrating to urban and suburban areas. More than two-thirds of the state's five million people now live in urban and suburban centers, which is the opposite of how the state's population was distributed several decades ago. Second, per capita consumption of goods and energy, and per capita production of wastes continue to increase. Together, population growth and migration, along with consumptive behavior, will likely exacerbate environmental impacts from transportation, energy production, and waste disposal.

Human Health Impacts: Noncancer acute impacts

Stressor	Overall comparative contribution / Confidence level / Geographic extent	Stressor trend	Adequacy of ambient monitoring	Source	Comparative contribution of sources / Confidence level	Source trend	Specific pollutants	Rationale/Comments
Particles in air	● ■■□ Urban	↔	■■□	Coal-fired power Plants	● ■■□	↑↓	Fine particles (PM2.5) Diesel particulates Nanoparticles Toxics attached to particles (PAHs, PBTs, semivolatiles) Metals PM10	• Large portion of population exposed; risk for ambient exposure levels not well understood. • Pathway is inhalation. • Respiratory irritation, cardiopulmonary problems, asthma attacks, premature death. • Toxicity may come from particles or attached chemicals; we have good data on the former, poor on the latter. • There is limited PM2.5 data. Stressor trend is based on PM10 data. Primary health concern is with PM2.5 and nanoparticles. • Many listed sources do not emit particles. Instead they emit compounds which form particles downwind of the emission point. These compounds are known as particle precursors (e.g., agricultural practices and wastewater emit NH3, not particles). • Fossil fuel combustion emits particles and precursors. • It is unknown if effects are primarily linked to mass of particulate or to another parameter such as number of particles. It is difficult to assess trends because, for example, while the mass of particles has remained steady or even decreased, the trend on number of particles is unknown. • Coal-fired power plants, on-road vehicles, and off-road engines are all important sources of particles and their precursors. Research is ongoing to describe the relative importance of these sources in atmospheric particle formation and culpability for various health effects.
				On-road vehicles	● ■□□	↑↓		
				Off-road equipment	● ■□□	↑↓		
				Area source combustion	◒ ■□□	↑↓		
				Agriculture	◒ ■□□	↑↓		
				Municipal and industrial wastewater	○ ■□□	↑↓		
				Fugitive dust	○ ■□□	↑↓		
				Industry	○ ■□□	↑↓		
Temperature increase/ climate change	○ ● ■□□ Statewide The first circle represents current impacts; the second circle represents future impacts.	↑	■■■	Coal-fired power plants	● ■■■	↑	Carbon dioxide Methane Nitrous oxide CFCs Ozone Hydrofluorocarbons Hydrofluoroethers Sulfur hexafluoride Carbon tetrafluoride Carbon black	• Many people potentially exposed in the future. Current human health effects are considered low. • Potential health effects include heat stress, increased disease associated with warm weather vectors, and weather-related injuries. • Crop production is the primary agricultural source. The primary effect of crop production is on release of nitrous oxide from organic and inorganic fertilizers. Other agricultural sources include feedlots and land-applied manure.
				On-road vehicles	● ■■■	↑		
				Agriculture	◒ ■□□	↑		
				Industry	◒ ■■■	↔		
				Permitted waste disposal	◒ ■■□	↔		
				Residential fuel combustion	○ ■■■	↔		

Stressor	Overall comparative contribution / Confidence level / Geographic extent	Stressor trend	Adequacy of ambient monitoring	Source	Comparative contribution of sources / Confidence level	Source trend	Specific pollutants	Rationale/Comments
Ground-level Ozone	◒ ■■□ Urban	↑	■■■	On-road vehicles	● ■■□	↔	Nitrogen dioxide Nitric oxide VOCs	• Many people exposed; health effects are moderate at current ambient levels. • Pathway is inhalation. • Respiratory irritation; asthma attacks; possible cardiac effects. • Ozone is created by chemical reactions involving VOCs, NO_x and sunlight. Concentrations may increase with more warm weather. • Preliminary modeling suggests that ozone would be most effectively controlled by VOC emission reduction. • Monitored ground-level ozone concentrations are rising in the Twin Cities area although statewide sources of VOCs and NO_X have remained steady. Ozone formation results from a complex, non-linear series of reactions, therefore, the precise reason for rising ozone concentrations is uncertain. However, increased temperatures, urban traffic congestion, and transportation of ozone into Minnesota from metro areas to the south may be contributing to the increase in ozone concentration.
				Off-road equipment	● ■■□	↔		
				Coal-fired power plants	◒ ■■□	↔		
				Solvent utilization	◒ ■■□	↓		
				Area source combustion	○ ■■□	↔		
				Industry	○ ■■□	↔		
				Petroleum storage and transfer	○ ■■□	↔		
Pathogens in water	◒ ■□□ Agricultural; localized	↔	■□□	Feedlots	● ■■□	↔	Bacteria Viruses Parasites	• Moderate impacts. Number of exposures may be high, assuming many cases of exposure are not reported. • Pathway is ingestion (including while swimming). • Endpoint is gastrointestinal effects. • Pollutants have low persistence. • Highest incidence of exposure is probably through swimming.
				Land-applied manure	◒ ■■□	↔		
				Septic systems	◒ ■■□	↑		
				Municipal and industrial wastewater	○ ■■■	↔		
				Land-applied municipal and industrial byproducts	○ ■□□	↔		

Stressor	Overall comparative contribution / Confidence level / Geographic extent	Stressor trend	Adequacy of ambient monitoring	Source	Comparative contribution of sources / Confidence level	Source trend	Specific pollutants	Rationale/Comments
Odorous chemicals from biological processes	◒ ■□□ Localized	↑	■□□	Feedlots	● ■□□	↑	Hydrogen sulfide Ammonia VOCs Alcohols	• Small number of exposures; health effects are slight to moderate at ambient levels. • Pathway is inhalation. • Health effects include nausea, headaches, and respiratory irritation. Effects may be severe at high concentrations. • Pollutants have low persistence. • Difficult to determine trends since odors are not tracked.
				Treatment/settling ponds	◒ ■□□	↔		
				Agriculture	◒ ■□□	↔		
				Ethanol production	○ ■□□	↑		
Toxic chemicals in water	◒ ■■□ Agricultural; nonsewered communities	↑	■■□	Fertilizer use	● ■■■	↔	Nitrate	• Many people exposed; risk from nitrate limited to pregnant women and infants younger than six months. Most exposures occur through private drinking supplies, which are not routinely tested. • Pathway is ingestion. • The major human health endpoint is methemoglobinemia. Other chemicals in water do not have acute endpoints. • Nitrate is persistent in drinking water under certain hydrogeologic conditions.
				Septic systems	◒ ■■■	↑		
				Land-applied manure	◒ ■■□	↔		
				Feedlots	○ ■■□	↔		
Explosive/ flammable materials – high-level accidental releases	◒ ■■□ Localized	↔	Not Applicable	On-road vehicles	● ■■■	↑	VOCs	• Few people exposed but severe health effects. • Pathway is direct exposure. • Endpoints include death, burns, and injury. • Most pollutants have low persistence. • Contribution of sources based on number of releases, not volume of releases or severity of incidents.
				Tanks	● ■■■	↓		
				Pipelines	◒ ■■■	↓		
				Trains	◒ ■■■	↔		
				Industry	○ ■■■	↔		
				Residences	○ ■■■	↔		

Human Health Impacts: Noncancer acute impacts (cont'd)

Stressor	Overall comparative contribution Confidence level Geographic extent	Stressor trend	Adequacy of ambient monitoring	Source	Comparative contribution of sources / Confidence level	Source trend	Specific pollutants	Rationale/Comments
Noise	◒ ■□□ Urban; localized	↑	■■□	On-road vehicles	● ■■■	↑		• Many people exposed; most effects are minor. • Pathway is direct exposure. • Endpoint is hearing impairment and physical and psychological stress. • Contribution based on monitored noise levels. • Only major sources are considered. • Occupational noise and noise associated with lifestyle are not considered.
				Aircraft	● ■■■	↑		
				Industry	◒ ■■■	↔		
				Off-road equipment	◒ ■■■	↑↓		
Toxic chemicals – high-level accidental releases	○ ■■□ Localized	↔	Not Applicable	On-road vehicles	● ■■■	↑	Chlorine VOCs Pesticides Acids/bases Phosphate	• Few people exposed but severe health effects. • Pathways are inhalation, skin contact. • Various health effects including respiratory impairment, chemical burns, central nervous system effects, and death. • Most pollutants have low persistence. • Contribution of sources based on number of releases, not volume of releases or severity of incidents.
				Trains	● ■■■	↔		
				Industry	◒ ■■■	↔		
				Residences	○ ■■■	↔		
				Tanks	○ ■■■	↓		
				Pipelines	○ ■■■	↓		
Toxic volatile organic chemicals in air	○ ■□□ Urban; localized	↑↓	■■■	On-road vehicles	● ■■■	↑↓	Acrolein Benzene Formaldehyde 1,3-Butadiene Acetaldehyde	• Large portion of population exposed. It is unlikely that ambient levels would cause severe acute health effects in humans. • Pathway is inhalation. • Possible heath effects range from eye irritation to reproductive/developmental toxicity. Acute risks from exposures to multiple chemicals not well understood. • Pollutants and pollutant sources are ubiquitous; not all are listed. • Highest exposures likely to occur in microenvironments (e.g., gas stations).
				Off-road equipment	◒ ■■□	↑↓		
				Residential fuel combustion	◒ ■□□	↔		
				Industry	◒ ■■■	↑↓		

Stressor	Overall comparative contribution / Confidence level / Geographic extent	Stressor trend	Adequacy of ambient monitoring	Source	Comparative contribution of sources / Confidence level	Source trend	Specific pollutants	Rationale/Comments
Other criteria pollutants in air	○ ■■□ Urban	↔	■■■	On-road vehicles	● ■■□	↓	Carbon monoxide Nitrogen dioxide Nitric oxide Sulfur dioxide	• Likelihood of exposure at levels above ambient standards is low. • Pathway is inhalation. • Headaches, nervous system effects, respiratory irritation, and cardiopulmonary problems. • Only direct health effects from NO_x considered. Effects as precursors to ozone are not considered. • Effects from carbon monoxide might occur in microenvironments (e.g. inside automobiles). • Trends in monitored concentrations of criteria pollutants may not mirror nationwide emissions trends due to long-range transport, source/monitor proximity, and differences in regional emissions inventory source inclusion and trends.
				Coal-fired power plants	● ■■□	↔		
				Off-road equipment	◒ ■□□	↔		
				Industry	◒ ■■□	↓		
				Residential fuel combustion	○ ■□□	↔		
Toxic chemicals in soil	○ ■□□ Urban	↓	■□□	Pesticide use	◒ ■■□	↔	Lead Pesticides Dioxins and furans Cyanide PCBs	• Likelihood of exposure at levels of concern is low. • Pathways are skin contact and ingestion. • Variety of health effects (e.g. acute exposures of PCBs and dioxin can cause dermal lesions and chloracne). Children are at greatest risk because they have greater contact with and ingestion of soil for their size than adults. • Pollutants range from low to very high persistence.
				Unpermitted waste disposal	◒ ■■□	↓		
				Land-applied industrial and municipal byproducts	○ ■■□	↑		
				Road salt	○ ■□□	↔		
				Lead paint	○ ■■□	↓		

Human Health Impacts: *Noncancer chronic impacts*

Overview of impact: The scope of this section is human health impacts in which the exposure is of a prolonged duration (i.e., weeks to years). Examples of chronic health effects include long-term respiratory impairment, heart and lung disease, and immunological impairment. It is important to point out, however, that the lines of distinction between acute and chronic impacts in the field of environmental risk assessment are unclear (also the EPA distinguishes between chronic and sub-chronic exposures). Noncancer chronic impacts are an issue for all media—air, surface water, ground water and soils—and the exposure pathways include inhalation, ingestion, and dermal contact. The factors considered in the comparisons of stressors below included the estimated extent of exposure in the state as well as the severity of the impact(s).

It is difficult to put environmental-related chronic health impacts into context with other health impacts (chronic or otherwise) mainly because of incomplete knowledge on cause and effect and the limited nature of disease and death statistics. The leading causes of death in Minnesota according to 1999 MDH statistics are: major cardiovascular diseases (36% of all deaths), cancer (24%), "violent" deaths (6%), chronic lower respiratory disease (5%), diseases of the nervous system (5%), and accidents (5%).

Public/Stakeholder information: Because the range of stressors for chronic effects is so varied, it is hard to make specific conclusions about public/stakeholder views. However, a 1996 joint U of M-MPCA survey showed that the public cited "protecting human health" and "protecting future generations" as their first and second reasons, respectively, for why their most important environmental issue concerns them (and in this survey their top issues in order were polluted lakes, general water pollution, and motor vehicle pollution). Concerning specific environmental-related health threats, a 1999 national public health survey showed that the highest percentage of respondents believed that environmental factors play a more important role in causing childhood asthma (as well as sinus and allergy problems) than in other diseases.

Socioeconomic & future trends: Two primary socioeconomic trends in Minnesota may have implications for noncancer chronic impacts on human health. First, Minnesota's human population is expanding and migrating to urban and suburban centers. More than two-thirds of the state's five million people now live in urban and suburban centers, which is the opposite of how the state's population was distributed several decades ago. Second, per capita consumption of goods and energy, and per capita production of wastes continue to increase. Together, population growth and migration, along with consumptive behavior, will likely exacerbate environmental impacts from transportation, energy production, and waste disposal.

Human Health Impacts: Noncancer chronic impacts

Stressor	Overall comparative contribution / Confidence level / Geographic extent	Stressor trend	Adequacy of ambient monitoring	Source	Comparative contribution of sources / Confidence level	Source trend	Specific pollutants	Rationale/Comments
Particles in air	● ■■□ Urban	⟷	■■□	Coal-fired power plants	● ■■□	↑↓	Fine particles (PM2.5) Diesel Particulates Nanoparticles Toxics attached to particles (PAHs, PBTs, semivolatiles) Metals PM10	• Large portion of population exposed; risk for ambient exposure levels not well understood. • Pathway is inhalation. • Respiratory irritation, cardiopulmonary problems, long-term respiratory impairment, premature death, and possibly other adverse effects. • Toxicity may come from particles or attached chemicals; we have good data on the former, poor on the latter. • There is limited PM2.5 monitoring data. Stressor trend is based on PM10 data. Primary health concern is with PM2.5 and nanoparticles. • Many listed sources do not just emit directly formed particles. Instead they emit compounds which form particles downwind of the emission point. These compounds are known as particle precursors (e.g., agricultural practices and wastewater emit NH3, not fine particles). • Fossil fuel combustion emits particles and precursors. • It is currently unknown if adverse effects are primarily linked to the mass of particulate matter or to another parameter such as the number of particles. Therefore, it is difficult to assess trends because, for example, while the mass of particles has remained steady or even decreased, the trend for the number of particles is unknown. • Coal-fired power plants, on-road vehicles, and off-road engines are all important sources of particles and their precursors. Research is ongoing to describe the relative importance of these sources in atmospheric particle formation and culpability for various health effects.
				On-road vehicles	● ■□□	↑↓		
				Off-road equipment	● ■□□	↑↓		
				Area source combustion	◒ ■□□	↑↓		
				Agriculture	◒ ■□□	↑↓		
				Municipal and industrial wastewater	○ ■□□	↑↓		
				Fugitive dust	○ ■□□	↑↓		
				Industry	○ ■□□	↑↓		

Human Health Impacts: Noncancer chronic impacts (cont'd)

Stressor	Overall comparative contribution / Confidence level / Geographic extent	Stressor trend	Adequacy of ambient monitoring	Source	Comparative contribution of sources / Confidence level	Source trend	Specific pollutants	Rationale/Comments
Toxic chemicals in food	◒ □□□ Statewide	↑↓	■□□	Residential fuel combustion	● ■□□	↔	Dioxins and furans Hormones PAHs Pesticides Metals (including mercury) Phthalates PCBs PBBs Alkyl phenols Hexachloro-benzene Octachloro-styrene Polychlorinated naphthalenes	• Overall comparative contribution is due to increasing toxicological evidence of food chain effects. Laboratory tests indicate that effects of these chemicals may be very serious. • Pathway is ingestion. • Potential effects on the endocrine (hormone), central nervous, and immune systems. May cause developmental, behavioral, and reproductive problems. • Food chain effects typically are passed from the contaminant source through other media. For example, many chemicals originate in air and are deposited to soil and surface waters. • Most pollutants of concern are classified as Persistent Bioaccumulative Toxics (PBTs). • Chlorinated insecticides are the pesticides of greatest concern because they accumulate in the food chain. Their use has decreased and many have been banned in the United States. • Residential fuel combustion includes wood burning; pollutants of concern are PAHs and dioxins. • Mercury contamination of fish is a well-documented problem in Minnesota and the Minnesota Department of Health advises to limit consumption of gamefish on virtually every lake tested. Much of the mercury deposited comes from outside the state (as much as 90 percent in more remote areas of the state, e.g., northern Minnesota).
				Pesticide use	● ■■□	↓		
				On-road vehicles	◒ ■□□	↑↓		
				Off-road equipment	◒ ■□□	↑↓		
				Unpermitted waste disposal	◒ ■□□	↓		
				Mining	◒ ■□□	↔		
				Municipal and industrial wastewater	◒ ■□□	↔		
				Coal-fired power plants	◒ ■□□	↔		
				Waste incineration	◒ ■□□	↑↓		
				Industry	◒ ■□□	↓		
				Permitted waste disposal	◒ ■□□	↑↓		

Human Health Impacts: Noncancer chronic impacts (cont'd)

Stressor	Overall comparative contribution / Confidence level / Geographic extent	Stressor trend	Adequacy of ambient monitoring	Source	Comparative contribution of sources / Confidence level	Source trend	Specific pollutants	Rationale/Comments
Toxic chemicals in water	◒ ■□□ Urban; agricultural	↑↓	■■□	Pesticide use	● ■■□	↔	Pesticides VOCs Metals Pharmaceuticals Phthalates Hormones PAHs	• Relatively small number of people exposed to pollutants at levels of concern. Most Minnesotans use public water supplies, which are routinely tested for VOCs, some metals, and some pesticides. Intervention (blending, treatment, drilling new wells) ensures low exposure from public supplies. Private water supplies are generally not tested and people using these supplies may be at greater risk than people using public water supplies. • Pathway is ingestion. • Endpoints vary with chemical (e.g. atrazine affects the cardiovascular system). • Occurrence and health effects of numerous chemicals are unknown (i.e. prescription drugs and over-the-counter drugs). Some drugs may affect hormone levels. • Some pollutants of concern are persistent. Some pollutants are continually added to the environment (e.g., pharmaceuticals).
				Unpermitted waste disposal	◒ ■■□	↓		
				Land-applied municipal and industrial byproducts	○ ■■□	↑		
				Municipal and industrial wastewater	○ ■■□	↔		
				Tanks	○ ■■■	↓		
				Septic systems	○ ■■□	↑		
				Spills	○ ■■□	↔		
Noise	◒ ■□□ Urban; localized	↑	■■□	On-road vehicles	● ■■■	↑		• Many people exposed; most effects are minor. • Pathway is direct exposure. • Endpoint is hearing impairment and physical and psychological stress. • Contribution from sources is based on monitored noise levels. • Only major sources were considered. • Does not consider occupational exposure.
				Aircraft	● ■■■	↑		
				Industry	◒ ■■■	↔		
				Off-road equipment	◒ ■■■	↑↓		

Stressor	Overall comparative contribution / Confidence level / Geographic extent	Stressor trend	Adequacy of ambient monitoring	Source	Comparative contribution of sources / Confidence level	Source trend	Specific pollutants	Rationale/Comments
Odorous chemicals from biological processes	◒ ■□□ Localized	↑	■□□	Feedlots	● ■□□	↑	Hydrogen sulfide Ammonia VOCs Alcohols	• Small number of exposures; health effects are slight to moderate at ambient levels. • Pathway is inhalation. • Primary effect is respiratory damage. • Pollutants have low persistence. • Difficult to determine trends since odors are not tracked.
				Treatment/ settling ponds	◒ ■□□	↔		
				Agriculture	◒ ■□□	↔		
				Ethanol production	○ ■□□	↑		
Toxic volatile organic chemicals in air	◒ ■□□ Localized	↑↓	■■■	On-road vehicles	● ■■■	↑↓	Acrolein Benzene Formaldehyde 1,3-Butadiene Acetaldehyde	• Large portion of population exposed. A few chemicals may be approaching health benchmarks. • Pathway is inhalation. • Health effects may range from minor irritation to effects on blood, development and reproduction. Risks from exposures to multiple chemicals are not well understood. • Pollutants and pollutant sources are ubiquitous; not all are listed. • Effects might occur in microenvironments (e.g. gas stations).
				Off-road equipment	◒ ■■□	↑↓		
				Residential fuel combustion	◒ ■□□	↔		
				Industry	◒ ■■■	↑↓		

Human Health Impacts: Noncancer chronic impacts (cont'd)

Stressor	Overall comparative contribution / Confidence level / Geographic extent	Stressor trend	Adequacy of ambient monitoring	Source	Comparative contribution of sources / Confidence level	Source trend	Specific pollutants	Rationale/Comments
Ground-level ozone	◒ ■■□ Urban	↑	■■■	On-road vehicles	● ■■□	↔	Nitrogen dioxide Nitric oxide VOCs	• Many people exposed; health effects are moderate at ambient levels. • Pathway is inhalation. • Effect is long-term respiratory impairment. • Ozone is created by chemical reactions involving VOCs, NO_x and sunlight. Concentrations may increase with more warm weather. • Preliminary modeling suggests that ozone would be most effectively controlled by VOC emission reduction. • Monitored ground-level ozone concentrations are rising in the Twin Cities area although statewide sources of VOCs and NO_X have remained steady. Ozone formation results from a complex, non-linear series of reactions, therefore, the precise reason for rising ozone concentrations is uncertain. However, increased temperatures, urban traffic congestion, and transportation of ozone into Minnesota from metro areas to the south may be contributing to the increase in ozone concentration.
				Off-road equipment	● ■■□	↔		
				Coal-fired power plants	◒ ■■□	↔		
				Solvent utilization	◒ ■■□	↓		
				Area source combustion	○ ■■□	↔		
				Industry	○ ■■□	↔		
				Petroleum storage and transfer	○ ■■□	↔		
Excess UV radiation from stratospheric ozone depletion	○ ■■□ Statewide	↔	■■■	Refrigerants	◒ ■□□	↑↓	Chloro-fluorocarbons Hydrochloro-fluorocarbons 1,1,1-Trichloroethane Methyl Bromide Carbon Tetrachloride Methylene chloride Halons Hydrobromo-fluorocarbons	• Large portion of population exposed, but it is uncertain to what extent ozone depletion increases the occurrence of more serious health effects. • Pathway is exposure to sunlight. • Immunological effects and eye damage (cataract, photokeratoconjunctivitis, and pterygium) are the primary health concerns. • Ozone depleting chemical emissions are reported by many industries; for other sources we have little information. • Chlorofluorocarbons have been banned. Brominated compounds have a greater oxidizing potential; extent of releases is unknown. Hydrofluorocarbons have a lesser oxidizing potential; releases are increasing. • There appears to be no trend in overall effects. • Minnesota does not monitor; international organizations are tracking what is happening with the ozone layer.
				Fire extinguishers	○ ■□□	↑↓		
				Unpermitted waste disposal	○ ■□□	↑↓		
				Industry	○ ■■□	↑↓		

Stressor	Overall comparative contribution / Confidence level / Geographic extent	Stressor trend	Adequacy of ambient monitoring	Source	Comparative contribution of sources / Confidence level	Source trend	Specific pollutants	Rationale/Comments
Toxic chemicals in soil	○ ■□□ Urban	↓	■□□	Pesticide use	● ■■□	↔	Metals Pesticides PCBs PAHs VOCs	• Likelihood of exposure at levels of concern is low. • Pathways are skin contact and ingestion. • Potential effects on the endocrine (hormone), central nervous, and immune systems. May cause developmental, behavioral, and reproductive problems. Children are at greatest risk because they have greater contact with and ingestion of soil for their size than adults. • Most pollutants of concern are persistent. • Industry impacts soil through air deposition.
				Industry	◒ ■□□	↔		
				Unpermitted waste disposal	○ ■■□	↓		
				Land-applied industrial and municipal byproducts	○ ■■□	↑		
				Lead paint	○ ■■□	↓		
				Spills	○ ■■□	↔		
Other criteria pollutants in air	○ ■■□ Urban	↔	■■■	On-road vehicles	● ■■□	↓	Carbon monoxide Nitrogen dioxide Nitric oxide Sulfur dioxide	• Likelihood of exposure at levels of concern is low. • Pathway is inhalation. • Nervous system effects, respiratory irritation, and cardiopulmonary problems. • Only direct health effects from NO_x considered. Effects as precursors to ozone are not considered. • Effects from carbon monoxide might occur in microenvironments (e.g. inside automobiles). • Trends in monitored concentrations of criteria pollutants may not mirror nationwide emissions trends due to long-range transport, source/monitor proximity, and differences in regional emissions inventory source inclusion and trends.
				Coal-fired power plants	● ■■□	↔		
				Off-road equipment	◒ ■□□	↔		
				Industry	◒ ■■□	↓		
				Residential fuel combustion	○ ■□□	↔		

Ecosystem Impacts: *Aquatic Organisms*

Overview of impact: Across the state, approximately 2/3 of monitored river and stream miles meet water quality standards and criteria designed to protect aquatic life and are considered "non-impaired." Likewise, approximately 2/3 of monitored lake acres are considered "non-impaired." The remaining 1/3 of river miles and lake acres fail to meet at least one of their various protective standards or criteria. (5% of state river and stream miles and 60% of state lake acres are actually monitored). For wetlands, very little monitoring has been done to assess the health of the 50% of pre-settlement wetland acres that remain.

Regulatory control of point source wastewater discharges formed the MPCA's original mission and is a mature program with significant and visible results. The remaining surface water quality problems are largely nonpoint — stream miles and lake acres considered impaired by nonpoint sources are approximately 7 times greater than those considered impaired by point sources. Nonpoint source pollution is closely tied to agricultural and urban land use and varies across the state according to the intensity of those two factors. In part because it is the result of diffuse land use practices, nonpoint source pollution has proven more difficult to address, both programmatically and culturally. The technology for doing so is generally well established and not difficult, and implementation costs in many cases are not high, but success will require substantial changes in land-use practices by a great number of different parties. The agency has a number of programs addressing nonpoint sources, generally in partnership with local governments and organizations, but overall the efforts are relatively young and have yet to show general, statewide results.

Finally, existing programs have for the most part dealt with a relatively small number of traditional water pollutants; much less is known regarding the extent or, in some cases, even the effects (such as endocrine disruption) of newer and more exotic pollutants such as heavy metals, pesticides and their breakdown products, pharmaceuticals, and other organic chemicals.

Public/stakeholder information: As indicated in Appendix E, Public/Stakeholder Information, most public opinion-gathering efforts rank water quality-related issues near the top of Minnesotans' environmental concerns (though some research suggests that their reasoning may be less out of concern for protecting aquatic life than it is for protecting human health). Regarding pollution sources, public opinion varies depending on location in the state, but it appears that the most significant contrasts between the public's perceived threats to water quality and those in the matrix below are septic systems and, for rivers, industrial point sources. Both of these sources generally rate as more significant by the public than is portrayed in the matrix.

<u>Socioeconomic & future trends</u>: In urban and rural Minnesota, trends in agriculture and land development practices will continue to stress aquatic organisms. As population increases in urban areas such as Mankato, Saint Cloud, and the Twin Cities metropolitan area, commercial and residential development continues at a rapid rate. As more houses are built and roads and commercial infrastructure are added, stress on aquatic organisms increases. As opposed to undeveloped land, developed land yields increased runoff that carries phosphorus, nitrogen, sediment, and toxics, much to the detriment of streams and lakes that receive this runoff.

The story in rural Minnesota is different, but the result for aquatic organisms is the same. Although losing permanent human population, rural Minnesota continues to produce large amounts of pollution due to sustained levels of agricultural activity (primarily row crop production and livestock operations). Rural Minnesota is also experiencing rapid development, much of it to satisfy the desires of urban residents who want to "get away." An example is the Brainerd Lakes Area, which experiences a summer "weekend population" that uses the area's lakes, resorts, and golf courses.

NOTE: Exotic species, including invasive fish, mussels and plants, comprise another important category of environmental stressors affecting the health of native aquatic species. They are not assessed in this report, as the MPCA does not have a role in controlling them. However, the Minnesota Departments of Natural Resources and Agriculture have programs aimed at prevention and control of aquatic and terrestrial exotic species.

Ecosystem Impacts: Aquatic Organisms

Stressor	Overall comparative contribution / Confidence level / Geographic extent	Stressor trend	Adequacy of ambient monitoring	Source	Comparative contribution of sources / Confidence level	Source trend	Specific pollutants	Rationale/Comments
Habitat modification	● ■■□ Agricultural; developed areas	↑	■□□	Urban/suburban/ lake-shore development	● ■■■	↑		• Habitat is critical to the health of the aquatic community. Modification of this habitat, whether from stream straightening and channelization, loss of riparian vegetation and cover, increased variation in flow because of greater and more rapid runoff, or from various other changes, can severely affect an aquatic organism's ability to live, feed, and reproduce. While not really a form of pollution, and thus outside the MPCA's usual responsibilities, habitat modification is nevertheless a critical anthropogenic stressor impacting aquatic organisms. Even if all pollutant sources are eliminated and water quality is high, healthy aquatic communities can be precluded by the absence of necessary habitat. • Habitat modification is widespread in the state, most obviously where streams have been ditched or where streambanks or lakeshores have been seriously altered, but also where land-uses in the watershed have resulted in changes in watershed hydrology. • Habitat modification generally is not readily reversible. • While there is a good general sense of the degree to which habitat has been modified and lost, very little systematic monitoring or quantification has been done. At the same time, the land-use practices that modify habitat are subject to widely diffused and incomplete regulatory controls.
				Agriculture	● ■■■	↔		
				Drainage and channelization	● ■■■	↑		
				Dredging	◒ ■■■	↔		
Transported sediment	● ■■□ Agricultural; developing areas	↔	■■□	Agricultural runoff	● ■■■	↔		• Transported sediment or suspended soil, almost entirely from nonpoint sources, is a widespread problem in the state. It can significantly affect aquatic health by interfering with breathing, decreasing visibility and available light, and destroying habitat through siltation. In addition to the effects of transported sediment itself, sediment can also carry adsorbed nutrients, pesticides, other organics, bacteria, and metals. • Levels of a related measure, total suspended solids (TSS), have decreased at almost 50% of monitored sites over the past 30 years. TSS includes transported sediment, but also other suspended particles. Most of the progress in TSS levels has been the result of point source controls, now widely in place at municipal and industrial wastewater treatment facilities. Nonpoint source sediment runoff and TSS levels, however, have decreased in certain areas where improved cultivation practices have been put in place.
				Construction	● ■■□	↔		
				Urban runoff	◒ ■■□	↔		
				Streambank erosion	◒ ■■□	↔		
				Municipal and industrial wastewater	○ ■■■	↔		

Ecosystem Impacts: Aquatic Organisms (cont'd)

Stressor	Overall comparative contribution / Confidence level / Geographic extent	Stressor trend	Adequacy of ambient monitoring	Source	Comparative contribution of sources / Confidence level	Source trend	Specific pollutants	Rationale/Comments
Phosphorus	● ■■□ Agricultural; developed areas	↔	■■□	Agricultural runoff	● ■■■	↔		• Phosphorus is generally the limiting nutrient contributing to the production of excess algae in surface waters and to lake eutrophication. More than 100 lakes are on the proposed TMDL list for excess phosphorus levels. • Sources of phosphorus are both point and nonpoint, with the former dominating in low-flow conditions and the latter during normal and high-flow conditions. Overall, on a national level, 80% of phosphorus inputs to water are thought to be nonpoint. • Nonpoint phosphorus is generally attached to sediment and closely related to soil erosion. • Over the past 30 years, phosphorus levels have decreased at 75% of monitored stream sites, probably as a result of point source controls. Further analysis, however, may well show a reversal of this downward trend, as fertilizer inputs to agricultural lands have increased significantly In more recent years.
				Municipal and industrial wastewater	◒ ■■■	↔		
				Feedlots	◒ ■■□	↔		
				Urban runoff	◒ ■■□	↑		
				Septic systems	○ ■■□	↔		
Temperature increase/ Climate change	○ ● ■□□ Statewide The first circle represents current impacts; the second circle represents future impacts.	↑	■■□	Urban runoff	◒ ■□□	↑	Heat Carbon dioxide Methane Nitrous oxide CFCs Ozone Hydrofluoro-carbons Hydrofluoro-ethers Sulfur hexafluoride Carbon tetrafluoride Carbon black	• Temperature is a major environmental factor for aquatic organisms. The most marked effects in Minnesota are on cold-water streams and organisms, but even for other waters temperature increases can result in mortality in the short term and changed species composition over the longer term. • Past regulatory efforts have largely focussed on localized effects from power plants. More widespread, however, are the largely unregulated effects of warming related to land-use, such as parking lot runoff and habitat modification which results in loss of shade and changes in flow (see discussion above). The effects of global warming threaten to be the most widespread, with significant disruption of the aquatic ecosystem.
				Power plants (thermal discharge)	○ ■■■	↔		
				* Coal-fired power plants	● ■■■	↑		
				* On-road vehicles	● ■■■	↑		
				* Agriculture	◒ ■□□	↑		
				* Industry	◒ ■■■	↔		* The asterisked sources are sources of greenhouse gasses leading to global warming. Crop production is the primary agricultural source of greenhouse gasses; other agricultural sources include feedlots, land-applied manure, and fertilizer use. (The comparative contribution rankings for the greenhouse gas sources are relative only to each other, and are not necessarily comparable with the rankings for the other sources of temperature increase.)
				* Permitted waste disposal	◒ ■■□	↔		
				* Residential fuel combustion	○ ■■■	↔		

Ecosystem Impacts: Aquatic Organisms (cont'd)

Stressor	Overall comparative contribution / Confidence level / Geographic extent	Stressor trend	Adequacy of ambient monitoring	Source	Comparative contribution of sources / Confidence level	Source trend	Specific pollutants	Rationale/Comments
Nitrogen	◒ ■■□ Agricultural; developed areas	↑	■■□	Agricultural runoff	● ■■■	↑		• Nitrogen is present in water in various forms, related through a complex cycle. While nitrogen is an essential nutrient for aquatic plants, phosphorus is generally the limiting nutrient in Minnesota waters. In the case of hypoxia in the Gulf of Mexico, however, nitrogen generated in the Mississippi River watershed (Minnesota's contribution is approximately 7%, according to the White House Office of Science and Technology) is the limiting factor and primary cause. • Nitrogen is the only common water pollutant to show an increasing trend across the state. Nitrogen levels have increased at 75% of monitored sites over the past 30 years. Probable causes are increased fertilizer usage, coupled with more efficient agricultural drainage and increased rainfall in the 1990s. • Nitrogen is highly soluble, and agricultural runoff includes transport to surface waters through tile lines and ground water.
				Municipal and industrial wastewater	◒ ■■■	↔		
				Feedlots	◒ ■■□	↔		
				Urban runoff	◒ ■□□	↑		
				Septic systems	○ ■■□	↑		
Oxygen-demanding pollutants	◒ ■■□ Agricultural; developed areas	↓	■■□	Feedlots	● ■■□	↔	Organic matter	• As organic matter in water decomposes, dissolved oxygen is used. High biochemical oxygen demand (BOD) can result in oxygen depletion and fish kills. • At one time perhaps the foremost water quality problem (and a primary reason the MPCA was formed), BOD levels have decreased at almost 90% of monitored sites over the past 30 years, reflecting point source controls.
				Municipal and industrial wastewater	◒ ■■■	↓		
				Agricultural runoff	◒ ■■□	↔		
				Urban runoff	◒ ■■□	↑		
				Septic systems	○ ■■□	↔		
				Spills	○ ■■■	↔		

Ecosystem Impacts: Aquatic Organisms (cont'd)

Stressor	Overall comparative contribution / Confidence level / Geographic extent	Stressor trend	Adequacy of ambient monitoring	Source	Comparative contribution of sources / Confidence level	Source trend	Specific pollutants	Rationale/Comments
Toxic organic chemicals	◒ ■□□ Statewide with dispersed hotspots	↔	■□□	Municipal and industrial wastewater	● ■■□	↔	Dioxins, furans PAHs Pesticides Phthalates PCBs PBBs Alkyl phenols Hexachloro- benzene Octachloro- styrene Polychlorinated naphthalenes Petroleum products Pharmaceuticals	• Toxic organic chemicals can result in a range of toxic effects, such as acute poisoning, immune suppression, growth of tumors, and reproductive failure. • While studies have shown that toxic effects can occur, even at very low concentrations, little monitoring has been done of actual chemical levels in Minnesota waters or of actual effects. • Includes a very large number of chemicals which may be discharged from point sources or contained in runoff (generally found in water in very low concentrations) or remain in bottom sediments as a result of past releases. • Some of the chemicals can be both persistent and bio-accumulative. • Includes the emerging issues of pharmaceuticals and endocrine disruption, about which little is yet known. • Contributions listed as being from area source combustion and industry are primarily through air deposition.
				Agricultural runoff	● ■■□	↔		
				Area source combustion	● ■□□	↔		
				Urban runoff	◒ ■□□	↑		
				Industry	◒ ■□□	↔		
				Spills	○ ■■□	↔		
Toxic metals	◒ ■□□ Statewide with dispersed hotspots	↔	■□□	Coal-fired power plants	● ■■■	↔	Mercury Lead Cadmium Chromium Zinc Copper	• Metals, like organic chemicals, can result in a range of toxic effects, even at low levels. Many are both persistent and bio-accumulative. • While significant work is being done on mercury, little is known regarding the levels of other trace metals in Minnesota's waters or their actual effects. • With the exception of metals entering water through air deposition (primarily mercury), problems are generally localized and generally urban. • While mercury is a persistent bio-accumulative toxic that can have significant effects on animals and people that eat aquatic organisms such as fish, the toxic effects on the aquatic organisms themselves are thought to be minor. • Contributions listed as being from power plants, waste incineration, and industry are primarily through air deposition.
				Urban runoff	● ■■□	↑		
				Municipal and industrial wastewater	◒ ■■□	↔		
				Waste incineration	◒ ■■■	↓		
				Industry	○ ■□□	↔		
				Mining	○ ■■■	↔		
Ammonia	○ ■■□ Localized	↓	■■□	Feedlots	● ■■□	↔		• Ammonia is acutely toxic to aquatic organisms. • Ammonia levels have decreased at more than 75% of monitored sites over the past 30 years, reflecting point source controls. Relatively few, localized instances of impairment remain. • While ammonia, through the nitrogen cycle, also contributes to nutrient levels in water, the ranking here considers only its toxic effects.
				Municipal and industrial wastewater	◒ ■■■	↓		
				Septic systems	○ ■■□	↔		

Ecosystem Impacts: Aquatic Organisms (cont'd)

Stressor	Overall comparative contribution / Confidence level / Geographic extent	Stressor trend	Adequacy of ambient monitoring	Source	Comparative contribution of sources / Confidence level	Source trend	Specific pollutants	Rationale/Comments
Dissolved solids	○ / ■□□ / Urban areas	↑	■□□	Urban runoff	● ■■□	↑	Salts	• Elevated chloride levels from road salts can be toxic to sensitive aquatic animals and plants. • Chloride levels above aquatic life standards have frequently been monitored in winter months in a limited number of Twin Cities streams near freeways. • While dissolved solids include any minerals, salts, metals, or ions dissolved in water, the primary concern is road salts, generally from major highway systems and from storage piles.
				Municipal and industrial wastewater	○ ■■■	↔		
Acid deposition	○ / ■■□ / NE Minnesota	↔	■■■	Coal-fired power plants	● ■■■	↔	SO_2 NO_x	• Acid deposition lowers the pH in lakes and streams, and can cause slower growth, injury, or death in aquatic organisms, generally by decreasing the available nutrients and increasing the available toxic metals from soil. • Of 1,200 MN lakes surveyed, 80% exhibited adequate alkalinity while 20% were considered at risk for acidity. None were currently considered acidic. • Danger is greatest in areas where buffering capacity of soils is low, such as NE Minnesota.
				On-road vehicles	◒ ■■□	↔		
				Off-road equipment	◒ ■■□	↔		
Excess UV radiation from stratospheric ozone depletion	○ / ■□□ / Statewide	↔	■■■	Refrigerants	◒ ■□□	↑↓	Chlorofluorocarbons Hydrochlorofluorocarbons Hydrobromofluorocarbons 1,1,1-Trichloroethane Methyl bromide Carbon tetrachloride Methylene chloride Halons	• Excess UV radiation can cause decreased reproductive capacity and impaired early development in certain aquatic animals. There are likewise possible effects on plant photosynthesis, genetic material, morphology, and growth. • While exposure is obviously widespread and there is good evidence that UV exposure can be harmful to aquatic organisms, the extent of actual damage is uncertain. • Ozone-depleting chemical emissions are reported for many industries; little information exists regarding other sources. • Chlorofluorocarbons have been banned. Brominated compounds have a greater oxidizing potential; extent of releases is unknown. Hydrofluorocarbons have a lesser oxidizing potential; releases are increasing.
				Fire extinguishers	○ ■□□	↑↓		
				Unpermitted waste disposal	○ ■□□	↑↓		
				Industry	○ ■■□	↑↓		

Ecosystem Impacts: *Terrestrial Organisms*

<u>Overview of impact</u>: Many of mankind's activities — some pollution-related, some not — have had and continue to have undeniable negative effects on other terrestrial organisms. Some of the effects, such as the displacement of plants and animals by human development, are obvious. Others are less obvious, and the impacts are often not well monitored or, in some cases, even well understood.

By the same token, environmental impacts on terrestrial organisms have not always been an obvious part of the MPCA's traditional responsibilities. Yet many of the Agency's actions or potential actions do affect — directly or indirectly — the complicated ecosystem interrelationships that determine the health of Minnesota's terrestrial animal and plant communities.

<u>Public/stakeholder information</u>: The public's views on environmental effects on terrestrial species are difficult to discern from available public opinion gathering efforts. The issue of habitat destruction, however, ranked "medium" at the 1999 MPCA Governor's Forum. It is probably the case that the public is either not as concerned or as aware about terrestrial species issues. Two of the more prominent sources below—urban development and greenhouse gases—are areas in which the public's views are either not well understood or are extremely varied.

<u>Socioeconomic & future trends</u>: Humans, the most obtrusive terrestrial organism, continue to thrive in Minnesota, growing in population from 1.75 to 5 million in the last 100 years. At the same time, migration has changed the make-up of our state from one that was once two-thirds rural, to one that is now more than two-thirds urban/suburban. Although fewer people now live in rural areas, pressure on terrestrial organisms there probably hasn't eased, as agriculture continues at historic levels, and tourism pressure continues to increase. On the other hand, increased population in urban/suburban areas has added to the pressure there. Land is in high demand around urban areas of all sizes, from places like Mankato and Saint Cloud, to the Twin Cities Metropolitan area. Development of suburban neighborhoods, including the roads and the commercial infrastructure that support them, reduces the habitat available to other terrestrial organisms.

NOTE: Exotic species, including invasive plants, insects and birds, comprise another important category of environmental stressors affecting the health of native terrestrial species. They are not assessed in this report, as the MPCA does not have a role in controlling them. However, the Minnesota Departments of Natural Resources and Agriculture have programs aimed at prevention and control of aquatic and terrestrial exotic species.

Ecosystem Impacts: Terrestrial Organisms

Stressor	Overall comparative contribution / Confidence level / Geographic extent	Stressor trend	Adequacy of ambient monitoring	Source	Comparative contribution of sources / Confidence level	Source trend	Specific pollutants	Rationale/Comments
Habitat modification	● ■■■ Statewide	↑	■■□	Urban/suburban/ lake-shore development	● ■■■	↑		• Habitat is critical to the health of all living organisms. Modification of this habitat, whether from conversion of land from its natural state by urban development, agriculture, forestry, mining, or any of the other human land uses, can severely affect an organism's ability to live, feed, and reproduce. While not really a form of pollution, and thus outside the MPCA's usual responsibilities, habitat modification is nevertheless a critical anthropogenic stressor impacting terrestrial organisms. Even if all pollutant sources are eliminated and environmental quality is otherwise high, healthy terrestrial communities can be precluded by the absence of necessary habitat. • Habitat modification generally is not readily reversible. • While there is a good general sense of the degree to which habitat has been modified and lost, very little systematic monitoring or quantification has been done. At the same time, the land-use practices that modify habitat are subject to widely diffused and incomplete regulatory controls.
				Agriculture	● ■■■	⟷		
				Silvaculture	● ■■■	⟷		
				Mining	○ ■■■	⟷		
Temperature increase/ climate change	○ ● ■□□ Statewide The first circle represents current impacts; the second circle represents future impacts.	↑	■■■	Coal-fired power plants	● ■■■	↑	Carbon dioxide Methane Nitrous oxide CFCs Ozone Hydrofluoro-carbons Hydrofluoro-ethers Sulfur hexafluoride Carbon tetrafluoride Carbon black	• Any significant changes in temperature/climate will have significant and statewide effects on terrestrial organisms through species selection. • In addition, temperature increase and climate change may intensify the effects of certain other stressors: nitrogen enrichment, ground-level ozone, mercury contamination, and stratospheric ozone depletion. • Crop production is the primary agricultural source of greenhouse gasses; other agricultural sources include feedlots, land-applied manure, and fertilizer use.
				On-road vehicles	● ■■■	↑		
				Agriculture	◒ ■□□	↑		
				Industry	◒ ■■■	⟷		
				Permitted waste disposal	◒ ■■□	⟷		
				Residential fuel combustion	○ ■■■	⟷		

Stressor	Overall comparative contribution / Confidence level / Geographic extent	Stressor trend	Adequacy of ambient monitoring	Source	Comparative contribution of sources / Confidence level	Source trend	Specific pollutants	Rationale/Comments
Toxic organic chemicals	◒ ■■□ Statewide with dispersed hotspots	↑	■□□	Pesticide use	● ■□□	↔	Dioxins, furans PAHs Pesticides Phthalates PCBs PBBs Alkyl phenols Hexachloro-benzene Octachloro-styrene Polychlorinated naphthalenes Petroleum products Pharmaceuticals	• Toxic organic chemicals can result in a range of toxic effects, such as acute poisoning (particularly with pesticides and non-target organisms), immune suppression, growth of tumors, and reproductive failure. • While studies have shown that toxic effects can occur, even at very low concentrations, for most organic chemicals, little monitoring has been done of actual levels in Minnesota's environment or of actual effects. • Pathways are inhalation, ingestion through food and water, and direct contact. • Includes a very large number of chemicals, put to a very large number of different uses, and released into land, air, or water. • Some of the chemicals can be both persistent and bio-accumulative. • Includes the emerging issues of pharmaceuticals and endocrine disruption, about which little is yet known. • Contributions listed as being from industry and area source combustion are primarily through air deposition.
				Municipal and industrial wastewater	◒ ■□□	↔		
				Urban runoff	◒ ■□□	↑		
				Industry	◒ ■□□	↔		
				Area source combustion	◒ ■□□	↔		
				Spills	○ ■■□	↔		
				Land applied municipal and industrial byproducts	○ ■■□	↑		
Nitrogen	◒ ■□□ Statewide	↑	■■□	On-road vehicles	● ■■□	↑		• Generally a limiting nutrient, the amount of nitrogen available for plant uptake has increased dramatically over the last several decades. Driven by large increases in the use of fertilizer and the burning of fossil fuels, as well as by increased land-clearing and deforestation, human activities now contribute more to the global supply of fixed nitrogen than do natural sources. • The increased flux of nitrogen has resulted in significant disruptions of the natural nutrient cycle. As a result, nitrogen-responsive species can be selected over others, leading to potentially large ecosystem changes and decreased biodiversity. In the Netherlands, where nitrogen deposition rates are among the highest in the world, species-rich heathlands have been converted to species-poor forests and grasslands that better accommodate the nitrogen load. • Other potential results include the disruption of soil chemistry. • While a significant potential problem, the nitrogen enrichment issue is a relatively new environmental concern and has engendered relatively little publicity, research, or action.
				Coal-fired power plants	● ■■□	↔		
				Fertilizer use	◒ ■■□	↔		
				Off-road equipment	◒ ■□□	↑		
				Land-applied manure	◒ ■□□	↔		
				Area source combustion	○ ■□□	↔		
				Feedlots	○ ■□□	↔		

Stressor	Overall comparative contribution / Confidence level / Geographic extent	Stressor trend	Adequacy of ambient monitoring	Source	Comparative contribution of sources / Confidence level	Source trend	Specific pollutants	Rationale/Comments
Ground-level ozone	◒ ■■□ Urban areas	↑	■■□	On-road vehicles	● ■■□	↔	Nitrogen dioxide Nitric oxide VOCs	• Current ground-level ozone levels are thought to reduce Minnesota agricultural crop yields by 2 to 5%, and may have similar effects on natural systems. The effects are worse in southern Minnesota where ozone concentrations are higher. Possible effects on animals are suggested by effects on humans (respiratory irritation and impairment), but have not actually been documented. • Pathway for animals is inhalation. • Ozone is created by chemical reactions between VOCs and NOx; formation and dispersion are affected by heat and meteorology. • Preliminary modeling suggests that ozone would be most effectively controlled by VOC emission reduction. • Monitored ground-level ozone concentrations are rising in the Twin Cities area although statewide sources of VOCs and NO_X have remained steady. Ozone formation results from a complex, non-linear series of reactions, therefore, the precise reason for rising ozone concentrations is uncertain. However, increased temperatures, urban traffic congestion, and transportation of ozone into Minnesota from metro areas to the south may be contributing to the increase in ozone concentration.
				Off-road equipment	● ■■□	↔		
				Coal-fired power plants	◒ ■■□	↔		
				Solvent utilization	◒ ■■□	↓		
				Area source combustion	○ ■■□	↔		
				Industry	○ ■■□	↔		
				Petroleum storage & transfer	○ ■■□	↔		
Toxic metals	○ ■■□ Statewide with dispersed hotspots	↔	■□□	Coal-fired power plants	● ■■■	↔	Mercury Lead Cadmium Chromium Zinc Copper Selenium	• Metals, like organic chemicals, can result in a range of toxic effects, even at low levels. Many are both persistent and bio-accumulative. • While significant work is being done on mercury, little is known regarding the levels of other trace metals in the environment. Few actual effects attributable to metals have been observed. • Mercury is a persistent bio-accumulative toxic that can have significant effects on animals and people that ingest it or that eat other animals containing it. Mercury levels have been found to be relatively high in certain species of fish in certain Minnesota waterbodies and, in turn, in loons. Loon populations, however, are considered stable. • With the exception of metals from air deposition (primarily mercury), problems are generally localized and generally urban. • Contributions listed as being from power plants, waste incineration, and industry are primarily through air deposition.
				Urban runoff	● ■■□	↑		
				Municipal and industrial wastewater	◒ ■■□	↔		
				Waste incineration	◒ ■■■	↓		
				Recreational use (shooting ranges, fishing tackle)	○ ■■□	↔		
				Industry	○ ■□□	↔		
				Mining	○ ■■■	↔		

Ecosystem Impacts: Terrestrial Organisms (cont'd)

Stressor	Overall comparative contribution / Confidence level / Geographic extent	Stressor trend	Adequacy of ambient monitoring	Source	Comparative contribution of sources / Confidence level	Source trend	Specific pollutants	Rationale/Comments
Acid deposition	○ ■■□ NE Minnesota	↔	■■■	Coal-fired power plants	● ■■■	↔	SO_2 NO_x	• Acid deposition can cause slower growth, injury, or death in plants, especially trees, generally by decreasing the available nutrients and increasing the available toxic metals from soil. • Actual effects in Minnesota have been limited. • Danger is greatest in areas where buffering capacity of soils is low, such as NE Minnesota.
				On-road vehicles	◒ ■■□	↔		
				Off-road equipment	◒ ■■□	↔		
Excess UV radiation from stratospheric ozone depletion	○ ■□□ Statewide	↔	■■■	Refrigerants	◒ ■□□	↑↓	Chlorofluoro-carbons Hydrochloro-fluorocarbons Hydrobromo-fluorocarbons 1,1,1-Trichloro-ethane Methyl bromide Carbon tetrachloride Methylene chloride Halons	• Excess UV radiation can cause decreased reproductive capacity and impaired early development in certain animals. (It is thought by some to be a contributing cause of amphibian deformities.) There are likewise possible effects on plant photosynthesis, genetic material, morphology, and growth. • While exposure is obviously widespread and there is good evidence that it can be harmful to terrestrial organisms, the extent of actual damage is uncertain. • Ozone-depleting chemical emissions are reported for many industries; little information exists regarding other sources. • Chlorofluorocarbons have been banned. Brominated compounds have a greater oxidizing potential; extent of releases is unknown. Hydrofluorocarbons have a lesser oxidizing potential; releases are increasing.
				Fire extinguishers	○ ■□□	↑↓		
				Unpermitted waste disposal	○ ■□□	↑↓		
				Industry	○ ■■□	↑↓		

Quality of Life

This section is a summary of those aspects of environmental damage/degradation relating to Minnesotans' quality of life that have not been fully captured in the previous sections.

A. Diminished Aesthetic Qualities

<u>Overview of impact</u>: The previous matrices have focused on environmental stressors that directly impact human health or the health of terrestrial or aquatic organisms. However, these stressors can simultaneously degrade our quality of life, often beginning at low levels where health effects are not expected. This matrix is highly subjective since it attempts to characterize individual reactions to what we see, smell, taste and hear.

Since individuals view quality of life stressors very differently it is impossible to meaningfully assess overall comparative contributions among the listed stressors. Therefore the stressors are not ranked and are not listed in any particular order. Also, it is likely that the matrix below is only a partial representation of environmental aesthetic issues.

Some stressors like odor and noise can be both a nuisance and an actual health threat. The dividing line between these effects is often not well understood and varies from person to person.

<u>Public/Stakeholder information</u>: While the issues here don't typically rank high in public research studies, when these types of problems arise (e.g., odors from feedlots or ethanol plants or potential noise from an amphitheater or metal shredder) they sometimes generate intense public outcry from those potentially affected.

<u>Socioeconomic & future trends:</u> One of the trends that has the potential to degrade some people's quality of life is the expansion of urban and suburban areas, and the land development, transportation and energy demands that follow from this expansion. As more and more Minnesotans make their homes in urban areas, decisions made about land use, energy, and transportation will dictate how quality of life is affected by odor, noise and smog, among other things. There are also trends in tourism areas that may be detrimental to aesthetics. Development along the north shore of Lake Superior and in the Brainerd lakes area has added vehicular traffic and new sources of air pollution, that may increase noise, odor and visibility. There are a few trends that may improve our environmental quality of life including, expansion of alternative methods of transportation (e.g. light rail), use of quieter airplanes, and restrictions in the use of phosphorus in some parts of the Twin Cities area.

Diminished aesthetic qualities

Stressor	Overall comparative contribution / Confidence level / Geographic extent	Stressor trend	Adequacy of ambient monitoring	Source	Comparative contribution of sources / Confidence level	Source trend	Specific pollutants	Rationale/Comments
Odorous chemicals from biological processes	? / N/A / Localized	↑	■□□	Feedlots	● ■□□	↑	Hydrogen sulfide Ammonia VOCs Alcohols	• Source contribution roughly corresponds to complaints received by MPCA. • Perception of odors varies greatly among individuals.
				Treatment/settling ponds	◒ ■□□	↔		
				Agriculture	◒ ■□□	↔		
				Ethanol production	○ ■□□	↑		
Noise	? / N/A / Urban; localized	↑	■□□	On-road vehicles	● ■■■	↑		• Contribution based on monitored noise levels and also roughly corresponds to complaints received by MPCA. • Only major sources are considered.
				Aircraft	● ■■■	↑		
				Industry	◒ ■■■	↔		
				Off-road equipment	◒ ■■■	↑↓		
Ground-level ozone	? / N/A / Urban	↑	■■■	On-road vehicles	● ■■□	↔	Nitrogen dioxide Nitric oxide VOCs	• Effect on visibility—ozone together with particles creates smog. • Visibility impairment due to ozone is mainly an urban issue and occurs in the summer. • Monitored ground-level ozone concentrations are rising in the Twin Cities area although statewide sources of VOCs and NO_X have remained steady. Ozone formation results from a complex, non-linear series of reactions, therefore, the precise reason for rising ozone concentrations is uncertain. However, increased temperatures, urban traffic congestion, and transportation of ozone into Minnesota from metro areas to the south may be contributing to the increase in ozone concentration.
				Off-road equipment	● ■■□	↔		
				Coal-fired power plants	◒ ■■□	↔		
				Solvent utilization	◒ ■■□	↓		
				Area source combustion	○ ■■□	↔		
				Industry	○ ■■□	↔		
				Petroleum storage & transfer	○ ■■□	↔		

Diminished aesthetic qualities (cont'd)

Stressor	Overall comparative contribution / Confidence level / Geographic extent	Stressor trend	Adequacy of ambient monitoring	Source	Comparative contribution of sources / Confidence level	Source trend	Specific pollutants	Rationale/Comments
Particles in air	? N/A Scenic areas; urban	⟷	■■□	Coal-fired power plants	● ■■□	↑↓	Fine particles (PM2.5) Diesel particulates Nanoparticles Toxics attached to particles -- PAHs, PBTs, semivolatiles Metals PM10	• Effect on visibility. • Nationally standards are set for regional haze in Class 1 scenic areas. In MN this is limited to the BWCAW and Voyageurs National Park. Haze in these areas is worst in the winter. • Visibility can be impaired near the sources of PM, e.g., urban areas. Haze in urban areas is worst in the summer. • According to the EPA, haze may reduce visibility from 90 miles down to 14-24 miles in eastern U.S. and from 140 miles down to 33-90 miles in the west. • Particles also make things dirty, e.g., snow on roads. • Coal-fired power plants, on-road vehicles, and off-road engines are all important sources of particles and their precursors. Research is ongoing to describe the relative importance of these sources in atmospheric particle formation and culpability for various health effects.
				On-road vehicles	● ■□□	↑↓		
				Off-road equipment	● ■□□	↑↓		
				Area source combustion	◒ ■□□	↑↓		
				Agriculture	◒ ■□□	↑↓		
				Municipal and industrial wastewater	○ ■□□	↑↓		
				Fugitive dust	○ ■□□	↑↓		
				Industry	○ ■□□	↑↓		
Phosphorus	? N/A Agricultural and developed areas	⟷	■■□	Agricultural runoff	● ■■■	⟷		• Excess phosphorus causes increased algae growth in water and thus affects appearance (clarity). • If surface water is used for drinking water, algae growth can affect flavor. • More than 100 lakes are on the proposed TMDL list for excess phosphorus levels.
				Municipal and industrial wastewater	◒ ■■■	⟷		
				Feedlots	◒ ■■□	⟷		
				Urban runoff	◒ ■■□	↑		
				Septic systems	○ ■■□	⟷		

Diminished aesthetic qualities (cont'd)

Stressor	Overall comparative contribution / Confidence level / Geographic extent	Stressor trend	Adequacy of ambient monitoring	Source	Comparative contribution of sources / Confidence level	Source trend	Specific pollutants	Rationale/Comments
Transported sediment	? N/A Agricultural; developing areas	↔	■■□	Agricultural runoff	● ■■■	↔		• Main aesthetic effect is reduced clarity of surface water. • Clarity levels are generally low in rivers of western Minnesota, esp. following rainfall.
				Construction	● ■■□	↔		
				Streambank erosion	◒ ■■□	↔		
				Urban runoff	◒ ■■□	↔		
				Municipal and industrial wastewater	○ ■■■	↔		
Oxygen-demanding pollutants	? N/A Agricultural; developed areas	↓	■■□	Feedlots	● ■■□	↔	Organic matter	• Can be both an appearance and an odor issue, depending on the amount of organic material entering the surface water. • Biochemical oxygen demand levels have decreased at almost 90% of monitored sites over the past 3 decades, reflecting point source controls.
				Municipal and industrial wastewater	◒ ■■■	↓		
				Agricultural runoff	◒ ■■□	↔		
				Urban runoff	◒ ■■□	↑		
				Septic systems	○ ■■□	↔		
				Spills	○ ■■■	↔		

Diminished aesthetic qualities (cont'd)

Stressor	Overall comparative contribution / Confidence level / Geographic extent	Stressor trend	Adequacy of ambient monitoring	Source	Comparative contribution of sources / Confidence level	Source trend	Specific pollutants	Rationale/Comments
Habitat modification	? N/A Statewide	↑	■■□	Urban/suburban/lake-shore development	● ■■■	↑		• This stressor—the alteration of green space to developed land—seems to be an aesthetic concern for many people. • The sources possibly include those that produce greenhouse gases and thereby contribute to global warming (with its accompanying habitat alteration). Whether this will be a negative aesthetic change for most people is an open question.
				Silvaculture	● ■■■	↔		
				Agriculture	● ■■■	↔		
				Mining	○ ■■■	↔		

B. Reduced Access to Resources

The report team felt that trying to represent resource access issues in a matrix format could mean repeating significant portions of the other matrices and might become somewhat unwieldy. Also, it would be impossible to do any meaningful ranking of the stressors. For these reasons a brief discussion rather than a matrix is provided.

In addition to the impacts that the stressors listed in previous matrices have on human health and ecosystems, many of these stressors also affect our quality of life through reducing our access to resources. Below is an attempt to represent, at least partially, some categories in which access to resources is affected. Some described impacts affect basic Minnesotan values and ways of life (e.g., fishing, outdoor recreation) as well as other important freedoms.

Land use: Land use can be restricted in some places due to health and/or liability concerns or perceptions relating to the stressor *toxic chemicals in soil*.

Aquifer use: Restricted use (or the need to perform costly treatment) of some aquifers can occur due to *toxic chemicals in water (e.g., VOCs and nitrate).*

Food: While various foods may contain toxic pollutants, perhaps the pollutants resulting in actual reduced access are *mercury* and *PCBs* in fish. Because of the accumulation of these pollutants in fish in some water bodies, fish consumption advisories are issued and people must limit their intake of certain species or risk compromising their health.

Fishing: Our access to fishing (both recreational and commercial) is limited by the same list of stressors outlined in the Aquatic Organisms matrix.

Swimming: Standards for swimmability of surface waters are only issued for pathogens, but certainly people's desire to swim in rivers and lakes is also affected directly or indirectly by stressors like *oxygen-demanding pollutants, phosphorus* and *transported sediment*.

Winter recreation: Our access to snow and ice-covered lakes will likely be affected by global climate change.

Use of outdoors: The public's freedom to spend time outdoors can be affected by some air stressors (e.g., *ground-level ozone and odorous chemicals from biological processes*). Also, the public's access to open space is affected by habitat/hydrologic modification.

III. Program Matrix

The Program Matrix identifies where the MPCA and other organizations or agencies have statutory authority and identifies the level of activity associated with this authority. The comments identify only MPCA statutory obligations and authority, and the assigned level of activity is based solely on this statutory requirement. The Program Matrix categorizes information by sources. Programs align with sources better than with stressors. Information in the Program Matrix allows us to compare activity level with contributions from sources and from stressors, since sources can be linked to specific stressors.

For each source in the Program Matrix, we identified MPCA and external activity in the areas of cleanup, control, prevention, and education. These are defined below. Typically, we first identified the statutory basis for existence of programs and activities. We then identified all programs and activities associated with this statutory authority. Next, we determined how established the program or activity is by using information in the MPCA and other Web sites. Well-established programs have at least a moderate level of resources are deployed in an identifiable program or activity. Superfund is an example of a well-established cleanup program. Land application of manure is an example of a well-established control program. Examples of MPCA programs that exist but are not well established include programs that deal with agricultural issues. The Minnesota Department of Agriculture has the lead on agricultural issues, but the MPCA is active in areas such as Clean Water Partnership. After initially completing the matrix, we sought input from MPCA and non-MPCA staff working in the various source areas to finalize the matrix.

NOTE: the Program Matrix does not provide information on the effectiveness or adequacy of programs. Another limitation of the matrix is that we received comments from only 10 of 49 MPCA staff solicited for input. Finally, we attempted to identify as many programs and activities as possible, but the information cannot be considered complete.

KEY:

☐ Programs or activities do not exist

◪ Limited programs or activities exist

■ Well-established programs or activities exist

(Again, "limited" does not necessarily mean *inadequate*. Likewise, "well-established" does not necessarily mean *adequate*.)

DEFINITIONS:

Cleanup (Cl): A program dedicated to cleaning up or reducing exposure to pollutants that have been released to the environment.

Control (Ctrl): A program dedicated to controlling the release of pollutants through management practices or equipment rather than use of preventive strategies. Control programs include compliance or regulatory outreach and training, which should not be confused with education. Education is treated as a separate category in this report. Permitting activities are largely classified as control activities.

Prevention (P): Strictly speaking, "pollution prevention" means to reduce the quantity or toxicity of wastes or inputs at the source (source reduction)(*Minn. Stat. § 115D and Executive Order 99-4).* Reusing wastes or products and recycling are other preventative approaches. These preventive practices contrast with treatment and disposal of wastes. In addition to source reduction, the US EPA considers eliminating pollution through increased efficiency in the use of raw materials, energy and water, and the protection of natural resources by conservation to be pollution prevention.

Education (E): Programs or activities concerned with the interrelationships among components of the natural and human-made world, producing growth in the individual and leading to responsible stewardship of the earth (http://www.sru.edu/Depts/pcee/ProfDevInit/Resources/DEFINITION.html). Activities such as training, outreach, and technical assistance generally are not included under education but more typically are considered under control.

External: Any non-MPCA organization or agency. These include other federal, regional, state, or local agencies, or organizations affiliated with a federal, regional, state, or local agency, or other organizations involved with an environmental issue.

Program Matrix

Source	Program/activity effect on reducing impacts from sources								Comments on MPCA activities[1,2]
	MPCA				External				
	Cl	Ctrl	P	E	Cl	Ctrl	P	E	
Agricultural runoff	□	◪	◪	□	□	◪	■	■	- Section 303(d) of the Clean Water Act requires the MPCA to publish, every two years, an updated list of Streams and lakes that are not meeting their designated uses because of excess pollutants.
Agriculture	◪	◪	◪	□	◪	◪	◪	■	- MN R. 7001.0020, 7002.0210 to 7002.0280, and MN R. Ch. 7020 govern the storage, transportation, and utilization of manure. - Minnesota Statute 116.07 subd. 7(p) allows the MPCA to take enforcement action, including cleanup, at feedlots. - MPCA has regulatory authority over hydrogen sulfide emissions resulting from manure management (Minn. R. 7009.0080). - MPCA works with counties to implement feedlot rules. - MPCA supports CWP activities (Minnesota Statutes Sections 103F.701 to 103F.761.
Aircraft	□	□	□	□	□	◪	◪	□	- The PCA adopts standards describing the maximum levels of noise in terms of sound pressure level which may occur in the outdoor atmosphere (Minn. R. 7030.0010-7030.0080).
Area Source Combustion	□	◪	◪	□	□	◪	◪	◪	- Minn. R. 7007.0050-7007.300 describes the requirements for obtaining an air permit from the MPCA. Many area source industries must obtain a permit from the MPCA.
Coal-fired power plants	□	■	□	□	□	□	□	□	- The Clean Air Act (Part 70 of Title 40 of the Code of Federal Regulations) authorizes the MPCA, under authority delegated from the EPA, to address air pollution from large stationary sources, but this authority is limited for facilities built before 1970. Minn. R. 7019.3000-7019.3100 requires the MPCA to conduct annual emission inventories for facilities regulated under Part 70.
Construction	◪	■	□	□	◪	◪	□	□	- MPCA administers National Pollutant Discharge Elimination System (NPDES) permitting (under federal authority of the Federal Clean Water Act; Section 402; 33 USC 1251-1376; Chapter 758; PL 845; 62 Stat. 1155) and the State Disposal System (Minn. Stat. § 115).
Drainage and channelization	□	□	□	□	◪	■	◪	◪	- No MPCA regulatory authority identified.
Dredging	□	□	□	□	◪	■	◪	◪	- No MPCA regulatory authority identified.

[1] Note that specific pollution prevention activities are not discussed under Comments. This is because, although the MPCA has regulatory authority to conduct prevention activities under *Minn. Stat. § 115D and Executive Order 99-4*, prevention activities are dispersed among the various Agency programs rather than being part of an integrated prevention program.
[2] These comments only identify MPCA statutory requirements. The assigned activity level was based solely on these statutory requirements. If the specific source being considered affects stressors not covered by the statutory requirement, then it can be assumed the MPCA has minimal obligation and therefore activity related to these affects.

Source	Program/activity effect on reducing impacts from sources								Comments on MPCA activities[1,2]
	MPCA				External				
	Cl	Ctrl	P	E	Cl	Ctrl	P	E	
Ethanol production	☐	■	☐	☐	☐	☐	☐	☐	- Air permits are regulated under Minn. R. 7007 and more generally under Minn. R. 7001-7030.
Feedlots	◪	■	◪	☐	◪	■	☐	◪	- MN R. 7001.0020, 7002.0210 to 7002.0280, and MN R. Ch. 7020 govern the storage, transportation, and utilization of manure. - MPCA works with counties to implement feedlot rules.
Fertilizer use	☐	◪	☐	☐	☐	■	■	■	- MPCA is involved in activities related to fertilizer use. General authority comes from the Clean Water Act, including TMDLs (Section 303(d)), the Clean Water Partnership Program (Minnesota Statutes Sections 103F.701 to 103F.761), and Minnesota's Nonpoint Source Grants Program (Section 319 of the federal Clean Water Act).
Fire extinguishers	☐	☐	☐	☐	☐	☐	◪	☐	- No MPCA regulatory authority identified.
Fugitive Dust	☐	◪	☐	☐	☐	☐	☐	☐	- Under Minn. R. 7011.0150, the MPCA has broad regulatory authority for a variety of activities that affect contributions from fugitive dust. The MPCA has no authority for the major contributor, however (dust from roads).
Industry	◪	■	◪	☐	◪	☐	◪	☐	- MPCA has broad regulatory authority for a variety of industries that impact air, water, and land quality. Some examples are provided below. - Air permits are regulated under Minn. R. 7007 and more generally under Minn. R. 7001-7030. - MPCA administers National Pollutant Discharge Elimination System (NPDES) permitting (under federal authority of the Federal Clean Water Act; Section 402; 33 USC 1251-1376; Chapter 758; PL 845; 62 Stat. 1155) and the State Disposal System (Minn. Stat. § 115). - The PCA adopts standards describing the maximum levels of noise in terms of sound pressure level which may occur in the outdoor atmosphere (Minn. R. 7030.0010-7030.0080)
Land-applied manure	☐	■	☐	☐	☐	◪	◪	■	- Land-applied manure is regulated through Minn. R. Chap. 7020.2225.
Land-applied municipal and industrial byproducts	☐	■	☐	☐	☐	☐	☐	☐	- Land application of biosolids is regulated through MN Rule Chap. 7041. - Land application of industrial by-products is regulated through a permitting process.
Lead paint	☐	■	◪	☐	☐	■	■	☐	- MPCA regulates use of lead in packaging and has requirements for removal of materials containing lead paint (Minn. Stat. Sec.115A.9651; 61FR 45778; Section 406 of TSCA).
Mining	◪	■	☐	☐	◪	■	◪	◪	- MPCA administers National Pollutant Discharge Elimination System (NPDES) permitting (under federal authority of the Federal Clean Water Act; Section 402; 33 USC 1251-1376; Chapter 758; PL 845; 62 Stat. 1155) and the State Disposal System (Minn. Stat. § 115). - The MPCA administers waste cleanup programs through MN Rules, Chapter 115B. - MPCA administers air permits under the Clean Air Act, and Part 70 of Title 40 of the Code of Federal Regulations.

Source	Program/activity effect on reducing impacts from sources								Comments on MPCA activities[1,2]
	MPCA				External				
	Cl	Ctrl	P	E	Cl	Ctrl	P	E	
Municipal and industrial wastewater	◪	■	◪	□	□	□	■	◪	- MPCA administers National Pollutant Discharge Elimination System (NPDES) permitting (under federal authority of the Federal Clean Water Act; Section 402; 33 USC 1251-1376; Chapter 758; PL 845; 62 Stat. 1155) and the State Disposal System (Minn. Stat. § 115)
Off-Road Equipment	□	□	□	◪	□	□	◪	□	- MPCA regulatory authority includes permitting motor vehicles that cause visible air pollution (Minn. R. 7023.0100-7023.0120). - The PCA adopts standards describing the maximum levels of noise in terms of sound pressure level which may occur in the outdoor atmosphere (Minn. R. 7030.0010-7030.0080).
On-Road Vehicles	□	□	□	◪	□	□	◪	□	- MPCA regulatory authority includes permitting motor vehicles that cause visible air pollution (Minn. R. 7023.0100-7023.0120). - The PCA adopts standards describing the maximum levels of noise in terms of sound pressure level which may occur in the outdoor atmosphere (Minn. R. 7030.0010-7030.0080).
Permitted waste disposal	■	■	◪	□	□	◪	◪	□	- The MPCA administers Landfill programs through MN Rules, Chapter 115B. - The MPCA administers solid Waste programs through MN Rules, Chapter 7035.
Pesticide use	□	◪	□	□	□	◪	◪	◪	- MPCA is involved in activities related to pesticide use. General authority comes from the Clean Water Act, including TMDLs (Section 303(d)), the Clean Water Partnership Program (Minnesota Statutes Sections 103F.701 to 103F.761), and Minnesota's Nonpoint Source Grants Program (Section 319 of the federal Clean Water Act).
Petroleum storage and transfer	□	◪	□	□	□	□	□	□	- MPCA administers air emission permits under Minn. R. 7030.0010-7030.0080 and Part 70 of Title 40 of the Code of Federal Regulations.
Pipelines	◪	◪	□	□	◪	◪	□	□	- MPCA has regulatory authority for pipelines associated with petroleum storage tanks through MN Rules Chapter 7150, MN Rules Chapter 7001.4205-4250 (large tanks), MN Rules Chapter 7151 for small facilities, MN Stat. 115C, and MN Rules Ch. 7105.
Power plants (thermal discharge)	□	■	□	□	□	□	□	□	- MPCA administers National Pollutant Discharge Elimination System (NPDES) permitting (under federal authority of the Federal Clean Water Act; Section 402; 33 USC 1251-1376; Chapter 758; PL 845; 62 Stat. 1155) and the State Disposal System (Minn. Stat. § 115), which regulate thermal discharge.
Recreational use (shooting ranges, fishing tackle)	□	□	□	□	□	◪	◪	◪	- No MPCA regulatory authority identified.
Refrigerants	□	□	□	□	□	□	■	□	- MPCA has regulatory authority to require technician certification for persons servicing and disposing of appliances containing refrigerant and the servicing, and in some cases, disposal of motor vehicle air conditioners (40 CFR – Chapter I – Part 82), but no Agency program exists.
Residential Fuel Combustion	□	□	□	□	□	□	□	□	- No MPCA regulatory authority identified.
Residences	◪	◪	◪	□	□	◪	□	□	- MN Rules Ch. 115.061 and 115E give the MPCA authority to require reporting of spills, and preventing and preparing for spills.

Source	Program/activity effect on reducing impacts from sources								Comments on MPCA activities[1,2]
	MPCA				External				
	Cl	Ctrl	P	E	Cl	Ctrl	P	E	
Road salt	□	◪	◪	□	□	□	◪	◪	- MPCA administers National Pollutant Discharge Elimination System (NPDES) permitting (under federal authority of the Federal Clean Water Act; Section 402; 33 USC 1251-1376; Chapter 758; PL 845; 62 Stat. 1155) and the State Disposal System (Minn. Stat. § 115), for those municipalities requiring a permit.
Septic systems	□	◪	□	□	◪	◪	◪	◪	- The MPCA administers ISTS programs through Statutes §§ 115.55 and 115.56 and MN Rules CH. 7080 and works with counties to implement ISTS programs.
Silvaculture	□	□	□	□	□	■	■	■	- No MPCA Regulatory authority identified.
Solvent utilization	□	◪	◪	□	□	□	■	□	- Air permits are regulated under Minn. R. 7007 and more generally under Minn. R. 7001-7030.
Spills	■	■	□	□	■	◪	□	□	- MN Rules Ch. 115.061 and 115E give the MPCA authority to require reporting of spills, and preventing and preparing for spills.
Streambank erosion	□	□	□	□	□	■	◪	◪	- The Agency conducts some activity through the CWP program (Minnesota Statutes Sections 103F.701 to 103F.761).
Tanks	■	■	□	□	□	■	□	□	- The MPCA administers UST programs through MN Rules Chapter 7150. - The MPCA administers AST programs through MN Rules Chapter 7001.4205-4250 (large tanks) and MN Rules Chapter 7151 for small facilities. - The MPCA administers corrective actions under MN Stat. 115C. - The MPCA administers a certification program through MN Rules Ch. 7105. - MPCA's Emergency Response Program is involved in spill cleanup.
Trains	◪	◪	□	□	□	◪	□	□	- MN Rules Ch. 115.061 and 115E give the MPCA authority to require reporting of spills, and preventing and preparing for spills.
Treatment/settling ponds	□	◪	◪	□	□	◪	◪	□	- MN R. 7001.0020, 7002.0210 to 7002.0280, and MN R. Ch. 7020 govern storage, transportation, and utilization of manure.
Unpermitted waste disposal	■	■	◪	□	■	■	◪	◪	- The MPCA administers waste cleanup programs through MN Rules, Chapter 115B. Cleanup programs include Superfund, VIC, Closed Landfill, and RCRA Corrective Action.
Urban development	□	◪	◪	◪	□	◪	◪	■	- No direct MPCA regulatory authority identified; many MPCA programs have the potential to impact urban development. - Under Minnesota State Statute 115.07, subdivision 3, permits are required for extensions of sanitary sewers.
Urban runoff	◪	■	◪	◪	◪	◪	◪	◪	- MPCA administers National Pollutant Discharge Elimination System (NPDES) permitting (under federal authority of the Federal Clean Water Act; Section 402; 33 USC 1251-1376; Chapter 758; PL 845; 62 Stat. 1155) and the State Disposal System (Minn. Stat. § 115).

Source	Program/activity effect on reducing impacts from sources								Comments on MPCA activities[1,2]
	MPCA				External				
	Cl	Ctrl	P	E	Cl	Ctrl	P	E	
Waste incineration	□	■	◪	□	□	■	◪	◪	- Air permits are regulated under Minn. R. 7007, more generally under Minn. R. 7001-7030, and under Part 70 of Title 40 of the Code of Federal Regulations.

IV. Using Information in the EIR

Matrices within the EIR contain a large amount of information that is potentially useful to MPCA management. Filtering relevant information from the EIR may be difficult, however, because of the large amount of information and the use of multiple matrices. A database was established to allow a variety of queries on information in the EIR. This section provides examples of queries that can be conducted, along with results for some of those queries.

This section indicates potential uses of the EIR. The queries and examples are illustrations of how to use the EIR and are not intended to provide answers for decision-making. Rather, our intention is to illustrate the diversity of information in the EIR so users will develop their own list of relevant questions.

A. Examples of Simple Queries

A simple query provides information for one or two categories from the EIR and consists of just one question. Examples of categories include stressor overall comparative contribution, source comparative contribution, stressor trend information, or program activity level. Table 1 shows simple queries that can be run. The list is not exhaustive. Table 1 shows potential use of each query. Example output for some queries is provided below. For definitions of terms used in this section (e.g. stressor, source), see the ***Environmental Matrices*** section of the EIR.

Table 1: Examples of simple queries.

Query	***Use***
Stressors	
1. What are the high- and low-overall comparative contribution stressors?	Potential areas for MPCA to focus or not focus resources
2. Do high and medium overall comparative contribution stressors have primarily rural, urban or statewide effects?	Identify geographic areas where specific environmental issues are important
3. What are the pollutants of concern for stressors with high overall comparative contribution?	Identify pollutants that are problematic
Sources	
1. What are the sources that contribute to multiple high and medium overall comparative contribution stressors?	Potential areas for MPCA to focus resources
2. For each source, how many times is the source rated as having high, medium, and low comparative contribution?	Potential areas for MPCA to focus resources
Stressor Trends	
1. Which high- or medium-overall comparative contribution stressors have upward trends?	Potential areas for MPCA to focus or not focus resources
2. What is our level of monitoring for high-comparative overall contribution stressors with upward trends?	Identify monitoring needs
Program Activity	
1. What are high contribution sources for high-overall comparative contribution stressors for which there are no well-established programs?	Determine if the Agency should play a role in addressing certain problematic environmental issues
2. What are low comparative contribution sources into which the MPCA has well-established programs?	Determine if the Agency should continue to put resources into certain programs or if low comparative contribution is the result of existing programs

3. For which sources does the MPCA have well-established cleanup or control programs?	Identify areas where the Agency could potentially shift the focus of existing resources

Table 2: What are the high- and low-overall comparative contribution stressors?

Stressor	*Impact*
High overall comparative contribution	
Habitat modification	Aquatic species health
Habitat modification	Terrestrial species health
Particles in air	Human health-cancer
Particles in air	Human health-noncancer acute
Particles in air	Human health-noncancer chronic
Phosphorus	Aquatic species health
Temperature increase/climate change	Aquatic species health
Temperature increase/climate change	Human health-noncancer acute
Temperature increase/climate change	Terrestrial species health
Transported sediment	Aquatic species health
Low overall comparative contribution	
Acid deposition	Terrestrial species health
Acid deposition	Aquatic species health
Ammonia	Aquatic species health
Dissolved solids	Aquatic species health
Excess UV radiation from stratospheric ozone depletion	Human health-noncancer chronic
Excess UV radiation from stratospheric ozone depletion	Terrestrial species health
Excess UV radiation from stratospheric ozone depletion	Aquatic species health
Other criteria pollutants in air	Human health-noncancer acute
Other criteria pollutants in air	Human health-noncancer chronic
Toxic chemicals-high level accidental release	Human health-noncancer acute
Toxic chemicals in soil	Human health-cancer
Toxic chemicals in soil	Human health-noncancer acute
Toxic chemicals in soil	Human health-noncancer chronic
Toxic chemicals in water	Human health-cancer
Toxic metals	Terrestrial species health
Toxic volatile chemicals in air	Human health-noncancer acute

Table 3: How many times does each stressor appear with high or medium overall comparative contribution?

Stressor	Number of instances	
	High overall comparative contribution	**Medium overall comparative contribution**
Particles in air	3	0
Temperature increase/climate change	3	0
Habitat modification	2	0
Phosphorus	1	0
Transported sediment	1	0
Ground-level ozone	0	3
Nitrogen	0	2
Noise	0	2
Odorous chemicals from biological processes	0	2
Toxic chemicals in food	0	2
Toxic chemicals in water	0	2
Toxic organic chemicals	0	2
Toxic volatile chemicals in air	0	2
Excess UV radiation from stratospheric ozone depletion	0	1
Explosive/flammable materials - high level accidental releases	0	1
Oxygen-demanding pollutants	0	1
Pathogens in water	0	1
Toxic metals	0	1
Toxic chemicals – high level accidental releases	0	0
Acid deposition	0	0
Ammonia	0	0
Dissolved solids	0	0
Other criteria pollutants in air	0	0
Toxic chemicals in soil	0	0

Table 4: For each source, how many times is the source rated as having high, medium, and low comparative contribution?

Source	High	Medium	Low
Agricultural runoff	6	1	0
Agriculture	3	13	0
Aircraft	3	0	0
Area source combustion	1	5	5
Coal-fired power plants	16	7	0
Construction	2	0	0
Drainage and channelization	1	0	0
Dredging	0	1	0
Ethanol production	0	0	3
Feedlots	6	4	2
Fertilizer use	2	1	0
Fire extinguishers	0	0	4
Fugitive dust	0	0	4
Industry	3	18	15
Land-applied manure	0	2	1
Land-applied municipal and industrial byproducts	0	0	7
Lead paint	0	0	2
Mining	0	2	4
Municipal and industrial wastewater	1	11	10
Off-road equipment	8	9	4
On-road vehicles	24	5	0
Permitted waste disposal	0	8	0
Pesticide use	7	2	0
Petroleum storage and transfer	0	0	4
Pipelines	0	1	1
Power plants (thermal discharge)	0	0	2
Recreational use (shooting ranges, fishing	0	0	1
Refrigerants	0	4	0
Residential fuel combustion	2	3	8
Residences	0	0	2
Road salt	0	0	1
Septic systems	0	2	6
Silvaculture	2	0	0
Solvent utilization	0	4	0
Spills	0	1	8
Streambank erosion	0	2	0
Tanks	1	1	2
Trains	1	1	0
Unpermitted waste disposal	0	5	7
Treatment/settling ponds	0	3	0
Urban/suburban/lakeshore development	3	0	0
Urban runoff	3	10	0
Waste incineration	0	4	0

Table 5: Which high- and medium-overall comparative contribution stressors have upward trends?

Impact	*Stressor*
High overall comparative contribution	
Aquatic species health	Temperature increase/climate change
Aquatic species health	Habitat modification
Human health-noncancer acute	Temperature increase/climate change
Terrestrial species health	Habitat modification
Terrestrial species health	Temperature increase/climate change
Medium overall comparative contribution	
Aquatic species health	Nitrogen
Human health-noncancer acute	Noise
Terrestrial species health	Toxic organic chemicals
Human health-noncancer acute	Toxic chemicals in water
Human health-noncancer chronic	Noise
Terrestrial species health	Nitrogen

Table 6: Which low-overall comparative contribution stressors have downward trends?

Impact	Stressor
Aquatic species health	Ammonia
Human health-noncancer acute	Toxic chemicals in soil
Human health-noncancer chronic	Toxic chemicals in soil

Table 7: For which sources does the MPCA have well-established cleanup or control programs?*

Cleanup Activities
Permitted waste disposal
Tanks
Spills
Unpermitted waste disposal
Control Activities
Coal-fired power plants
Construction
Ethanol production
Feedlots
Industry
Land-applied manure
Land-applied municipal and industrial byproducts
Lead Paint
Mining
Municipal and industrial wastewater
Permitted waste disposal
Power plants (thermal discharge)
Spills
Tanks
Unpermitted waste disposal
Waste incineration

***** "Well-established" does not necessarily mean *adequate*.

B. Examples of Complex Queries

Complex queries provide information from more than one category and consist of multiple questions. Each successive query is dependent on the results from the previous query. There are hundreds of potential complex queries. Two examples are provided below.

Example 1: For high-overall comparative contribution stressors, which high-comparative contribution sources have upward trends? What are the MPCA's monitoring efforts and program activity levels for these sources?

Tables 8 through 12 provide this information. One conclusion is that consumption of fossil fuels and human development appear to pose the greatest comparative contribution to ecosystem health. These are areas in which the MPCA has a limited or no presence. Fossil fuel consumption and human development are increasing, and their impact on the environment is likely to increase.

Table 8: High-overall comparative contribution stressors.

Impact	Stressor
Aquatic species health	Temperature increase/climate change
Aquatic species health	Habitat modification
Aquatic species health	Phosphorus
Aquatic species health	Transported sediment
Human health-noncancer acute	Temperature increase/climate change
Human health-noncancer acute	Particles in air
Human health-noncancer chronic	Particles in air
Human health-cancer	Particles in air
Terrestrial species health	Habitat modification
Terrestrial species health	Temperature increase/climate change

Table 9: High contribution sources for high-overall comparative contribution stressors.

Impact	Stressor	Source
Aquatic species health	Temperature increase/climate change	Coal-fired power plants
Aquatic species health	Habitat modification	Drainage and channelization
Aquatic species health	Temperature increase/climate change	On-road vehicles
Aquatic species health	Habitat modification	Urban/suburban/lakeshore development
Aquatic species health	Phosphorus	Agricultural runoff
Aquatic species health	Transported sediment	Agricultural runoff
Aquatic species health	Transported sediment	Construction
Human health-noncancer acute	Temperature increase/climate change	Coal-fired power plants
Human health-noncancer acute	Temperature increase/climate change	On-road vehicles
Human health-cancer	Particles in air	Coal-fired power plants
Human health-noncancer acute	Particles in air	Coal-fired power plants
Human health-noncancer chronic	Particles in air	Coal-fired power plants
Human health-cancer	Particles in air	On-road vehicles
Human health-noncancer acute	Particles in air	On-road vehicles
Human health-noncancer chronic	Particles in air	On-road vehicles
Terrestrial species health	Habitat modification	Agriculture
Terrestrial species health	Temperature increase/climate change	Coal-fired power plants
Terrestrial species health	Temperature increase/climate change	On-road vehicles
Terrestrial species health	Habitat modification	Silvaculture
Terrestrial species health	Habitat modification	Urban/suburban/lakeshore development

Table 10: High contribution sources within high-overall comparative contribution stressors that have upward trends.

Impact	Stressor	Source
Aquatic species health	Temperature increase/climate change	Coal-fired power plants
Aquatic species health	Habitat modification	Drainage and channelization
Aquatic species health	Temperature increase/climate change	On-road vehicles
Aquatic species health	Habitat modification	Urban/suburban/lakeshore development
Human health-noncancer acute	Temperature increase/climate change	Coal-fired power plants
Human health-noncancer acute	Temperature increase/climate change	On-road vehicles
Terrestrial species health	Temperature increase/climate change	Coal-fired power plants
Terrestrial species health	Temperature increase/climate change	On-road vehicles
Terrestrial species health	Habitat modification	Urban/suburban/lakeshore development

Table 11: Adequacy of monitoring efforts for high-overall comparative contribution stressors.

Impact	Stressor	Adequacy of Monitoring
Aquatic species health	Phosphorus	adequate monitoring of hotspots
Aquatic species health	Temperature increase/climate change	adequate monitoring of hotspots
Aquatic species health	Habitat modification	very limited
Aquatic species health	Transported sediment	adequate monitoring of hotspots
Human health-cancer	Particles in air	adequate monitoring of hotspots
Human health-noncancer acute	Temperature increase/climate change	reasonable
Human health-noncancer acute	Particles in air	adequate monitoring of hotspots
Human health-noncancer chronic	Particles in air	adequate monitoring of hotspots
Terrestrial species health	Habitat modification	adequate monitoring of hotspots
Terrestrial species health	Temperature increase/climate change	reasonable

Table12: MPCA activity for sources identified in Table 10.

Source	Activity Type	Activity Level*
Coal-fired power plants	Cleanup	Do not exist
Coal-fired power plants	Control	Well-established
Coal-fired power plants	Education	Do not exist
Coal-fired power plants	Prevention	Do not exist
Drainage and channelization	Cleanup	Do not exist
Drainage and channelization	Control	Do not exist
Drainage and channelization	Education	Do not exist
Drainage and channelization	Prevention	Do not exist
On-road vehicles	Cleanup	Do not exist
On-road vehicles	Control	Do not exist
On-road vehicles	Education	Limited
On-road vehicles	Prevention	Do not exist
Urban/suburban/lakeshore development	Cleanup	Limited
Urban/suburban/lakeshore development	Control	Limited
Urban/suburban/lakeshore development	Education	Limited
Urban/suburban/lakeshore development	Prevention	Limited

* ”Well-established” does not necessarily mean *adequate* and “limited” does not necessarily mean *inadequate*.

Example 2: For which high contribution sources does the MPCA have no cleanup and control programs or activities? What are the prevention and education activity levels for these sources?

Table 13 summarizes MPCA and external education and prevention activity levels for high contribution sources in which the Agency has no cleanup or control activity. The MPCA does little with education for these sources. MPCA appears to have a limited level of activity for agricultural sources. This activity is primarily concentrated in support of external programs, such as 319 and Clean Water Partnership projects. There is limited or no MPCA activity in the education and prevention activity associated with fossil fuel consumption and urban growth. External activity in these areas is higher, but is still generally limited.

Table 13: High contribution sources with no Agency cleanup or control activity.*

Source	MPCA Education programs	MPCA Prevention programs	External Education programs	External Prevention programs
SOURCES WITH NO MPCA CLEANUP				
Off-road vehicles	Limited	Do not exist	Do not exist	Limited
Pesticide use	Do not exist	Do not exist	Limited	Limited
Residential fuel combustion	Do not exist	Do not exist	Do not exist	Do not exist
Aircraft	Do not exist	Do not exist	Do not exist	Limited
Area source combustion	Do not exist	Limited	Limited	Limited
Urban/suburban/lakeshore development	Limited	Limited	Well-established	Limited
Fertilizer use	Do not exist	Do not exist	Well-established	Well-established
Drainage and channelization	Do not exist	Do not exist	Limited	Limited
On-road vehicles	Do not exist	Do not exist	Do not exist	Limited
Agricultural runoff	Do not exist	Limited	Well-established	Well-established
Coal-fired power plants	Do not exist	Do not exist	Do not exist	Do not exist
Silvaculture	Do not exist	Do not exist	Well-established	Well-established
SOURCES WITH NO MPCA CONTROL				
Aircraft	Do not exist	Do not exist	Do not exist	Limited
Drainage and channelization	Do not exist	Do not exist	Limited	Limited
Off-road vehicles	Limited	Do not exist	Do not exist	Limited
On-road vehicles	Limited	Do not exist	Do not exist	Limited
Residential fuel combustion	Do not exist	Do not exist	Do not exist	Do not exist
Silvaculture	Do not exist	Do not exist	Well-established	Well-established

* "Well-established" does not necessarily mean *adequate* and "limited" does not necessarily mean *inadequate*.