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Environmental Information Report:

An Assessment of Stresses Facing Minnesota's Environment

2009

An Environmental Analysis and Outcomes Division Report

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Acknowledgments

This report was prepared by Dave Christopherson, Tom Clark, Patricia Engelking, Paul Hoff, Catherine O'Dell and Kari Palmer of the MPCA Environmental Analysis and Outcomes Division.

1. Introduction

This is the second edition of the Environmental Analysis and Outcomes (EAO) Division's Environmental Information Report (EIR). It updates the original EIR completed in 2003. The EIR is prepared to help fulfill the mission of the division: 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.

The report is an assessment of a wide variety of environmental stresses facing Minnesota, provided in a matrix format. Six environmental matrices are included. Three focus on human health, two on the ecosystem health of aquatic and terrestrial organisms and one on overall quality-of-life concerns.
Each matrix identifies stressors and the sources that contribute to each stressor, according to the importance of their relative contribution. Symbols (circles, squares and arrows) are used to graphically indicate the respective magnitude of the contribution, confidence level and trend for each stressor and source. The definitions for the symbols used in this report follow this introduction.

The EIR's primary audience is agency decision-makers, although it may also have application to external audiences such as the legislature and citizens. Note that the EIR assesses health and ecological stresses that remain *after* the impact of current environmental programs are taken into account.

A core team of staff from the EAO Division was assigned to update the original 2003 EIR following a similar but more streamlined process, which is described below.

As before, a panel of 10 to 15 technical experts from the Minnesota Pollution Control Agency (MPCA), the Minnesota Department of Natural Resources (MDNR) and the Minnesota Department of Health (MDH) was convened to share information and evaluate and score the comparative contribution of environmental stressors for each matrix. Each expert panel used the 2003 matrix as a starting point for discussion. The group of experts also scored their confidence level for evaluating the comparative contribution and adequacy of monitoring of each stressor.

Prior to and following the expert panels, the EAO team met frequently to gather and evaluate existing environmental data and information; assess status and trends of environmental impacts, stressors and sources; and identify gaps in information that needed to be filled.

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. The team also sought feedback from the panelists on the final draft matrices.

Major changes/highlights since 2003 report

The environmental stressors affecting the health of Minnesotans, their quality of life and the health of aquatic and terrestrial organisms have evolved since the first EIR was completed in 2003. Global climate change has become a more important concern in Minnesota as scientists have gained greater understanding of its seriousness and its effects have started to become visible in the landscape. These effects include shorter periods between ice-in and ice-out on Minnesota lakes, shorter duration of continuous snow cover, early signs of the boreal forest shifting north, and the decline in northern Minnesota moose populations.

As in 2003, fine particles in air continue to rank high for noncancer and cancer health impacts. Many studies have shown an association between fine particle exposure and a rise in heart attacks, chronic bronchitis, asthma attacks and cancer. Although fine particle concentrations in Minnesota are fairly low and decreasing, the seriousness of their health effects coupled with the daily exposure of most Minnesotans to these chemicals warrants a high level of concern.

Habitat loss/hydrologic modification continues to rank as an important stressor for aquatic and terrestrial organisms. This is a widespread problem in the state that includes tile drainage, filling in of wetlands, loss of riparian cover and increased variation in flow due to increased runoff in watersheds.

Invasive species, newly added this year, ranked as an important stressor for terrestrial organisms because of their threats to the health of native species. They can also severely alter habitat, thus affecting species beyond those they directly displace.

New and emerging issues

The report also includes endocrine-disrupting chemicals (EDCs) as a new stressor in several matrices. While these chemicals are an emerging concern and little is yet known about their impact on human health and animals at ambient concentrations, they are widely present in the environment and pose enough concern to warrant addition as stressors.

Nanoparticles were also included for the first time in the aquatic matrix with a low overall comparative contribution based on laboratory studies that have shown toxicity effects in fish. Research into environmental effects of nanoparticles, which are used in a wide variety of applications, is in its infancy. Nanoparticles were not included in the human health matrices because of lack of definitive evidence linking environmental exposure to human health. However, it is important to note that many Minnesotans may receive significant exposure to these chemicals through daily use of products such as sunscreens and clothing.

Participants in EIR expert panels

The following people participated on one or more of the EIR panels: Hillary Carpenter (MDH), Joel Chirhart, David Christopherson, Peter Ciborowski, Tom Clark, Mary Dymond, Patricia Engelking, Mike Feist, Mark Ferrey, Mark Gernes, Lisa Herschberger, Steven Hennes, Paul Hoff, Joseph Magner, Phil Monson, Catherine Neuschler, Catherine O'Dell, Kari Palmer, Ann Pierce (MNDR), Gregory Pratt, Angela Preimesberger, Johanna Schussler, Jim Stockinger, Jim Sullivan, Edward Swain, Charles Welling (MDNR), Chun Yi Wu and Chris Zadak.

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. The same symbols were used to describe sources as well as stressors.

Explanation of terms and guide to symbols

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.

○ = low overall comparative contribution

◒ = medium overall comparative contribution

● = high overall comparative contribution

Confidence level: Degree of assurance or certainty of our knowledge of comparative contribution of a stressor.

□□□ = very unsure; near zero level of confidence

■□□ = somewhat speculative; many assumptions at play

■■□ = moderately confident, although holes in understanding exist

■■■ = reasonable level of confidence

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

Stressor/Source trend*:* Stressor and source trends were assigned using best professional judgment of the EIR team members, in consultation with others who assisted with the expert panels.

↑ = upward trend

↓ = downward trend

↔ = no trend

↑↓ = upward and downward trend (some contributing sources or pollutants are up and others are down)

? = inadequate information exists to determine a trend

Adequacy of ambient monitoring*:* Effectiveness of monitoring efforts to determine ambient levels and trends (not necessarily actual impacts) of an environmental stressor.

□□□ = no monitoring exists

■□□ = extent and quality of monitoring very limited; barely a presence

■■□ = adequate monitoring but with spatial and temporal limitations

■■■ = reasonable monitoring network

A. Human Health Impacts: Cancer

Introduction

Over half of all Minnesotans will be diagnosed with a potentially serious cancer in their lifetime (Cancer Facts and Figures, 2006). Cancer is a group of diseases that share in common the uncontrolled growth and spread of abnormal cells. Since cancer often does not occur until many years after exposure to a cancer-causing substance, it is difficult to determine definitively how closely linked ambient pollution is with cancer. Therefore, preventing exposure to cancer-causing substances from ambient air, water and soil is an important part of MPCA's mission.

Discussion

The risk of cancer from environmental pollutants is a function of the potential of a given pollutant to cause cancer and exposure to that pollutant. Exposure occurs through breathing, eating, drinking and skin contact.

The comparisons shown in the cancer impacts matrix are only among the stressors listed, not to other non-environmental sources of cancer. Exposures resulting from the use of consumer products, occupational exposures, indoor air sources and naturally occurring chemicals were not included. The factors used in making comparisons included the confidence in the cause and effect relationship between the stressor and cancer incidence, the estimated number of incidences of cancer for each stressor, and the cancer type related to each stressor.

Particles in air are the only high stressor for cancer impacts. They warranted this rating due to the strength of studies linking particles (especially diesel particles) to lung cancer, the high mortality rate of lung cancer, and the fact that most Minnesotans are exposed to ambient particles in their daily lives.

Changes from 2003 report

Several stressors were added to the Cancer Impacts matrix in this 2009 update to the EIR.

- Endocrine-disrupting chemicals (EDCs): Continuing research on EDCs has shown cancer potential. While little definitive evidence exists at this time linking EDCs with cancer, the amount of EDCs in the environment combined with the exposure of nearly all Minnesotans makes EDCs a significant concern.
- Fibers in air: There has been significant concern surrounding fibers in air in Minnesota. Mesothelioma, a rare cancer of the tissues that line the chest and abdominal cavity, is caused by inhaling amphibole/chrysotile fibers. Rates of mesothelioma in northeastern Minnesota are higher than elsewhere in the state; however, it is thought that the increased rates are a result of occupational rather than ambient exposure to fibers.

- Metals and semi-volatile chemicals were added as new toxics in air stressors since they can contribute to cancer risk from breathing the air and have different trends, monitoring and sources from volatile chemicals.

Future trends

Of the cancer stressors of greatest concern, emissions of particles in air, fibers in air, toxic chemicals in air (metals) and toxic chemicals in air (volatiles) have been decreasing in the ambient environment. This is due in large part to government's and society's recognition that these pollutants pose potential health concerns and a concentrated effort to minimize the emission of these pollutants into the natural environment.

However, the impact of other pollutants on cancer incidence, such as endocrine-disrupting chemicals and semi-volatile toxic chemicals in air are not as well understood. As a result, these chemicals are not carefully tracked and their emission and concentration trends are unknown.

Other stressor trends such as toxic chemicals in food and stratospheric ozone depleting chemicals have remained flat.

Human Health Impacts: Cancer

Stressor	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	● ■■□ statewide	↓	■■□	Agriculture	● ■■□	↔	Fine particles ($PM_{2.5}$ microns) Coarse particles ($PM_{2.5\text{-}10}$ microns) Diesel particles Ultrafine particles ($P_{<0.1}$ microns)	• Mechanism for cancer not well enough understood to sort out risk from coarse and fine particles. • Pathway is inhalation. • Large percent of population exposed. • Particles linked in studies to lung cancer, but they may contribute to other cancers. Studies have shown that diesel particles, in particular, are linked to lung cancer. • Chemical composition may be important. Toxicity may come from particles or attached chemicals. Unclear if particle mass or number of particles is more important. • Sources based on $PM_{2.5}$. • Listed sources may not emit particles. Instead, they may emit compounds which form particles downwind of the emission point (e.g., agricultural practices emit ammonia rather than particles). • Road dust is a major mass component of direct emissions of $PM_{2.5}$; however, it is expected to be a lesser component of total $PM_{2.5}$ and of lesser health concern.
				Off-road equipment	● ■■□	↑↓		
				On-road vehicles	● ■■□	↑↓		
				Power plants (biomass/fossil fuel)	● ■■□	↑↓		
				Industrial combustion	◒ ■□□	↔		
				Residential combustion	◒ ■□□	↑		
				Road dust	○ ■□□	↔		
Fibers in air	◒ ■■□ localized	↓	■□□	Mining	● ■■■	↑↓	Amphibole/ chrysotile fibers	• Concern is inhalation of ambient air. • There are many different types of fibers, only some of which are linked to cancer. • Few people impacted relative to statewide population. • Definite links to mesotheliomas and lung cancers. • Health studies show increased risk of mesotheliomas in males on eastern part of Iron Range. Thought to be the result of occupational rather than ambient exposure. • Mining is a source in northeastern Minnesota. • Friction products, demolition and contaminated soils are sources across Minnesota.
				Clutch & brake-line wear	◒ ■□□	↓		
				Contaminated soils	◒ ■□□	?		
				Demolition	◒ ■□□	↓		

Human Health Impacts: Cancer continued

Stressor	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
Stratospheric ozone-depleting chemicals (excess uv radiation)	◒ ■■□ statewide	↔	■■□	Refrigeration & air conditioning	◒ ■■□	↓	Chlorofluoro-carbons Hydrochloro-fluorocarbons Halons Carbon tetrachloride Methyl chloroform Methyl bromide	• Large percentage of population is exposed. • Pathway is exposure to sunlight. • Confirmed relationship between UV radiation and skin cancer. Severity varies from basal cell to squamous to melanoma. • Ozone layer showing signs of stabilization. • CFCs were replaced by HCFCs, which have a lower ozone potential, in refrigeration. However, they are a concern due to their global warming potential.
				Fire extinguishers	○ ■□□	↔		
				Fumigants	○ ■□□	↓		
				Industrial solvents	○ ■□□	↔		
				Waste disposal	○ ■□□	↓		
Toxic chemicals in air—metals	◒ ■■□ statewide	↓	■■□	Metal production	● ■■□	↔	Arsenic Beryllium Cadmium Chromium VI Nickel	• Pathway is inhalation. • Large portion of population exposed. A few chemicals may be approaching health benchmarks. • Health effects can occur at low metal concentrations. • Cancers vary with metal. Risks from exposures to multiple metals are not well understood. • May be sensitive exposure times and endpoints (fetuses, children, adolescents, elderly). • Metals listed have been shown in Minnesota air monitoring, modeling or risk assessments to be of possible concern; however, risks from other metals may also be important. • Sources based on 2005 Minnesota emissions inventory.
				Power plants (biomass/fossil fuel)	● ■■□	↑↓		
				Industrial combustion	◒ ■□□	↔		

Human Health Impacts: Cancer continued

Stressor	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 air—semi-volatiles	◒ ■■□ localized	?	■□□	Burn barrels, fireplaces, outdoor boilers	● ■■■	↑↓	Acrylamide Dioxins/furans Naphthalene PAHs	• Pathway is inhalation. • Large portion of population exposed. • Health effects can occur at low concentrations. • Cancer type can vary with chemical. Risks from exposures to multiple chemicals are not well understood. • May be sensitive exposure times and endpoints (fetuses, children, adolescents, elderly). • The major exposure pathway is through food for dioxins/furans. • Pollutants listed have been shown in Minnesota air monitoring, modeling or risk assessments to be of possible concern; however, risks from other pollutants may also be important. • Sources based on 2005 Minnesota emissions inventory.
				Industrial combustion	◒ ■□□	↔		
				Off-road equipment	◒ ■□□	↔		
				Power plants (biomass/ fossil fuel)	◒ ■□□	↑↓		
				Other combustion	○ ■□□	?		
				Solvent utilization	○ ■■□	↓		
Toxic chemicals in air—volatile organic compounds	◒ ■■□ urban; localized	↓	■■□	Off-road equipment	● ■■□	↔	Acetaldehyde Benzene 1,3-Butadiene Carbon tetrachloride 1,2- Dibromoethane 1,4-Dichlorobenzene 1,2-Dichloroethane 1,3-Dichloropropene Ethyl benzene Ethylene oxide Formaldehyde Methyl chloride 1,1,2,2-Tetrachloroethane Tetrachloroethylene Trichloroethylene	• Pathway is inhalation. • Large portion of population exposed. A few chemicals may be approaching health benchmarks. • Cancers vary with chemical (e.g., benzene causes leukemia). Risks from exposures to multiple chemicals are not well understood. • May be sensitive exposure times and endpoints (fetuses, children, adolescents, elderly). • Pollutants listed have been shown in Minnesota air monitoring, modeling or risk assessments to be of possible concern; however, risks from other pollutants may also be important. • Exposure varies throughout the day with highest exposures in microenvironments such as roadways. • Sources based on 2005 Minnesota emissions inventory.
				On-road vehicles	● ■■□	↑↓		
				Residential combustion	◒ ■□□	↔		
				Solvent utilization	◒ ■■□	↓		
				Other combustion	○ ■□□	?		
				Waste disposal	○ ■□□	?		

Human Health Impacts: Cancer continued

Stressor	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	◒ ■□□ localized	↔	■□□	Burn barrels, fireplaces, outdoor boilers	● ■■■	↑↓	Dioxins/furans Metals Organochlorine pesticides PAHs PCBs	• Most pollutants of concern are classified as persistent bioaccumulative toxics, including dioxins, furans, PAHs and some metals. • Overall comparative contribution due to increasing toxicological evidence of food chain effects. Lab 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. With dioxins/furans, ingestion of animal products thought to be more important than ingestion of vegetables. • 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. • 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 (e.g., DDT).
				Industrial air emissions	◒ ■□□	↓		
				Land applic./ spray irrigation of wastewater	◒ ■■□	↔		
				Mining	◒ ■□□	↑		
				Pesticides	◒ ■■■	↓		
				Power plants (biomass/ fossil fuel)	◒ ■□□	↑↓		
				Waste disposal	◒ ■□□	↓		
				Waste incineration	◒ ■□□	↑↓		
				On-road vehicles/off road equipment	○ ■□□	↑↓		

Human Health Impacts: Cancer continued

Stressor	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
Endocrine-disrupting chemicals	○ ■□□ statewide	?	■□□	Paper mill effluent	● ■■□	?	Industrial-use compounds Natural and synthetic hormones Organochlorine compounds Organometallic compounds Pesticides and degradates Pharmaceutical and personal care products	• Tthere is little conclusive evidence at this time that links endocrine disruption to the development of cancer. However, continuing research on EDCs has shown cancer potential. Nevertheless, many chemicals considered to be EDCs have other toxic endpoints and/or modes of action that are strongly linked to development of cancer in human beings. • Endocrine-disrupting chemicals (EDCs) include a variety of chemicals that are present in the environment. • EDCs exert their effects through the endocrine system, which regulates many important functions in humans, fish and wildlife. • EDCs interfere with normal hormonal functions. • The 'Specific pollutants' are actually chemical categories that include many individual chemicals thought to be EDCs. Specific chemicals are not listed because of the large number of potential EDCs and because of the lack of scientific agreement about which chemicals are EDCs. • At this time, the only trend that can be stated with certainty is that more and more chemicals (often widely used chemicals) are being found to have endocrine-disrupting effects.
				Pesticides	● ■■□	?		
				Wastewater treatment plant effluent/ISTS	● ■■□	?		
				Backyard burning of trash	◒ ■□□	?		
				Feedlots	◒ □□□	?		
				Landfill leachate	◒ ■■□	?		
				Municipal waste incineration	◒ ■□□	?		
				Sewage sludge application	◒ □□□	?		
				Aquaculture	○ ■■□	?		

Human Health Impacts: Cancer continued

Stressor	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	○ ■■□ statewide	↑↓	■□□	Pesticides	◒ ■■□	↓	PAHs Metals Pesticides and degradates Volatile organic compounds (VOCs)	• 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. People using private water supplies may be at greater risk. • 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. • Many 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.
				Underground and above-ground storage tanks	◒ ■■■	↓		
				Unpermitted waste disposal	◒ ■■□	↓		
				Land-applied municipal and industrial byproducts	○ ■■□	↑		
				Municipal and industrial wastewater	○ ■■□	↔		
				Spills	○ ■■□	↔		
Toxic chemicals in soil	○ ■■□ localized	↑↓	■□□	Pesticides	● ■□□	↓	Dioxins/furans Metals PAHs PBDEs PCBs Legacy pesticides Volatile organic compounds (VOCs)	• 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. • Industrial air emissions impact soil through air deposition of pollutants. • Legacy pesticides (banned pesticides or pesticides used in the past) include Lindane, DDT, Dieldrin and arsenic-based products. • Much of this knowledge comes from testing at hazardous waste sites or sites being redeveloped. There is little data on toxic chemicals in background soils in old urban areas of the city, where many children may be exposed.
				Industrial air emissions	◒ ■□□	↔		
				Land-applied industrial and municipal byproducts	○ ■■□	↑		
				Spills	○ ■■□	↔		
				Unpermitted waste disposal	○ ■■□	↓		

B. Human Health Impacts: Noncancer Acute

Introduction

Exposure to high concentrations or levels of certain stressors for even a short period of time can result in serious injury. The noncancer acute impacts matrix focuses on these acute health effects including heart attacks, asthma attacks or other respiratory symptoms. These health impacts may result from high exposure to particles, ozone or other toxic chemicals in the air or water. MPCA has a role in regulating the emission of pollutants into the air and discharges into the water and assists in controlling conditions such as excessive noise and climate change.

Discussion

Even short (minutes, hours, days) exposures to high concentrations of chemicals or extreme conditions can result in serious and long-lasting health impacts. Some of these impacts may not show up until many years after the initial exposure. Noncancer acute impacts are an issue for all media—air, surface water, ground water and soils. People may have acute health impacts from exposure to chemicals by breathing, eating, drinking and skin contact and also by exposure to extreme conditions of heat, storms and noise. The factors considered in the comparison of stressors in the noncancer acute matrix included the estimated extent of exposure in the state as well as the severity of the health effects.

Fine particles in air (those with a diameter less than 2.5 microns) are the only stressor ranked high for noncancer acute impacts. Multiple studies have showed an association between fine particle exposure and a rise in heart attacks, acute bronchitis, asthma attacks, respiratory symptoms, and increased respiratory disease in children. Although concentrations of fine
particles in Minnesota are relatively low, the seriousness of the health effects along with the fact that most Minnesotans are exposed to ambient particles in their daily lives warrants a high level of concern.

Changes from 2003

There were several changes to the noncancer acute impacts matrix in the 2009 update.

- Particles in air were divided into three categories: fine (particles with a diameter less than 2.5 microns) coarse (particles with a diameter between 2.5 and 10 microns) and ultrafine (particles with a diameter less than 0.1 micron). New studies have added greatly to the knowledge of particles. It is better understood that small particles such as $PM_{2.5}$ have a greater health impact than larger particles. In addition, large and small particles have different sources. Ultrafine particles are emerging as a potentially serious concern that needs more study.

- Temperature increase/climate change was changed to greenhouse gases (climate change) to better reflect MPCA's role in tracking and mitigating emissions of greenhouse gases. The understanding of climate change has also grown since 2003 and early effects of a warming climate are being felt in Minnesota.
- High-level accidental releases of explosive/flammable materials were combined with releases of toxic chemicals to create a single stressor in this matrix. This was done since accidental releases of both categories are often regulated and tracked together.
- The stressor "toxic volatile organic chemicals in air" was changed to "toxics in air" to include chemicals such as arsenic and some acids which may have acute health effects.
- The stressor "odorous chemicals from biological processes" was changed to simply "odorous chemicals" to include chemicals from other sources besides biological processes which may pose odor issues.
- The stressor "toxic chemicals in water" was dropped in favor of "nutrient-related toxicity in water" since it was felt that the term was more descriptive of actual acute concerns.
- The stressor "other criteria pollutants in air" was dropped because monitoring data indicates that criteria pollutants other than ozone and particles are unlikely to result in acute health impacts at current ambient concentrations.

Future trends

Emissions and concentrations of fine and coarse particles in air and toxics in air have been decreasing in Minnesota's air over the last few years. (Note: ultrafine particles are not understood well enough to evaluate trends). This is due in large part to government's and society's recognition that these pollutants pose potential health concerns resulting in a concentrated effort to minimize the emission of these pollutants into the natural environment. Concentrations of these pollutants are expected to continue to decrease if current conditions persist.

Other stressors have remained flat or have mixed results with increases in some locations and decreases in others. For example, control of odorous chemicals from many industries has greatly improved; however, as industries such as large feedlots and ethanol plants have proliferated, odors are being introduced into areas previously unaffected.

Some serious stressors such as greenhouse gases continue to increase. The levels of carbon monoxide and other greenhouse gases in the atmosphere are rising, potentially leading to more intense climate effects. Society and government are struggling to develop a cohesive plan to address this issue effectively.

Human Health Impacts: Noncancer acute

Stressor	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—fine (diameter ≤ 2.5 μm)	● ■■□ statewide	↓	■■□	Agriculture	● ■■□	↔	Fine particles ($PM_{2.5}$ microns) Diesel particles	• Pathway is inhalation. • Large percent of population exposed. • Fine particles exposure is associated with a rise in heart attacks, acute bronchitis, asthma attacks, respiratory symptoms, and increased respiratory illness in children. • Chemical composition may be important. Toxicity may come from particles or attached chemicals. Unclear if particle mass or number of particles is more important. • Listed sources may not emit particles. Instead they may emit compounds which form particles downwind of the emission point (e.g., agricultural practices emit ammonia rather than particles). • Road dust is a major mass component of direct emissions of $PM_{2.5}$; however, it is expected to be a lesser component of total $PM_{2.5}$ and of lesser health concern.
				Off-road equipment	● ■■□	↑↓		
				On-road vehicles	● ■■□	↑↓		
				Power plants (biomass/fossil fuel)	● ■■□	↑↓		
				Industrial combustion	◒ ■□□	↔		
				Residential fuel combustion	◒ ■□□	↑		
				Road dust	○ ■□□	↔		
Greenhouse gases (climate change)	◒ ■■□ statewide	↑	■■■	Coal-fired power plants	● ■■■	↔	Carbon dioxide Methane Water vapor Nitrous oxide Fluorinated gases	• The stressor trend for greenhouse gases is measured globally and is increasing. Statewide sources, which are based on the Minnesota greenhouse gas inventory, are steady or decreasing. • Entire population may be affected. • Potential acute concerns include: increased levels of other toxic pollutants such as ozone; increased deaths, disease and injury due to heat waves, floods, storms, fires and droughts; respiratory effects of flooding (mold, physical hazards plus asbestos exposures); and increased disease due to vector migration. • Methane from feedlots and greenhouse gases (GHGs) from energy use in agricultural vehicles are included in agriculture. • Industrial sources of GHGs are mostly fossil fuel combustion. • Biomass burning is not currently in the Minnesota greenhouse gas inventory, but could contribute to greenhouse gases. • Sources are based on CO_2 and methane, but other GHGs may contribute significantly to climate change.
				On-road vehicles	● ■■■	↔		
				Agriculture	◒ ■□□	↔		
				Industry	◒ ■■■	↔		
				Permitted waste disposal	○ ■■□	↓		
				Residential fuel combustion	○ ■■■	↔		

Human Health Impacts: Noncancer acute continued

Stressor	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
Ground-level ozone	◒ ■■■ statewide	↔	■■■	Off-road equipment	● ■■□	↔	Nitrogen dioxide Nitric oxide Volatile organic compounds (VOCs)	• Pathway is inhalation. • Large percent of population exposed. • At elevated concentrations, ozone can irritate the respiratory system, reduce lung function, aggravate asthma, increase susceptibility to respiratory illnesses, cause permanent lung damage and potentially result in premature death. • Ozone is not directly emitted into the air; instead, it is created when nitrogen oxides and volatile organic compounds (VOCs) react in a hot, stagnant atmosphere. • Primarily a concern during the summer since sunlight and heat are needed for ozone formation. • Combustion releases both VOCs and nitrogen oxides. Solvent use is a major VOC source. Listed sources include only man-made VOCs; however, there are also many natural or biogenic sources of VOCs.
				On-road vehicles	● ■■■	↑↓		
				Power plants (biomass/fossil fuel)	● ■■■	↑↓		
				Residential combustion	◒ ■■□	↔		
				Solvent utilization	◒ ■■□	↓		
				Industrial combustion	○ ■■□	↔		
				Petroleum storage and transfer	○ ■■□	↔		
High-level accidental releases of flammable, explosive or toxic substances	◒ ■■■ localized	↔	■■■	On-road vehicles	● ■■■	↔	Chlorine Ammonia Volatile organic compounds (VOCs) Pesticides Acids/bases Phosphate Mercury	• Few people exposed but may be severe health effects. • Includes explosions, spills, accidental fires. • Mercury responses increasing due to increased public awareness. • Pathways are inhalation, skin contact. • Various health effects including respiratory impairment, chemical burns, central nervous system effects and death. Petroleum releases resulted in three fatalities in 2007. • 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 continued

Stressor	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
Nutrient-related toxicity in water	◒ ■■□ agricultural; localized	↑	■■□	Fertilizer use	● ■■■	↑↓	Nitrate Phosphorus	• Nutrient-related toxicity much better understood than in 2003. • Well-documented effects to infants from nitrate exposure. (methemoglobinemia); less certainty with algal toxins. • Phosphorus is a concern since it can lead to toxic algal blooms. • In general, fertilizer use per acre is down as more farmers are applying best management practices, but in some areas acres that were previously held as CRP parcels are coming under cultivation.
				Land-applied manure	◒ ■■□	⟷		
				Septic systems	◒ ■■■	↑↓		
				Feedlots	○ ■■□	⟷		
Odorous chemicals	◒ ■■□ localized	↓↑	■□□	Feedlots	● ■■■	⟷	Hydrogen sulfide Ammonia Volatile organic compounds (VOCs) Alcohols	• Health concerns include nausea, headaches and respiratory irritation. • Limited population exposed, but an important concern from a hot-spot perspective. • Pathway is inhalation. • Pollutants generally have low persistence. • Difficult to measure and track trends.
				Agriculture	◒ ■□□	⟷		
				Treatment and settling ponds	◒ ■□□	⟷		
				Ethanol production	○ ■□□	↑		

Human Health Impacts: Noncancer acute continued

Stressor	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—coarse (diameter >2.5 μm ≤ 10 μm)	◒ ■■□ statewide	↓	■□□	Agricultural	● ■■■	↔		• Pathway is inhalation. • Large percent of population exposed. • Exposure to coarse particles is associated with the aggravation of respiratory conditions such as asthma. It has also been linked to cardiovascular health effects, but many studies indicate a stronger association with $PM_{2.5}$. • Studies indicate that smaller particles such as $PM_{2.5}$ and potentially ultrafine particles are of greater health concern than coarse particles because they travel deeper into the lung and can enter the blood stream. • Sources based on PM_{10}. Since the emissions are based on mass, PM_{10} is an adequate surrogate for $PM_{2.5\text{-}10}$ since larger particles weigh significantly more than smaller particles. Sources are based on the 2005 Minnesota emissions inventory. • Road dust is a major mass component of direct emissions of PM_{10}; however, it may be less of a health concern than combustion sources.
				Road dust	● ■■■	↔		
				Construction	◒ ■■□	↔		
				Residential fuel combustion	◒ ■■□	↔		
				Industrial combustion	○ ■■□	↔		
				On and off-road vehicles	○ ■■□	↑↓		
				Power plants (biomass/fossil fuels)	○ ■■□	↑↓		
Particles in air—ultrafine (diameter < .1 μm)	◒ ■■□ localized	?	■□□	Diesel vehicles	● ■■□	↑↓		• Pathway is inhalation. • Large percent of population exposed. • Ultrafine particles are particles with a diameter of less than 0.1 microns. • Although the mass of ultrafines is small, there are lots of these particles, especially near sources. They are able to pass into the blood stream quite effectively compared to larger particles, so they can have effects on other organs besides the lungs. • The health effects of ultrafines are still uncertain and further study is needed. • Ultrafines are numerous near combustion sources, but tend to combine quickly into larger particles.
				Gasoline vehicles	● ■■□	↔		
				Stationary source fuel combustion	● ■□□	↔		
				Commercial food preparation	◒ ■□□	?		
				Other combustion	○ ■□□	?		

Human Health Impacts: Noncancer acute continued

Stressor	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
Pathogens in water	◒ ■■□ agricultural; localized	↔	■□□	Feedlots, including pastures	● ■■□	↔	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. • Streams are monitored more frequently than lakes. • New threats include cryptosporidium (drinking water) and antibiotic resistance. • Relative importance of sources can differ in high flow vs. low flow conditions.
				Land-applied manure and septage	● ■■□	↔		
				Septic systems	◒ ■■□	↔		
				Municipal and industrial storm water and wastewater	○ ■■■	↔		
				Wildlife	○ ■□□	↔		
Noise	○ ■■□ urban; localized	↓↑	■□□	Aircraft	● ■■■	↔		• 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 the number of people exposed. • Only major sources were considered. • Does not consider occupational exposure.
				On-road vehicles	● ■■■	↑		
				Industry	◒ ■■■	↔		
				Locomotives	◒ ■■■	↔		
				Off-road equipment	◒ ■■■	↑		

Human Health Impacts: Noncancer acute continued

Stressor	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
Toxics in air	○ ■■□ urban; localized	↓	■■□	Industrial air emissions	● ■□□	↔	Acetic acid Acrolein Arsenic Formaldehyde Hydrogen chloride Hydrogen fluoride Nitrogen dioxide Sulfuric acid	• Pathway is inhalation. • It is unlikely that ambient levels would cause severe acute health effects in humans, but there may be increased concern for sensitive individuals. • Possible health effects range from eye irritation to reproductive/developmental toxicity. Acute risks from exposures to multiple chemicals are not well understood. • Pollutants listed have been shown in Minnesota air monitoring or risk assessments to be of possible concern; however, risks from other pollutants may also be important. • Highest exposures likely to occur in microenvironments (e.g., gas stations or roadways). • Sources based on 2005 Minnesota emissions inventory.
				Off-road equipment	● ■■□	↔		
				On-road vehicles	● ■■□	↑↓		
				Metal production	◒ ■□□	↔		
				Power plants (biomass/fossil fuel)	◒ ■□□	↑↓		
				Other combustion	○ ■□□	?		
Toxic chemicals in soil	○ ■□□ localized	↓↑	■□□	Pesticides	◒ ■■□	↓	Cyanide Dioxins/furans PCBs Lead Legacy pesticides	• Likelihood of exposure at levels of concern is low. • Pathways are skin contact, ingestion and inhalation. • Variety of health effects (e.g., acute exposures of PCBs and dioxin can cause dermal lesions and chloracne) are possible. 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. • Legacy pesticides (banned pesticides or pesticides used in the past) include Lindane, DDT, Dieldrin and arsenic-based products.
				Unpermitted waste disposal	◒ ■■□	↓		
				Burn barrels, fire-places, wood-fired boilers	○ ■□□	↑		
				Land-applied industrial and municipal by-products	○ ■■□	↑		
				Lead paint and leaded gasoline	○ ■■□	↓		
				Road salt (i.e., cyanide in yellow cake)	○ ■■□	↑		

C. Human Health Impacts: Noncancer Chronic

Introduction

Ambient levels of some stressors in Minnesota's air, water, food and environment may seem quite low. However, exposure to even low levels of a stressor over many years can result in human health impacts. Examples of chronic health effects include long-term respiratory impairment, heart and lung disease, developmental and reproductive effects, immunological impairment, and hearing loss. MPCA has a role in regulating the emission of pollutants into the air and discharges into water and assists in controlling conditions such as noise and climate change, which can increase the average daily heat index. These conditions may damage human health over the long term.

Discussion

Years of exposure to low levels of chemicals or conditions can result in serious and long-lasting health impacts. Since effects often do not occur until many years after exposure to a stressor, it is difficult to determine definitively how closely linked ambient pollution is with health effects. Noncancer chronic impacts are an issue for all media—air, surface water, ground water and soils. People may have chronic health impacts from exposure to chemicals by breathing, eating, drinking and skin contact and also by exposure to rising temperatures, storms and noise. The factors considered in the comparison of stressors in the noncancer chronic matrix included the estimated extent of exposure in the state as well as the severity of the health effects.

Fine particles in air (those with a diameter less than 2.5 microns) are the only stressor ranked high for noncancer chronic impacts. Many studies have showed an association between fine particle exposure and a rise in heart attacks, chronic bronchitis, asthma attacks, respiratory symptoms, and reduced lung function growth and increased respiratory illness in children. Although concentrations of fine particles in Minnesota are relatively low, the seriousness of the health effects along with the fact that most Minnesotans are exposed to ambient particles in their daily lives warrants a high level of concern.

Changes from 2003

There were several changes to the noncancer chronic impacts matrix in the 2009 update.

- Particles in air were broken up into three categories: fine (particles with a diameter less than 2.5 microns), coarse (particles with a diameter between 2.5 and 10 microns) and ultrafine (particles with a diameter less than 0.1 microns). New studies have added greatly to the knowledge of particles since 2003. It is now clear that small particles such as $PM_{2.5}$ have a greater health impact than larger particles. In addition, large and small particles

- have different sources. Ultrafine particles are emerging as a potentially serious concern that needs more study.
- Endocrine-disrupting chemicals (EDCs) were added as a stressor. While EDCs are an emerging concern and little is known about their impact to human health at ambient concentrations, they are widely present in the environment and pose enough concern to warrant addition as a stressor.
- Temperature increase/climate change was changed to greenhouse gases (climate change) to better reflect MPCA's role in tracking and mitigating emissions of greenhouse gases. The understanding of climate change has also grown, and in 2009, early effects of a warming climate are being felt in Minnesota.
- Toxic chemicals in air (metals) and toxic chemicals in air (semi-volatiles) were added as stressors in addition to volatile chemicals since they can contribute to noncancer chronic impacts from breathing the air and have different trends, monitoring and sources.
- The stressor "excess UV radiation from stratospheric ozone depletion" was dropped because the main concern is increased skin cancers. While there are concerns regarding immunological effects and eye damage, it was felt that the potential increase due to UV radiation did not warrant inclusion in the matrix.

Future trends

Emissions and concentrations of fine and coarse particles in air, other criteria pollutants and toxics in air have been decreasing in Minnesota's air over the last few years. This is due in large
part to government's and society's recognition that these pollutants pose potential health concerns and a concentrated effort to minimize the emission of these pollutants into the natural environment. Concentrations of these pollutants are expected to continue to decrease if current conditions persist.

Other stressors have remained flat or have mixed results with increases in some locations and decreases in others. For example, control of odorous chemicals from many industries has greatly improved; however, industries such as large feedlots and ethanol plants have proliferated, introducing odors into areas previously unaffected.

Trends in some emerging stressors such as endocrine disrupters and ultrafine particles cannot currently be evaluated due to lack of information.

Some serious stressors such as greenhouse gases continue to increase. The levels of carbon dioxide and other greenhouse gases in the atmosphere are rising, potentially leading to more intense climate effects. Society and government are struggling to develop a cohesive plan to address this issue effectively.

Human Health Impacts: Noncancer chronic

Stressor	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—fine (diameter ≤ 2.5μm)	● ■■■ statewide	↓	■■□	Agriculture	● ■■□	↔	Fine particles ($PM_{2.5}$) Diesel particles	• Pathway is inhalation. • Large percent of population exposed. • Fine particles exposure is associated with a rise in heart attacks, chronic bronchitis, asthma attacks, respiratory symptoms, and reduced lung function growth and increased respiratory illness in children. • Chemical composition may be important. Toxicity may come from particles or attached chemicals. Unclear if particle mass or number of particles is more important. • Listed sources may not emit particles. Instead they may emit compounds which form particles downwind of the emission point (e.g., agricultural practices emit ammonia rather than particles). • Road dust is a major mass component of direct emissions of $PM_{2.5}$; however, it is expected to be a lesser component of total $PM_{2.5}$ and of lesser health concern.
				Off-road equipment	● ■■□	↑↓		
				On-road vehicles	● ■■□	↑↓		
				Power plants (biomass/fossil fuel)	● ■■□	↑↓		
				Industrial combustion	◒ ■□□	↔		
				Residential Combustion	◒ ■□□	↑		
				Road dust	○ ■□□	↔		
Endocrine-disrupting chemicals	◒ ■□□ statewide	?	■□□	Paper mill effluent	● ■■□	?	Industrial-use compounds Natural and synthetic hormones Organochlorine compounds Organometallic compounds Pesticides Pharmaceutical and personal care products	• Endocrine-disrupting chemicals (EDCs) include a variety of compounds that are found virtually everywhere in the environment. • EDCs exert their effects through the endocrine system that regulates many important functions in humans, fish and wildlife. • Widespread exposure in air, food and water. • EDCs are an emerging issue and little is known about the effects of exposure on animals in natural systems. • Human impacts at low levels are uncertain. • Feedlots are not well studied as source of EDCs. • The specific pollutants listed are general categories of chemicals. Not all chemicals within the categories are EDCs.
				Pesticides	● ■■□	?		
				Wastewater treatment plant effluent/ISTS	● ■■□	?		
				Feedlots	◒ □□□	?		
				Landfill leachate	◒ ■■□	?		
				Municipal waste incineration and backyard burning	◒ ■□□	?		
				Sewage sludge application	◒ □□□	?		
				Aquaculture	○ ■■□	?		

Human Health Impacts: Noncancer chronic continued

Stressor	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
Greenhouse gases (climate change)	◒ ■■□ statewide	↑	■■■	Coal-fired power plants	● ■■■	↔	Carbon dioxide Methane Water vapor Nitrous oxide Fluorinated gases	• The stressor trend for greenhouse gases (GHGs), which is measured globally, is increasing. Statewide sources, which are based on the Minnesota greenhouse gas inventory, are steady or decreasing. • Entire population may be affected. • Long-term health effects not well understood, but potential concerns include: health effects from food and water shortages, increased levels of other toxic pollutants such as ozone, increased spatial distribution of infectious disease vectors and increased deaths, disease and injury due to heat waves, floods, storms, fires and droughts. • Most chronic health effects are potential as opposed to current. • Methane from feedlots and GHGs from energy use in agricultural vehicles are included in agriculture. • Industrial sources are mostly fossil fuel combustion. • Biomass burning is not currently in the Minnesota greenhouse gas inventory, but could be an important source of GHGs. • Sources are based on CO_2 and methane, but other GHGs may contribute significantly to climate change.
				On-road vehicles	● ■■■	↔		
				Agriculture	◒ ■□□	↔		
				Industry	◒ ■■■	↔		
				Permitted waste disposal	○ ■■□	↓		
				Residential fuel combustion	○ ■■■	↔		
Ground-level ozone	◒ ■■■ statewide	↔	■■■	Off-road equipment	● ■■□	↔	Nitrogen dioxide Nitric oxide Volatile organic compounds (VOCs)	• Pathway is inhalation. • Large percent of population exposed. • At elevated concentrations, ozone can irritate the respiratory system, reduce lung function, aggravate asthma, increase susceptibility to respiratory illnesses, cause permanent lung damage and potentially result in premature death. • Ozone is not directly emitted into the air; instead, it is created when nitrogen oxides and VOCs react in a hot, stagnant atmosphere. • Primarily a concern during the summer since sunlight and heat are needed for ozone formation. • Combustion releases both VOCs and nitrogen oxides. Solvent use is a major VOC source. Listed sources include only man-made sources of VOCs; however, there are also many natural or biogenic sources of VOCs.
				On-road vehicles	● ■■■	↑↓		
				Power plants (biomass/fossil fuel)	● ■■■	↑↓		
				Industrial combustion	◒ ■■□	↔		
				Residential fuel combustion	◒ ■■□	↑		
				Solvent utilization	◒ ■■□	↓		
				Petroleum storage and transfer	○ ■■□	↔		

Human Health Impacts: Noncancer chronic continued

Stressor	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
Odorous chemicals	◒ ■■□ localized	↓↑	■□□	Feedlots	● ■□□	⟷	Hydrogen sulfide Ammonia Volatile organic compounds (VOCs) Alcohols Algal blooms	• Source contribution roughly corresponds to number of complaints received by MPCA. • Perception of odors varies greatly among individuals; most common complaints include headaches and nausea. • Long-term exposure to odors may cause increased levels of adrenaline, which can be harmful. • Measurement is resource intensive and may include odor panels as well as legal (performance) standards. • Ethanol plants have shown recent increases in productivity with better odor control.
				Agriculture	◒ ■□□	⟷		
				Treatment and settling ponds	◒ ■□□	⟷		
				Ethanol production	○ ■□□	↑		
Particles in air—coarse (diameter > 2.5μm ≤10μm)	◒ ■■□ statewide	↓	■□□	Agriculture	● ■■■	⟷		• Pathway is inhalation. • Large percent of population exposed. • Emissions are based on mass rather than risk. Sources are based on PM_{10}, which is an adequate surrogate for $PM_{2.5-10}$ since larger particles weigh significantly more than smaller particles. • Exposure to coarse particles is associated with the aggravation of respiratory conditions such as asthma. It has also been linked to cardiovascular health effects, but many studies indicate a stronger association with $PM_{2.5}$. • Studies indicate that smaller particles such as $PM_{2.5}$ and potentially ultrafine particles are of greater health concern than coarse particles because they travel deeper into the lung and can enter the blood stream. • Road dust is a major mass component of direct emissions of $PM_{2.5}$; however, it may be less of a health concern than combustion sources. • Sources based on the 2005 Minnesota emissions inventory.
				Road dust	● ■■■	⟷		
				Construction	◒ ■■□	⟷		
				Residential combustion	◒ ■■□	↑		
				Industrial combustion	○ ■■□	⟷		
				On and off-road vehicles	○ ■■□	↑↓		
				Power plants (biomass/fossil fuels)	○ ■■□	↑↓		

Human Health Impacts: Noncancer chronic continued

Stressor	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— ultrafine (diameter <.1 μm)	◒ ■■□ localized	?	■□□	Diesel vehicles	● ■■□	↑↓		• Pathway is inhalation. • Large percent of population exposed. • Ultrafine particles are particles with a diameter of less than 0.1 microns. • Although the mass of ultrafines is small, there are lots of these particles, especially near sources. They are able to pass into the blood stream quite effectively compared to larger particles, so they can have effects on other organs besides the lungs. • The health effects of ultrafines are still uncertain and further study is needed. • Ultrafines are numerous near combustion sources, but tend to combine quickly into larger particles.
				Gasoline vehicles	● ■■□	↔		
				Stationary source fuel combustion	● ■□□	↔		
				Commercial food preparation	◒ ■□□	?		
				Other combustion	○ ■□□	?		
Toxic chemicals in food	◒ ■■□ statewide	↔	■□□	Burn barrels, outdoor boilers	● ■■■	↑↓	Dioxins/furans Mercury Legacy pesticides PAHs PCBs	• Most pollutants of concern are classified as persistent bioaccumulative toxics, including dioxins, furans, PAHs and some metals. • Overall comparative contribution due to increasing toxicological evidence of food chain effects. Lab tests indicate that effects of high doses of these chemicals may be very serious. • Pathway is ingestion. For dioxins and furans, ingestion of animal products (including fish) is thought to be more important than ingestion of plant products. • The legacy pesticides of greatest concern are chlorinated insecticides because they accumulate in the food chain. Their use has decreased and many have been banned in the United States (e.g., DDT). • 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.
				Industrial air emissions	◒ ■□□	↓		
				Land application/ spray irrigation	◒ ■■□	↔		
				Mining	◒ ■□□	↑		
				Pesticides	◒ ■■■	↓		
				Power plants (biomass/ fossil fuel)	◒ ■□□	↑↓		
				Waste disposal	◒ ■□□	↓		
				Waste incineration	◒ ■□□	↑↓		
				On-road /off road vehicles & equipment	○ ■□□	↑↓		

Human Health Impacts: Noncancer chronic continued

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
Toxics chemicals in water	◒ ■■□ statewide	↓↑	■□□	Pesticides	● ■■□	↓	Metals PAHs PFCs Pesticides and degradates Volatile organic compounds (VOCs)	• Relatively small number of people exposed to pollutants at levels of concern. Most Minnesotans use public water supplies, which are routinely tested for volatile organic compounds (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 (e.g, prescription drugs and over-the-counter drugs). Some drugs may affect hormone levels. • Some pollutants of concern are persistent. • Land application of waste water treatment plant biosolids shows no distinct trend, but land application of industrial and municipal byproducts (such as lime from water softening, wood ash, and wastes from food and beverage industries) is clearly increasing.
				Un regulated waste disposal	● ■■□	↓		
				Land-applied municipal and industrial byproducts	○ ■■□	↑		
				Municipal and industrial wastewater	○ ■■□	↔		
				Septic systems	○ ■■□	↔		
				Spills	○ ■□□	↔		
				Underground and above ground storage tanks	○ ■■□	↓		
Toxic chemicals in air—metals	◒ ■■□ statewide	↓	■■□	Metal production	● ■■□	↔	Chromium VI Lead Manganese Nickel	• Pathway is inhalation. • Large portion of population exposed. A few chemicals may be approaching health benchmarks. • Health effects can occur at low metal concentrations. • Possible health effects include respiratory and cardiovascular problems, neurological impairment and reproductive/developmental toxicity. Chronic risks from exposures to multiple metals are not well understood. • Pollutants listed have been shown in Minnesota air monitoring, modeling or risk assessments to be of possible concern; however, risks from other pollutants may also be important. • Sources based on 2005 Minnesota emissions inventory.
				Power plants (biomass/fossil fuel)	● ■■□	↑↓		
				Aircraft	◒ ■■□	↔		
				Industrial combustion	◒ ■□□	↔		
				Mineral products	◒ ■□□	?		
				Pulp and paper	○ ■□□	↔		

Human Health Impacts: Noncancer chronic continued

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 air—volatile organic compounds	◒ ■■□ urban; localized	↓	■■□	Off-road equipment	● ■■□	↔	Acetaldehyde Acrolein Chlorine Formaldehyde	• Pathway is inhalation. • Large portion of population exposed. A few chemicals may be approaching health benchmarks. • Possible health effects range from minor irritations to chronic respiratory problems and reproductive/developmental toxicity. Chronic risks from exposures to multiple chemicals are not well understood. • Pollutants listed have been shown in Minnesota air monitoring, modeling or risk assessments to be of possible concern; however, risks from other pollutants may also be important. • Exposure varies throughout the day with highest exposures in microenvironments such as roadways. • Sources based on 2005 Minnesota emissions inventory.
				On-road vehicles	● ■■□	↑↓		
				Other combustion	◒ ■□□	?		
				Waste disposal	◒ ■□□	?		
				Industrial combustion	○ ■□□	↔		
Noise	○ ■■□ urban; localized	↓↑	■□□	Aircraft	● ■■■	↔		• Many people exposed; most effects are minor. • Endpoint is hearing impairment and physical and psychological stress. • Contribution from sources is based on the number of people exposed. • Noise, even within standards, can be disruptive (“disruption of quietude”). • Wind turbines are a source of general concern; noise levels must be demonstrated to be within standards for siting, and are not likely to exceed standards. • Only major sources are considered. • Does not consider occupational exposure.
				On-road vehicles	● ■■■	↑		
				Industry	◒ ■■■	↔		
				Locomotives	◒ ■■■	↔		
				Off-road equipment	◒ ■■■	↑		

Human Health Impacts: Noncancer chronic continued

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
Other criteria pollutants in air	○ ■■□ urban	↓	■■□	On-road vehicles	● ■■■	↑↓	Carbon monoxide Nitrogen dioxide Nitric oxide Sulfur dioxide	• Pathway is inhalation. • Concentrations in Minnesota are well below ambient air standards. • Health concerns include nervous system effects, respiratory irritation and cardiopulmonary problems. Difficult for studies to differentiate between effects from particles and other criteria pollutant effects. • Only direct health effects are considered. Effects as precursors to fine particles or ozone are not included. • Effects from carbon monoxide might occur in microenvironments (e.g., inside automobiles). • Sources based on 2005 Minnesota emissions inventory.
				Power plants (biomass/fossil fuel)	● ■■■	↓		
				Off-road equipment	◒ ■■□	↑↓		
				Industrial combustion	◒ ■■□	⟷		
				Residential fuel combustion	○ ■■□	↑		
Toxic chemicals in air—semi-volatiles	○ ■■□ localized	↓↑	■□□	Burn barrels, fireplaces, outdoor boilers	● ■■■	↑↓	Dioxin/furans Methylene diphenyl diisocyanate 2,4 Toluene diisocyanate	• Pathway is inhalation. • Large portion of population exposed to dioxins/furans. Dioxin/furan exposure can affect the liver, reproduction, development, endocrine, respiratory, and blood systems. Health effects can occur at low concentrations. The major exposure pathway is through food. • Isocyanates affect the respiratory system. Sensitized individuals can have health effects at very low concentrations. • Pollutants listed have been shown in Minnesota air monitoring, modeling or risk assessments to be of possible concern; however, risks from other pollutants may also be important. • Sources based on 2005 Minnesota emissions inventory.
				Industrial combustion	◒ ■□□	⟷		
				Power plants (biomass/ fossil fuel)	◒ ■□□	↓		
				Solvent utilization	○ ■■□	↓		

Human Health Impacts: Noncancer chronic continued

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 soil	○ ■■□ localized	↓↑	■□□	Industrial air emissions	◒ ■■□	↓	Metals Pesticides and degradates PAHs PCBs PFCs Volatile organic compounds (VOCs)	• Likelihood of exposure at levels of concern is low. • Pathways are skin contact, inhalation 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. • Industrial air emissions impact soil through air deposition of pollutants. • Volatile pollutants can also cause impacts via volatilization and vapor intrusion, with exposure through inhalation.
				Lead paint and leaded gasoline	◒ ■■□	↓		
				Pesticide use	◒ ■■□	↓		
				Burn barrels, fire places, outdoor boilers	○ ■□□	↑		
				Land-applied industrial and municipal byproducts	○ ■■□	↑		
				Spills	○ ■■□	↔		
				Unpermitted waste disposal	○ ■■□	↓		

D. Ecosystem Impacts: Aquatic Organisms

Introduction

Most public opinion-gathering efforts rank water quality-related issues near the top of Minnesotans' environmental concerns. Indeed, the MPCA was originally formed as a water quality agency, and the subsequent years have seen significant achievements in addressing a large number of water quality concerns. Nevertheless, Minnesota's impaired waters inventory currently shows 2,575 impairments of various types and from various pollutants on more than 300 rivers and 1,000 lakes. Of the 14 percent of streams and 18 percent of lakes that have thus far been assessed, roughly 40 percent do not meet at least one of their various protective water quality standards. More than 90 percent of these impairments are for harm to aquatic organisms.

Discussion

The stressors most highly ranked by panel members are habitat/hydrologic modification and transported sediment. While the first is not really a "pollutant," and is sometimes seen as outside the MPCA's usual responsibilities and the second is almost entirely a nonpoint source pollutant, the two are closely related. Both are the result of widespread land-use practices that can be difficult to deal with, if not technically, at least from regulatory, economic, social and political standpoints.

Likewise, the other most important stressors are for the most part either non-traditional water pollutants such as endocrine - disrupting chemicals, greenhouse gases, invasive species, toxic organics and metals or largely the result of nonpoint sources, such as nitrogen, phosphorus, and biochemical oxygen demand (BOD). While large improvements have been made over a number of decades in dealing with municipal and industrial wastewater discharges, programs addressing newer, exotic chemicals and diffuse nonpoint sources are more recent and have not yet achieved the same kind of general, statewide results.

Changes from 2003

The most obvious changes are the addition of endocrine-disrupting chemicals and nanoparticles as stressors. Both are growing and potentially critical issues, yet relatively little is known about their ambient levels in Minnesota waters or the extent of their actual effects on the aquatic communities.

Likewise, invasive species, which were not included in 2003 as being outside the agency's purview, are now present because of the MPCA's involvement in the Great Lakes ballast water issue as well as increased recognition of their widespread importance.

Finally, as mentioned elsewhere, there is now much more agreement in the scientific community regarding climate change, as well as increased public recognition of the problem.

Future trends

As technology and environmental programs, both regulatory and non-regulatory, continue to improve, advances will be made in controlling many of the pollutants affecting aquatic plants and animals. The same technology, however, also continues to introduce new potential pollutants, the effects of which are often found only after they are in use and introduced into the environment.

Further, many of the key aquatic stressors are the result of development and land-use practices. As more houses, roads, and commercial infrastructure are built in urban areas, the developed land yields increased runoff carrying a variety of pollutants. As more agricultural land is brought into production and as lakeshores in rural Minnesota continue to experience rapid development, runoff and pollutants are likewise increased and habitat is altered or lost. As population continues to increase, these pressures on the aquatic environment are likewise almost certain to increase.

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 trends	Specific pollutants	Rationale/Comments
Habitat modification and loss/hydrologic modification	● ■■■ statewide	↑	■■□	Agriculture	● ■■■	↑		• Perhaps the most widespread and diverse aquatic stressor: includes tile drainage, stream straightening and channelization, loss of riparian vegetation and cover, migration barriers such as poorly designed culverts and low head dams, changes in hydrology such as increased variation in flow because of increased runoff, filling of wetlands, increases in water temperature, etc. • Widespread in the state and an increasing problem as population grows and development continues. • 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 diffuse and incomplete regulatory controls.
				Drainage and channelization	● ■■■	↑		
				Urban/suburban/ lake-shore development	● ■■■	↑		
				Dredging and filling	◒ ■■■	↔		
				Power plants (thermal discharges)	○ ■■■	↓		
Transported sediment	● ■■■ statewide	↓↑	■■□	Agricultural runoff	● ■■■	↔		• Closely linked to habitat and hydrologic modification. • In addition to the effects of transported sediment itself, sediment can also carry adsorbed nutrients, pesticides, other organics, metals, and bacteria. • Transported sediment is almost entirely nonpoint in origin, and the increased use of BMPs, particularly with construction and urban stormwater, has led to significant reductions in some areas. These improvements, however, are being offset by increased development and agricultural pressures as well as extreme storm events linked to climate change.
				Channel erosion	● ■■□	↑		
				Construction	● ■■□	↔		
				Urban runoff	◒ ■■□	↑		
				Municipal and industrial wastewater	○ ■■■	↔		

Ecosystem Impacts: Aquatic organisms continued

Stressor	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
Endocrine-disrupting chemicals	◒ ■□□ statewide with dispersed hot spots	?	■□□	Paper mill effluent	● ■■□	?	Industrial-use compounds Natural and synthetic hormones Organochlorine compounds Organometallic compounds Pesticides and degradates Pharmaceutical and personal care products	• Endocrine-disrupting chemicals (EDCs) include a variety of chemicals that are present in the environment. • EDCs exert their effects through the endocrine system, which regulates many important functions in humans, fish and wildlife. • EDCs interfere with normal hormonal functions. The adverse effects of EDCs have been demonstrated by extensive laboratory and field research in humans, fish and wildlife. • The "specific pollutants" are actually chemical categories that include many individual chemicals thought to be EDCs. Specific chemicals are not listed because of the large number of potential EDCs and because of the lack of scientific agreement about which chemicals are EDCs. • At this time, the only trend that can be stated with certainty is that more and more chemicals (often widely used chemicals) are being found to have endocrine-disrupting effects.
				Pesticides	● ■■□	?		
				Wastewater treatment plant effluent/ISTS	● ■■□	?		
				Feedlots	◒ □□□	?		
				Land-applied biosolids	◒ □□□	?		
				Landfill leachate	◒ ■■□	?		
				Municipal waste incineration and resid. burning	◒ ■□□	?		
				Aquaculture	○ ■■□	?		
Greenhouse gases (climate change)	◒ ■■□ statewide	↑	■■■	Coal-fired power plants	● ■■■	↔	Carbon dioxide Methane Water vapor Nitrous oxide Fluorinated gases	• The stressor trend for greenhouse gases (GHGs), is measured globally and is increasing. Statewide sources, which are based on the Minnesota GHG inventory, are steady or decreasing. • Temperature is a major environmental factor for aquatic organisms. The most marked effects in Minnesota will be on cold-water streams and organisms, but even for other waters, temperature increases can result in changed species composition. • Methane from feedlots and GHSs from energy use in agricultural vehicles are included in agriculture. • Industrial sources of GHGs are mostly fossil-fuel combustion. • Biomass burning is not currently in the inventory. • Sources are based on CO_2 and methane, but other GHGs may contribute significantly to climate change.
				On-road vehicles	● ■■■	↔		
				Agriculture	◒ ■□□	↔		
				Industry	◒ ■■■	↔		
				Permitted waste disposal	○ ■■□	↓		
				Residential fuel combustion	○ ■■■	↔		

Ecosystem Impacts: Aquatic organisms continued

Stressor	Overall comparative contribution	Stressor trend	Adequacy of ambient monitoring	Source	Comparative contribution of sources/ Confidence level	Source trends	Specific pollutants	Rationale/Comments
Invasive species	◒ ■■□ statewide	↑	■□□	Ballast water	● ■■■	↔	Great Lakes invasive species include the zebra mussel, Eurasian ruffe, round goby, sea lamprey, spiny waterflea, New Zealand mudsnail. Common invasive aquatic plants include curly leaf pondweed, Eurasian watermilfoil, purple loosestrife, reed canary grass and yellow iris.	• Invasive species are any non-native species that cause environmental, economic or human health concerns. They are the major cause of biological diversity loss throughout the world. • Invasive species may displace native species, and can severely alter habitat, thus affecting species beyond those they directly displace. • Invasive species can also cause problems for those who use water resources for recreational and industrial uses. • Of the more than 180 different invasive species already in the Great Lakes, 55-70% entered through ballast water released from ships.
				Transport by recreational watercraft	● ■■■	↔		
				Commerce	◒ ■■■	↑		
				Transport by wind and wildlife	◒ ■■■	↔		
Nitrogen	◒ ■■□ agricultural; developed areas	↑	■■□	Agricultural runoff	● ■■■	↑		• Nitrogen as nitrate is the only common water pollutant to show an increasing trend across the state. Nitrate 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. • While a great deal has yet to be learned about nitrogen cycling and its relation to eutrophication, recent studies suggest that it can be more important as a limiting nutrient than previously thought for at least some aquatic systems, particularly “drier end” wetlands.
				Atmospheric deposition	◒ ■■□	↑		
				Feedlots	◒ ■■□	↔		
				Municipal and industrial wastewater	◒ ■■■	↔		
				Urban runoff	◒ ■□□	↑		
				Septic systems	○ ■■□	↔		

Ecosystem Impacts: Aquatic organisms continued

Stressor	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
Oxygen-demanding pollutants	◒ ■■□ agricultural; developed areas	↓	■■□	Feedlots	● ■■□	↔	Organic matter	• At one time perhaps the foremost water quality problem (and a primary reason the MPCA was formed), biochemical oxygen demand (BOD) levels have decreased at almost 90% of monitored sites over the past 30 years, reflecting point source controls. Remaining problems are largely nonpoint in origin.
				Agricultural runoff	◒ ■■□	↔		
				Municipal and industrial wastewater	◒ ■■■	↓		
				Urban runoff	◒ ■■□	↑		
				Septic systems	○ ■■□	↔		
				Spills	○ ■■■	↔		
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 300 lakes are on the impaired waters inventory 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 the result of increased agricultural pressures.
				Atmospheric deposition	◒ ■■□	↔		
				Channel erosion	◒ ■■□	↑		
				Feedlots	◒ ■■□	↔		
				Municipal and industrial wastewater	◒ ■■■	↓		
				Urban runoff	◒ ■■□	↑		
				Septic systems	○ ■■□	↔		

Ecosystem Impacts: Aquatic organisms continued

Stressor	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 organic chemicals	◒ ■□□ statewide with dispersed hot spots	↓↑	■□□	Agricultural runoff	● ■■□	↔	Dioxins/furans PAHs Pesticides and degradates including legacy pesticides PCBs PBBs Hexachloro-benzene Octachloro-styrene Polychlorinated naphthalenes Petroleum products	• A variety of toxic effects may occur such as acute poisoning, immune suppression, tumor growth and reproductive failure. • Studies show that toxic effects can occur even at low concentrations of single chemicals, and cumulative effects are likely with mixtures of chemicals. • Includes a 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. • Many of the chemicals can be both persistent and bioaccumulative in fish and fish-eating wildlife. • Area source combustion and industry sources are primarily through air deposition.
				Area source combustion	● ■□□	↔		
				Municipal and industrial wastewater	● ■■□	↔		
				Urban runoff	● ■□□	↑		
				Industry	◒ ■□□	↔		
				Spills	○ ■■□	↔		
Toxic metals	◒ ■■□ statewide with dispersed hot spots	↔	■□□	Coal-fired power plants	● ■■■	↔	Mercury Lead Cadmium Chromium Zinc Copper	• 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. • Mercury levels have been found to be relatively high in certain species of fish in certain Minnesota waters, and in turn, loons. Loon populations, however, are considered stable. • With the exception of metals entering water through air deposition (primarily mercury), problems are generally localized and generally urban. • Contributions listed from power plants, waste incineration, and industry are primarily through air deposition.
				Urban runoff	● ■■□	↑		
				Municipal and industrial wastewater	◒ ■■□	↔		
				Waste incineration	◒ ■■■	↓		
				Industry	○ ■□□	↔		
				Mining	○ ■■□	↔		

Ecosystem Impacts: Aquatic organisms continued

Stressor	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
Acid deposition	○ ■■■ northeastern Minnesota	↓	■■■	On-road vehicles	● ■■■	↑↓	Sulfur dioxide (deposited as H_2SO_4) Nitrogen oxides (deposited as HNO_3)	• Controls on point source emissions in recent years have reduced the threat from acid deposition. • Except for northeastern Minnesota, where the danger is greatest, the state's soils are generally well-buffered against acidification. • Of 1200 Minnesota lakes surveyed, 80% exhibited adequate alkalinity while 20% were considered at risk for acidity. None were currently considered acidic. • H_2SO_4 deposition exacerbates mercury pollution by enhancing methylation and bioavailability. • Sources based on 2005 Minnesota emissions inventory.
				Power plants (biomass/fossil fuel)	● ■■■	↓		
				Industrial combustion	◒ ■■□	⟷		
				Off-road equipment	◒ ■■□	↑↓		
				Residential fuel combustion	○ ■■□	⟷		
Ammonia	○ ■■□ localized	↓	■■□	Feedlots	● ■■□	⟷		• While ammonia is acutely toxic to aquatic organisms, 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.
				Municipal and industrial wastewater	◒ ■■■	↓		
				Septic systems	○ ■■□	⟷		
Dissolved solids	○ ■■□ urban	↑	■□□	Urban runoff	● ■■□	↑	Salts Sulfate	• The primary concern is road salts, generally from major highway systems and storage piles. • Sulfate from atmospheric deposition and mining can play a significant role in stimulating mercury methylation in northeastern Minnesota.
				Mining	○ ■□□	⟷		
				Municipal and industrial wastewater	○ ■■■	⟷		

Ecosystem Impacts: Aquatic organisms continued

Stressor	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
Nanoparticles	○ ■□□ statewide	↑	□□□	Area source combustion and emissions	? □□□	↑	Buckyballs Dendrimers Carbon nanotubes Nanobioparticles Nanosilver Nanoflowers Nanofoams Nanoshells Nanowire Quantum dots	• Nanoparticles are increasingly being applied to a diverse array of applications because of their unique properties and behavior that are unlike the properties and behavior displayed at the macro-scale (greater than one billionth of a meter scale). Current studies show a potential for nanoparticles to cause harm; however, at this point there is not enough information to assess exposure and toxicity. More than 50 Minnesota companies use or apply nanotechnology in their work, but there are no existing state or federal regulations that govern their use, handling or disposal. • Research into environmental effects from nanoparticles is in its infancy. Laboratory studies have shown toxicity effects in daphnia, fathead minnows and other fish species.
				Fertilizer use	? □□□	↑		
				Land-applied municipal and industrial byproducts	? □□□	↑		
				On- and off-road vehicles	? □□□	↑		
				Pesticides	? □□□	↑		
Stratospheric-ozone-depleting chemicals (uv radiation)	○ ■■□ statewide	↔	■■■	Refrigeration & air conditioning	◒ ■■□	↓	Chlorofluoro-carbons Hydrochloro-fluorocarbons Halons Carbon tetachloride Methyl bromide Methyl chloroform	• Excess UV radiation can cause decreased reproductive capacity and impaired early development in certain aquatic animals. It is a potential cause of amphibian malformations and population loss. There are also possible effects on plant photosynthesis, genetic material, morphology and growth. • Exposure is widespread. • The extent of actual damage is uncertain. • Ozone layer showing signs of stabilization. • CFCs were replaced by HCFCs, which have a lower ozone potential, in refrigeration. However, they are a concern due to their global warming potential.
				Fire extinguishers	○ ■□□	↔		
				Fumigants	○ ■□□	↓		
				Industrial solvents	○ ■□□	↔		
				Waste disposal	○ ■□□	↓		

E. Ecosystem Impacts: Terrestrial Organisms

Introduction

Many human activities — some related to pollution, some not— have had and continue to have negative effects on other terrestrial organisms. The most obvious example is the displacement of plants and animals by human development. Other effects are not as obvious and the impacts are often not well monitored or even well understood.

Although ecosystem impacts on terrestrial organisms are not ordinarily part of the MPCA's responsibilities, 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.

Discussion

Panel members unanimously ranked the stressors of habitat loss and modification, invasive species, and greenhouse gases as having the most important and immediate effect on the terrestrial community. While the loss and modification of habitat is most apparent, it is also the most profound, affecting organisms' ability to live, feed and reproduce. Additionally, the interplay between these stressors reinforces the negative impacts of the other two. For example, hardships experienced by terrestrial organisms because of habitat degradation and fragmentation can be compounded by the arrival of new competitors in the form of invasive species; similarly, organisms suffering from a changed or deficient diet resulting from degraded habitat or diversity loss can be further weakened by the stresses of a changing climate (i.e., temperature increases, precipitation fluctuations).

While habitat loss is not really a form of pollution, it is connected to land-use practices that influence water quality, affect the sustainability of our life style and reduce our quality of life. Because the MPCA is now incorporating preventive strategies into its mission to improve and conserve the environment, issues such as habitat loss, invasive species, and climate change are closer to the core activities of the agency.

Sources of traditional, pollutant-based stressors to terrestrial ecosystems, such as toxic organic chemicals, ground level ozone and toxic metals, can be characterized using data collected by the MPCA's regulatory programs. However, only a few MPCA programs (primarily those in the Remediation Division) monitor for the presence of or assess the impact of these pollutants in and on terrestrial ecosystems.

Changes from 2003

A significant change since 2003 is the increased scientific agreement about the existence and causes of climate change, and the public's recognition of the phenomenon. Also, while in 2003 many effects of climate change were predicted, as of 2009 a number of the effects from climate change are actually evident. These include the changing composition of northern Minnesota forests, an exploding deer population, a decline in the moose population, and boreal (northern) species being unable to reproduce.

Invasive species was added to the 2009 matrix for Ecosystem Impacts on Terrestrial Organisms as a new stressor. Invasive species were considered outside the agency's purview in 2003 and as a result were not included in the matrix. As of 2009, however, the impact of invasive species on ecosystem health is too important to exclude. Moreover, the MPCA is becoming directly involved in this issue through its preparations to regulate the discharge of ballast water from vessels in Lake Superior.

Future trends

The increasing human population and the need for food, energy and infrastructure will likely increase pressure on terrestrial ecosystems and organisms; energy policy and crop prices have already begun to affect terrestrial habitat in agricultural areas (e.g., loss of conservation reserve land and planting of marginal lands with feedstocks for biofuels).

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 trends	Specific pollutants	Rationale/Comments
Greenhouse gases (climate change)	● ■■■ statewide	↑	■■■	Coal-fired power plants	● ■■■	↔	Carbon dioxide Methane Water vapor Nitrous oxide Fluorinated gases	• The stressor trend for greenhouse gases (GHGs), which is measured globally, is increasing. Statewide sources, which are based on the Minnesota greenhouse gas inventory, are steady or decreasing. • Temperature is a major environmental factor for terrestrial organisms, and increases will result in changed species composition. • Species adapted to specific habitat are most vulnerable to temperature shifts. The disappearance of Minnesota's boreal forest would dislocate species such as pine martin and fisher. A recent six-year study of moose in northeastern Minnesota has documented a declining herd. Increased temperatures and humidity and lack of habitat providing cover are thought to be reasons for the decline. • Methane from feedlots and GHGs from energy use in agricultural vehicles are included in agriculture. • Industrial sources of GHGs are mostly fossil fuel combustion. • Biomass burning is not in Minnesota's greenhouse gas inventory.
				On-road vehicles	● ■■■	↔		
				Agriculture	◒ ■□□	↔		
				Industry	◒ ■■■	↔		
				Permitted waste disposal	○ ■■□	↓		
				Residential fuel combustion	○ ■■■	↔		
Habitat loss and modification	● ■■■ statewide	↑	■■□	Agriculture	● ■■■	↑		• The single most important factor affecting terrestrial plants and animals, resulting in large-scale changes in plant and animal numbers, species and biodiversity. Further, pressures on habitat are increasing as population grows, energy production increases and development continues. Habitat loss and modification are generally not readily reversible. • Besides the obvious loss of habitat through conversion of land to human uses, the issue also includes related concerns such as fragmentation, water availability and soil modification, and is also closely related to the issues of climate change and invasive species. • While there is a good sense of the degree to which habitat has been modified and lost, little systematic analysis has been done. At the same time, the relevant land-use practices are subject to diffused and incomplete regulatory controls.
				Silvaculture	● ■■■	↔		
				Urban/suburban/ lakeshore development	● ■■■	↑		
				Mining	○ ■■■	↔		

Ecosystem Impacts: Terrestrial organisms continued

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
Invasive species	● ■■■ statewide	↑	■□□	Management activities	● ■■■	⟷	Common invasive plants and animals include spotted knapweed, buckthorn, garlic mustard, purple loosestrife, wild parsnip, leafy spurge, bull thistle, Canada thistle, crown vetch, sweet clover, earthworms and gypsy moths.	• Invasive species are any non-native species that cause environmental, economic or human health concerns. They are the major cause of biological diversity loss throughout the world. • Invasive species may displace native species, and can severely alter habitat, thus affecting species beyond those they directly displace. • Climate change and habitat loss add to issues related to invasive species by creating entry points and conditions suitable for new invasive species, which often readily adapt to alterations in terrestrial communities. • Genetically modified organisms (GMOs) are noted here because of their potential effects on native plants and other organisms. As the number and diversity of GMOs increases, the risk of escape of organisms increases. This could lead to ecological impacts similar or greater than that of comparable introduced invasive species.
				Transportation	● ■■■	⟷		
				Commerce (trade)	◒ ■■■	⟷		
				Natural movement	◒ ■■■	⟷		
				Transport by wildlife	◒ ■■■	⟷		
Nitrogen	◒ ■■□ statewide	↑	■■■	Fertilizer use	● ■■□	↑		• Generally a limiting nutrient, the amount of nitrogen available for plant uptake has increased dramatically over the last several decades. Driven by 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. • Other potential results include the disruption of soil chemistry. • While it is a significant potential problem, the nitrogen enrichment issue is a relatively new environmental concern and has engendered relatively little publicity or action. However, the scientific community is researching this issue.
				Coal-fired power plants	◒ ■■□	⟷		
				On-road vehicles	◒ ■■□	⟷		
				Area source combustion	○ ■□□	⟷		
				Feedlots	○ ■□□	⟷		
				Land-applied manure/ biosolids	○ ■□□	⟷		
				Off-road equipment	○ ■□□	↑		

Ecosystem Impacts: Terrestrial organisms continued

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 organic chemicals	◒ ■■□ statewide with dispersed hot spots	↓↑	■□□	Pesticides	● ■□□	↓	Dioxins/furans PAHs Pesticides Phthalates PCBs PBBs PFCs Alkyl phenols Hexachloro-benzene Octachloro-styrene Polychlorinated naphthalenes Petroleum products Pharmaceuticals PBDEs	• A number of toxic effects are possible 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, little monitoring has been done of actual levels in Minnesota's environment or of actual effects. • Pathways are inhalation and ingestion through food and water, and direct contact. • Includes a very large number of chemicals, released into land, air or water. • Some of the chemicals can be both persistent and bioaccumulative. • Includes the emerging issues of pharmaceuticals, antibiotic use and endocrine-disrupting chemicals, about which little is yet known. • Contributions listed as being from industry and area source combustion are primarily through air deposition. • Pesticide use trend is based on MDA corn and soybean herbicide-use estimates.
				Area source combustion	◒ ■□□	↔		
				Industry	◒ ■□□	↔		
				Municipal and industrial wastewater	◒ ■□□	↔		
				Urban runoff	◒ ■□□	↑		
				Land application	○ ■■□	↑		
Acid deposition	○ ■■□ NE Minnesota	↓	■■■	Power plants (biomass/fossil fuel)	● ■■■	↓	Sulfur dioxide (deposited as H_2SO_4) Nitrogen oxides (deposited as HNO_3)	• Controls on point source emissions in recent years have reduced the threat from acid deposition. • Except for northeastern Minnesota, where the danger is greatest, the state's soils are generally well-buffered against acidification. • H_2SO_4 deposition exacerbates mercury pollution by enhancing methylation and bioavailability. • Sources are from the 2005 Minnesota emissions inventory.
				Industrial combustion	◒ ■■□	↔		
				Off-road equipment	◒ ■■□	↑↓		
				Residential fuel combustion	○ ■■□	↔		

Ecosystem Impacts: Terrestrial organisms continued

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
Ground-level ozone	○ ■■□ statewide	↔	■■□	Off-road equipment	● ■■□	↔	Nitrogen dioxide Nitric oxide Volatile organic Compounds (VOCs)	• Ground-level ozone concentrations are thought to reduce Minnesota agricultural yields by 2 to 5%, and may have similar effects on natural systems. The effects are worse in southern MN where ozone concentrations are higher. Possible effects on animals are suggested by effects on humans (respiratory irritation and impairment), but have not been confirmed. • Pathway for animals is by inhalation. • Ozone is created when nitrogen oxides and VOCs react in a hot, stagnant atmosphere. • Primarily a concern during the summer since sunlight and heat is needed for ozone formation. • Combustion releases both VOCs and nitrogen oxides. Solvent use is a major VOC source. Listed sources include only man-made VOCs; however, there are also many natural or biogenic sources of VOCs.
				On-road vehicles	● ■■□	↔		
				Coal-fired power plants	◒ ■■□	↔		
				Solvent utilization	◒ ■■□	↓		
				Area source combustion	○ ■■□	↔		
				Industry	○ ■■□	↔		

Ecosystem Impacts: Terrestrial organisms continued

Stressor	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
Stratospheric-ozone-depleting chemicals (uv radiation)	○ ■□□ statewide	↔	■■■	Refrigeration & air conditioning	◒ ■■□	↓	Chlorofluoro-carbons Hydrochloro-fluorocarbons Halons Carbon tetrachloride Methyl chloroform Methyl bromide	• Excess UV radiation can cause decreased reproductive capacity and impaired early development in certain animals. It is a potential cause of amphibian malformations and population loss. There are also possible effects on plant photosynthesis, genetic material, morphology and growth. • Exposure is widespread. • The extent of actual damage is uncertain. • Ozone layer showing signs of stabilization. • CFCs were replaced by HCFCs, which have a lower ozone potential, in refrigeration. However, they are a concern due to their global warming potential.
				Fire extinguishers	○ ■□□	↔		
				Fumigants	○ ■□□	↓		
				Industrial solvents	○ ■□□	↔		
				Waste disposal	○ ■□□	↓		
Toxic metals	○ ■■□ statewide with dispersed hot spots	↔	■□□	Coal-fired power plants	● ■■■	↔	Mercury Lead Cadmium Chromium Zinc Copper Selenium Manganese Platinum Palladium Rhodium	• Metals, like organic chemicals, can result in a range of toxic effects, even at low levels. Many are both persistent and bioaccumulative. • 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 bioaccumulative toxic that can have significant effects on animals and people that ingest it or that eat other animals containing it. With the exception of metals from air deposition (primarily mercury), problems are generally localized and generally urban. • Recently, it has been shown that mercury in aquatic systems can move into terrestrial food webs. • Urban runoff can contain rare metals used in catalytic converters as well as zinc released from tire wear and manganese fuel additives. • 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	○ ■□□	↔		
				Land-applied biosolids	○ ■■□	↔		
				Mining	○ ■■□	↔		
				Recreational use (shooting ranges, fishing tackle)	○ ■■□	↔		

F. Quality of Life: Aesthetics and Reduced Access to Resources

Introduction

This section is a summary of those aspects of environmental damage or degradation that relate to Minnesotan's quality of life or aesthetic concerns, and that have not been fully captured in previous sections.

Discussion

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 more subjective than the others in this report since it attempts to characterize individual reactions to what we see, smell, taste and hear. 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.

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 by reducing our access to natural resources. Following is a partial list of some impacts that affect basic Minnesota values and ways of life (e.g., fishing, outdoor recreation).

- *Land use:* Land use can be restricted in some places due to health and/or liability concerns relating to toxic chemicals in soil.
- *Aquifer use:* Restricted use of some aquifers or the need to perform costly treatment can occur due to toxic chemicals in water.
- *Food:* While various foods may contain toxic pollutants, the one pollutant resulting in greatest reduced access to resources is mercury. Fish consumption advisories have been issued for some waters and people must limit their intake or risk compromising their health.
- *Fishing:* Access to fishing (recreational and commercial) is limited by the same list of stressors discussed in the Aquatic Organisms matrix.
- *Swimming:* People's desire to swim in rivers and lakes is affected directly or indirectly by stressors like oxygen-demanding pollutants, phosphorus and transported sediment
- *Winter recreation:* Access to snow and ice-covered lakes is affected by greenhouse gases (climate change)
- *Use of outdoors:* The public's freedom to spend time outdoors can be affected by air stressors like particles in air, ground-level ozone and odorous chemicals from biological processes. Also, the public's access to open space is affected by habitat loss and hydrologic modification.

Changes from 2003

In the 2003 EIR, stressors in the quality of life/aesthetics matrix were not ranked according to comparative contribution, nor were confidence levels assigned to individual stressors. With the convening of an expert panel to discuss and rank quality of life/aesthetic stressors in 2009, the current EIR team felt that it was tenable to determine and report comparative contributions as well as confidence levels in this matrix, similar to the other five matrices. This resulted in two stressors, greenhouse gases (climate change) and phosphorus being ranked with a high overall comparative contribution and moderate and high levels of confidence respectively.

Greenhouse gases (climate change), or temperature change as it was referred to in the 2003 EIR, was not included as a stressor in the quality of life/aesthetics matrix in the original report. In the current report, greenhouse gases are ranked "high" with coal-fired power plants and on-road vehicles being the most important sources. Much additional monitoring and observation of the effects of greenhouse gases on Minnesota resources has taken place in the last five years including continued documentation of shorter periods between ice-in and ice-out on Minnesota lakes, shorter duration of continuous snow cover, early signs of the boreal forest shifting north, and concern about more frequent and earlier toxic algal blooms because of rising lake temperatures.

Likewise, the effect of increased phosphorus contribution to Minnesota waters from agricultural and urban runoff is ranked in the current report as having a high comparative contribution. In the 2003 EIR, five sources of phosphorus were identified, with agricultural runoff having the highest source contribution. Other sources included municipal and industrial wastewater, feedlots, urban runoff and septic systems. For the 2009 EIR, two additional sources of phosphorus were identified by the expert panel, channel erosion and atmospheric deposition, both ranked as having a moderate comparative contribution and a moderate confidence level.

Future trends

Between the time the 2003 EIR was published and the current report, Minnesota's population exceeded the five million mark. Expansion of urban and suburban areas and the land development, transportation and energy demands that follow from this expansion are likely to continue in the future. With the population of Minnesota increasing, decisions made about land use, energy and transportation will dictate how quality of life is affected by such stressors as odor, noise and smog in the future. There are also trends in resource use that may be detrimental to aesthetics, such as drainage of phosphorus to lakes resulting in algal blooms and possible decrease in lakeshore property values.

There are some trends that hopefully will improve quality of life for future Minnesotans including expansion of alternative methods of transportation (including light rail and more bicycle routes), construction of additional noise barriers along freeways, and restrictions on the use of phosphorus in fertilizers.

Quality of Life: Aesthetics and reduced access to resources

Stressor	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
Greenhouse gases (climate change)	● ■■□ statewide	↑	■■■	Coal-fired power plants	● ■■■	↔	Carbon dioxide Methane Water vapor Nitrous oxide Fluorinated gases	• The stressor trend for greenhouse gases (GHGs), which is measured globally, is increasing. Statewide sources, which are based on the Minnesota greenhouse gas inventory, are steady or decreasing. • Minnesota may look more like Nebraska. • Similar effects to habitat loss and modification. • Loss of winter recreation and possible decreased summer recreation (due to excessive heat). • The boreal forest of the BWCAW may not survive climate change. • Minnesota forests will change as birch and aspen are replaced by hardwood forests of oak and hickory. • Minnesota's fishery may be radically changed; smaller, medium depth lakes may no longer be able to support cold-water species like lake trout; warm water fish will be increasingly common. • Surface-fed streams may not be able to support cold-water species like brook trout and rainbow trout.
				On-road vehicles	● ■■■	↔		
				Agriculture	◒ ■□□	↔		
				Industry	◒ ■■■	↔		
				Permitted waste disposal	○ ■■□	↓		
				Residential fuel combustion	○ ■■■	↔		
Phosphorus	● ■■■ statewide	↔	■■□	Agricultural runoff	● ■■■	↔		• Excess phosphorus causes increased algae growth in water and thus affects appearance (clarity) and may generate odors. • If surface water is used for drinking water, algae growth can affect flavor. • More than 300 lakes have been TMDL listed for excess phosphorus (nutrient) levels. • Deaths of pets and wildlife and illness in humans have been linked to contact with toxic algae. • Algal blooms may affect recreational use of lakes and reduce property values of lakeshore owners. • Earlier ice outs and warm springs mean algae can get a head start and reach nuisance conditions sooner.
				Atmospheric deposition	◒ ■■□	↔		
				Channel erosion	◒ ■■□	↑		
				Feedlots	◒ ■■□	↔		
				Municipal and industrial wastewater	◒ ■■■	↓		
				Urban runoff	◒ ■■□	↑		
				Septic systems	○ ■■□	↔		

Quality of Life: Aesthetics and reduced access to resources continued

Stressor	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
Habitat loss and modification	◒ ■■□ statewide	↑	■■□	Agriculture	● ■■■	↑		• The alteration of green space to developed land is an aesthetic concern for many people. • Sources may include those that produce greenhouse gases, contributing to climate change and accompanying habitat modification. • Fragmentation (loss of connectivity) may result in "dead space" and species isolation. • Loss of biodiversity can affect hunting, fishing and wildlife viewing. • Lifestyles and cultural heritage may be impacted (wild rice; maple syrup; farming). • Loss of scenic vistas and wilderness is a concern for many people.
				Development	● ■■■	↑		
				Silvaculture	● ■■■	↔		
				Transportation	◒ ■■■	↑		
				Mining	○ ■■■	↑		
Noise	◒ ■■□ localized, urban	↓↑	■□□	Aircraft	● ■■■	↔		• 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 the number of people exposed. • Only major sources were considered. • Does not consider occupational exposure.
				On-road vehicles	● ■■■	↑		
				Industry	◒ ■■■	↔		
				Locomotives	◒ ■■■	↔		
				Off-road equipment	◒ ■■■	↑		
Odorous chemicals	◒ ■■□ localized, urban	↓↑	■□□	Feedlots	● ■□□	↔		• Perception of odors varies greatly among individuals; most common complaints include headaches and nausea. • Source contribution roughly corresponds to number of complaints received by MPCA. • Long-term exposure to odors may cause increased levels of adrenaline, which can be harmful. • Measurement is resource intensive and may include odor panels as well as legal (performance) standards. • Ethanol plants have shown recent increases in productivity with better odor control.
				Agriculture	◒ ■□□	↔		
				Treatment and settling ponds	◒ ■□□	↔		
				Ethanol production	○ ■□□	↑		

Quality of Life: Aesthetics and reduced access to resources continued

Stressor	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
Oxygen-demanding pollutants	◒ ■■□ statewide	↓	■■□	Feedlots	● ■■□	↔	Organic matter	• Can be both an appearance and 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 since 1970, reflecting point source controls.
				Agricultural runoff	◒ ■■□	↔		
				Municipal and industrial wastewater	◒ ■■■	↓		
				Urban runoff	◒ ■■□	↑		
				Septic systems	○ ■■□	↔		
				Spills	○ ■■■	↔		
Particles in air	◒ ■■□ statewide	↓	■■□	Agriculture	● ■■□	↔	Fine particles	• The biggest aesthetic concern is visibility due to haze. • Nationally, standards are set for regional haze in Class 1 scenic areas (in MN, this includes BWCAW and Voyageurs National Park). • Visibility can be impaired near greatest concentration of PM; e.g., urban areas. • With the State Implementation Plan (SIP), visibility goals are established for 2018. • Coal-fired power plants, on-road vehicles, and off-road equipment are all important sources of particles and their precursors.
				Off-road equipment	● ■■□	↑↓		
				On-road vehicles	● ■■□	↑↓		
				Power plants (biomass/fossil fuel)	● ■■□	↑↓		
				Industrial combustion	◒ ■□□	↔		
				Residential combustion	◒ ■□□	↔		
				Road dust	○ ■□□	↔		

Quality of Life: Aesthetics and reduced access to resources continued

Stressor	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
Transported sediment	◒ ■■□ statewide	↓↑	■■■	Agricultural runoff	● ■■■	↔		• Main aesthetic effect is reduced clarity of surface water. • Increased nutrients (especially phosphorus) often tied to sediment levels. • Clarity levels are generally low in rivers of southern and western Minnesota, especially following rainfall.
				Channel erosion	● ■■□	↑		
				Construction	● ■■□	↔		
				Urban runoff	◒ ■■□	↑		
				Municipal and industrial wastewater	○ ■■■	↔		
Ground-level ozone	○ ■■□ statewide	↔	■■■	Off-road equipment	● ■■□	↔	Nitrogen dioxide Nitric oxide Volatile organic compounds (VOCs)	• Minnesota does not have a large ozone problem, nor does ozone have a major visibility impact; however, ozone together with particles creates smog. • Ability to participate in outdoor activities may be impaired on poor air quality days.
				On-road vehicles	● ■■■	↑↓		
				Power plants (biomass/fossil fuel)	● ■■■	↑↓		
				Residential combustion	◒ ■■□	↔		
				Solvent utilization	◒ ■■□	↓		
				Industrial combustion	○ ■■□	↔		
				Petroleum storage and transfer	○ ■■□	↔		