

## **Appendix C: Documentation for Sources**

**Note to readers:** This appendix and others refer to reports and documents indicated as clickable internet links, which were live when the report was drafted. It is likely that some of these links are no longer live and current, as the MPCA cannot maintain those belonging to other organizations. If you are interested in a particular reference and cannot access it, please contact Michael Trojan at 651/297-5219.

Information in this Appendix was collected by the EIR Team with assistance from MPCA technical staff. Information was used in internal discussions among the EIR team in assigning scores for sources.

This document is organized by stressors, since the EIR focuses on stressors. The Table of Contents lists the 24 stressors used in the EIR. Within each stressor, we identify the sources that contribute to that stressor. For each source, we provide documentation on relative contribution of each source, our confidence in assigning relative contribution, and our assessment of the trend in contribution from that source. In some cases, sources occurred more than once for a particular stressor. For example, off-road equipment occurs twice for Acid Deposition because it is a source that contributes to Acid Deposition in both aquatic and terrestrial ecosystems.

We do not discuss relative contribution, confidence, and trend for each of the 304 stressor-impact-source combinations, but rather discuss sources within a stressor only. When there are differences for a particular source within a stressor, we identify these differences and provide a general discussion of the overall impact of that source on that stressor.

At the end of this Appendix, we include an index that allows the reader to identify stressors that have common sources. We included this because many references for a particular source within a stressor may not be included for the same source under a different stressor, even though the information may be relevant. For example, Feedlots is a source for the stressors Nitrogen and Phosphorus. There may be references listed for Nitrogen that would also apply to Phosphorus, but that we did not include in the Phosphorus section.

While this document provides supporting information for our estimates of contribution, confidence, and trend, those estimates were largely based on knowledge of expert staff participating in development of the EIR. Many of these staff are listed in Appendix A. The assumption is that our technical staff are experts within their field and therefore have sufficient knowledge of the environmental importance of different sources. When reviewing this document, readers are encouraged to review the additional references listed within the references that we provide. In many cases, we simply provide a general link through which the reader can obtain more information.

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## 1. Acid Deposition

*Impact Categories: Aquatic Organisms, Terrestrial Organisms*

*Sources: Coal-fired Power Plants, On-road Vehicles, Off-road Equipment*

Acid deposition occurs when gases released to the atmosphere, primarily NO<sub>x</sub> and SO<sub>2</sub>, are oxidized and deposited in wet or dry form. Natural acids may also be released to the atmosphere, particularly hydrochloric acid. Acid deposition can lower ambient pH in aquatic and terrestrial ecosystems to 4.5 or less, which can have a variety of negative impacts on the ecosystems and individual organisms

(<http://royal.okanagan.bc.ca/mpidwirm/atmosphereandclimate/acidprecip.html#a>).

### Comparative Contribution of Sources

*Coal-fired Power Plants:* High contribution. About 25 percent of nitrogen oxides (NO<sub>x</sub>) come from thermoelectric generating stations. About 73 percent of sulfur dioxide (SO<sub>2</sub>) emissions come from point sources, primarily coal-fired power plants

(<http://www.pca.state.mn.us/hot/legislature/reports/2001/at-appendix-c.pdf>;

<http://www.ns.ec.gc.ca/msc/as/acidfaq.html>;

<http://www.epa.gov/oar/aqtrnd00/acidrain.html>).

*On-road Vehicles:* Medium contribution. About 32% of nationwide NO<sub>x</sub> emissions come from on-road vehicles. On-road sources emit a much smaller percentage of SO<sub>2</sub> emissions (~2%). (<http://www.pca.state.mn.us/hot/legislature/reports/2001/at-appendix-c.pdf>;

<http://www.ns.ec.gc.ca/msc/as/acidfaq.html>;

<http://www.epa.gov/oar/aqtrnd00/acidrain.html>;

<http://www.epa.gov/ttn/chief/trends/trends98/trends98.pdf>).

*Off-road Equipment:* Medium contribution. Off-road engines and other equipment contribute about 22% of US NO<sub>x</sub> emissions and 6% of SO<sub>2</sub> emissions.

(<http://www.pca.state.mn.us/hot/legislature/reports/2001/at-appendix-c.pdf>;

<http://www.ns.ec.gc.ca/msc/as/acidfaq.html>;

<http://www.epa.gov/ttn/chief/trends/trends98/trends98.pdf>).

### Confidence Level

*Coal-fired power plants:* Reasonably confident. Coal-fired power plants are required to have a permit to discharge to the atmosphere. Therefore, we have reasonably good information about discharges from these facilities. In addition, there are several monitoring sites in Minnesota, primarily located near point sources

(<http://www.pca.state.mn.us/air/pubs/aqtrends.pdf>).

*On-road vehicles:* Moderately confident. We have reasonably good information on the number of vehicles in Minnesota. We can estimate vehicle miles driven and fuel consumption. Vehicle emissions of SO<sub>2</sub> have decreased in the past ten years because of mandated improvements in vehicles

(<http://www.pca.state.mn.us/hot/legislature/factsheets/mobile.pdf>;

<http://www.pca.state.mn.us/hot/legislature/reports/2001/at-appendix-i.pdf>;

<http://www.pca.state.mn.us/hot/legislature/reports/2001/aq-report.pdf>).

*Off-road vehicles:* Moderately confident. Minnesota has limited data regarding off-road emissions of SO<sub>2</sub> and NO<sub>x</sub>. Several western states have compiled this information, which indicates off-road mobile sources constitute more than half of all non-

industrial SO<sub>2</sub> and less than half the nitrogen oxide emissions. Construction, planes, and agricultural equipment are the most important off-road sources (<http://www.wrapair.org/forums/MSF/MOBILE.HTM>; <http://transaq.ce.gatech.edu/epatac/documents/cackette.pdf>; [http://www.gbcpa.org/state\\_imp\\_plan.htm](http://www.gbcpa.org/state_imp_plan.htm)).

### Source Trends

*Coal-fired Power Plants:* No trend. Emissions of SO<sub>2</sub> have increased about 25 percent in the past ten years because of increased energy demand. Concentrations in the atmosphere, however, have decreased by nearly 50 percent over the same period. This apparent discrepancy may be due to decreasing emissions nationally and location of monitoring sites in areas that do not reflect recent increases in emissions. There has been a slight upward trend in emissions of NO<sub>x</sub> in Minnesota, but this trend does not appear statistically significant. Because of the uncertainty about SO<sub>x</sub> emissions and the lack of significant upward trend for NO<sub>x</sub> emissions, we assigned no trend to this source (<http://www.pca.state.mn.us/hot/legislature/reports/2001/at-appendix-c.pdf>; <http://www.epa.gov/oar/aqtrnd00/acidrain.html>).

*On-road vehicles:* No trend. Emissions of SO<sub>2</sub> from automobiles have decreased significantly in the past 15 to 20 years because of improved technology (<http://environment.about.com/library/weekly/blair3.htm>). However, vehicle traffic has increased and fuel efficiency has lowered over the past ten years. There has been a slight upward trend in emissions of NO<sub>x</sub> in Minnesota, but this trend does not appear statistically significant. Mobile sources, particularly automobiles, would likely account for any trend in emissions of NO<sub>x</sub>. Nationally, NO<sub>x</sub> emissions have decreased slightly over the past ten years (<http://www.pca.state.mn.us/hot/legislature/reports/2001/at-appendix-c.pdf>; <http://www.epa.gov/oar/aqtrnd00/acidrain.html>).

*Off-Road Vehicles:* No trend. It is difficult to evaluate trends in contributions from off-road vehicles. Construction, air transportation, and agricultural activity have not decreased, and regulations for improved fuel efficiency apply only to diesel vehicles (<http://environment.about.com/library/weekly/blair3.htm>). Since use of off-road vehicles has not decreased and may have increased over the past ten years, decreases in emissions due to improved fuel efficiency have probably been offset.

## **2. Ammonia**

*Impact Categories: Aquatic Organisms*

*Sources: Feedlots, Municipal and Industrial Wastewater, Septic Systems*

Ammonia is a natural constituent of many wastes, primarily animal wastes. Ammonia is toxic to fish. Ammonia may also be formed through oxidation of nitrogen in organic matter. Because this reaction requires oxygen, however, this ammonia is often converted to more oxidized forms of nitrogen, such as nitrate. We therefore do not include fertilizer as a source for this stressor ([http://ohioline.osu.edu/b896/b896\\_2.html](http://ohioline.osu.edu/b896/b896_2.html); <http://www.cryotech.com/urea.html>).

### Comparative Contribution of Sources

*Feedlots:* High contribution. There are nearly 9.5 million pigs, 0.9 million cows (dairy and cattle), 0.2 million sheep, 43.5 million turkeys, 44.2 million chickens, and 35000 permitted feedlots in Minnesota (<http://www.nass.usda.gov/mn/agstat99.htm#sect3>; <http://www.nass.usda.gov:81/ipedb/>; <http://www.pca.state.mn.us/water/nonpoint/nsmpp-ch7.pdf>; <http://www.nass.usda.gov/mn/agstat00/page889.PDF>). Although the average farm size has increased from 332 to 367 acres and livestock operations have increased in size over the past ten years, many livestock operations continue to occur in open lots or areas where surface water is easily contaminated from manure (<http://www.nass.usda.gov:81/ipedb/>; <http://www.ae.iastate.edu/L&EHomestudy/openall3.htm>; <http://www.spatialhydrology.com/journal/paper/feedlot/Feedlot.pdf>). Land application of manure is another potential source of surface water contamination (<http://www.agric.gov.ab.ca/agdex/500/576-3.html>). Nitrogen concentrations in animal waste are high and feedlot waste has a high biochemical oxygen demand. Consequently, most nitrogen will be in a reduced form (ammonia and organic nitrogen). Ammonia concentrations in animal manure are about 0.1 percent, but vary widely (Douglas, B.F., and F.R. Magdoff. 1991. *An Evaluation of Nitrogen Mineralization Indices for Organic Residues*. Jour. Environ. Qual. 20:368-372). Ammonia may enter surface water bodies from either direct overland runoff or seepage into ground water that eventually discharges to surface water. Ammonia concentrations in ground water beneath unlined manure basins may be as high as 250 mg/L, although concentrations are typically less than 30 mg/L under lined basins. Ammonia is not very mobile in ground water, but high concentrations can occur more than 200 feet from unlined basins that have been in operation for several years (<http://www.pca.state.mn.us/water/groundwater/gwmap/gw-manure.html>). A 1979 MPCA study estimated that only 4.9 percent of the 5000 feedlots located in shoreland areas did not discharge pollutants during a 25-yr/24-hr rainstorm (<http://www.pca.state.mn.us/water/nonpoint/nsmpp-ch7.pdf>). Much of the nitrogen generation from livestock occurs in hydrologically sensitive areas, such as central, southeast, and southwest Minnesota (<http://www.pca.state.mn.us/water/nonpoint/nsmpp-ch7.pdf>). An Iowa study on impaired waters indicates lakes, rivers, and streams are primarily impacted from agricultural nonpoint sources, which includes feedlot runoff (<http://www.agric.gov.ab.ca/sustain/water/quality/primer5.html>). In a Nebraska study, agriculture was the most important source of ammonia discharged to surface water (<http://www.ianr.unl.edu/pubs/water/nf460.htm>). In Minnesota, all but one of the locations where the TMDL for ammonia was exceeded occurred in agricultural areas. In most of the areas, particularly in southern Minnesota, locations on the TMDL list for ammonia were also on the list for fecal coliform (<http://www.pca.state.mn.us/water/pubs/tmdl-list98.pdf>). The primary contributor to surface water is nonpoint pollution, such as feedlots (<http://www.pca.state.mn.us/water/basins/305briver.html>).

*Municipal and Industrial Wastewater:* Medium contribution. Historically, wastewater was an important source of ammonia contamination in surface water. Studies show that wastewater treatment plants remain an important source for ammonia (<http://www.bham.ac.uk/CivEng/resproj/heng/>; <http://www-dinind.er.usgs.gov/nawqa/wr03006.htm>).

<http://water.usgs.gov/pubs/circ/circ1162/nawqa91.6.html>). Wastewater treatment plants are regulated through the NPDES permitting process, which includes effluent limitations. Ammonia is not always required but is frequently monitored in effluent (<http://www.pca.state.mn.us/publications/wq-wwprm1-02.pdf>). Because of effluent regulations, instances of ammonia contamination of surface water have decreased, although concentrations of ammonia downgradient of treatment facilities exceed upgradient concentrations.

*Septic Systems:* Low contribution. Septic systems can contribute to ammonia contamination by discharging ammonia to ground water that eventually enters surface water, or by direct runoff from failing septic systems. Septic systems are designed to minimize loss of organic carbon. This is achieved by allowing a separation between the bottom of the drainfield and the top of the ground water table. This zone contains oxygen. Ammonia that passes into this oxygenated zone is transformed to nitrate. Consequently, little ammonia is lost from septic systems that are in compliance. If there is no oxygenated zone between the water table and the bottom of the drainfield, ammonia may enter ground water. Ammonia is not very mobile in ground water, however, and is rarely found more than 50 feet from the drainfield. The greatest risk from ammonia contamination comes from failing systems where septage occurs at the land surface. These systems must be quickly remedied, however, because they represent an immediate health risk (<http://www.pca.state.mn.us/water/groundwater/gwmap/gw-nonsewered.html>; <http://www.pca.state.mn.us/programs/ists/index.html>). Septic systems therefore contribute only small amounts of ammonia to surface water.

#### Confidence Level

*Feedlots:* Moderately confident. We have good estimates of the number of livestock and feedlots in Minnesota. Minnesota milestone sites represent a small percentage of Minnesota's surface water and results at each site cannot be easily linked to land use (i.e. contaminant sources). Several research studies illustrate the relationship between surface water quality and manure management, but extrapolation of these results to an entire state may be misleading. We therefore assigned a moderate confidence to our estimate, since we have good information on the amount of potential waste but lack of information linking actual effects to the source.

*Municipal and Industrial Wastewater:* Reasonably confident. Regulations have resulted in decreased discharge of ammonia to surface water. Several studies illustrate the link between treatment plants and water quality. Some information in Minnesota illustrates improvements in surface water quality following upgrade of treatment facilities. We are therefore reasonably confident about impacts from municipal and industrial wastewater.

*Septic Systems:* Moderately confident. We have good estimates of the number of septic systems in Minnesota. Minnesota milestone sites represent a small percentage of Minnesota's surface water and results at each site cannot be easily linked to land use (i.e. contaminant sources). Several research studies illustrate the relationship between surface water quality and septic systems, but extrapolation of these results to an entire state may be misleading. We therefore assigned a moderate confidence to our estimate, since we have good information on the amount of potential waste but lack of information linking actual effects to the source.

### Source Trends

*Feedlots:* No trend. There were downward trends in ammonia concentrations at 83 percent of Minnesota milestone sites, with 14 percent having no trend (<http://www.pca.state.mn.us/publications/reports/305bfinalreport-2000.pdf>). The average increase in farm size, a shift to larger animal operations, improvements in manure storage and management (<http://www.extension.iastate.edu/Publications/AE3077G.pdf>), and increasingly stringent regulations on open lots and discharges from permitted facilities lead to a decreasing trend in releases to surface water. This is counterbalanced, however, by increased land application of manure and increased livestock numbers. Because of these uncertainties, no trend was assigned to this source.

*Municipal and Industrial Wastewater:* Downward trend. Increased regulation of treatment facilities and improved treatment has resulted in decreases in ammonia contamination of surface waters. Data for Minnesota are lacking, but studies from other states reveal a downward trend in ammonia released to surface water from treatment facilities (<http://www.ga.usgs.gov/publications/abstracts/wrir96-4101.html>; <http://www.anl.gov/OPA/env/EMfacts.html>).

*Septic Systems:* No trend. Between 1980 and 1990, the number of homes served by an individual sewage treatment system increased 22 percent. Despite this increase, these newer systems are likely to be in compliance and therefore contribute little ammonia to surface water. Simultaneously, older systems are increasingly being brought into compliance as some municipalities and counties in Minnesota attempt to upgrade old septic systems (<http://www.pca.state.mn.us/water/nonpoint/nsmpp-ch14-1.pdf>; <http://www.pca.state.mn.us/programs/ists/index.html>). We therefore assigned no trend to this source.

### **3. Dissolved Solids**

*Impact Categories: Aquatic Organisms*

*Sources: Municipal and Industrial Wastewater, Urban Runoff*

Dissolved solids include a large number of chemicals that may impact aquatic ecosystems. The primary chemical of concern is chloride because there are many anthropogenic sources and elevated chloride concentrations are widely observed in surface waters. Other dissolved solids may have local impacts on aquatic ecosystems, but they are not considered in this discussion. Although there are many sources of chloride, we only discuss municipal and industrial wastewater and urban runoff, since these may lead to concentrations of chloride that negatively impact aquatic organisms. Thus, other sources, such as septic systems, manure, and fertilizers, are not included ([http://www.texasep.org/html/wql/wql\\_2sfc.html](http://www.texasep.org/html/wql/wql_2sfc.html)).

### Comparative Contribution of Sources

*Municipal and Industrial Wastewater:* Low contribution. Wastewaters, particularly some industrial wastewaters, have high chloride concentrations. These concentrations may be of concern because the wastewater is discharged directly to surface water and there are few effective strategies for reducing chloride concentrations

in wastewater (<http://www-oh.er.usgs.gov/reports/Abstracts/wrir.99-4201.html>; [http://www.gns.cri.nz/earthres/groundwater/sites/tasman/site\\_wwd3314.htm](http://www.gns.cri.nz/earthres/groundwater/sites/tasman/site_wwd3314.htm); [http://emmap.mtu.edu/gem/community/publications/wellspring/salt\\_follow-up.html](http://emmap.mtu.edu/gem/community/publications/wellspring/salt_follow-up.html); <http://www.dnr.state.wi.us/org/water/wm/ww/wwpubs/slides4.htm#CHLOR>). Impacts are likely to be limited in geographic extent, however.

*Urban Runoff*: High contribution. Road salt is the primary urban source of chloride ([http://www.epa.gov/npdes/menuofbmps/poll\\_12.htm](http://www.epa.gov/npdes/menuofbmps/poll_12.htm)). Research conducted by the United States Geological Survey clearly shows elevated chloride concentrations in urban areas of Minnesota. These studies suggest that many locations in urban areas could be placed on the TMDL list because of chloride concentrations (<http://water.usgs.gov/nawqa/informing/tmdls.html>). Studies in other urban areas show similar results (<http://radburn.rutgers.edu/andrews/projects/nbcpr/pdfs/salt.htm>; <http://www.cciw.ca/wqrjc/34-4/34-4-545.htm>).

#### Confidence Level

*Municipal and Industrial Wastewater*: Reasonably confident. Effluent limits exist for major wastewater discharges and we therefore have reasonably good information on release of chloride to surface water from these point sources.

*Urban Runoff*: Moderately confident. Few studies exist that show concentrations of chloride in urban runoff, but there are numerous studies that illustrate increased chloride concentrations in urban surface and ground water (<http://www.pca.state.mn.us/publications/mnenvironment/fall2000/salt.html>; <http://water.usgs.gov/nawqa/informing/tmdls.html>; <http://radburn.rutgers.edu/andrews/projects/nbcpr/pdfs/salt.htm>; <http://www.cciw.ca/wqrjc/34-4/34-4-545.htm>). We therefore have moderate confidence about the relative contribution of chloride to aquatic organism impacts.

#### Source Trends

*Municipal and Industrial Wastewater*: No trend. Although effluent limits are set for many pollutants associated with wastewater, chloride cannot be effectively removed from the waste stream. Consequently, there is no trend in releases of chloride from wastewater.

*Urban Runoff*: Upward trend. Use of road salt continues to increase in Minnesota, despite no trend in national use (<http://www.pca.state.mn.us/publications/mnenvironment/fall2000/salt.html>; <http://gulliver.trb.org/publications/sr/sr235/017-030.pdf>).

## **4. Excess UV Radiation from Stratospheric Ozone Depletion**

*Impact Categories: Aquatic Organisms, Terrestrial Organisms, Human Health Cancer, Human Health Noncancer Chronic*

*Sources: Fire Extinguishers, Industry, Refrigerants, Unpermitted Waste Disposal*

Ozone is very reactive and is constantly being formed and destroyed in the stratosphere. The total amount normally remains relatively stable. Halogens such as

chlorine and bromine, however, can act as catalysts in the destruction of ozone, resulting in the net effect that ozone is destroyed faster than it is naturally created.

The chemicals of concern (Chlorofluorocarbons, hydrochlorofluorocarbons, 1,1,1-trichloroethane, methyl bromide, carbon tetrachloride, methylene chloride, halons, hydrobromofluorocarbons) are very stable, so they are able to reach the stratosphere after being released. Once they reach the stratosphere, they are broken down by UV radiation, resulting in chlorine and bromine being released. The chlorine and bromine then catalyze the destruction of ozone and result in a net loss of stratospheric ozone. Therefore, less UVB radiation is absorbed and more reaches the earth.

Different chemicals of concern have different ozone-depleting potentials (ODPs) and different half-lives. For example, CFC-11 has an ODP of 1, while HCFC-141b has an ODP of 0.1. This means that a molecule of CFC-11 can destroy ten times as much ozone as HCFC-141b. In addition, CFC-11 has an atmospheric lifetime of 70 years while carbon tetrachloride has an atmospheric lifetime of about 10 years.

Large fires and certain types of marine life produce one stable form of chlorine that does reach the stratosphere. However, numerous experiments have shown that CFCs and other widely used chemicals produce roughly 85% of the chlorine in the stratosphere, while natural sources contribute only 15%.

#### Comparative Contribution of Sources

Due to the long atmospheric lifetime of ozone depleting substances, it is difficult to determine comparative contributions. Many of the sources that contributed chemicals with high ODPs have been phased out in the United States. However, these sources were the main contributors of the halogens that are currently in the stratosphere. For this exercise, we attempted to list the current sources of ozone depleting substances.

*Refrigerants: Medium Contribution.* CFCs have been phased out as a source of refrigerants. Their replacements (HCFCs), however, are also ozone-depleting substances and may continue to be released into the atmosphere. HCFCs have a lower ODP than hard CFCs.

*Fire extinguishers: Low Contribution.* Halon production was banned in 1994 and the formulation of halon blends was banned in 1998. Although existing halon fire protection systems are still in use and can be recharged using recycled halons or halons produced before the ban, new fire protection systems do not contain halons..

*Unpermitted waste disposal: Low Contribution.* CFCs were used in refrigerants and foams. Many of these sources are still in existence. If they are not properly recycled and disposed of, the CFCs are released into the atmosphere. Some fire protection systems are also currently charged with halon. If these systems are replaced without recycling of the halon, it may also be released into the atmosphere.

*Industry: Low Contribution.* Many ozone depleting substances were used in industry. CFCs were used as cleaning solvents for electrical components. Solvents such as carbon tetrachloride and methyl chloroform were also used. This industrial usage has been banned and has for the most part ceased.

#### Confidence Level

*Refrigerants, Fire Extinguishers, Unpermitted Waste Disposal:* Somewhat speculative. For each of these it is known that some ozone-depleting substances are still

being released, but it is difficult to track actual releases or to know how many CFC and HCFC refrigerants are in use or how many halon fire systems exist or how much illegal waste disposal is occurring. Therefore, the ranking is somewhat speculative.

*Industry:* Moderately confident. We are more confident, compared to the other sources, that industry has minimal releases of ozone depleting substances because industrial solvents are more carefully tracked by regulatory agencies. In addition, solvent stockpiles would be gone through quickly and should no longer exist.

### Source Trends

Overall, there is no trend in UV radiation. This is because ozone depletion is believed to be leveling off. The source trends are generally down from the highest 1993/94 levels. However, over the last few years, some ozone depleting substances are actually increasing (such as HCFCs). Total chlorine is decreasing, but total bromine is increasing in the atmosphere. We thus assigned an upward and downward trend to the sources for this stressor.

### **References**

- The EPA Ozone Depletion Website: <http://www.epa.gov/ozone/index.html>
- UNITED NATIONS ENVIRONMENT PROGRAMME ENVIRONMENTAL EFFECTS OF OZONE DEPLETION: 1994 ASSESSMENT. November 1994. <http://sedac.ciesin.org/ozone/UNEP/UNEP94toc.html>
- Environmental Chemistry 2<sup>nd</sup> edition, Nigel Bunce, Wuerz Publishing Ltd. Winnipeg, Canada.
- Scientific Assessment of Ozone Depletion: 1998. World Meteorological Organization Global Ozone Research and Monitoring Project -Report No. 44. National Oceanic and Atmospheric Administration

## **5. Explosive/Flammable Materials – High Level Accidental Exposure**

*Impact Categories: Human Health Noncancer Acute*

*Sources: Industry, On-road Vehicles, Pipelines, Residences, Tanks, Trains*

This stressor involves various petroleum products and materials that are released and have the potential to ignite. The comparative contributions of the sources are based on the database maintained by the MPCA's Emergency Response Program (as reported to us by Dorene Fier-Tucker in an e-mail on 9/6/01). The estimates are based on numbers of releases, not volume (which might result in different comparative contributions).

### Comparative Contribution of Sources

*On-Road Vehicles:* High Contribution.

*Tanks:* High Contribution.

*Pipelines:* Medium Contribution.

*Trains:* Medium Contribution.

*Industry:* Low Contribution.

*Residences:* Low Contribution.

### Confidence Level

The confidence level for the comparative contribution of sources is considered “reasonable” for all the sources. This is because unlike most other stressors we have a database from which to calculate numbers.

### Source Trends

*On-Road Vehicles*: Upward.

*Tanks*: Downward.

*Pipelines*: Downward.

*Trains*: No trend.

*Industry*: No trend.

*Residences*: No trend.

These trends are based on the judgment of Steve Lee, Supervisor of Emergency Response program (in an e-mail dated 9/25/01).

## **6. Ground-level Ozone**

*Impact Categories: Terrestrial Organisms, Human Health Noncancer Acute, Human Health Noncancer Chronic, Quality of Life Aesthetics*

*Sources: Area Source Combustion, Coal-fired Power Plants, Industry, Off-road Equipment, On-road Vehicles, Petroleum Storage and Transfer, Solvent Utilization*

Ground level ozone is formed when nitrogen oxides (NO<sub>x</sub>) react with hydrocarbons (also known as volatile organic compounds (VOCs)) and oxygen in the atmosphere. Ozone concentrations increase during periods of high temperatures and stagnant atmospheric conditions. Atmospheric reactions to form ozone are limited by either the amount of NO<sub>x</sub> or VOC in the air, but it is not known which group of chemicals limits the formation of ozone in Minnesota.

### Comparative Contribution of Sources

*On-Road Vehicles*: High Contribution. On-road vehicles emit 32% of NO<sub>x</sub> and 30% of VOCs nationwide.

*Off-Road Vehicles*: High Contribution. Off-road engines are responsible for 22% of NO<sub>x</sub> and 14% of VOC emissions, according to EPA’s 1998 Trends report.

*Area Source Combustion*: Low Contribution. Residential fuel combustion is a small, but significant, source of NO<sub>x</sub> emissions, and contributes to VOC emissions.

*Industrial Sources*: Low Contribution. Industrial fuel combustion, like residential combustion, emits comparably small amounts of NO<sub>x</sub>. Industrial combustion is an important source of VOC.

*Coal-Fired Power Plants*: Medium Contribution. Nationwide, 25% of NO<sub>x</sub> emissions come from electric utilities.

*Solvent Utilization*: Medium Contribution. 29% of VOC emissions are emitted by solvent utilization for industrial and commercial uses.

*Petroleum Storage & Transfer: Low Contribution.* Storing and transporting gasoline and other petroleum fuels to their distribution points releases large amounts of VOC into the air: 7% of total emissions.

#### Confidence Level

The confidence level for the comparative contribution is considered moderately confident for all the sources, although holes in understanding exist. Emissions of NO<sub>x</sub> and VOCs from industrial sources are tracked at the state level on an annual basis. Emissions estimates from small industrial or commercial (“area”) and mobile sources are tracked at the national level by EPA. Uncertainties in the methodologies exist, but the main sources of the pollutants are known. More uncertainty exists in the contribution of specific sources to ozone formation. The atmospheric chemistry and meteorology is complex and Minnesota has not conducted modeling studies looking at specific sources of ozone in Minnesota.

#### Source Trends

Overall, emissions of VOCs in the United States are decreasing. The decrease is driven by the reductions in emissions by on-road vehicles and the solvent utilization sector, although most emissions reductions occurred during the 70's and 80's. In recent years, emissions are level or decreasing slightly. Emissions of VOCs from petroleum solvent and transport and non-road vehicles and engines has been steady in recent years. Coal fired power plants, other industrial sources, and area source combustion are not large sources of VOCs but their contribution has recently been steady. Nationwide, NO<sub>x</sub> emissions remained constant over the past several years. Emissions from off-road vehicles and engines increased slightly, but other sources, such as on-road vehicles and coal-fired power plants, neither increased nor decreased. Solvent utilization and petroleum storage and transfer are insignificant sources of NO<sub>x</sub>. Ozone is formed secondarily in the atmosphere through chemical reaction, so trends in source emissions of pollutants that react to form ozone may not be exactly reflected in ozone concentrations. Other factors, such as heat, play a significant role in ozone formation.

#### References

US Environmental Protection Agency (USEPA). March 2000. *National Air Pollutant Trends, 1900-1998*. <http://www.epa.gov/ttn/chieftrends/trends98/trends98.pdf>. Accessed 2/6/02.

### **7. Habitat Modification**

*Impact Categories: Aquatic Organisms, Terrestrial Organism, Quality of Life Aesthetics  
Sources: Drainage and Channelization, Dredging, Urban/Suburban/Lakeshore  
Development, Agriculture, Mining, Silviculture*

Habitat modification affects aquatic and terrestrial organisms, which in turn can affect the aesthetic quality of environmental resources. Habitat modification, as discussed here, includes any human activity that affects habitat to such an extent that it can no longer fully sustain its original use. Thus agriculture, for example, creates habitat suitable for certain species of terrestrial organisms, but we only consider effects

associated with shifts in habitat from grassland or forest to agriculture, particularly row crop agriculture. Similarly, attempts to improve habitat through modification are not considered in this discussion.

### Comparative Contribution of Sources

It is nearly impossible to quantify the comparative contribution of different sources for habitat modification. The primary obstacle is lack of a uniform way for determining impacts from habitat modification. For example, in one case, habitat may be modified at a local level but result in loss of a population, while in another case, there may be widespread modification that diminishes the health of a particular species.

*Agriculture:* High contribution. There are about 21 million acres of cropland in Minnesota, most in row crop agriculture. Cultivation of soil and loss of native vegetation as a result of agriculture has irreversibly changed the native habitat of Minnesota (<http://www.mnplan.state.mn.us/mm/indicator.html?Id=68&G=41>).

*Drainage and Channelization:* High contribution. About 5 million acres of Minnesota wetlands have been drained, 20 percent with tiles and 80 percent with ditches (<http://www.house.leg.state.mn.us/hrd/pubs/drainage.pdf>). The loss of wetlands is irreversible or at best, very slowly reversible. Drainage therefore represents a direct loss of habitat. Drainage also impacts the hydrology of water bodies ([http://ohioline.osu.edu/b871/b871\\_24.html](http://ohioline.osu.edu/b871/b871_24.html)). For example, loss of wetlands may lead to increased peaks in flooding. Channelization may significantly alter aquatic environments by changing flow and riparian habitat ([http://www.epa.gov/opperspd/futures/risk/crexamples/examples/Arizona/ecosystems/strm\\_riv.txt](http://www.epa.gov/opperspd/futures/risk/crexamples/examples/Arizona/ecosystems/strm_riv.txt); <http://www.wri.org/wr-98-99/freshwat.htm>).

*Dredging:* Medium contribution. Dredging results in the temporary elevation of suspended solids emanating from the project area as a turbidity plume. The suspended sediments are generally high in organic matter and clay, both of which may be biologically and chemically active. The removal of bottom sediments during dredging operations can disrupt the entire benthic community and eliminate a significant percentage of the feeding habitat available to fish for a significant period of time (<http://www.psmfc.org/efh/Jan99-sec3-23B.html#Dredging>; <http://www.isu.edu/departments/bios/Minshall/Publications/Report.pdf> ). Dredging in Minnesota is primarily limited to the states navigation routes, such as the Minnesota River, Mississippi River, and Lake Superior. Some urban lakes are dredged periodically. Effects on habitat, while significant locally, are therefore limited in geographic extent.

*Mining:* Low contribution. Open pit mining has severe effects on habitat, with nearly complete destruction of habitat in a mined area (<http://www.kudremukh.org/news/iisc.html>). Excluding peat mining, the extent of mined areas is limited to the Mesabi Range in northern Minnesota, however. There is also evidence that abandoned mine areas, if somewhat limited in geographic extent, recover relatively quickly when surface water has not been contaminated (<http://www.mii.org/babbitt/babbitt.html>; <http://www.mii.org/steeprook/steeprook.html>; <http://www.mii.org/Sunrise/Sunrise.html>). Thus, this stressor ranked low for overall comparative contribution.

*Silvaculture:* High contribution. Silviculture, like agriculture, has had dramatic impacts on the ecological landscape. In 1999, 3.8 million cords of wood were harvested

in Minnesota (<http://www.mnplan.state.mn.us/mm/indicator.html?Id=60&G=39>; [http://www.afandpa.org/forestry/Facts/Forest\\_Ownership.pdf](http://www.afandpa.org/forestry/Facts/Forest_Ownership.pdf)). Impacts include loss of old growth forests, soil erosion, fire suppression, sedimentation, and nutrient loading of surface water. An important impact of silviculture is reduced species diversity (<http://www.sprise.com/shs/habitatnet/FieldProblems.htm>; [http://www.ire.ubc.ca/fepa/proj\\_silva\\_proposal.html](http://www.ire.ubc.ca/fepa/proj_silva_proposal.html)). This stressor rated high because of the geographic extent of silvacultural activities, although silvacultural practices have increasingly incorporated environmental management practices.

*Urban/suburban/lakeshore development:* High contribution. Minnesota converted to urban use a total of 232,000 acres between 1992 and 1997, placing it 17th among the 50 states for its rate of development of non-federal land. There are about 2.2 million acres of urban area in Minnesota. Although a relatively small percentage of Minnesota's land is urban, highly dispersed development patterns can fragment habitats into small, disconnected plots and significantly affect ecosystems and the viability of species that depend on them (<http://www.mnplan.state.mn.us/mm/indicator.html?Id=68&G=41>; <http://ceres.ca.gov/planning/hcp/>). Highly developed urban areas essentially destroy the original ecological environment. Development also results in sedimentation and nutrient enrichment of surface water. Lakeshore development can also degrade habitat through fragmentation, sedimentation, and nutrient enrichment ([http://www.uwsp.edu/cnr/uwexlakes/fs\\_12.pdf](http://www.uwsp.edu/cnr/uwexlakes/fs_12.pdf); <http://es.epa.gov/ncer/progress/grants/99/futures/lemborg00.html>; <http://royal.okanagan.bc.ca/kokanee/fishredu.htm>).

#### Confidence Level

Our confidence level for all sources was reasonable. Habitat modification is readily observed. Sources of modification are typically easy to determine. Examples of habitat modification can be found in the references cited above (for Comparative Contribution).

#### Source Trends

*Agriculture:* No trend. Cropland acreage in Minnesota decreased by about 7 percent in the 1980's but remained relatively constant during the 1990's (<http://www.mnplan.state.mn.us/mm/indicator.html?Id=68&G=41>).

*Drainage and Channelization:* Upward trend. In Minnesota, wetland acres continue to be drained faster than they are restored, although the rate of drainage has decreased dramatically in the past few decades. Drainage associated with development continues to increase (<http://www.epa.gov/owow/wetlands/vital/status.html>; [http://www.na.fs.fed.us/spfo/pubs/n\\_resource/wetlands/wetlands2\\_trends.htm](http://www.na.fs.fed.us/spfo/pubs/n_resource/wetlands/wetlands2_trends.htm)).

*Dredging:* No trend. There is limited information to determine trends in dredging in Minnesota. We assumed that dredging primarily occurs on navigable waters and has therefore changed little in the past few decades.

*Mining:* No trend. In 2000, about 43 million tons of taconite were produced in Minnesota, compared to about 45 million tons in 1980. Acres in mining increased from about 50,000 in 1969 to 80,000 in 1990. The increase in acreage is somewhat offset by ecological recovery of previously mined areas

([http://www.iic.state.mn.us/finfo/landscap/1/assess/G2\\_nomap.pdf](http://www.iic.state.mn.us/finfo/landscap/1/assess/G2_nomap.pdf);  
[http://www.state.mn.us/ebranch/mdor/mining/forms/pdf/01mining\\_guide.pdf](http://www.state.mn.us/ebranch/mdor/mining/forms/pdf/01mining_guide.pdf)).

*Silvaculture*: No trend. Forested acres in Minnesota increased slightly from 1.60 million to 1.62 million acres between 1982 and 1997. Timber production increased slightly from 3.5 million cords in 10090 to 3.8 million cords in 1999. These changes are relatively insignificant

(<http://www.mnplan.state.mn.us/mm/indicator.html?Id=68&G=41>;  
<http://www.mnplan.state.mn.us/mm/indicator.html?Id=60&G=39>).

*Urban/suburban/lakeshore development*: Upward trend. Between 1982 and 1997, urban land climbed from 1.7 million to 2.2 million acres, up 27 percent, while Minnesota's population rose about 14 percent

(<http://www.mnplan.state.mn.us/mm/indicator.html?Id=68&G=41>). Seasonal or vacation home growth was about 7 percent statewide between 1980 and 1990  
([http://www.iic.state.mn.us/finfo/landscap/1/assess/G2\\_nomap.pdf](http://www.iic.state.mn.us/finfo/landscap/1/assess/G2_nomap.pdf)).

## 8. Nitrogen

*Impact Categories: Aquatic Organism, Terrestrial Organisms*

*Sources: Agricultural Runoff, Feedlots, Municipal and Industrial Wastewater, Septic Systems, Urban Runoff, Area Source Combustion, Coal-fired Power Plants, Fertilizer Use, Land-Applied Manure, Off-road Equipment, On-road Vehicles*

Nitrogen is an important element in the environment, comprising 78 percent of the earth's atmosphere. Nitrogen is an essential element for all life, although in excessive amounts, it can be toxic to various forms of life. The standard for nitrate-nitrogen in drinking water is 10 ppm. Ingestion of nitrate above 10 ppm can cause methemoglobinemia (blue-baby disease), which affects infants six months of age or younger and may also affect young farm animals. Nitrogen is also an important nutrient in surface water. Although phosphorus is generally the limiting nutrient in surface water, nitrogen can occasionally lead to algae blooms. Nitrogen is also the primary chemical of concern for hypoxia in coastal waters

(<http://www.colca.cr.usgs.gov/midconherb/hypoxia.html>;  
<http://www.esa.org/education/factsheets/hypoxia.htm>). Nitrogen deposited from the atmosphere can impact terrestrial ecosystems. Impacts include changes in productivity, shifts in species, and changes in carbon cycling. Terrestrial impacts may also result from non-atmospheric forms of deposition, but these are poorly documented and not considered in this discussion (<http://www.usgcrp.gov/usgcrp/ProgramElements/bio.htm>;  
<http://www.nps.gov/noca/Ltem/AtmText.htm>;  
[http://www.marine.unc.edu/Paerllab/research/atmospheric/adn\\_opening.html](http://www.marine.unc.edu/Paerllab/research/atmospheric/adn_opening.html);  
<http://h2osparc.wq.ncsu.edu/wetland/aqlife/atmosdep.html>;  
[http://www.usgs.gov/public/press/public\\_affairs/press\\_releases/pr1361m.html](http://www.usgs.gov/public/press/public_affairs/press_releases/pr1361m.html)).

### Comparative Contribution of Sources

*Agricultural runoff*: High contribution. Agricultural runoff affects aquatic ecosystems and includes fertilizer use. It therefore was assigned a high relative contribution, since fertilizer use is generally acknowledged as the most important source

of nitrogen in most surface water, including the Minnesota and Mississippi Rivers (<http://wwwrcolka.cr.usgs.gov/midconherb/st.louis.hypoxia.html>; <http://ohioline.osu.edu/agf-fact/0204.html>; [http://www.epa.gov/ceisweb1/ceishome/atlas/nationalatlas/threats\\_to\\_health\\_of\\_us\\_waters.htm](http://www.epa.gov/ceisweb1/ceishome/atlas/nationalatlas/threats_to_health_of_us_waters.htm); <http://www.pca.state.mn.us/water/basins/mnriver/mgmt-fw.html>; <http://ks.water.usgs.gov/Kansas/pubs/fact-sheets/fs.135-00.html#HDR3>).

*Municipal and industrial wastewater:* Medium contribution. The contribution of nitrate from municipal and industrial wastewater discharges to waters of the state has been relatively stable over the past five years. Reported discharges from the 85 major treatment facilities comprising 27 industrial and 58 municipal sources have averaged about 4500 thousand kilograms over this time, according to Discharge Monitoring Reports (DMRs) submitted to the MPCA. Point source contributions, of which wastewater is the most important, account for less than 10 percent of nitrogen discharged to the Minnesota River (<http://www.pca.state.mn.us/water/basins/mnriver/mgmt-fw.html>; [http://www.texasep.org/html/wql/wql\\_2sfc.html](http://www.texasep.org/html/wql/wql_2sfc.html)).

*Feedlots:* Low to Medium contribution. Contributions to terrestrial ecosystems come from volatilization of manure and subsequent atmospheric deposition, as well as runoff from feedlots and subsequent deposition in terrestrial habitats. These effects are not well documented, but even if they were considerable, effects would be local in nature. Impacts to terrestrial ecosystems are therefore considered to be low. Impacts to aquatic ecosystems are significant. Open feedlots contribute large quantities of organic matter and ammonia to surface waters, and the nitrogen from these sources can be persistent in oxygenated waters. Manure handling remains a critical concern in some areas of the state where large confined feedlot operations are concentrated. Although there is concern about increasing size of feedlots, these feedlots are generally permitted, have concrete liners, and may require an NPDES permit. Consequently, they contribute significantly less nitrogen to surface water than open feedlots and feedlots having unpermitted liners (<http://lakeaccess.org/feedlots.html>; <http://ace.orst.edu/info/extoxnet/faqs/safedrink/feed.htm>; <http://www.pca.state.mn.us/water/groundwater/gwmap/gw-manure.html>).

*Urban runoff:* Medium contribution. Increased urbanization and use of fertilizers on lawns and plantings have been offset somewhat by better management practices for fertilizer application and implementation of runoff controls (<http://www.mda.state.mn.us/appd/ace/turfideas.pdf>; <http://www.epa.gov/OWOW/NPS/facts/point7.htm>; <http://www.ga.usgs.gov/edu/urbannitrogen.html>).

*Septic systems:* Low contribution. Septic systems contribute large quantities of nitrogen to ground water. Although this nitrogen may be discharged to surface water and thus impact aquatic ecosystems, studies show that most nitrogen is removed in riparian zones adjacent to surface water. Impacts to surface water can be significant when these riparian zones do not exist or have been modified (<http://www.pca.state.mn.us/water/groundwater/gwmap/gw-nonsewered.html>; <http://www.crjc.org/riparianbuffers.htm>; <http://www.dnrec.state.de.us/dnrec2000/Library/RIPARIANBUFFERS1.PDF>).

*Area Source Combustion:* Low contribution. Residential fuel combustion is a small, but significant, source of NO<sub>x</sub> emissions. About 6 percent of NO<sub>x</sub> comes from

area sources (<http://www.pca.state.mn.us/hot/legislature/reports/2001/at-appendix-c.pdf>; <http://h2osparc.wq.ncsu.edu/wetland/aqlife/atmosdep.html>).

*Coal-fired Power Plants:* High contribution. Point sources account for an estimated 39 percent of NO<sub>x</sub> emissions. Total nitrogen released annually to the atmosphere in the form of NO<sub>x</sub> is more than 450,000 tons. Coal-fired power plants are the most important point source

(<http://www.pca.state.mn.us/hot/legislature/reports/2001/at-appendix-c.pdf>; <http://h2osparc.wq.ncsu.edu/wetland/aqlife/atmosdep.html>).

*Fertilizer Use:* Medium contribution. In agricultural watersheds, fertilizers are considered an important source of atmospheric nitrogen, primarily through volatilization of ammonia, although contributions from dust can also be important

([http://water.usgs.gov/nawqa/sparrow/coast/agu\\_sparrow.html](http://water.usgs.gov/nawqa/sparrow/coast/agu_sparrow.html); <http://www.dnr.state.md.us/streams/atmosphere/sources.html>; <http://h2osparc.wq.ncsu.edu/wetland/aqlife/atmosdep.html>; [http://www.usgs.gov/public/press/public\\_affairs/press\\_releases/pr1361m.html](http://www.usgs.gov/public/press/public_affairs/press_releases/pr1361m.html)).

*Land-Applied Manure:* Medium contribution. About 20 percent of nitrogen in nonincorporated, land-applied manure is lost through volatilization. Considering the generation of approximately 1 million tons of nitrogen in livestock manure annually, and assuming that a significant portion of this is applied to agricultural fields, land-applied manure represents a significant anthropogenic source of atmospheric nitrogen

(<http://www.gov.mb.ca/agriculture/soilwater/manure/fdb01s03.html>; <http://www.agcom.purdue.edu/AgCom/Pubs/AY/AY-277.html>; <http://www.ces.uga.edu/pubcd/c826-w.html>; <http://www.nps.ars.usda.gov/programs/programs.htm?npnumber=206&docid=344>).

*Off-road Equipment:* Medium contribution. Non-point sources account for an estimated 55 percent of NO<sub>x</sub> emissions. Off-road equipment is considered less important than on-road vehicles (<http://www.pca.state.mn.us/hot/legislature/reports/2001/at-appendix-c.pdf>).

*On-road Vehicles:* High contribution. Nonpoint sources account for an estimated 55 percent of NO<sub>x</sub> emissions. Total nitrogen released annually to the atmosphere in the form of NO<sub>x</sub> is more than 450,000 tons. On-road vehicles are the most important nonpoint source (<http://www.pca.state.mn.us/hot/legislature/reports/2001/at-appendix-c.pdf>; <http://h2osparc.wq.ncsu.edu/wetland/aqlife/atmosdep.html>).

#### Confidence Level

Except for urban runoff, where the extent of monitoring is very limited, our confidence level for the contribution of the above sources to nitrogen in our water resources (aquatic organisms) is medium to reasonable. Municipal and industrial wastewater treatment plants are required to monitor and report nitrogen levels in their discharges. Runoff controls and some site-specific monitoring are required of larger feedlots and some septic systems. A number of research studies have quantified the amount of nitrogen entering surface water as a result of runoff from agricultural tile lines. Minnesota's contribution to hypoxia in the Gulf of Mexico is approximately 7%, according to the White House Office of Science and Technology. Our confidence for terrestrial sources is more uncertain.

*Agricultural Runoff*: Reasonably confident. Fertilizer contributions to overall nitrogen loading have been estimated for some important surface water basins in Minnesota, including the Minnesota and Mississippi. Similar estimations have been made for other surface water basins in the United States (<http://www.colka.cr.usgs.gov/midconherb/st.louis.hypoxia.html>; <http://ohioline.osu.edu/agf-fact/0204.html>; [http://www.epa.gov/ceisweb1/ceishome/atlas/nationalatlas/threats\\_to\\_health\\_of\\_us\\_waters.htm](http://www.epa.gov/ceisweb1/ceishome/atlas/nationalatlas/threats_to_health_of_us_waters.htm); <http://www.pca.state.mn.us/water/basins/mnriver/mgmt-fw.html>).

*Feedlots*: Somewhat speculative to moderately confident. Runoff from feedlots into surface water is well documented (moderately confident for aquatic ecosystems). Less is known about impacts of feedlots on terrestrial ecosystems (somewhat speculative).

*Municipal and Industrial Wastewater*: Reasonably confident. Wastewater treatment facilities are largely regulated and have effluent limits.

*Septic Systems*: Moderately confident. We have good information on the approximate number of septic systems in Minnesota. Research clearly shows effects of septic systems on water quality. There are few studies, however, linking these effects to impacts on aquatic ecosystems.

*Urban Runoff*: Somewhat speculative. Fertilizer application in urban areas has been increasing in recent years, but there is little information regarding the fate of that fertilizer. There are few studies that directly link nitrogen in urban runoff with impacts to aquatic ecosystems.

*Area Source Combustion*: Somewhat speculative. Area sources are largely unregulated and we therefore have limited information on emissions. Since there are a large number of area sources, the cumulative effect of these is speculative.

*Coal-fired Power Plants*: Moderately confident. Emissions of NO<sub>x</sub> from industrial sources are tracked at the state level on an annual basis. Emissions estimates from small industrial or commercial (“area”) and mobile sources are tracked at the national level by EPA. Uncertainties in the methodologies exist, but the main sources of the pollutants are known. What is not understood, however, is the fate of nitrogen that is deposited to terrestrial systems from the atmosphere. Quantities of nitrogen in the atmosphere vary by region (<http://www.nstl.gov/research/onepage/rainqual.html>; <http://www.wri.org/trends/>; [http://www.ubavie.gv.at/tfmm/reports/agenda02/Trends\\_Uk.pdf](http://www.ubavie.gv.at/tfmm/reports/agenda02/Trends_Uk.pdf)).

*Fertilizer Use*: Moderately confident. We have information on fertilizer use and have some information on rates of loss from fertilizers, but impacts to terrestrial systems are largely unknown.

*Land-Applied Manure*: Somewhat speculative. There is limited information on the quantities of manure that are land applied, although it is likely to be a significant percent of the manure generated by livestock in the state. There is limited information on methods of manure application, and the method of application significantly affects the fate of nitrogen.

*Off-road Equipment*: Somewhat speculative. We have limited information on the amount of nitrogen released from off-road equipment.

*On-road Vehicles*: Moderately confident. There is reasonably good information on number of vehicle miles driven and gasoline consumption for Minnesota. We can

make estimates of quantities of nitrogen released from these vehicles. There is less certainty about the environmental fate of that nitrogen.

### Source Trends

Nitrogen is the only common water pollutant to show an increasing trend in both surface and ground water over the last 30 years. Nitrogen levels have increased at 75 percent of monitored surface water sites across the state in the past 30 years. More efficient agricultural drainage systems (primarily through tiling) and a trend toward increased rainfall in the 1990's have contributed to this trend. The increasing trend is due to factors such as increased tiling of agricultural land and increased urbanization. We do not have monitoring data for terrestrial ecosystems, but globally, there is an upward trend in nitrogen concentrations of terrestrial ecosystems

(<http://www.usgcrp.gov/usgcrp/ProgramElements/bio.htm>;  
<http://www.geog.ouc.bc.ca/physgeog/contents/9s.html>;  
<http://www.geog.ouc.bc.ca/physgeog/contents/9s.html>).

*Agricultural Runoff*: Upward trend. Since this source includes fertilizer use and aquatic ecosystems, the trend is upward. Nitrogen fertilizer use has leveled in the past ten years, but agricultural drainage continues, although at a decreasing rate. This drainage results in loss of nitrogen to tile lines, which eventually is discharged to streams and rivers. Increasing nitrogen trends are observed at about 90 percent of Minnesota Milestone sites in the Minnesota, Des Moines, and Missouri River basins. These are areas that are intensively farmed and extensively drained

([http://www.ag.ndsu.nodak.edu/aginfo/entomology/ndsucpr/Years/2000/July/27th/soils\\_27july00.htm](http://www.ag.ndsu.nodak.edu/aginfo/entomology/ndsucpr/Years/2000/July/27th/soils_27july00.htm); <http://www.pca.state.mn.us/publications/reports/305bfinalreport-2000.pdf>).

*Feedlots*: No trend. There appears to be no trend in the number of livestock and feedlots in Minnesota, although there is an increasing trend in size of newly permitted lots. These newer, larger lots are less likely to pollute surface water than older lots if they are properly managed, since many have concrete-lined manure basins and they must have a NPDES permit (<http://hermes.ecn.purdue.edu/cgi/convwqtest?wq-7.in.ascii>;  
<http://ace.orst.edu/info/extoxnet/faqs/safedrink/feed.htm>;  
<http://www.pca.state.mn.us/water/groundwater/gwmap/gw-manure.html>).

*Municipal and Industrial Wastewater*: No trend. Although wastewater effluent is regulated, nitrogen is not a specific chemical required for monitoring in effluent. New treatment practices may be effective at removing reduced forms of nitrogen, but will not be useful for reducing nitrate concentrations. Because treatment practices have been in place for several years, we assumed no trend in nitrogen concentrations from wastewater treatment facilities.

*Septic Systems*: Upward trend. The number of septic systems in Minnesota continues to increase as urban areas expand beyond municipal services. Nitrate, unlike most other chemicals in septic waste, is not treated within the septic system and therefore readily enters ground water. Several researchers have observed elevated ground water nitrate concentrations in areas serviced by septic systems. This ground water may discharge to surface water and impact aquatic ecosystems  
(<http://www.pca.state.mn.us/water/groundwater/gwmap/gw-nonsewered.html>).

*Urban Runoff*: Upward trend. The percent of urban land in Minnesota increased about 27 percent between 1982 and 1997. Several studies have demonstrated negative

impacts of urban runoff on aquatic organisms  
(<http://www.epa.gov/OWOW/NPS/facts/point7.htm>;  
<http://www.ocrm.nos.noaa.gov/pcd/6217.html>;  
<http://capita.wustl.edu/NEW/oconnor.html>;  
<http://www.mnplan.state.mn.us/mm/indicator.html?Id=68&G=41>).

*Area Source Combustion:* No trend. The effect of area source combustion is on nitrogen loading to terrestrial ecosystems. We have limited data on trends in area source combustion. Nitrogen increases in the atmosphere are considered to primarily originate from on-road and off-road equipment and vehicles.

*Coal-fired Power Plants:* No trend. The effect of coal-fired power plants is on atmospheric nitrogen loading to terrestrial ecosystems. There has been a slight upward trend in emissions of NO<sub>x</sub> in Minnesota, but this trend does not appear statistically significant. Mobile sources, particularly automobiles, would likely account for any trend in emissions of NO<sub>x</sub>. Nationally, NO<sub>x</sub> emissions have decreased slightly over the past ten years (<http://www.pca.state.mn.us/hot/legislature/reports/2001/at-appendix-c.pdf>;  
<http://www.epa.gov/oar/aqtrnd00/acidrain.html>).

*Fertilizer Use:* No trend. Fertilizer use has not changed dramatically in agricultural areas in the past years. Use appears to have increased in urban areas.

*Land-Applied Manure:* No trend. There is little documentation about the amount of manure applied to agricultural fields. Since the number of livestock has not increased dramatically in the past ten years, and assuming farmers are not applying different quantities of manure than in the past, we estimated there was no trend in contributions from land-applied manure.

*Off-road Equipment:* Upward trend. The effect of off-road equipment is on atmospheric nitrogen loading to terrestrial ecosystems. There has been a slight upward trend in emissions of NO<sub>x</sub> in Minnesota, but this trend does not appear statistically significant. Mobile sources, particularly automobiles, would likely account for any trend in emissions of NO<sub>x</sub>. Nationally, NO<sub>x</sub> emissions have decreased slightly over the past ten years (<http://www.pca.state.mn.us/hot/legislature/reports/2001/at-appendix-c.pdf>;  
<http://www.epa.gov/oar/aqtrnd00/acidrain.html>).

*On-road Vehicles:* Upward trend. The effect of on-road vehicles is on atmospheric nitrogen loading to terrestrial ecosystems. There has been a slight upward trend in emissions of NO<sub>x</sub> in Minnesota, but this trend does not appear statistically significant. Mobile sources, particularly automobiles, would likely account for any trend in emissions of NO<sub>x</sub>. Nationally, NO<sub>x</sub> emissions have decreased slightly over the past ten years (<http://www.pca.state.mn.us/hot/legislature/reports/2001/at-appendix-c.pdf>;  
<http://www.epa.gov/oar/aqtrnd00/acidrain.html>).

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- Minnesota Pollution Control Agency, June 2001, *Air and Water Emissions Report*,  
<http://www.pca.state.mn.us/hot/legislature/reports/2001/air-water-emissions.html>

## 9. Noise

*Impact Categories: Human Health Noncancer Acute, Human Health Noncancer Chronic, Quality of Life-Aesthetics*

*Sources: Aircraft, Industry, Off-road Equipment, On-road Vehicles*

Noise has acute and chronic impacts to human health, as well as aesthetic effects. Health effects include hearing impairment, headaches, loss of sleep, cardiovascular effects, etc. (<http://www.nonoise.org/library/whonoise/whonoise.htm>).

There are many sources of noise. Occupational exposure, which is not considered in the EIR, is the most common cause of adverse health effects from noise. In the EIR, we considered on-road vehicles (e.g. cars, trucks, etc.), industry, aircraft, and off-road equipment (e.g. jackhammers, snowmobiles, chainsaws, etc.). Berglund and Lindvall, 1995 (<http://www.nonoise.org/library/whonoise/whonoise.htm#4.2>), provide a discussion of sources of noise and potential health effects resulting from exposure to various sources for a variety of durations. The Noise Pollution Clearinghouse is an additional source of information on sources of noise and human health effects associated with noise (<http://www.nonoise.org/cgi-bin/query.cgi?query=noise+complaints&db=news&db=lawlib&db=library&format=long>).

Although many agencies have regulations, standards, or criteria for noise, there appears to be little environmental monitoring (<http://www.pca.state.mn.us/programs/pubs/noise.pdf>). Despite this, the contribution of sources was based on monitored levels, since there is little documentation of health impacts or complaints associated with noise.

### Comparative contribution of sources

In a poll conducted by the U.S. EPA Office of Noise Abatement and Control (1977), 46% of respondents from 24 large U.S. metropolitan areas indicated they had been annoyed by noise in their neighborhoods. Thirty-one percent of the “annoyed” people were highly annoyed. About one percent cited noise as a sufficient reason for moving (<http://www.nonoise.org/library/urban/urban.htm#top>). Motor vehicle noise was considered the most pervasive source in larger metropolitan areas, while aircraft were more important in smaller metropolitan areas. Overall, on-road sources accounted for the three most important sources, followed by construction and then aircraft.

*On-road Vehicles:* High contribution. Typical noise levels adjacent to major highways are about 70 dB. Noise criteria (75 dB) for federal highways are used to trip a federal funding mechanism for noise abatement on highway projects. Criteria (80 dB) also exist for state highways. There are more than 100 monitored sites along major highways and roadways in the Twin Cities Metro Area. The Minnesota Department of Transportation estimates it will take about 17 years to install noise abatement structures at the most important locations

(<http://www.dot.state.mn.us/govrel/positionstatements/noisewal.html>;  
[http://www.dot.state.mn.us/metro/tps/htms/noise/mndot\\_noise\\_policy.html](http://www.dot.state.mn.us/metro/tps/htms/noise/mndot_noise_policy.html);  
<http://www.dot.state.mn.us/govrel/positionstatements/noisewal.html>).

*Aircraft:* High contribution. Typical noise levels within 100 meters of aircraft exceed 100 dB. In January of 2002, there were 573 complaints filed by 73 complainants

in the Twin Cities Metro Area

([http://macavsat.org/pdf\\_files/monthly\\_reports/jan02\\_ta.pdf](http://macavsat.org/pdf_files/monthly_reports/jan02_ta.pdf)). The FAA has source regulations for commercial jet engines. All commercial jet engines must meet noise emission criteria prior to being certified for flight (<http://macavsat.org/technologies/anoms/index.htm>).

*Industry:* Medium contribution. The MPCA has a receiver-based standard intended to limit noise levels and protect the health and welfare of the general public. These typically are applied to industrial sources (<http://www.pca.state.mn.us/programs/noise.html>). Industries generally do not contribute to excessive noise, but do contribute to background noise in metropolitan areas. There are cases of MPCA fining individual industries for exceeding noise standards (<http://www.pca.state.mn.us/news/nr041601.html>).

*Off-Road Equipment:* Medium contribution. The Minnesota DNR has source standards for snowmobiles, motorboats, personal watercraft and off-highway vehicles (<http://www.pca.state.mn.us/programs/pubs/noise.pdf>). Monitoring occurs only within specific locations, such as the Iron Range Off-Highway Vehicle Recreation Area ([http://www.dnr.state.mn.us/trails\\_and\\_waterways/iron\\_range/gilbert/monitoring.html](http://www.dnr.state.mn.us/trails_and_waterways/iron_range/gilbert/monitoring.html)). Noise complaints, although not tabulated, do occur in specific locations as a result of use of off-road equipment ([http://news.mpr.org/features/199708/27\\_losurem\\_skis/](http://news.mpr.org/features/199708/27_losurem_skis/); <http://www.nonoise.org/news/snow.htm>).

#### Confidence Level

The confidence level for the stressor (Noise) was somewhat speculative. The primary concerns were a lack of monitoring information, uncertainty in relating observed health effects to noise levels, and lack of tabulation of noise complaints for most sources. All of the sources had a reasonable confidence level, however, because these are widely known to be the most important sources of noise and there is ample documentation that these are the most important sources of noise.

#### Source Trends

There was little information to suggest a trend in actual monitored noise levels. Air and on-road vehicle traffic, however, have increased (<http://www.atag.org/natf/>; <http://www.pca.state.mn.us/air/mvetlocation.html>).

### **10. Odorous Chemicals from Biological Processes**

*Impact Categories: Human Health Noncancer Acute, Human Health Noncancer Chronic, Quality of Life Aesthetics*

*Sources: Agriculture, Ethanol Production, Feedlots, Treatment/settling Ponds*

Noxious odors from businesses are a common complaint. This is a difficult issue to deal with because odor is not necessarily directly associated with harmful effects (<http://www.health.state.mn.us/divs/eh/hazardous/gopher/#odors>). Some chemicals are lethal well below the odor threshold, while others have an odor threshold well below any health benchmark. MPCA and other agencies do not have a consistent tracking method for odors, so it was difficult to prepare a comparative contribution for sources.

The chemicals that are most frequently cited in odor complaints are hydrogen sulfide (and other chemicals in the H<sub>2</sub>S family), ammonia, alcohols, and other VOCs. These chemicals often cause odor complaints at levels where health effects are not expected (<http://www.pca.state.mn.us/hot/fl-odor.html>).

The contribution was primarily ranked according to the perception of number of complaints, since MPCA does not conduct odor monitoring (MPCA does some H<sub>2</sub>S monitoring as a surrogate for comparison to odor benchmarks). Complaints are not coded by SIC code.

### Comparative Contribution of Sources

*Feedlots: High Contribution.* The majority of odor complaints are associated with feedlot operations. The suspected source of approximately 600 of the 900 odor complaints received by the Minnesota Pollution Control Agency between 1995 and 2000 were hog feedlots. About 50 percent of the 600 complaints were attributed to six or seven large hog feedlots (<http://www.pca.state.mn.us/hot/fl-odor.html>).

*Treatment/settling ponds: Medium Contribution.* Treatment ponds such as sugar beet wastewater ponds, municipal settling ponds, etc. also cause odor complaints, though these are considerably less in number than complaints from feedlots.

*Agriculture: Medium Contribution.* Manure spreading on fields and other agricultural processes can result in odor complaints.

*Ethanol Production: Low Contribution.* There are only a few ethanol plants in Minnesota. However, some of them such as the ethanol plant in St Paul are in urban areas and have received many complaints (<http://www.health.state.mn.us/divs/eh/hazardous/gopher/>).

### Confidence Level

The confidence level for all of the sources to odorous chemicals is somewhat speculative, with many assumptions at play. The sources are based on professional judgment regarding the extent of odor complaints. Complaints are dependent on many factors and MPCA does not track SIC codes for facility complaints. In addition, there is not necessarily a correlation between odor complaints and health impacts from odors.

### Source Trends

It is difficult to determine trends since odors are not monitored. For feedlots, controls and processes for reporting and responding to odor complaints are improving, but this is countered by increasing facility size, particularly for hogs, which pose the greatest risk for odors

(<http://www.extension.umn.edu/distribution/livestocksystems/DI7637.html>). We can only speculate trends based on trends in the sources, rather than based on actual data.

*Feedlots: Upward trend.* The upward trend is based on increasing size of hog facilities, which have a much greater potential for adverse effects from odors than other livestock operations

(<http://www.extension.umn.edu/distribution/livestocksystems/DI7637.html>).

*Treatment/settling ponds: No trend.* There is limited information about the number and size of treatment and settling ponds that could create odor problems. There appears to be no trend in the number of industries most likely to cause odor problems,

however, such as sugar beet or other vegetable wastewater ponds and municipal settling ponds.

*Agriculture:* No trend. Since livestock numbers have not changed significantly in the past ten years, we assume no trend in the contribution from agriculture, since manure spreading will be the primary source of odors from agriculture.

*Ethanol Production:* Upward trend. Ethanol production is increasing in both Minnesota and the United States, and there is increased demand for ethanol fuel (<http://www.mda.state.mn.us/Ethanol/MEP4'99.HTM>; [http://news.mpr.org/features/200111/08\\_postt\\_harvest-m/ethanol.shtml](http://news.mpr.org/features/200111/08_postt_harvest-m/ethanol.shtml); [http://www.energy.ca.gov/reports/2001-08-29\\_600-01-017.PDF](http://www.energy.ca.gov/reports/2001-08-29_600-01-017.PDF)). Although most facilities are located in rural areas, increasing populations and construction of ethanol plants in urban areas are likely to result in a greater potential for odor impacts.

## **11. Other Criteria Pollutants in Air**

*Impact Categories: Human Health Noncancer Chronic, Human Health Noncancer Acute Sources: Coal-fired Power Plants, industry, Off-road Equipment, On-road Vehicles, Residential fuel Combustion*

Criteria pollutants are those for which we have National Ambient Air Quality Standards (NAAQS) established by the federal government under the Clean Air Act. There are six criteria pollutants: sulfur dioxide (SO<sub>2</sub>), nitrogen dioxide (NO<sub>2</sub>), lead (Pb), ozone (O<sub>3</sub>), carbon monoxide (CO), and particulate matter (PM). These pollutants have effects on both human health and the environment. The 'Other Criteria Pollutants in Air' stressor covers the human health effects of SO<sub>2</sub>, NO<sub>x</sub>, and CO. Other stressors cover the remaining pollutants and non-human health effects.

### Comparative Contribution of Sources

*On-Road Vehicles:* High Contribution. According to EPA's 1998 Trends Report, on-road vehicles account for 32% of nation-wide NO<sub>x</sub> and 56% of CO emissions. On-road vehicles are a small source of SO<sub>2</sub>.

*Coal-Fired Power Plants:* High Contribution. Electric utilities are responsible for 25% of NO<sub>x</sub> emissions and 64% of total SO<sub>2</sub> emitted.

*Off-Road Equipment:* Medium Contribution. Off-road equipment and vehicles emit 22% of NO<sub>x</sub>, 22% of CO, and 6% of SO<sub>2</sub> emissions nationwide.

*Industry:* Medium Contribution. Industrial fuel combustion is a significant, but smaller, source of NO<sub>x</sub> compared to on-road vehicles and coal-fired power plants. Industry, excluding coal-fired power plants, is responsible for 15% of SO<sub>2</sub> emissions.

*Residential Fuel Combustion:* Low Contribution. Residential fuel combustion emits significant amounts of NO<sub>x</sub> into the air, although the total is small compared to mobile sources. Home wood burning is a small source of CO emissions.

### Confidence Level

All of the source contributions had a moderate confidence level, with the exception of Off-road vehicles and Residential fuel combustion. Emissions of CO, NO<sub>x</sub>, and SO<sub>2</sub> from industrial sources are tracked at the state level on an annual basis. Emission

estimates from small industrial or commercial (“area”) and mobile sources are tracked at the national level by EPA. Uncertainties in the methodologies exist, but the main sources of the pollutants are known. The highest uncertainties are for non-road sources, where local activity data is difficult to ascertain, and residential fuel combustion, where scant activity data and poor emission factors impede accurate emission estimates. Consequently, we assigned a confidence of Somewhat Speculative to these two sources.

### Source Trends

*On-Road Vehicles:* Downward Trend. Improvements in vehicle emission control technology as newer cars enter the fleet caused reductions in CO and SO<sub>2</sub> emissions. NO<sub>x</sub> emissions are also lower than they were twenty years ago but the increase in vehicle miles traveled caused the downward trend in NO<sub>x</sub> emissions to level out recently.

*Coal-Fired Power Plants:* No trend. Trends in CO emissions from coal-fired power plants are level or increasing slightly, but power plants are not a significant source of overall CO levels. Overall, emissions levels of SO<sub>2</sub> and NO<sub>x</sub> appear to be steady.

*Off-Road Equipment:* No trend. Emissions contributions from off-road engines and vehicles are level.

*Industry:* Downward trend. CO and NO<sub>x</sub> emissions from industrial fuel combustion (the largest industrial source of these pollutants) have neither increased nor decreased overall over the past several years. SO<sub>2</sub> emissions have decreased somewhat over time.

*Residential Fuel Combustion:* No trend. Emissions of SO<sub>2</sub>, NO<sub>x</sub>, and CO from residential burning of wood have not significantly varied over time.

### References

- US Environmental Protection Agency (USEPA). March 2000. *National Air Pollutant Trends, 1900-1998*.  
<http://www.epa.gov/ttn/chief/trends/trends98/trends98.pdf>. Accessed 2/6/02.

## **12. Oxygen-demanding Pollutants**

*Impact Categories: Aquatic Organisms, Quality of Life-Aesthetics*

*Sources: Agricultural runoff, Feedlots, Municipal and Industrial Wastewater, Septic Systems, Spills, Urban Runoff*

The primary chemicals of concern for dissolved oxygen depletion are organic matter, phosphorus, and nitrogen. Phosphorus and nitrogen are discussed in separate sections. Much of the discussion from Sections 8 (Nitrogen), 15 (Phosphorus), and 24 (Transported Sediment) can be applied to this section. Sources for these stressors are typically the same in their relative contribution as they are for oxygen-demanding pollutants. Trends and our confidence in estimating the comparative contribution are also similar for these different stressors.

### Comparative Contribution of Sources:

*Agricultural Runoff:* Medium contribution. Agricultural runoff considers only overland flow from agricultural fields (i.e. not runoff from feedlots). Organic matter and

nutrients, particularly phosphorus, can lead to oxygen depletion in surface water by stimulating microbiological activity ([http://www.cwn.org/docs/reports/wet\\_h2o/wetmajorpoll.htm](http://www.cwn.org/docs/reports/wet_h2o/wetmajorpoll.htm); [http://ohioline.osu.edu/b374/b374\\_10.html](http://ohioline.osu.edu/b374/b374_10.html); <http://www.great-lakes.net/teach/pollution/water/water2.html>). Hypoxia is a depletion of oxygen in coastal waters that is partly attributable to inputs nitrogen from human activity. Tile line drainage of agricultural lands is an important contributor of nitrogen, particularly in southern Minnesota rivers. Hypoxia, however, was considered under Nitrogen (Section 8), and effects from hypoxia are not considered here ([http://state-of-coast.noaa.gov/bulletins/html/hyp\\_09/hyp.html](http://state-of-coast.noaa.gov/bulletins/html/hyp_09/hyp.html)). Effects of phosphorus on algae growth and, hence, oxygen depletion, are discussed in Section 15. Highly cultivated agricultural lands may lose relatively small amounts of organic matter through erosion because much of the organic matter in highly erodible soils has already eroded or been oxidized after cultivation. The primary concerns come with application of manure, particularly on steeper slopes or when manure is not properly applied.

*Feedlots*: High contribution. Open feedlots, where animals are active on bare soils, have very high runoff rates because of compaction caused by animal movement. Since manure exists at the soil surface, large quantities of manure are eroded from these open lots. Animals may also contribute organic matter directly to surface waters if they are allowed access to a water body. The large quantities of relatively fresh organic matter make feedlots a high contributor for oxygen depletion (<http://www.ces.uga.edu/pubcd/c827-w.html#Non-Point Source>; <http://www.ces.uga.edu/pubcd/c827-w.html>; <http://www.pca.state.mn.us/water/pubs/feedlot33.pdf>; <http://www.cotf.edu/ete/modules/waterq/wqglossary.html>).

*Municipal and Industrial Wastewater*: Medium contribution. At one time, wastewater was the primary contributor to oxygen depletion in surface waters. Wastewater treatment is now regulated and effluent limits are in force for chemicals that contribute to biochemical oxygen demand (<http://www.pca.state.mn.us/water/wastewater.html>). Oxygen demand of municipal wastewater is widely documented, as are improvements in surface waters in the past ten years as a result of wastewater effluent controls (<http://ohioline.osu.edu/aex-fact/0768.html>; <http://h2osparc.wq.ncsu.edu/info/do.html>; <http://www.ci.san-jose.ca.us/esd/wpcp.htm>; <http://www.soundkeeper.org/programinitdetail.asp?ID=38>; <http://www.silverton.or.us/ogpwwp1.htm>; [http://themes.eea.eu.int/Specific\\_media/water/indicators](http://themes.eea.eu.int/Specific_media/water/indicators); [http://themes.eea.eu.int/Specific\\_media/water/indicators/bod/index.html](http://themes.eea.eu.int/Specific_media/water/indicators/bod/index.html)). A study from New York indicates that wastewater treatment facilities account for about 20 percent of the biochemical oxygen demand in an urban stream (<http://www.stormwater-resources.com/Library/071PLAlleyCreek.pdf>). Less is known about other types of wastewater, although many wastewaters, such as agricultural wastewater, have very high oxygen demand (<http://foodsci.unl.edu/fmc/need-07.htm>; <http://www.jpfr.org/LRV/wetlands%20constructed.htm>).

*Septic Systems*: Low contribution. Although human waste has a high oxygen demand, septic systems are designed to minimize loss of organic matter. Consequently, septic systems, except those that are failing, have minimal impact on oxygen depletion in

surface waters (<http://www.pca.state.mn.us/water/groundwater/gwmap/gw-nonsewered.html>). A study from New York indicates that failing septic systems account for about 1 percent of the biochemical oxygen demand in an urban stream (<http://www.stormwater-resources.com/Library/071PLAlleyCreek.pdf>).

*Spills*: Low contribution. Spills of oxygen demanding chemicals, such as raw sewage, can have dramatic and catastrophic short-term effects on aquatic ecosystems. Spills, however, generally have limited impact both in geographic extent and over long periods of time. In addition, environmental agencies have emergency response staff who respond to spills that threaten or impact the environment

(<http://www.pca.state.mn.us/cleanup/ert.html>;

<http://www.owasa.org/wastemgt/wwm1.asp>;

[http://www.ae.iastate.edu/Ae573\\_ast475/Water\\_Impacts\\_Notes.htm](http://www.ae.iastate.edu/Ae573_ast475/Water_Impacts_Notes.htm)).

*Urban runoff*: Medium contribution. Urban runoff includes chemicals that have oxygen demand, including yard waste, fertilizers, oil, and human waste from sewer systems. A study from New York indicates that stormwater runoff and loss from combined sewer overflows account for about 65 percent of the biochemical oxygen demand in an urban stream (<http://www.stormwater-resources.com/Library/071PLAlleyCreek.pdf>). Runoff from industries, such as salvage facilities where oil is drained and contaminates surface soils, can have very high oxygen demand ([http://www.ce.berkeley.edu/~hermanowicz/ce212/notes/water\\_pollut\\_b.pdf](http://www.ce.berkeley.edu/~hermanowicz/ce212/notes/water_pollut_b.pdf)).

#### Confidence Level

*Agricultural Runoff*: Moderately confident. Oxygen demand of agricultural runoff is documented. There is limited recent information on the amount of runoff occurring from agriculture and effects on aquatic ecosystems.

*Feedlots*: Moderately confident. Oxygen demand of animal waste and runoff from open feedlots are well documented. There is limited information on the amount of runoff occurring from feedlots and effects on aquatic ecosystems.

*Municipal and Industrial Wastewater*: Reasonably confident. Wastewater facilities are regulated and effluent standards exist for chemicals having an oxygen demand (<http://www.pca.state.mn.us/water/wastewater.html>).

*Septic Systems*: Moderately confident. There is considerable research that demonstrates likely impacts from adequately-performing septic systems are low. We have poor information, however, on the extent of nonconforming systems.

*Spills*: Reasonably confident. Spills must be reported, and emergency response plans are established to remedy spills. We therefore feel there is good information on environmental impacts associated with spills.

*Urban runoff*: Moderately confident. Research shows that urban runoff, particularly runoff associated with sewer overflow, has a high oxygen demand. There is limited information linking urban runoff to impacts on aquatic ecosystems.

#### Source Trends

*Agricultural Runoff*: No trend. The number of acres in agricultural production has not changed significantly in the past 15 years

(<http://www.mnplan.state.mn.us/mm/indicator.html?Id=68&G=41>).

*Feedlots:* No trend. There are about 45,000 feedlots in Minnesota, with more than 30,000 of these being permitted. The number of permits issued to feedlots having less than 500 animal units did not change between 1990 (134 permits) and 1999 (131 permits). These are facilities likely to be of greatest concern for surface water quality. The trend toward larger operations is likely to lead to improvements in water quality because of better manure management, but it is difficult to relate permits to actual environmental changes. We therefore assigned no trend to this source (<http://www.pca.state.mn.us/hot/fl-permits.html#trends>; <http://www.auditor.leg.state.mn.us/ped/1999/pe9904.htm>).

*Municipal and Industrial Wastewater:* Downward trend. Regulatory control of discharges from wastewater facilities has resulted in improvements in wastewater treatment. In addition, wastewater management has been one of the areas where successful pollution prevention practices have been implemented. Consequently, oxygen demand in surface waters has decreased in many areas, including 89 percent of monitored streams and rivers in Minnesota (<http://www.pca.state.mn.us/publications/reports/305bfinalreport-2000.pdf>; <http://www.mntap.umn.edu/POTW/Potw.htm>; [http://themes.eea.eu.int/Specific\\_media/water/indicators/bod/index\\_html](http://themes.eea.eu.int/Specific_media/water/indicators/bod/index_html))

*Septic Systems:* No trend. The number of septic systems is increasing in Minnesota as suburban areas lacking municipal services increase in their extent. There is an increased awareness, however, of potential water impacts from septic systems, and many municipalities are therefore upgrading old systems. Failing systems, which represent the greatest threat to aquatic ecosystems, are imminent environmental hazards and must be remedied (<http://www.pca.state.mn.us/programs/ists/index.html>).

*Spills:* No trend. Despite preventive efforts, spills still occur. There appears to be no trend in the occurrence of spills.

*Urban runoff:* Upward trend. The percent of land in urban use in Minnesota increased by more than 27 percent between 1982 and 1997. Studies of aquatic habitat in coastal areas of the United States show a trend of increasing degradation associated with urban runoff. Similar studies are limited for Minnesota, but impacts to aquatic ecosystems are likely to be similar in Minnesota as in other areas of the United States (<http://www.epa.gov/OWOW/NPS/facts/point7.htm>; <http://www.ocrm.nos.noaa.gov/pcd/6217.html>; <http://capita.wustl.edu/NEW/oconnor.html>).

### **13. Particles in Air**

*Impact Categories:* Human Health Cancer, Human Health Noncancer Acute, Human Health Noncancer Chronic, Quality of Life Aesthetics

*Sources:* Agriculture, Area Source Combustion, Coal-fired Power Plants, Fugitive Dust, Industry, Municipal and Industrial Wastewater, Off-road Equipment, On-road Vehicles

Air particles may be directly emitted (e.g., from grinding operations or combustion processes) or formed by other chemicals in the atmosphere. Directly emitted particles tend to be larger (on the order of 10 microns or sometimes larger) than those that

are secondarily formed. Recent studies on the impacts of particles on human health have focused on the smaller particles (on the order of 2.5 microns or smaller); therefore sources of the large particles may be less of a concern when looking at the health impacts of the stressor as a whole. In addition, the health impacts may be from the nature of the particles themselves or from the chemicals of which the particles are comprised. Metals and some semi-volatile compounds can condense with acid gases such as NO<sub>x</sub> and SO<sub>2</sub> to form particles. The nature of particles from particular sources may also be important. Some researchers of focusing on the effects of particles released from diesel-powered engines.

### Comparative Contribution of Sources

Coal-fired power plants, on-road vehicles, and off-road engines are all important sources of particles and their precursors. Research is ongoing to describe the relative importance of these sources in atmospheric particle formation and culpability for various health effects.

*Coal-Fired Power Plants: High Contribution.* Coal combustion by electric utilities emits 5% of the directly emitted, non-fugitive dust PM<sub>2.5</sub> according to the EPA 1998 emissions inventory. In addition, coal combustion by utilities accounts for 63% of SO<sub>2</sub> and 22% of NO<sub>x</sub> emissions in the US. Both pollutants are important precursors for secondary formation of fine particles.

*On-Road Vehicles: High Contribution.* On-road sources account for 7% of the primary, non-fugitive dust emissions of PM<sub>2.5</sub> in EPA's 1998 national emissions inventory. On-road vehicles emit 32% of NO<sub>x</sub> emissions, an important precursor to secondary particle formation. On-road diesel engines are responsible for 23% of diesel PM emissions according to the 1997 Minnesota Air Toxics Emissions Inventory.

*Off-Road Vehicles and Engines: High Contribution.* Off-Road engines emit 14% of the primary, non-fugitive dust emissions of PM<sub>2.5</sub> in EPA's 1998 national emissions inventory. Off-road sources also account for 6% of nationwide SO<sub>2</sub> and 22% of nationwide NO<sub>x</sub> emissions, both of which are particle precursors. Off-road engines emit 77% of the diesel PM emissions in Minnesota.

*Area Source Combustion: Medium Contribution.* According to EPA's 1998 Trends report, small combustion sources (such as open and agricultural burning) account for 37% of the primary, non-fugitive dust emissions of PM<sub>2.5</sub>. Residential wood burning accounts for an additional 12% of the direct PM<sub>2.5</sub> emissions.

*Agricultural Practices: Medium Contribution.* Livestock management, fertilizer application, and other agricultural activities emit 86% of national ammonia emissions. Ammonia is an important precursor for secondary particle formation.

*Wastewater Treatment: Low Contribution.* The treatment of wastewater is a minor source of ammonia, an important particle precursor.

*Fugitive Dust: Low Contribution.* Fugitive dust sources emit large amounts of small particles according to EPA emission inventory data, but many of the particles do not travel long distances and may play a much smaller role in the health impacts of fine particle exposure.

*Industry: Low Contribution.* Non-combustion industrial processes emit smaller amounts of primary PM<sub>2.5</sub> and particle precursors. Specific sources may emit large amounts of fine particles.

### Confidence Level

The confidence in coal-fired power plants contribution to fine particulates is moderately confident due to the relative ease in measuring emissions from large smokestacks (vs. many tailpipes or atmospheric reaction). The confidence in the other sources' contributions to total fine particle loadings in Minnesota is somewhat speculative. EPA's emissions inventory data reported in the 1998 Trends report provides a rough outline of the direct emissions of PM<sub>2.5</sub> and the emissions of several precursors to atmospheric formation. EPA is working to improve nearly all the methodologies for estimating emissions of PM<sub>2.5</sub>. The role of secondary formation is also poorly understood; it may account for a majority or few of the fine particles in ambient air. Ongoing research is attempting to determine what 'parts' of the fine particles lead to the well-known health effects.

### Source Trends

Source trends are difficult to determine. As described above, many of the sources emit both particles and their precursors. The uncertainties surrounding the estimates of primary emissions and the formation of secondary particles make the determination of trends in source contributions nearly impossible. It is possible to track the trends of some sources, such as agricultural practices, that emit only precursors. We can say the emissions of ammonia are increasing, but it is not clear if that means the amount of particles attributed to that source is also increasing. Overall, direct emissions of both large (PM<sub>10</sub>) and small (PM<sub>2.5</sub>) particles are increasing from some sources and decreasing from others. The same can be said about precursor compounds such as NO<sub>x</sub>, SO<sub>2</sub>, and ammonia. Consequently, we assigned a trend of increasing and decreasing to each of the sources for Particles in Air.

### References

- US Environmental Protection Agency (USEPA). March 2000. *National Air Pollutant Trends, 1900-1998*.  
<http://www.epa.gov/ttn/chief/trends/trends98/trends98.pdf>. Accessed 2/6/02.
- Minnesota Pollution Control Agency. 2001. *Air Quality in Minnesota: Problems and Approaches. Appendix B: Particulate Matter and Appendix E: Diesel Exhaust*.  
<http://www.pca.state.mn.us/hot/legislature/reports/2001/airquality.html>. Accessed 2/6/02.

## **14. Pathogens in Water**

*Impact Categories: Human Health Noncancer Acute*

*Sources: Feedlots, Land-applied Manure, Land-applied Municipal and Industrial Byproducts, Municipal and Industrial Wastewater, Septic Systems*

Disease-causing pathogens, such as giardia and cryptosporidium, have been found occasionally in public-water supplies and have caused illness in a large number of people in a few locations. Pathogens can enter our water from an animal source. Our assessment of contribution is based on number of illness incidents associated with pathogens.

### Comparative Contribution of Sources

*Feedlots*: High contribution. Pathogens are an important component of runoff from animal feedlots, particularly open lots. There is little information on actual quantities of pathogens released to surface water, but runoff from open feedlots is considerable. Ground water beneath feedlots typically contains high concentrations of bacteria, but there are few studies of pathogens in ground water (<http://www.cropsci.uiuc.edu/agronomyday/2000/filter-strips/>; <http://www.pca.state.mn.us/water/groundwater/gwmap/rpt-liquidmanurestorage-summary.pdf>; [http://www.hogwatch.org/html/rscen/text/sos/rscen\\_txtol\\_sos\\_sobsey.html](http://www.hogwatch.org/html/rscen/text/sos/rscen_txtol_sos_sobsey.html); <http://www.iwla.org/fishkill/Minnesota2000FactSheet.pdf>).

*Land-applied manure*: Medium contribution. Manure contains high concentrations of pathogens, and the quantity of land-applied manure is high (<http://www.nps.ars.usda.gov/programs/programs.htm?npnumber=206&docid=863>; [http://www.hogwatch.org/html/rscen/text/sos/rscen\\_txtol\\_sos\\_sobsey.html](http://www.hogwatch.org/html/rscen/text/sos/rscen_txtol_sos_sobsey.html)).

*Septic systems*: Medium contribution. Studies seem to indicate relatively low concentrations of bacteria in ground water under communities with septic systems. These are communities, however, where private wells typically occur, so that the potential exposure can be high in certain hydrologic settings (<http://www.pca.state.mn.us/water/groundwater/gwmap/gwq-unseweredsub.pdf>).

*Municipal and industrial wastewater*: Low contribution. Although large quantities of wastewater are discharged to surface water, this water requires treatment to remove pathogens. Where discharge of raw sewage occurs, high concentrations of pathogens may occur in surface water (<http://www.pca.state.mn.us/water/basins/mnriver/bacteria.pdf>; <http://www.nebiosolids.org/qanda.html>).

*Land-applied municipal and industrial byproducts*: Low contribution. Land-applied municipal and industrial byproducts typically does not contain pathogens (<http://www.pca.state.mn.us/water/landapp.html>).

### Confidence Level

*Feedlots*: Moderately confidence. There is ample documentation that feedlots contribute pathogens to surface water, but health impacts are not well documented.

*Land-applied manure*: Moderately confident. We have information on the quantity of livestock in Minnesota, the amount waste that is likely produced as a result, pathogen contents in manure, and affects of management practices, such as composting, on pathogen concentrations. New feedlot rules contain information about land application of manure. Farmers in general, apply manure for nutrient value and thus should apply the manure in a manner that minimizes loss from runoff. There is little monitoring information about actual losses, however (<http://www.mofga.org/mofgs00a.html>; [http://www.ecochem.com/t\\_cbpa\\_app.html](http://www.ecochem.com/t_cbpa_app.html); [http://manure.unl.edu/adobe/v7n2\\_01.pdf](http://manure.unl.edu/adobe/v7n2_01.pdf)).

*Septic systems*: Moderately confident. We have reliable information on the number of septic systems that occur in Minnesota and that septic systems contribute

bacteria to drinking water. There is limited information about the fate of bacteria and the occurrence of pathogens from septic systems.

*Municipal and industrial wastewater:* Reasonable confidence. Most wastewater facilities are permitted and have effluent limits. We are therefore reasonably confident about the contribution from these facilities (<http://www.pca.state.mn.us/water/wastewater.html>).

*Land-applied municipal and industrial byproducts:* Somewhat speculative. We have limited information on the contribution from land-applied municipal and industrial byproducts. Not all of these wastes are permitted. Although there are requirements for wastes that are permitted, there is little environmental monitoring to determine the environmental fate of pathogens contained in the wastes (<http://www.pca.state.mn.us/water/landapp.html>; <http://www.pca.state.mn.us/water/landapp.html>).

### Trends

There is little monitoring data available for contribution of health effects from pathogens. We therefore estimate trends based on trends in the sources.

*Feedlots:* No trend. There is no significant trend in the number of feedlots in Minnesota. More feedlots are becoming permitted with time, which should lead to improved management practices that decrease release of pathogens to surface water. Relative to the number of feedlots in Minnesota, however, these improvements are probably insignificant.

*Land-applied manure:* No trend. There is no significant trend in the number of livestock in Minnesota and, presumably, for manure that is applied to land.

*Septic systems:* Upward trend. There is an increasing trend in the number of septic systems in Minnesota. These systems are built in developing urban areas, where they may impact drinking water, and in lakeshore developments, where they may affect surface water.

*Municipal and industrial wastewater:* No trend. Most wastewater effluent has been regulated for several years, and there are no significant trends in emission from wastewater treatment facilities.

*Land-applied municipal and industrial byproducts:* No trend. We have poor information on the amount of land application that occurs in Minnesota. There does not appear to be an increase in the number of permits for application of wastes that contain pathogens, and many of these wastes are permitted through the Water Quality programs at the MPCA (<http://www.pca.state.mn.us/water/landapp.html>; <http://www.pca.state.mn.us/water/landapp.html>).

## **15. Phosphorus**

*Impact Categories: Aquatic Organisms, Quality of Life-Aesthetics*

*Sources: Agricultural Runoff, Feedlots, Municipal and Industrial Wastewater, Septic Systems, Urban Runoff*

Phosphorus is generally the limiting nutrient contributing to the production of excess algae in surface waters and to lake eutrophication. Both point and nonpoint

sources contribute to phosphorus, although nonpoint sources predominate. Nonpoint phosphorus is generally attached to sediment and closely related to soil erosion. Over the past 30 years, phosphorus levels have decreased at 75 percent of monitored stream sites, largely as a result of point source controls. The trend in phosphorus discharges from point sources has been relatively flat over the last five years, and was actually up slightly from 1999 to 2000. The MPCA is currently reviewing its phosphorus discharge standards to waters of the state and the outcome of this process may affect phosphorus discharges allowed from point sources in the future (<http://www.pca.state.mn.us/water/phosphorus.html>).

#### Comparative Contribution of Sources

*Agricultural runoff:* High contribution. Agricultural runoff includes overland loss of phosphorus from fertilizers and manure, and loss through tile lines. Overland loss is considerably greater than loss through tiles, since phosphorus is highly adsorbed to soil particles. Losses of phosphorus will thus occur primarily with eroded sediment. Annual phosphorus applied to Minnesota fields includes about 160 million pounds applied as inorganic fertilizer and an estimated 250,000 pounds applied with manure (assuming half of livestock manure is land applied)(<http://www.ces.uga.edu/pubcd/c826-w.html>; <http://usda.mannlib.cornell.edu/data-sets/inputs/9X171/97171/agch0997.txt>; <http://www.bae.umn.edu/extens/manure/landapp/>). These numbers greatly exceed all other sources of phosphorus.

*Municipal and industrial wastewater:* Medium contribution. The contribution of phosphorus from municipal and industrial wastewater discharges to waters of the state has been relatively stable over the past five years. Reported discharges from the 85 major treatment facilities comprising 27 industrial and 58 municipal sources have averaged about 1400 thousand kilograms over this time, according to Discharge Monitoring Reports (DMRs) submitted to the MPCA.

*Feedlots:* Medium contribution. Although there have been increased controls on the contribution of phosphorus from feedlot runoff and manure application to agricultural land in recent years, the size of feedlots and animals contained has increased, to some extent offsetting the effect of increased controls. Manure handling remains a critical concern in some areas of the state where large confined feedlot operations are concentrated.

*Urban runoff:* Medium contribution. Increased urbanization and use of fertilizers on lawns and plantings have been offset somewhat by better management practices for fertilizer application, implementation of runoff controls, and a ban on fertilizers containing phosphorus in some communities. Nevertheless, urban runoff is an important contributor to lakes and streams in urban areas ([http://www.epa.gov/iwi/303d/02030101\\_303d.html](http://www.epa.gov/iwi/303d/02030101_303d.html); <http://clean-water.uwex.edu/pubs/sheets/hiurban.pdf>; <http://www.chesapeakebay.net/info/stormwater.cfm>; <http://in.water.usgs.gov/nawqa/wr03006.htm>; <http://hermes.ecn.purdue.edu:8001/cgi/convertwq?8054>; <http://hermes.ecn.purdue.edu:8001/cgi/convertwq?8054>; <http://www.epa.gov/opptintr/fertilizer.pdf>).

*Septic systems:* Low contribution. Contribution of phosphorus to water resources from a properly functioning septic system should be low. New construction and operation requirements, an increased enforcement presence at the local (county) level, and increased public awareness have led to a decreasing number of overloaded and failing septic systems in recent years, even as the number of systems has increased in near-urban areas not served by centralized treatment systems. Phosphorus can reach surface water from failing systems and from very old systems, but these amounts will be low compared to the sources discussed above (<http://www.pca.state.mn.us/water/groundwater/gwmap/gw-nonsewered.html>).

#### Confidence Level

Our confidence level for the contribution of the above sources to phosphorus in our water resources is moderate to reasonable. We have reasonable confidence for municipal and industrial wastewater treatment plants, which are required to monitor and report phosphorus levels in their discharges. We also have reasonable confidence for agricultural runoff because of the large number of research studies illustrating loss of phosphorus from agricultural fields. A number of research studies have quantified the amount of phosphorus entering surface water as a result of runoff from agricultural tile lines (<http://www.nemp.aus.net/dav20.htm>; <http://www.dnr.state.wi.us/org/water/wm/nps/waterquality.htm>; <http://www.ars.usda.gov/is/np/Phos&Eutro/phos&eutro.pdf>; <http://www.dnr.state.md.us/bay/czm/nps/npspollution.html>). Runoff controls and some site-specific monitoring are required of larger feedlots and some septic systems. We have moderate confidence for septic systems, urban runoff, and feedlots, with the primary limitation being difficulties in quantifying losses from these sources.

#### Source Trends

Over the past 30 years, phosphorus levels have decreased at 75 percent of monitored stream sites, largely as a result of point source controls. In a recent five-year period (1996-2000), phosphorus from major point source discharges actually increased, but very slightly. The greatest threat to water resources from phosphorus is most likely from nonpoint sources that currently have only minimal monitoring. Examples include runoff from agricultural land, increasing urbanization, and increase in size and amount of animal waste generated from feedlot operations.

*Agricultural runoff:* No trend. An increasingly wetter climate in the last few decades has masked reductions in delivery of sediment and phosphorus to the Minnesota River due to improved crop and land management practices. While the wetter climate has actually increased sediment and phosphorus loads due to more frequent erosion-causing rainstorm events, producers have adopted better crop and land management practices that reduce erosion. After compensating for climate, there are about an equal number of surface water streams and rivers showing slightly increasing or decreasing trends in phosphorus load (<http://www.soils.umn.edu/research/mn-river/doc/trends.html>); <http://alfi.soils.wisc.edu/extension/FAPM/2002proceedings/porter.pdf>).

*Municipal and industrial wastewater.* No trend. In a recent five-year period (1996-2000), phosphorus from municipal and industrial wastewater point source discharges increased very slightly, based on results from discharge monitoring reports

(DMRs) submitted to MPCA

(<http://www.pca.state.mn.us/hot/legislature/reports/2002/airwater/pdf>).

*Feedlots.* No trend. There have been increased controls on the contribution of phosphorus from feedlot runoff and manure application to agricultural land in recent years, but the average size of feedlots and animals contained has increased, to some extent offsetting the effect of increased controls.

*Urban runoff.* Upward trend. Increased urbanization and the use of fertilizers on lawns and plantings have been offset somewhat by better management practices for fertilizer application and a ban on fertilizers containing phosphorus in some communities. Phosphorus from nonpoint sources is generally attached to sediment associated with urban runoff that is increasing with urban sprawl, despite tighter controls. It remains to be seen if recent bans on phosphorus in fertilizers sold for home use will have a measurable impact of phosphorus in runoff generated by relentless urbanization.

*Septic systems.* No trend. New construction and operation requirements, an increased enforcement presence at the local (county) level, and increased public awareness have led to a decreasing number of overloaded and failing septic systems in recent years, even as the number of systems has increased in near-urban areas not served by centralized treatment systems. Contribution of phosphorus to water resources from a properly functioning septic system is generally low, but the rapid rise in the number of systems being constructed, especially in the second and third-ring suburbs around major metropolitan areas such as the Twin Cities likely offsets this somewhat.

#### References

- Minnesota Pollution Control Agency, June 2001, *Air and Water Emissions Report*, <http://www.pca.state.mn.us/hot/legislature/reports/2001/air-water-emissions.html>
- Minnesota Pollution Control Agency, April 2002, *Annual Pollution Report: 2000 Air Emissions and Water Discharges*  
<http://www.pca.state.mn.us/hot/legislature/reports/2002/airwater/pdf>
- 2000 Minnesota Water Quality – Surface Water Section.  
<http://www.pca.state.mn.us/publications/reports/305bfinalreport-2000.pdf>

## **16. Temperature Increase/Climate Change**

*Impact Categories: Aquatic Organisms, Terrestrial Organisms, Human Health*

*Noncancer Acute*

*Sources: Agriculture, Coal-fired Power Plants, Industry, On-road Vehicles, Permitted Waste Disposal, Power Plants (thermal discharge), Residential Fuel Combustion, Urban Runoff*

Human health impacts from heat and severe weather and negative impacts on aquatic species from increases in water temperature are expected in the future as greenhouse gases accumulate in the atmosphere and contribute to increasing ambient temperatures. The sources of the greenhouse gases are listed below. Aquatic ecosystems may also be impacted by temperature changes associated with runoff in urban areas and direct thermal discharges from industry (<http://www.ramas.com/therm.htm>; <http://h2osparc.wq.ncsu.edu/info/temper.html>).

### Comparative Contribution of Sources

*Coal-Fired Power Plants:* High contribution. Electricity generation, primarily from coal, is the largest source of carbon dioxide (CO<sub>2</sub>), the principal greenhouse gas. Electric utilities are also a large source of NO<sub>x</sub>.

*On-Road Vehicles:* High contribution. On-road vehicles are the second highest emitter of CO<sub>2</sub> behind electric utilities. They also emit significant amounts of methane and NO<sub>x</sub>.

*Agriculture:* Medium contribution. Livestock are a source of methane and manure management is an important source of ammonia and other nitrogen compounds. Methane and nitrogen compounds are emitted from manure application and other crop practices.

*Industry:* Medium Contribution. Industrial fuel combustion is a large source of CO<sub>2</sub>.

*Permitted Waste Disposal:* Medium Contribution. Landfills are the second largest source of methane behind livestock.

*Residential Fuel Burning:* Low Contribution. Residential burning of wood, natural gas, and other fossil fuels is a source of CO<sub>2</sub>.

*Urban Runoff:* Medium Contribution. Impervious areas, such as parking lots and roof tops, absorb the sun's radiation and retain some of the heat. During a precipitation event, the heat is transferred to the runoff flowing over the impervious surface. This warm water is often discharged directly to a surface water body. The resulting temperature can directly affect aquatic organisms, but a more important effect may be on nutrient cycling and dissolved oxygen (<http://h2osparc.wq.ncsu.edu/info/temper.html>; <http://wow.nrri.umn.edu/wow/under/parameters/temperature.html>; <http://www.surfrider.org/longbeach/descriptions.htm>).

*Power Plants (thermal discharge):* Low Contribution. Many industries discharge effluent having elevated temperatures directly into surface water. The resulting increase in temperature may adversely impact aquatic habitats. These discharges are regulated, however, and effects are local (<http://h2osparc.wq.ncsu.edu/info/temper.html>).

### Confidence Level

*Coal-Fired Power Plants:* Reasonable confidence. NO<sub>x</sub> emissions from power plants are well understood and CO<sub>2</sub> emissions from combustion can be determined.

*On-Road Vehicles:* Reasonable confidence. Similar to power plants, NO<sub>x</sub> and CO<sub>2</sub> emissions are tracked and can be determined.

*Agriculture:* Somewhat speculative. The emission of greenhouse gases during crop production and related processes is not well understood. Emissions of methane and NO<sub>x</sub> from livestock and other agricultural practices are not as easy to determine as CO<sub>2</sub> emissions from fossil fuel combustion.

*Industry:* Reasonable confidence. Combustion-related CO<sub>2</sub> emissions are well understood for industries where we have good data on fuel type and use.

*Permitted Waste Disposal:* Moderately confident. Determining methane emissions from landfills is more straightforward than calculating contributions of nitrous oxide but less so than estimated CO<sub>2</sub> emissions from combustion processes.

*Residential Fuel Burning*: Reasonable confidence. The confidence in the contribution of residential fuel burning is similar to other fossil fuel combustion sources.

*Urban Runoff*: Somewhat Speculative. There is limited information that relates temperature effects to urban runoff.

*Power Plants (thermal discharge)*: Reasonable confidence. Thermal discharges are regulated. Numerous studies also show the limited geographic area of thermal effects.

### Source Trends

*Coal-Fired Power Plants*: Upward trend. Fossil fuel combustion (and therefore CO<sub>2</sub> emissions) associated with electricity generation is increasing.

*On-Road Vehicles*: Upward trend. Fossil fuel combustion (and therefore CO<sub>2</sub> emissions) associated with transportation is increasing.

*Agriculture*: Upward trend. N<sub>2</sub>O emissions from agricultural soil management, the largest source of N<sub>2</sub>O, is increasing. These emissions are created during bacterial nitrification processes, and are a function of available nitrogen. Nitrogen is added to the soil via commercial fertilizers, manure application, crop residues, and atmospheric deposition. Methane emissions from agricultural activities are also important, although to a lesser degree than N<sub>2</sub>O emissions. Methane emissions from manure management are neither increasing nor decreasing, and methane emissions from livestock are decreasing.

*Industry*: No trend. CO<sub>2</sub> emissions from industrial combustion are level.

*Permitted Waste Disposal*: No trend. Methane emissions have decreased the 1980s levels but are stable over the last several years.

*Residential Fuel Burning*: No trend. CO<sub>2</sub> emissions from residential fuel combustion are stable.

*Urban Runoff*: Upward trend. The percent of land in urban use in Minnesota increased by more than 27 percent between 1982 and 1997

(<http://www.mnplan.state.mn.us/mm/indicator.html?Id=68&G=41>).

*Power Plants (thermal discharge)*: No trend. The primary sources of heated effluent are industries that generate power, although other manufacturing industries, such as paper production, also generate heated effluent. There is no trend in these industries in Minnesota. We assume this means there is no trend in effluent generated by these industries.

### References

- US Environmental Protection Agency (USEPA). March 2000. *National Air Pollutant Trends, 1900-1998*.  
<http://www.epa.gov/ttn/chief/trends/trends98/trends98.pdf>. Accessed 2/6/02.
- Minnesota Pollution Control Agency. 2001. *Air Quality in Minnesota: Problems and Approaches. Appendix H: Global Climate Change*.  
<http://www.pca.state.mn.us/hot/legislature/reports/2001/airquality.html> Accessed 2/6/02.

## **17. Toxic Chemicals – High Level Accidental Releases**

*Impact Categories: Human Health Noncancer Acute*

*Sources: Industry, On-road Vehicles, Pipelines, Residences, Tanks, Trains*

This stressor involves various toxic materials that are released and cause immediately hazardous conditions. The comparative contributions of the sources are based on the database maintained by the PCA's Emergency Response program (as reported to us by Dorene Fier-Tucker in an e-mail on 9/6/01). The estimates are based on numbers of releases, not volume (which might result in different comparative contributions).

#### Comparative Contribution of Sources

*On-Road Vehicles*: High Contribution.

*Trains*: High Contribution.

*Industry*: Medium Contribution.

*Residences*: Low Contribution.

*Tanks*: Low Contribution.

*Pipelines*: Low Contribution.

#### Confidence Level

The confidence level for the comparative contribution of sources is considered "reasonable" for all the sources. This is based on the fact that, unlike most other stressors, we have an actual database to calculate numbers.

#### Source Trends

*On-Road Vehicles*: Upward.

*Trains*: No trend.

*Industry*: No trend.

*Residences*: No trend.

*Tanks*: Downward.

*Pipelines*: Downward.

These trends are based on the judgment of Steve Lee, Supervisor of Emergency Response program (in an e-mail dated 9/25/01).

### **18. Toxic Chemicals in Food**

*Impact Categories: Human Health Cancer, Human Health Noncancer Chronic Sources: Coal-fired Power Plants, Industry, Mining, Municipal and Industrial Wastewater, Off-road Equipment, On-road Vehicles, Permitted Waste Disposal, Pesticide Use, Residential Fuel Combustion, Unpermitted Waste Disposal, Waste Incineration*

A variety of toxic chemicals occur in food that humans consume. The primary chemicals of concern are persistent bioaccumulative toxics (pbts). These are chemicals that persist in the environment and accumulate in the food chain. Some pbts include PAHs, dioxin, some metals such as mercury, and chlorinated pesticides. PBTs are not the toxics of concern in the food chain, however. Many chemicals, including pesticides and metals, can be toxic but not bioaccumulate.

While toxics in food is not within the immediate regulatory authority of the MPCA, many of the sources of these toxics are regulated by the MPCA. This includes a variety of industries that discharge these toxics to the environment, permitted and unpermitted waste disposal, wastewater, and waste incineration.

#### Comparative Contribution of Sources

*Residential fuel combustion:* High contribution. The high contribution of residential fuel combustion is primarily attributed to burn barrels and wood burning, although a wide variety of persistent organic chemicals are released from other types of residential fuel combustion. While there are few of these sources compared to most other sources, these activities result in incomplete combustion and subsequent release of large quantities of PAHs and dioxins (<http://ens.lycos.com/ens/jan2000/2000L-01-04-06.html>; <http://www.dnr.state.wi.us/org/caer/ce/ob/health.htm>). Burn barrels, for example, are thought to contribute about 25 percent of the dioxins released annually to the atmosphere in the United States (EPA, 2000, Draft Dioxin Reassessment). Residential wood combustion is considered to contribute slightly more than a quarter of the total PAHs released annually to the atmosphere in the United States. These chemicals can be highly toxic and persistent in the environment (US EPA).

*Pesticide Use:* High contribution. The high contribution of pesticide use is attributed to the highly persistent nature of many pesticides, primarily chlorinated insecticides. While many of the chemicals have been banned, they were once widely used and still are found at levels of concern in the environment. Pesticides are found in food products due to improper, or in some cases, routine usage. (<http://www.epa.gov/pesticides/food/risks.htm>).

*On-road vehicles:* Medium contribution. While on-road vehicles are perhaps the largest contributor to air emissions, many of the chemicals emitted do not enter the food chain. PAHs and some metals, such as lead, are the primary concerns (US EPA).

*Off-road equipment:* Medium contribution. Off-road equipment contributes about one percent of the total PAHs and five percent of the lead released to the atmosphere annually in the United States (US EPA).

*Unpermitted waste disposal:* Medium contribution. Unpermitted waste disposal (e.g. unpermitted landfills) was once one of the most important contributors of persistent chemicals to the environment. The primary chemicals of concern were PCBs, chlorinated solvents, and dioxins. Because of programs such as Superfund, many of the largest sources have been cleaned up.

*Mining:* Medium contribution. Mining primarily contributes metals, such as cadmium, to the environment. Smelting operations, if included with mining, typically contribute 30 percent or more of the lead, cadmium, and arsenic released to the environment (US EPA).

*Municipal and industrial wastewater:* Medium contribution. Sewage and industrial wastewater contain a variety of chemicals, primarily metals such as cadmium, which are released to aquatic environments. These chemicals can accumulate in the environment and pass through the food chain to humans.

*Coal-fired power plants:* Medium contribution. Coal combustion contributes large quantities of mercury to the environment, perhaps as much as 25 percent of all

mercury emissions in the United States (US EPA). Coal combustion also releases several other metals, such as lead.

*Waste incineration:* Medium contribution. Nationally, waste incineration is perhaps the largest contributor to chemicals that bioaccumulate in the environment. Incineration is an important source for PCBs, dioxins, and PAHs (US EPA). In Minnesota, impacts from waste incineration are less than nationally because much of the municipal and industrial waste is landfilled.

*Industry:* Medium contribution. Industry is a broad category that contains a wide variety of sources. Taken together, industries release large quantities of persistent chemicals. Examples include PCBs from industrial boilers (about eight percent of releases in the United States), mercury from chlorine production (five percent), lead from manufacturing (five percent), and dioxins from combustion processes (two percent) (US EPA).

*Permitted Waste Disposal:* Medium contribution. Permitted waste disposal (e.g. landfills) is an important contributor for mercury, accounting for about 15 percent of releases in the Great Lakes region (GLATEI, 1996).

### Confidence Level

Our confidence in estimating relative contribution from the different sources that impact the food chain was somewhat speculative, with the exception of pesticides. Although there is reasonably good emission data for most of the major pollutant categories across the United States, there is limited information for Minnesota. Pesticide use is the exception, where we have good information on use and are therefore moderately confident of our estimates for comparative contribution. Another factor contributing to our uncertainty is the lack of documentation showing the connection between chemicals released to the atmosphere and those showing up in the food chain.

### Source Trends

Trends for toxic chemicals in food are difficult to estimate. Recognition of pbts in our environment and potential linkages with toxics in food has resulted in some reductions in use of pbts. In spite of this, the number of advisories for fish consumption has increased in Minnesota in the past 10 years (<http://www.epa.gov/pbt/fact.htm>). It is likely that concentrations of some chemicals, such as chlorinated insecticides and PCBs, are decreasing, while concentrations of other chemicals, such as dioxin, are increasing. Consequently, many of the sources discussed here exhibit both upward and downward trends, because some chemicals emitted by the sources are decreasing while others are increasing in concentration.

*Residential fuel combustion:* No trend. Burning of trash is outlawed in most municipalities but is commonly practiced in rural areas. Although the number of people burning trash has probably decreased significantly in the past 10 to 20 years, the amount of dioxin released from burning may have increased over the same period, since trash now contains large quantities of plastics and papers that contribute to dioxin formation (<http://www.co.carver.mn.us/EnviroServices/burnbarrel.htm>).

*Pesticide use:* Downward trend. While overall pesticide use in the United States has remained steady or increased in the past 20 years, use of chlorinated insecticides has decreased (<http://ceq.eh.doe.gov/nepa/reports/statistics/tab7x9.html>). These are the

chemicals of greatest concern, because they are persistent and bioaccumulate. Many insecticides have been banned, including DDT, chlordane, and dieldrin.

*On-road vehicles:* Up and down trend. Total vehicle miles driven have increased by more than 50 percent in the past 30 years in most parts of the United States. This has been somewhat offset by use of cleaner, more fuel-efficient cars. The 1970's and 1980's trend of decreasing overall fuel consumption in on-road vehicles appears to have reversed in recent years, however. This may be attributable to increased miles driven and use of less fuel efficient vehicles, such as SUVs (<http://www.eia.doe.gov/aer/ep/motor.html>).

*Off-road equipment:* Up and down trend. The up and down trend is attributable to many of the factors described for on-road vehicles. Although gasoline-powered engines are more fuel efficient and cleaner than they were 30 years ago, there are many more of them in use. Examples include lawn equipment, ATVs, and snowmobiles.

*Unpermitted waste disposal:* Downward trend. Unpermitted waste disposal sites continue to be cleaned up through programs such as Superfund and the Voluntary Investigation and Cleanup Program. RCRA and other legislation is designed to minimize unpermitted dumping. Consequently, impacts from unpermitted waste disposal are decreasing.

*Mining:* No trend. There is little data to suggest a trend in impacts from mining.

*Municipal and industrial wastewater:* No trend. There is some speculation that concentrations of pharmaceuticals and other household chemicals are increasing in municipal wastewater. There is little evidence to show that concentrations of these chemicals are increasing, although improved analytical detection methods confirm the presence of these chemicals in wastewater (<http://recetox.chemi.muni.cz/PBTs/content.htm>).

*Coal-fired power plants:* No trend. Emissions from coal-fired power plants have not changed significantly in the past decade.

*Waste incineration:* Up and down trend. Wastewater treatment facilities (both municipal and industrial) are regulated through a permitting system. Through this permitting system and improvements in operation, environmental releases of metals to water bodies have diminished with time (<http://www.pca.state.mn.us/water/wastewater.html>). Similar trends have been observed in other areas of the country ([http://www.wa.gov/puget\\_sound/Publications/workplan\\_01/MUNICPL.pdf](http://www.wa.gov/puget_sound/Publications/workplan_01/MUNICPL.pdf); <http://www.rice.edu/armadillo/Galveston/Chap6/ch6.html>). This is tempered, however, by data that suggests increases in release of some pbts from waste incineration, such as dioxins and PAHs (<http://www.epa.gov/opptintr/pbt/mercury.htm>; <http://recetox.chemi.muni.cz/PBTs/chapter7-2.htm>; <http://p2tools.utoledo.edu/PBTSyn.pdf>).

*Industry:* Downward trend. Many industries have decreased emissions of certain pbts, such as dioxin from paper mills (<http://recetox.chemi.muni.cz/PBTs/content.htm>).

*Permitted waste disposal:* Up and down trend. While there continue to be efforts to limit the amount of toxic wastes disposed in municipal solid waste, the amount of solid waste generated by Minnesotans increased 33 percent between 1993 and 2001. Solid waste continues to be an important source of pbts

<http://www.moea.state.mn.us/lc/score00.cfm>;  
<http://recetox.chemi.muni.cz/PBTs/chapter10-3-5.htm>;

<http://www.epa.gov/pbt/pbtsandyou.htm>;  
[http://www.ecy.wa.gov/programs/hwtr/shoptalkonline/PDF\\_HTML\\_versions/Spring01.pdf](http://www.ecy.wa.gov/programs/hwtr/shoptalkonline/PDF_HTML_versions/Spring01.pdf).

## **19. Toxic Chemicals in Soil**

*Impact Categories: Human Health Cancer, Human Health Noncancer Acute, Human Health Noncancer Chronic*

*Sources: Industry, Land-applied Municipal and Industrial Byproducts, Pesticide Use, Spills, Unpermitted Waste Disposal, Lead Paint, Road Salt*

Contaminants in soil affect human health through direct contact with soil, ingestion of soil particles in air, or ingestion of vapors released from soils. Our assessment of contribution is based on chemical mass, which may be somewhat misleading for sources that contribute small amounts of chemical but if exposures occur in heavily-populated urban areas.

### Comparative Contribution of Sources

*Pesticide Use:* Medium to high contribution. Commercial application of pesticides requires a license. Actual use of pesticides is not strictly regulated, however. Over 10 million pounds of pesticide are applied annually in Minnesota (<http://www.mda.state.mn.us/privapp/>). Ambient concentrations of pesticides have not been determined in either urban or rural soils, but pesticides appear pervasive in other media. High contribution was assumed for cancer and chronic effects because of the widespread occurrence of pesticides in the environment and because of the likelihood for long-term exposure. The contribution for acute effects was considered moderate, since these effects will only occur in the case of chemical spills.

*Industry:* Medium contribution. Industrial contributions to soil are primarily through air deposition. Soils in urban areas contain much higher concentrations of chemicals such as lead and PAHs compared to natural background concentrations (<http://www.state.nj.us/dep/dsr/soilrep.pdf>).

*Unpermitted Waste Disposal:* Low to medium contribution. Most heavily contaminated sites have been identified and human exposure is controlled. There continues to be an upward trend in the number of Superfund sites where remediation activities have been completed. Although there may be level to upward trends in the number of new sites entering Superfund, these do not reflect new sites but rather sites that have existed for many years and are just now identified as being contaminated ([http://www.epa.gov/children/indicators/land\\_contam.html](http://www.epa.gov/children/indicators/land_contam.html)). Future incidences of human exposure are limited as a result of property transfer programs, such the Voluntary Investigation and Cleanup Program. Programs such as RCRA limit the potential for exposure to hazardous chemicals that are improperly disposed, although some of this disposal continues to occur. Because of control programs, the likelihood of long-term exposure is low, and contribution for chronic health effects and cancer is low. The contribution for acute effects is moderate, since exposure to soil containing high concentrations of some chemicals, such as PCBs or chlorinated solvents, can result in immediate health effects.

*Land-applied Municipal and Industrial Byproducts:* Low contribution. Land application of biosolids (sewage sludge) is regulated through MN Rule Chap. 7041 and land application of industrial by-products is regulated through a permitting process (<http://www.pca.state.mn.us/water/landapp.html>). Most wastes are applied for beneficial use to crops and are thus not applied in quantities that will likely result in significant risk to human health (<http://www.ext.vt.edu/pubs/compost/452-304/452-304.html>; <http://www.cfe.cornell.edu/wmi/Sludge/Recommends.html>; <http://www.gov.on.ca/OMAFRA/english/research/oascc/swa/biosol.htm>).

*Lead Paint:* Low contribution. Lead paint has been banned in the United States since 1978. Much lead-based paint remains in older homes, but release of this is likely to be low. Training is required for people who handle lead-based paint (<http://www.lgean.org/html/fedregsguide/ixb.cfm>).

*Road Salt:* Low contribution. Although 320,000 tons of road salt were applied to Minnesota roads in 1999, and road salt contains cyanide, much of the cyanide is likely to end up in surface water or be degraded in the environment (<http://www.pca.state.mn.us/publications/mnenvironment/fall2000/salt.html>).

*Spills:* Low contribution. Although these may have an immediate impact on human health, they are usually detected quickly, thus preventing long-term exposure necessary for most cancers to develop (<http://www.pca.state.mn.us/cleanup/ert.html>). There is a potential for worker exposure to heavily contaminated soils resulting from poor waste management. This occurs primarily for small quantity generators such as salvage yards.

### Confidence Level

*Pesticide Use:* Moderately confident. We have reasonable information on pesticide sales and assume this represents the amount of chemical released to the environment. There is little information on concentrations of pesticides in urban and agricultural soils. Most herbicides are likely to be quickly degraded from the parent compound, but the fate and toxicity of degradates are largely unknown.

*Industry:* Somewhat speculative based on lack of data for air deposition and lack of monitoring data. There is a large amount of data showing that deposition of contaminants occurs near some point sources, such as coal and nuclear plants. (<http://www.econ.vu.nl/gis/education/Euphids/Pesticides.htm>; <http://www.metrokc.gov/health/hazard/vmdesign3.htm>; <http://recetox.chemi.muni.cz/PBTs/chapter10-8.htm>; <http://www.hanford.gov/docs/rl-98-33/section4.html>).

*Unpermitted Waste Disposal:* Moderately confident. Most of the larger sites have been identified. There are likely to be few sites in residential areas. Exposure is thus limited to workers. Except for Very Small Quantity Generators, disposal of hazardous materials is controlled through RCRA.

*Land-applied industrial and municipal byproducts:* Moderately confident. We have good information on the amount of several industrial and municipal wastes that are land applied. These wastes are not hazardous and are applied for agronomic benefit, thus reducing their risk to humans.

*Lead Paint:* Moderately confident. Human health effects of lead paint are well understood. Lead paint has been banned in the United States since 1978

(<http://www.lgean.org/html/fedregsguide/ixb.cfm>). Combined, these two factors give us moderate confidence of the impacts to soil from lead paint.

*Spills:* Moderately confident based on the low exposure due to quick detection and relatively small volumes of most spills.

*Road Salt:* Somewhat speculative. The primary concern with road salt is cyanide. Cyanide is acutely toxic and quantities in road salt are relatively well understood. Impacts and exposure to humans is not well understood, however (<http://www.pca.state.mn.us/publications/mnenvironment/fall2000/salt.html>).

### Source Trends

*Pesticide Use:* No change in concentration with time. Quantities of pesticides applied over the past ten years have not increased or decreased (<http://www.mda.state.mn.us/privapp/>).

*Industry:* While there has been a downward trend in emissions of some criteria pollutants, data for particles are less certain. Particles are likely to be the largest contributor to soil contamination (<http://www.pca.state.mn.us/air/aqemissions-trends.html>).

*Unpermitted Waste Disposal:* Downward due to remediation of contaminated sites and regulation of hazardous wastes under RCRA.

*Land-applied of industrial and municipal byproducts:* Increasing trend. Quantities of lime, which includes industrial ash, have increased over the past ten years (<http://www.mda.state.mn.us/lime/tonnagestats.pdf>). Applications of biosolids have increased in the past 12 years (MPCA data).

*Lead Paint:* Lead was banned for use in paint in 1978. Since 1994, training is required for professionals who work with lead-base paint (<http://www.lgean.org/html/fedregsguide/ixb.cfm>). There is therefore a downward trend in contributions from lead-based paint.

*Spills:* No trend. Although spill prevention and preparedness have improved, the actual number of spills has remained unchanged in the past ten years.

*Road Salt:* No trend. Minnesota used 320,000 tons of road salt in 1999. Use has leveled off in recent years because of mild winter conditions (<http://www.pca.state.mn.us/publications/mnenvironment/fall2000/salt.html>).

## **20. Toxic Chemicals in Water**

*Impact Categories:* Human Health Cancer, Human Health Noncancer Acute, Human Health Noncancer Chronic

*Sources:* Land-applied Municipal and Industrial Byproducts, Municipal and Industrial Wastewater, Pesticide Use, Spills, Tanks, Unpermitted Waste Disposal, Feedlots, Fertilizer Use, Septic Systems, Land-applied Manure

Toxic Chemicals in Water considers a wide range of chemicals that can have adverse health impacts when ingested with drinking water. Other effects, such as on aquatic organisms, are not considered. Although the discussion primarily focuses on and refers to ingestion of water, drinking water criteria also include other exposure routes for chemicals in water, such as dermal and inhalation.

## Comparative Contribution of Sources

*Pesticide Use:* High contribution. Use of pesticides is not strictly regulated and over 10 million pounds of pesticide are applied annually in Minnesota (<http://www.mda.state.mn.us/privapp/>). Pesticides are not routinely sampled in most public water supplies and not at all in private water supplies (<http://www.health.state.mn.us/divs/eh/dwp/pws/>). Even in public water supplies sampled for pesticides, only a narrow range of parent compounds are analyzed. Data show that pesticide degradates are much more likely to occur in surface water and ground water compared to parent compounds

(<http://www.pca.state.mn.us/water/groundwater/gwmap/rpt-landuse-stcloud.pdf>;  
<http://www.pca.state.mn.us/water/groundwater/gwmap/rpt-gwq-cottage.pdf>).

*Tanks:* Low to Medium contribution. Waste disposal sites are managed through programs at the MPCA. Contamination occurs on occasion and creates the potential for long-term exposure in some private wells. The chemical of greatest concern is benzene, which is a carcinogen. The contribution for cancer is thus medium, while the contribution for noncancer chronic is low (<http://www.pca.state.mn.us/cleanup/ust.html>;  
<http://www.pca.state.mn.us/cleanup/ast.html>;  
[http://www.pca.state.mn.us/programs/lust\\_p.html](http://www.pca.state.mn.us/programs/lust_p.html);  
[http://www.pca.state.mn.us/programs/vpic\\_p.html](http://www.pca.state.mn.us/programs/vpic_p.html)).

*Unpermitted Waste Disposal:* Medium contribution. Waste disposal sites are managed through programs at the MPCA. Contamination occurs on occasion and creates the potential for long-term exposure in some private wells. There is some evidence for widespread occurrence of VOCs in the environment, although concentrations appear to be below drinking standards (<http://www.pca.state.mn.us/water/groundwater/gwmap/gw-baseline.html>;  
<http://www.pca.state.mn.us/waste/index.html>).

*Land-applied Industrial and Municipal Byproducts:* Low contribution. Land application of biosolids (sewage sludge) is regulated through MN Rule Chap. 7041 and land application of industrial by-products are regulated through a permitting process (<http://www.pca.state.mn.us/water/landapp.html>). Most wastes are applied for beneficial use to crops and are thus not applied in quantities that will likely result in significant risk to human health (<http://www.ext.vt.edu/pubs/compost/452-304/452-304.html>;  
<http://www.cfe.cornell.edu/wmi/Sludge/Recommends.html>;  
<http://www.gov.on.ca/OMAFRA/english/research/oascc/swa/biosol.htm>).

*Fertilizer Use:* High Contribution. About 12 million short tons of nitrogen fertilizer are applied annually in the United States (<http://www.tfi.org/Statistics/index.asp>). About 0.58 million metric tons are applied annually in Minnesota (<http://www.me3.org/issues/climate/gordon.pdf>). Nitrate occurs widely in drinking water throughout Minnesota, often at concentrations exceeding drinking criteria. Effects are with infants under six months in age (<http://www.pca.state.mn.us/water/groundwater/gwmap/index.html>;  
<http://www.ianr.unl.edu/pubs/water/g1369.htm>).

*Municipal and Industrial Wastewater:* Low Contribution. Contributions are considered low since discharges to surface water are regulated and quantities are low relative to other sources ([http://www.pca.state.mn.us/programs/inpdes\\_p.html](http://www.pca.state.mn.us/programs/inpdes_p.html);  
<http://www.pca.state.mn.us/water/wastewater.html>).

*Septic Systems:* Low to Moderate contribution. Many household wastes, including human excretions, contain chemicals that may represent a health risk, particularly nitrate and possibly pathogens. Wells typically provide drinking water in areas served by septic systems. In certain hydrologic environments, these wells may be at risk of contamination. The chemical of greatest concern is nitrate. Acute effects are therefore considered moderate, while chronic effects are considered low (<http://www.pca.state.mn.us/water/groundwater/gwmap/gwq-unseweredsub.pdf>; <http://www.extension.umn.edu/extensionnews/1999/JP1052.html>).

*Spills:* Low contribution. These may have an immediate impact on human health, but they are almost always detected quickly, thus preventing long-term exposure (<http://www.pca.state.mn.us/cleanup/ert.html>).

*Feedlots:* Low contribution. Nitrate is the chemical of concern for acute effects. Feedlots contribute low quantities of nitrate to ground water, except under certain conditions (<http://www.pca.state.mn.us/water/groundwater/gwmap/rpt-liquidmanurestorage-summary.pdf>).

*Land-applied Manure:* Medium contribution. Land-applied manure may contribute nitrate to drinking water, which can have acute effects on human health. Potentially, contributions from land-applied manure are high. Annually in the United States, 869 million tons of manure are generated from livestock (<http://www.nhq.nrcs.usda.gov/land/RCArchive/wp14text.html>). It is difficult to gain good numbers on the quantity of manure applied in Minnesota, but the amount is probably considerable considering the livestock population in the state. Most of the nitrogen in land-applied manure is in the organic form and must therefore be converted to nitrate before it can leach to ground water. This likely limits the areas of concern to well-aerated, coarse-textured soils.

### Confidence Level

*Pesticide Use:* Moderately confident. We have reasonable information on pesticide sales and assume this represents the amount of chemical released to the environment. There is some data on the occurrence and environmental fate of the more commonly used pesticides (Kolpin et al., 1997; Blanchard and Donald; 1997; USGS, 1998). The major uncertainty concerns pesticide degradates and pesticides entering the market in the past few years (Kalkhoff et al., 1998). Research suggests that most herbicides, which are the most extensively used pesticides, are detoxified quickly in the environment (Field and Thurman, 1996). Other pesticides, which are typically more persistent and toxic to humans than herbicides, generally have low mobility in the environment and are not likely to be found in ground water but often occur in surface water.

*Tanks:* Reasonable confidence. MPCA has programs designed to address contaminants associated with tanks. These programs have led to cleanup at several thousand tank sites, including both soil and ground water remediation. Future releases from tanks are diminished because of control programs that are now in place (<http://www.pca.state.mn.us/cleanup/ast.html>; [http://www.pca.state.mn.us/programs/lust\\_p.html](http://www.pca.state.mn.us/programs/lust_p.html); <http://www.pca.state.mn.us/cleanup/ust.html>; [http://www.pca.state.mn.us/programs/vpic\\_p.html](http://www.pca.state.mn.us/programs/vpic_p.html)).

*Unpermitted Waste Disposal:* Moderately confident. Public water supplies, on which 90 percent of Minnesotans rely, are routinely tested. Preventive measures, such as tank leak detection systems and RCRA, should limit new incidences of exposure. We have good information on the location and impact of existing sites, although there may be many unpermitted sites not identified (<http://www.pca.state.mn.us/waste/index.html>; <http://www.pca.state.mn.us/cleanup/ast.html>; [http://www.pca.state.mn.us/programs/lust\\_p.html](http://www.pca.state.mn.us/programs/lust_p.html); <http://www.pca.state.mn.us/cleanup/ust.html>; [http://www.pca.state.mn.us/programs/vpic\\_p.html](http://www.pca.state.mn.us/programs/vpic_p.html)).

*Land-applied Industrial and Municipal Byproducts:* Moderately confident. We have good information on the amount of several industrial and municipal wastes land applied. These wastes are not hazardous and are applied for agronomic benefit, thus reducing their risk to humans. We, however, have limited environmental data to verify this assumption (<http://www.pca.state.mn.us/water/landapp.html>).

*Fertilizer use:* Reasonable for acute effects, since incidence of blue-baby syndrome is well documented. We have good data describing the distribution of nitrate in the major aquifers in the state.

*Municipal and industrial wastewater:* Moderately confident. MPCA regulates wastewater discharges and sets effluent limits. There is little information about some chemicals in wastewater, however, such as pharmaceuticals (<http://www.pca.state.mn.us/water/wastewater.html>).

*Septic systems:* Moderately confident to Reasonable. We have good information on the number of septic systems, where they occur, and nitrogen loss from septic systems. Nitrogen is the chemical of greatest concern for acute impacts to human health. We have limited information for other chemicals that may have chronic impacts. We thus assigned moderate confidence for chronic impacts and reasonable for acute impacts.

*Spills:* Moderately confident based on the low exposure due to quick detection and relatively small volumes of most spills.

*Feedlots:* Moderately confident. We are moderately confident of our estimate of contribution from feedlots. We have good information on number of feedlots and the fate of nitrogen from feedlots. We do not have good information on the number of unpermitted feedlots, which may be an important contributor to nitrogen in ground water.

*Land-applied manure:* Moderately confident. We have some information on the amount of manure applied to agricultural soils and good information on livestock numbers. We have a good understanding of the fate of nitrogen in manure under certain field conditions.

### Source Trends

*Pesticide Use, Fertilizer Use:* No change in concentration with time. Quantities of pesticides and fertilizer applied over the past ten years have not increased or decreased (<http://www.mda.state.mn.us/privapp/>).

*Spills:* stable to declining due to improved spill prevention and preparedness.

*Land application of industrial and municipal byproducts:* increasing trend. Quantities of lime, which includes industrial ash, have increased over the past ten years

(<http://www.mda.state.mn.us/lime/tonnagestats.pdf>). Application of biosolids have increased in the past 12 years (MPCA data).

*Tanks*: because of MPCA and programs, there is a downward trend in number of new sites with leaking tanks. New tank sites are generally equipped with detection systems.

*Unpermitted waste disposal*: because of MPCA and local programs, there is a decreasing trend in the number of unpermitted waste disposal sites. New unpermitted hazardous waste sites are less likely because of RCRA. Sites continue to be cleaned up, and it is assumed that preventive programs will limit potential exposure from these sources.

*Septic systems*: increasing trend. Prescription drug use and the number of septic systems continue to increase with time (<http://www.extension.umn.edu/extensionnews/1999/JP1052.html>)(<http://www.house.gov/berry/prescriptiondrugs/Resources/nihcmreport.pdf>).

*Municipal and Industrial Wastewater*: No trend. Assessing overall trends in wastewater contributions requires assessing a variety of wastewater sources. These range from industrial and municipal discharges to discharges of animal waste. Animal wastes decreased by approximately 3 percent between 1987 and 1997. Minnesota has limited information about other wastewater discharges (<http://www.scorecard.org/ranking/>). An original MPCA mission was to control point sources of contamination. Municipal and industrial wastewater treatment plants were targeted point sources and they have largely been brought into compliance. We therefore assume that impacts from wastewater discharge have decreased. This is countered, however, by evidence that chemicals such as pharmaceuticals are present in wastewater and may have impacts on human health. Concentrations of these chemicals in wastewater appear to be increasing (<http://www.earthsky.com/2000/es000901.html>; <http://ag.arizona.edu/AZWATER/awr/july00/feature1.htm>; <http://toxics.usgs.gov/pubs/OFR-02-94/>).

*Land-applied Manure*: No trend. There is little documentation about the amount of manure applied to agricultural fields. Since the number of livestock has not increased dramatically in the past ten years, and assuming farmers are not applying different quantities of manure than in the past, we estimated there was no trend in contributions from land-applied manure.

*Feedlots*: No trend. While the number of feedlots has decreased over the past ten years, the number of livestock has not changed during that same period. This reflects increasing size of operation. We based the assumption of no trend in contribution on the number of livestock, since the amount of waste produced has not changed in the past ten years (<http://www.leg.state.mn.us/lrl/issues/feedlots.htm>).

## 21. Toxic Metals

*Impact Categories: Aquatic Organisms, Terrestrial Organisms*

*Sources: Coal-fired Power Plants, Industry, Mining, Municipal and Industrial*

*Wastewater, Urban Runoff, Waste Incineration, Recreational Use (shooting ranges, fishing tackle)*

Toxic metals include lead, mercury, cadmium, zinc, copper, chromium, and others. For this stressor, we consider effects of metals on aquatic and terrestrial organisms. These include impacts from exposure to sediments containing metals. Human health is also affected by metals in the environment, but these effects were considered under Toxic Chemicals in Soil, Toxic Volatile Chemicals in Water, Toxic Chemicals in Air, and Toxic Chemicals in Food.

### Comparative Contribution

*Coal-fired Power Plants:* High Contribution. Coal contains a large number of metals. These may be emitted to air with particulates from coal-fired power plants. Mercury is a volatile metal and is emitted in its elemental form following coal combustion. These metals enter the aquatic ecosystem through air deposition. Coal combustion is the major source of mercury released to the environment ([http://www.fetc.doe.gov/publications/proceedings/96/96jpfs/jpfs\\_pdf/toxics.pdf](http://www.fetc.doe.gov/publications/proceedings/96/96jpfs/jpfs_pdf/toxics.pdf); <http://www.pca.state.mn.us/air/mercury-about.html>). Coal combustion accounts for less than 10 percent of air emissions for most metals, with the exception of arsenic, which is estimated at 19 percent, and mercury, which is estimated at about 25 percent (EPA 1998a; EPA 2000).

*Urban Runoff:* High Contribution. Urban runoff contributes large quantities of metals directly to ecosystems. The most recent National Water Quality Inventory reports that runoff from urban areas is the leading source of impairments to surveyed estuaries and the third largest source of water quality impairments to surveyed lakes (<http://www.epa.gov/OWOW/NPS/facts/point7.htm>). Automobile fluids are perhaps the most important source of metals. A study conducted by the MPCA in 1994 and 1995 showed that runoff from a 'typical' motor vehicle salvage facility greatly exceed aquatic life standards for cadmium, copper, lead, and zinc. Several other studies conducted outside Minnesota show direct ecosystem impacts from metal contamination associated with urban runoff (<http://www.kristar.com/level2/info/infoG.html>; <http://www.epa.state.oh.us/dsw/documents/fs2eas2000.pdf>; <http://environment.prsc.qld.gov.au/waterquality.asp>; <http://www.auracom.com/~bofep/Publications/Fundy%20issues/contamin.htm>).

*Area Source combustion:* Medium Contribution. Differences between area source contributions and industry are unclear. If we group smelting operations into area sources, then the contribution of area sources is medium. Smelting results in air emissions of lead, copper, cadmium, and arsenic. These chemicals may eventually be deposited in aquatic or terrestrial ecosystems. Smelting is a particularly important contributor of cadmium and arsenic (EPA 1999).

*Municipal and Industrial Wastewater:* Medium contribution. Concentrations of metals in some wastewater can be high (data from MPCA unpublished data base). Concentrations and metals of concern vary with the type of waste, since municipal and industrial wastewater covers a broad range of wastes. Effects of wastewater discharges on ecological ecosystems have been document (<http://dnr.state.il.us/orep/c2000/MANAGE/dupage/ataglance.htm>; <http://marine.usgs.gov/fact-sheets/fs150-97/>; [http://www.ce.berkeley.edu/~sedlak/research\\_4.php](http://www.ce.berkeley.edu/~sedlak/research_4.php); <http://sfbay.wr.usgs.gov/access/Cloern.html#HDR1>). Although effects can be severe,

they also tend to be localized and associated with a particular point source of contamination.

*Waste Incineration:* Medium contribution. Nationally, waste incineration accounts for metal emissions to air that are similar in magnitude to coal combustion (EPA 1998a; 1999; 2000). Waste incineration is a significantly less important contributor in Minnesota, with only about 30 percent of the state's solid waste being incinerated (<http://www.moea.state.mn.us/lc/DisposalAction.cfm>).

*Industry:* Low contribution. Industry includes a large number of point sources that primarily contribute metals through air emissions. If smelting is not included under industry, then contributions of metals are relatively low. Metal finishing industries may contribute significant quantities of metal locally, particularly chromium (EPA, 1999).

*Mining:* Low contribution. Mining is not an important source of metals released to the atmosphere (discounting smelting operations)(EPA 1998a; 1999; 2000). Metals released to the environment will therefore occur locally. Contributions from mining are therefore considered low, although locally aquatic and terrestrial ecosystems can be impacted. Most studies of mining impacts on ecosystems and ecological organisms have occurred outside Minnesota ([http://www.ainc-inac.gc.ca/pr/pub/nwr/li3\\_e.html](http://www.ainc-inac.gc.ca/pr/pub/nwr/li3_e.html); <http://www.nrcan.gc.ca/mets/aete/factshte.htm>; [http://www.fisheries.org/Public\\_Affairs/Policy\\_Statements/ps\\_13.shtml](http://www.fisheries.org/Public_Affairs/Policy_Statements/ps_13.shtml)).

*Recreational use:* Low contribution. A 15-year study, analyzing 222 dead loons from Minnesota and 17 other states, concluded that 10 percent died of lead poisoning. Half of those loons actually had lead fishing sinkers in their stomachs. In another study conducted by the Minnesota Pollution Control Agency, lead poisoning accounted for 17 percent of the dead loons sent to research centers for autopsy. In areas where loons breed – the Great Lakes region, northeastern United States, and eastern Canada – lead poisoning from sinkers or jigs may account for up to 50 percent of the dead adult loons found by researchers. Between 1980 and 1996, the University of Minnesota's Raptor Center reported lead poisoning in 138 of 650 eagles treated by the Center. Since 1996, 43 additional eagles were treated for lead poisoning including 22 last year. Most of the time, the source of the lead cannot be detected as the birds have cast the material out of their systems (<http://www.moea.state.mn.us/reduce/sinkers.cfm> ). Because lead shot was banned in waterfowl production areas in the early 1990s, lead jigs and sinkers are a major source of ongoing lead poisoning.

#### Confidence Level

*Coal-fired Power Plants:* Reasonably confident. Coal-fired power plants are permitted. We therefore have information about releases.

*Urban Runoff:* Moderately confident. We have good data to indicate that population is increasing and the state is becoming more urbanized. We have good information that shows urban water quality contains toxic metals. We have limited information that supports our understanding of impacts from these metals on ecological organisms.

*Municipal and Industrial Wastewater:* Moderately confident. Most wastewater sources are controlled through a permitting process. Discharge quantities are therefore known. There is limited understanding of the environmental fate and impact from metals in wastewater.

*Waste Incineration:* Reasonably confident. Waste incinerators are permitted. We therefore have information about releases.

*Industry:* Somewhat speculative. Our low confidence is due to the large number of industries that potentially contribute metals to the environment.

*Mining:* Reasonably confident. If we eliminate smelting as a mining source, we have reasonably good information on mining contributions, since these operations require an NPDES permit.

*Recreational Use:* Intermediate confidence. Although studies suggest lead poisoning occurs in waterfowl and raptors, evidence linking the poisoning to use of lead in recreation is lacking. Lead sinkers have frequently been found in animals that have been poisoned (<http://www.moea.state.mn.us/reduce/sinkers.cfm>).

## Trends

*Coal-fired Power Plants:* No trend. The primary metal of concern with coal-fired power plants is mercury. Emissions from power plants have increased about 25 percent in the past ten years as a result of increased energy demand. Concentrations of chemicals have not changed or decreased, however, partly because of decreasing emissions nationally (<http://www.pca.state.mn.us/hot/legislature/reports/2001/at-appendix-c.pdf>).

*Urban Runoff:* Upward trend. The upward trend is primarily a result of increasing population and an increase in the number of people living in urban areas (<http://govpubs.lib.umn.edu/guides/census2k.phtml>).

*Municipal and Industrial Wastewater:* No trend. Assessing overall trends in wastewater contributions to heavy metals in the environment requires assessing a variety of wastewater sources. These range from industrial and municipal discharges to discharges of animal waste. Animal wastes decreased by approximately 3 percent between 1987 and 1997. Minnesota has limited information about other wastewater discharges (<http://www.scorecard.org/ranking/>). An original MPCA mission was to control point sources of contamination. Municipal and industrial wastewater treatment plants were targeted point sources and they have largely been brought into compliance. We therefore assume that impacts from wastewater discharge have decreased significantly over the past 20 years, although current trends may be relatively flat.

*Waste Incineration:* Downward trend. Wastewater treatment facilities (both municipal and industrial) are regulated through a permitting system. Through this permitting system and improvements in operation, environmental releases of metals to water bodies have diminished with time (<http://www.pca.state.mn.us/water/wastewater.html>). Similar trends have been observed in other areas of the country ([http://www.wa.gov/puget\\_sound/Publications/workplan\\_01/MUNICPL.pdf](http://www.wa.gov/puget_sound/Publications/workplan_01/MUNICPL.pdf); <http://www.rice.edu/armadillo/Galveston/Chap6/ch6.html>).

*Industry:* No trend. Because of the large number of industries that could potentially contribute metals to the environment, it is difficult to assess trends. Overall, there are some industries with increasing emissions and some with decreasing emissions. Cumulatively, we took this to mean no trend (US Environmental Protection Agency. March 2000. *National Air Pollutant Trends, 1900-1998*. <http://www.epa.gov/ttn/chief/trends/trends98/trends98.pdf>; Minnesota Pollution Control Agency. 2001. *Air Quality in Minnesota: Problems and Approaches*. Appendix B:

*Particulate Matter and Appendix E: Diesel Exhaust.*

<http://www.pca.state.mn.us/hot/legislature/reports/2001/airquality.html>).

*Mining:* No trend. Data suggests a slight downward trend in the extent of mining in Minnesota, with a 14 percent decrease in the number of establishments between 1992 and 1997 and a 4 percent reduction in the number of employees. Value of shipments, however, has increased 17 percent over the same period. It is difficult to extrapolate these results to trends in environmental impacts from mining ([http://www.census.gov/epcd/ec97/mn/MN000\\_21.HTM](http://www.census.gov/epcd/ec97/mn/MN000_21.HTM); <http://www.census.gov/epcd/ec97sic/E97SUS.HTM>).

*Recreational use:* No trend. There are no bans on lead jigs and sinker use in Minnesota, but tackle manufacturers, retailers, associations, sports enthusiasts and government are partnering to educate anglers about this issue and increase the use of environmentally friendly sinkers. Lead shot has been banned in Minnesota for several years (<http://www.moea.state.mn.us/reduce/sinkers.cfm>)

## **22. Toxic Organic Chemicals**

*Impact Categories: Aquatic Organisms, Terrestrial Organisms*

*Sources: Agricultural Runoff, Pesticide Use, Area Source Combustion, Municipal and Industrial Wastewater, Spills, Urban Runoff, Industry, Land-applied Municipal and Industrial Byproducts*

Toxic organic chemicals include a wide range of chemicals. These include chemicals that have industrial, agricultural, and residential origins, and that vary widely in their persistence and toxicity. Only aquatic and ecosystem effects are considered in this discussion. Toxic organic chemicals that affect human health are included in discussions for Toxic Chemicals in Soil, Toxic Chemicals in Water, Toxic Volatile Chemicals in Air, and Toxic Chemicals in Food.

### Comparative Contribution

*Agricultural runoff:* High contribution. Effects are on aquatic organisms. The primary organic chemicals of concern in agricultural runoff are pesticides. Occurrence of pesticides in surface waters and effects on aquatic organisms are well documented (<http://www.ianr.unl.edu/pubs/water/g586.htm>; <http://www.ccohs.ca/headlines/text69.html>; <http://www.cotf.edu/ete/modules/waterq3/WQpollution3.html>; [http://www.epa.gov/ceisweb1/ceishome/atlas/nationalatlas/threats\\_to\\_health\\_of\\_us\\_waters.htm](http://www.epa.gov/ceisweb1/ceishome/atlas/nationalatlas/threats_to_health_of_us_waters.htm); <http://www.pca.state.mn.us/water/groundwater/gwmap/gw-landuse.html>).

*Pesticide Use:* High contribution. Effects are on terrestrial organisms. Many chlorinated insecticides, although banned or limited for use in the United States, continue to enter terrestrial ecosystems as a result of air deposition, since many of these chemicals are used in other areas around the world. Pesticide applications to forests, agricultural fields, and residential areas have immediate adverse impacts on terrestrial ecosystems near the application areas. Many pesticides are detected in rain water, although generally at low concentrations (<http://ace.orst.edu/info/extoxnet/tibs/ecologic.htm>; <http://ice.ucdavis.edu/cehr/33.htm>).

[http://www.mst.dk/default.asp?Sub=http://www.mst.dk/udgiv/publications/2000/87-7944-325-7/html/indhold\\_eng.htm](http://www.mst.dk/default.asp?Sub=http://www.mst.dk/udgiv/publications/2000/87-7944-325-7/html/indhold_eng.htm);

[http://www.mst.dk/default.asp?Sub=http://www.mst.dk/udgiv/publications/2000/87-7944-325-7/html/indhold\\_eng.htm](http://www.mst.dk/default.asp?Sub=http://www.mst.dk/udgiv/publications/2000/87-7944-325-7/html/indhold_eng.htm);

<http://www.epa.gov/athens/staff/members/birdsandra/>).

*Area Source Combustion:* Medium and High contribution. Effects on aquatic organisms are high. Effects on terrestrial organisms are moderate. The high contribution is primarily attributed to incomplete burning, which leads to release of PAHs and dioxin to the atmosphere (<http://ens.lycos.com/ens/jan2000/2000L-01-04-06.html>; <http://www.dnr.state.wi.us/org/caer/ce/ob/health.htm>). Burn barrels, for example, are thought to contribute about 25 percent of the dioxins released annually to the atmosphere in the United States (EPA, 2000, Draft Dioxin Reassessment). Residential wood combustion is considered to contribute slightly more than a quarter of the total PAHs released annually to the atmosphere in the United States. These chemicals can be highly toxic and persistent in the environment (US EPA). The effects are only medium in terrestrial ecosystems because soils typically bind and therefore limit mobility of PAHs and dioxins, whereas these chemicals are often cycled through sediments in aquatic ecosystems, thus increasing exposure of aquatic organisms.

*Municipal and Industrial Wastewater:* Intermediate and High contribution. Municipal and industrial wastewater contribution was high for aquatic organisms and medium for terrestrial organisms. The chemicals of greatest concern are pbts and endocrine-disrupting chemicals. Municipal and industrial wastewater contributes large quantities of these chemicals to aquatic ecosystems. Releases to terrestrial ecosystems occur through discharge to the atmosphere and subsequent deposition to terrestrial ecosystems, or locally due to direct discharge of organic chemicals. Atmospheric releases of pbts are considered less significant than from other sources (see Section 18).

*Industry:* Medium contribution. Industry encompasses a wide variety of sources for organic chemicals. The chemicals of greatest concern are pbts. Industry is considered to represent a significant source for these chemicals, but less than area sources (see Section 18).

*Urban Runoff:* Medium contribution. Urban runoff impacts both aquatic and terrestrial ecosystems. Impacts to aquatic ecosystems are evident and have been documented (<http://www.afsc.noaa.gov/abl/Habitat/urbanPAH.htm>; [http://endocrine.ei.jrc.it/gedri/pack\\_edri.FullScreen?p\\_rs\\_id=262](http://endocrine.ei.jrc.it/gedri/pack_edri.FullScreen?p_rs_id=262); [http://www.usgs.gov/public/press/public\\_affairs/press\\_releases/pr457m.html](http://www.usgs.gov/public/press/public_affairs/press_releases/pr457m.html); <http://www.nwri.ca/talk-green/urban-runoff.html>). Terrestrial organisms, such as waterfowl, are also impacted by organic contaminants that bioaccumulate.

*Land-applied Municipal and Industrial Byproducts:* Low contribution. Although municipal and industrial waste may contain organic contaminants, including pbts, applications are permitted and effects are generally local in nature (<http://www.pca.state.mn.us/water/landapp.html>).

*Spills:* Low contribution. Although spills can dramatically alter aquatic and terrestrial ecosystems, effects are generally local and spills are rapidly contained (<http://www.pca.state.mn.us/cleanup/ert.html>).

## Confidence Level

*Agricultural runoff*: Moderately confident. Agricultural runoff of pesticides and presence of pesticides in surface water have been well documented.

*Pesticide Use*: Somewhat speculative. Although we have observed direct impacts to some organisms, such as raptors, there is limited information about rates of pesticide deposition to terrestrial ecosystems.

*Area Source Combustion*: Somewhat speculative. Emissions from the primary sources for area source combustion are not monitored, although we have general estimates of atmospheric discharge of some chemicals.

*Municipal and Industrial Wastewater*: Somewhat speculative and moderately confident. We are moderately confident for aquatic ecosystems since discharges of wastewater are regulated and effluent limits are established. We are somewhat speculative for terrestrial effects since we have limited information on atmospheric discharge from wastewater facilities.

*Industry*: Somewhat speculative. There are estimates of some pbts released to the atmosphere from some industries. Because of the wide variety of industries that may contribute organic chemicals to the environment, we rated our confidence as somewhat speculative.

*Urban Runoff*: Somewhat speculative. There are limited studies showing concentrations of organic chemicals released to the environment.

*Spills*: Moderately confident. MPCA and other agencies have Emergency Response programs that document and contain spills.

*Land-applied Municipal and Industrial Byproducts*: Moderately confident. This source is regulated through a permitting process.

## Trends

*Agricultural runoff*: No trend. There has been no significant change in agricultural acres in the past 15 years. BMPs can diminish loss from agricultural fields, but there is little information about trends in use of BMPs. Some programs, such as the EQIP program, have been successful in getting farmers to implement BMPs, but the program is limited in scope (<http://www.mnplan.state.mn.us/mm/indicator.html?Id=68&G=41>; <http://wrc.coafes.umn.edu/EQIP/>).

*Area Source Combustion*: No trend. There is limited information related to trends in chemical release from area sources. We can use information on discharge of pbts, which shows some chemical releases increasing and others decreasing. Overall, we assume there is no trend in environmental concentrations of organic contaminants.

*Municipal and Industrial Wastewater*: No trend. Wastewater is regulated through a permitting process. Quantities of wastewater have not changed significantly in the past 10 years.

*Industry*: No trend. Because of the large number of industries that could potentially contribute metals to the environment, it is difficult to assess trends. Overall, there are some industries with increasing emissions and some with decreasing emissions. Cumulatively, we took this to mean no trend (US Environmental Protection Agency. March 2000. *National Air Pollutant Trends, 1900-1998*. <http://www.epa.gov/ttn/chieftrends/trends98/trends98.pdf>; Minnesota Pollution Control Agency. 2001. *Air Quality in Minnesota: Problems and Approaches*. Appendix B:

*Particulate Matter and Appendix E: Diesel Exhaust.*

<http://www.pca.state.mn.us/hot/legislature/reports/2001/airquality.html>)

*Urban Runoff:* Upward trend. The percent of urban land in Minnesota increased about 27 percent between 1982 and 1997. Several studies have demonstrated negative impacts of urban runoff on aquatic organisms. The greatest concern is perhaps from PAHs, which are increasing in surface water sediments in urbanizing environments

(<http://www.epa.gov/OWOW/NPS/facts/point7.htm>;

<http://www.ocrm.nos.noaa.gov/pcd/6217.html>;

<http://www.strategian.com/oct900.html#one>; <http://capita.wustl.edu/NEW/oconnor.html>;

<http://www.mnplan.state.mn.us/mm/indicator.html?Id=68&G=41>).

*Spills:* No trend. Despite preventive efforts, spills still occur. There appears to be no trend in the occurrence of spills.

*Land-applied Municipal and Industrial Byproducts:* Upward trend. Land application of byproducts is increasing, partly due to improved markets for byproducts

(<http://www.tfhr.gov/pubrds/fall94/p94au32.htm>;

<http://www.ctre.iastate.edu/pubs/semisesq/session2/ghafoori/>;

<http://www.p2pays.org/ref/03/02311.pdf>).

### **23. Toxic Volatile Organic Chemicals in Air**

*Impact Categories: Human Health Cancer, Human Health Noncancer Acute, Human Health Noncancer Chronic*

*Sources: Industry, Off-road Equipment, On-road Vehicles, Residential Fuel Combustion*

There are hundreds or thousands of different volatile chemicals released into the atmosphere from various industrial and commercial processes. For the sake of clarity and feasibility, it is necessary to define exactly which pollutants are described. In 1999, the MPCA's Staff Paper on Air Toxics identified ten 'pollutants of concern' in Minnesota based on modeling and monitoring (acrolein, benzene, 1,3-butadiene, formaldehyde, chromium, nickel, arsenic, ethylene dibromide, chloroform, and carbon tetrachloride). Follow-up work indicated that several pollutants may not be as large of a concern as previously thought. In the Environmental Information Report, the term air toxics refers to those pollutants identified by the MPCA to be near the relevant health benchmark: benzene, formaldehyde, 1,3-butadiene, acrolein, and acetaldehyde.

It should not be inferred that the other chemicals present in the air are known to cause no ill effects. Many of these pollutants are not tracked through modeling or monitoring and the information on health effects is incomplete or non-existent. In addition, the health impacts of mixtures of pollutants is not well understood; effects could be additive or synergistic.

#### Comparative Contribution of Sources

*On-Road Vehicles:* High Contribution. On-road vehicles emit large amounts of many volatile chemicals. According to Minnesota emissions inventory data, on-road vehicles are a primary source for benzene, formaldehyde, 1,3-butadiene, acrolein, and acetaldehyde.

*Off-Road Equipment: Medium Contribution.* The total contribution of off-road engines is less than that of on-road vehicles. The gasoline and diesel-powered engines are still significant sources of pollution, however.

*Residential Fuel Burning: Medium Contribution.* Residential burning of wood, natural gas, and other fossil fuels is a significant source of air toxics. Residential wood burning is a large source of benzene.

*Industry: Medium Contribution.* A variety of industrial operations emit volatile air pollutants. Although the cumulative emissions of cars, trucks, and other mobile sources are larger than the emissions for facilities, industrial emissions may adversely impact local communities.

### Confidence Level

*On-Road Vehicles: Reasonably confident.* On-road gasoline and diesel vehicles are known to emit large amounts of many air pollutants. The specific emission rates are continually improved as EPA works to improve our understanding and formulate reduction strategies, but the contribution of on-road vehicles to air quality problems across the country is well documented.

*Off-Road Equipment: Moderate confidence.* Emission estimation procedures for the wide variety of off-road engines are constantly improved, but emission rates of specific engines and their contribution to local pollutant emissions are not as well understood as those for on-road vehicles.

*Residential Fuel Burning: Somewhat speculative.* Emission factors are available for wood and fossil fuel burning. Better activity data is needed (i.e., the amount of wood burned by households in Minnesota).

*Industry: Reasonably confident.* Minnesota does not require facilities to report air toxics emissions, but many large facilities work with the MPCA on emissions estimates. Most facilities are included in Minnesota's emissions inventory.

### Source Trends

*On-Road Vehicles and Off-Road Equipment: Up and Down.* The on- and off-road vehicles categories contain a wide variety of vehicle and engine types powered by gasoline and diesel fuel. Different pollution control regulations apply to the different engines. Emissions from some sources are decreasing due to pollution control equipment while emissions from other engines are increasing due to increasing use. Some pollution control equipment may cause trade-offs (e.g., Some groups claim that burning gasoline blended with ethanol reduces emissions of some toxics, but increases aldehyde emissions).

*Residential Fuel Burning: No Trend.* Emissions trend information is not available for the ubiquitous residential combustion sources. The use of some fuels, such as wood, may be decreasing according to anecdotal evidence while others, like natural gas, may be increasing as the population of the region expands. Improved technology also plays a role in emissions.

*Industrial Processes: Up and Down.* Some industrial sectors and specific facilities are decreasing their emissions while the emissions from others are likely increasing.

## **References**

- Minnesota Pollution Control Agency (MPCA). 2001. *1997 Minnesota Air Toxics Emissions Inventory*. <http://www.pca.state.mn.us/air/toxics.html>. Accessed 2/6/02.
- Minnesota Pollution Control Agency. 1999. *MPCA Staff Paper on Air Toxics*.
- Minnesota Pollution Control Agency. 2001. *Air Quality in Minnesota: Problems and Approaches. Appendix B: Air Toxics*. <http://www.pca.state.mn.us/hot/legislature/reports/2001/airquality.html>. Accessed 2/6/02.

## **24. Transported Sediment**

*Impact Categories: Aquatic organisms, Quality of Life-Aesthetics*

*Sources: Agricultural Runoff, Construction, Municipal and Industrial Wastewater, Streambank Erosion, Urban Runoff*

Transported sediment primarily affects aquatic organisms and can have negative aesthetic impacts for people who utilize surface water. There are few studies that allow comparison of the relative contribution of different source areas to suspended sediment in surface water (<http://www.smm.org/SCWRS/sSchottler.php>; <http://nevada.usgs.gov/Activities/nv233.htm>; [http://wa.water.usgs.gov/ccpt/pubs/wrir-94-4215\\_abstract.html](http://wa.water.usgs.gov/ccpt/pubs/wrir-94-4215_abstract.html); <http://www.cleanwaterclearchoice.org/documents/Construction/Appendix%20A.pdf>; [http://www.inforain.org/mapsatwork/rockrichardson/rockrichardson\\_page4.htm](http://www.inforain.org/mapsatwork/rockrichardson/rockrichardson_page4.htm); <http://www.pca.state.mn.us/water/basins/redriver/studies.html#usgs-sediment>). Soil loss equations and other methods for estimating sediment loss typically include land use as a factor. The relative contribution from different land uses can therefore be compared using these estimation methods. Natural soil erosion is a process that averages 0.2 tons per acre. The loss rate is accelerated to 0.5 tons per acre for managed forests. The loss rate is accelerated to 1.5 to 20 tons per acre for pasture and cultivated lands. The loss rate is accelerated to 150 to 200 tons per acre for unprotected construction sites (<http://www.engr.utk.edu/research/water/primer/erosionsediment/>; [http://www.dwaf.gov.za/IWQS/reports/slopes\\_olifants/sed\\_olif.htm](http://www.dwaf.gov.za/IWQS/reports/slopes_olifants/sed_olif.htm)).

### Comparative Contribution of Sources

*Municipal and Industrial Wastewater:* Low contribution. Municipal and industrial wastewater contributes organic matter to surface waters, and may contribute phosphorus that leads to algae growth. The quantities of sediment are low however, and effects are typically localized.

*Urban runoff:* Medium contribution. Contributions from undisturbed urban areas are considered intermediate. These are primarily areas with established lawns and other vegetation. Sediment loss from disturbed soils are considered high unless soils are stabilized. These might include losses from industrial areas, such as salvage yards. Urban areas are considered to have dramatic impacts on lakes in urban areas (<http://www.epa.gov/OWOW/NPS/facts/point7.htm>; <http://clean-water.uwex.edu/pubs/sheets/hiurban.pdf>; ). Urban areas, however, make up less than 5 percent of Minnesota's land use, although that percentage is increasing

(<http://www.mnplan.state.mn.us/mm/indicator.html?Id=68&G=41>). Sediment loads are higher for urban areas relative to several other land uses, particularly forested and pastured areas (<http://www.chesapeakebay.net/info/stormwater.cfm>). In addition, average particle size for urban areas is smaller than other land uses. Smaller particle sizes are likely to increase loading of metals and organic pollutants, since these readily adsorb to small particles (<http://www.hsrb.org/hsrb/html/rbriefs/RB7/rbrief7.html>; <http://www.ga.usgs.gov/edu/urbanrun.html>).

*Agricultural runoff*: High contribution. Soils losses from agricultural land are considered intermediate in their severity. With more than 21 million acres of agricultural land in Minnesota, however, agriculture is a major contributor to suspended sediment. Much of this land is in row crop agriculture, which has a high erosion potential (<http://www.ent.iastate.edu/ipm/icm/2000/7-24-2000/erosion.html>). The US EPA suggests a high runoff potential for the southern half of Minnesota, which is where agriculture primarily occurs ([http://www.epa.gov/iwi/1999sept/iv12\\_usmap.html](http://www.epa.gov/iwi/1999sept/iv12_usmap.html)). In addition to soil particles, agriculture contributes organic matter and phosphorus, which can result in algae growth (<http://www.mnplan.state.mn.us/mm/indicator.html?Id=68&G=41>; <http://www.ianr.unl.edu/pubs/water/g586.htm>; <http://www.soils.umn.edu/research/npsp/research/lower/hansen/abstract.htm>).

*Streambank erosion*: Medium contribution. Streambank erosion is a natural process, but human activity can increase rates of sediment loss. These activities include increasing streamflow volumes and rates by paving areas and building storm sewers, straightening streams, building dams, and reducing vegetation in riparian areas. In many rivers, streambank erosion is perhaps the most important source of suspended sediment. Streambank erosion, however, may be related to other activities, such as construction, urban development, and agriculture (e.g. animal traffic, loss of riparian habitat). It is therefore difficult to separate streambank erosion from other sources of suspended sediment. We limited our definition to streambank erosion associated with alteration of water bodies, such as straightening and damming. This reduces the relative contribution of streambank erosion (<http://www.nal.usda.gov/ttic/tektran/data/000012/45/0000124555.html>; <http://www.oacd.org/fs04ster.htm>; <http://www.niwa.cri.nz/pubs/no8/foresthavest1>).

*Construction*: High contribution. For this source, we include most activities that result in land disturbance, such as building and road construction, mining, and timber production. We consider direct contributions of sediment, rather than modifications that later result in streambank erosion (see Streambank Erosion). Construction activities contribute large quantities of sediment per unit area (<http://www.engr.utk.edu/research/water/primer/erosionsediment/>; <http://www.engr.utk.edu/research/water/primer/erosionsediment/>).

#### Confidence Level

*Municipal and Industrial Wastewater*: Reasonably confident. Effluent limits exist for wastewater treatment facilities. Because of these limits, we have reasonable information about the quantity of organic matter and suspended material that is discharged (<http://www.pca.state.mn.us/water/wastewater.html>).

*Urban runoff:* Moderately confident. There is increasing evidence of urban impacts on sedimentation in surface waters. Impacts to aquatic are not well understood however. Specific sources of urban runoff are known, but the relative importance of each is not well understood (<http://www.epa.gov/OWOW/NPS/facts/point7.htm>; <http://www.epa.gov/OWOW/NPS/facts/point7.htm> ).

*Agricultural runoff:* Reasonably confident. Most studies of erosion have occurred in agricultural areas. There are soil erodibility indices for many soils in agricultural areas. In addition, the sheer number of acres in agricultural production provide a reasonable certainty that agriculture is an important source of sediment to surface water, although perhaps not on a unit area scale compared to construction and streambank erosion.

*Streambank erosion:* Moderately confident. There is considerable information on rates of streambank erosion and effects of management activities designed to reduce sediment loss. Relating this information directly to sediment contributions from streambank erosion is difficult, however.

*Construction:* Moderately confident. Recent studies indicate that sediment losses from construction are extremely high. It is difficult to determine aquatic impacts associated with construction activity, however (<http://www.engr.utk.edu/research/water/primer/erosionsediment/>; <http://www.cleanwaterclearchoice.org/documents/Construction/Appendix%20A.pdf>).

#### Source Trends

*Municipal and Industrial Wastewater:* No trend. Effluent limits have been in place for many years. There is therefore no trend in sediment contributions from wastewater treatment (<http://www.pca.state.mn.us/water/wastewater.html>).

*Urban runoff:* No trend. Although the amount of urban land is increasing in Minnesota, there is increased awareness of impacts of urban land use on water quality. Implementation of Best Management Practices may counter some of the impacts of increased urbanization (<http://www.state.tn.us/agriculture/nps/bmpu.html>; <http://www.mnplan.state.mn.us/mm/indicator.html?Id=68&G=41>).

*Agricultural runoff:* No trend. There has been no significant change in agricultural acres in the past 15 years. BMPs can diminish erosion loss from agricultural fields, but there is little information about trends in use of BMPs. Some programs, such as the EQIP program, have been successful in getting farmers to implement BMPs, but the program is limited in scope (<http://www.mnplan.state.mn.us/mm/indicator.html?Id=68&G=41>; <http://wrc.coafes.umn.edu/EQIP/>).

*Streambank erosion:* No trend. There is limited information about trends in sediment loss from streambank erosion. Rates of damming and stream straightening do not appear to be changing. BMPs are typically implemented in forest and mining activities. Other BMPs may be implemented in developing areas. Consequently we assigned no trend to this source (<http://www.epa.gov/OWOW/NPS/MMGI/Chapter2/ch2-2a.html>; <http://www.niwa.cri.nz/pubs/no8/foresthavest1>; [http://www.ieca.org/store/category.cfm?category\\_id=6](http://www.ieca.org/store/category.cfm?category_id=6)).

*Construction:* No trend. Although urbanization and development are increasing, increased awareness of sediment losses from construction sites has resulted in

development and implementation of BMPs, as well as increasing regulation of construction activity ([http://www.ieca.org/store/category.cfm?category\\_id=6](http://www.ieca.org/store/category.cfm?category_id=6); <http://www.epa.gov/OWOW/NPS/MMGI/Chapter4/ch4-3a.html>; <http://www.cleanwaterclearchoice.org/documents/Construction/Appendix%20A.pdf>; <http://www.pca.state.mn.us/water/stormwater-c.html>)

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