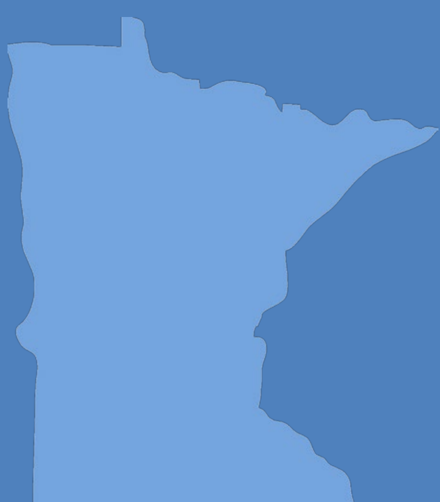
Groundwater Protection Recommendations Report



Minnesota Pollution Control Agency

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Foreword

The Fiscal Year 2014-15 Biennial Budget approved by lawmakers in the 2013 Legislative Session included policy language directing the Minnesota Pollution Control Agency (MPCA) to prepare a report with recommendations for reducing or preventing groundwater degradation from contaminants:

> *From 2013 Sessions Laws, Chapter 137, Article 2 (Clean Water Fund Appropriations)*
>
> "By January 15, 2016, the commissioner shall submit a report with recommendations for reducing or preventing groundwater degradation from contaminants to the chairs and ranking minority members of the senate and house of representatives committees and divisions with jurisdiction over environment and natural resources policy and finance."

This recommendation report draws on current information contained in recent reports and documents prepared by executive branch agencies carrying out their groundwater responsibilities under state and federal law. Links to these reports are imbedded in this report for readers seeking additional background information. The MPCA is one of several executive branch agencies that together carefully coordinate groundwater monitoring, protection, and management activities across specialized areas of groundwater expertise, as assigned in various laws, and funded in part by the Clean Water Land and Legacy Amendment. The MPCA prepared this report in consultation with these partners at the Minnesota Department of Health, Minnesota Department of Agriculture, Minnesota Department of Natural Resources, the Metropolitan Council, and the Board of Water and Soil Resources.

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Executive summary

Groundwater provides nearly 75% of Minnesotans with their primary source of drinking water, as estimated by the Minnesota Department of Health (MDH) and the Minnesota Department of Natural Resources (MDNR). Contamination can limit access to safe and reliable supplies. Monitoring of Minnesota's groundwater by state agencies has found that activities on the land have contaminated our more vulnerable, surficial aquifers with nitrate, volatile organic compounds (VOCs), chloride, pesticides, contaminants of emerging concern (CECs), perfluorochemicals (PFCs), and viruses. In addition, naturally occurring contaminants are also found in Minnesota's groundwater in certain geologic settings. These contaminants include arsenic, manganese, and radium.

As identified in Minnesota's Clean Water Roadmap report, nitrate (human-caused) and arsenic (naturally occurring) are two contaminants prevalent in Minnesota's groundwater. Concentrations of these two chemicals sometimes exceed drinking water standards in the state's groundwater.

In recommending strategies and actions to protect groundwater degradation from contaminants, it is important to remember that groundwater and surface waters are part of a single, interconnected hydrological system. So while monitoring, assessment, and protection approaches and techniques may vary between groundwater, lakes, streams, and wetlands, these water resources should not be viewed in isolation from each other.

This Minnesota Groundwater Protection Recommendations Report provides a contaminant-by-contaminant summary of the current status and efforts to prevent and minimize contaminant impacts on groundwater quality, followed by recommendations to improve these efforts so that Minnesotans have safe and reliable sources of drinking water. The report focuses primarily on recommended activities to address human-caused contaminants, followed by continued efforts needed to avoid tapping groundwater that contains naturally occurring contaminants.

The report also recommends actions to help advance our understanding of Minnesota's complex and varied hydrogeology, and groundwater-surface water interactions. The report recommends actions to continue building groundwater protection capability among government, the private sector, and landowners. All Minnesotans have a stake in sustaining healthy groundwater for drinking, for our economy, and for the integrity of natural systems that support life.

Introduction

Minnesota is blessed with abundant water in a variety of interconnected settings: groundwater aquifers, lakes, streams, and wetlands, as shown in the figure below. Groundwater occurs everywhere in Minnesota within water-bearing soil or rock formations called aquifers. These aquifers create a complex matrix of groundwater resources in many areas of the state that may yield either abundant or very limited water supplies. The water quality in these aquifers is influenced both by human activities and natural processes.

Groundwater provides nearly 75% of Minnesotans with their primary source of drinking water and nearly 90% of the water used for agricultural irrigation, as estimated by the MDH and the MDNR. For these reasons alone it is important that we protect, monitor, and report on the quality of this valuable natural resource.

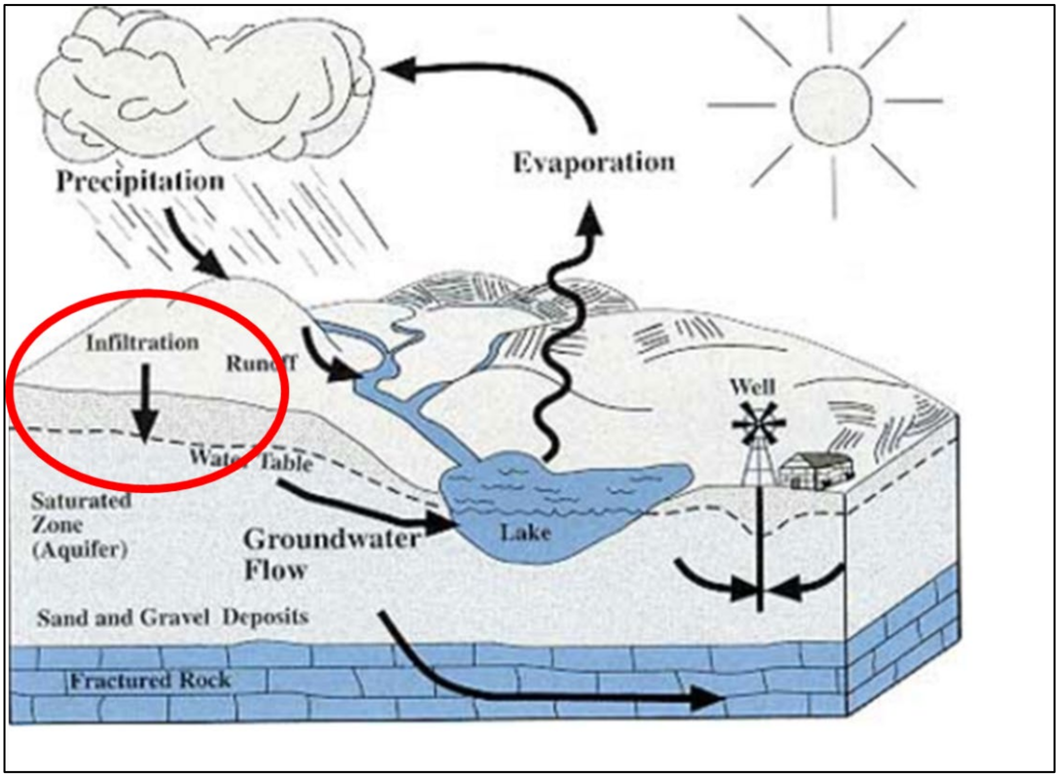

Figure 1. The hydrologic cycle

Groundwater can become contaminated through our land use activities, as illustrated by the arrow in the red oval in the figure above. Efforts to remove or mitigate the contaminated groundwater are challenging and expensive. According to the U. S. Environmental Protection Agency (EPA), it costs about 10 to 30 times more to clean up contaminated drinking-water wells than it does to prevent the contamination. Therefore, protecting drinking-water sources makes sense from two perspectives: public health and economic.

Monitoring of Minnesota's groundwater has identified contamination concerns from agricultural fertilizers and pesticides, urban runoff, manure applications, septic systems, de-icing salt, and stormwater infiltration, primarily in the more vulnerable, surficial aquifers. In addition, a variety of other contaminants have been detected that are associated with specific chemical releases that include: VOCs such as trichloroethylene, petroleum compounds and PFCs. Furthermore, chemicals that are not commonly monitored or regulated are being identified at low concentrations in groundwater, referred to as CECs and include endocrine active chemicals. These contaminants are a result of our land use activities.

In addition, naturally occurring contaminants are also found in Minnesota's groundwater in certain geologic settings. These contaminants are due to geologic materials which dissolve into aquifer waters and include: arsenic, manganese, and radium.

Roles in groundwater monitoring and protection

Three state agencies, the Minnesota Pollution Control Agency (MPCA); Minnesota Department of Agriculture (MDA); and MDH, have important statutory roles and responsibilities in protecting the quality of Minnesota's groundwater as shown in Figure 2. The MPCA and MDA both conduct statewide ambient groundwater quality monitoring for non-agricultural chemicals and agricultural chemicals, respectively. MDH monitors contaminants in public water supplies to evaluate and address human health risk and provides us with the drinking water standards and water consumption advisory levels. In addition to these agencies, the MDNR monitors groundwater quantity conditions across the state through a network of observation wells, and the Metropolitan Council (not included in Figure 2) conducts regional water supply planning using the information collected by the MPCA, MDA, MDH, and MDNR. Details of these monitoring efforts can be found in the 2015 Groundwater Monitoring Status Report, an appendix to the 2015 Minnesota Environmental Quality Board (EQB) Water Policy Report at: https://www.eqb.state.mn.us/beyond-status-quo-2015-eqb-water-policy-report.

These executive branch agencies, plus the Board of Water and Soil Resources, together carefully coordinate groundwater monitoring, protection, and management activities across specialized areas of groundwater expertise, as assigned in various laws, and funded in part by the Clean Water Land and Legacy Amendment.

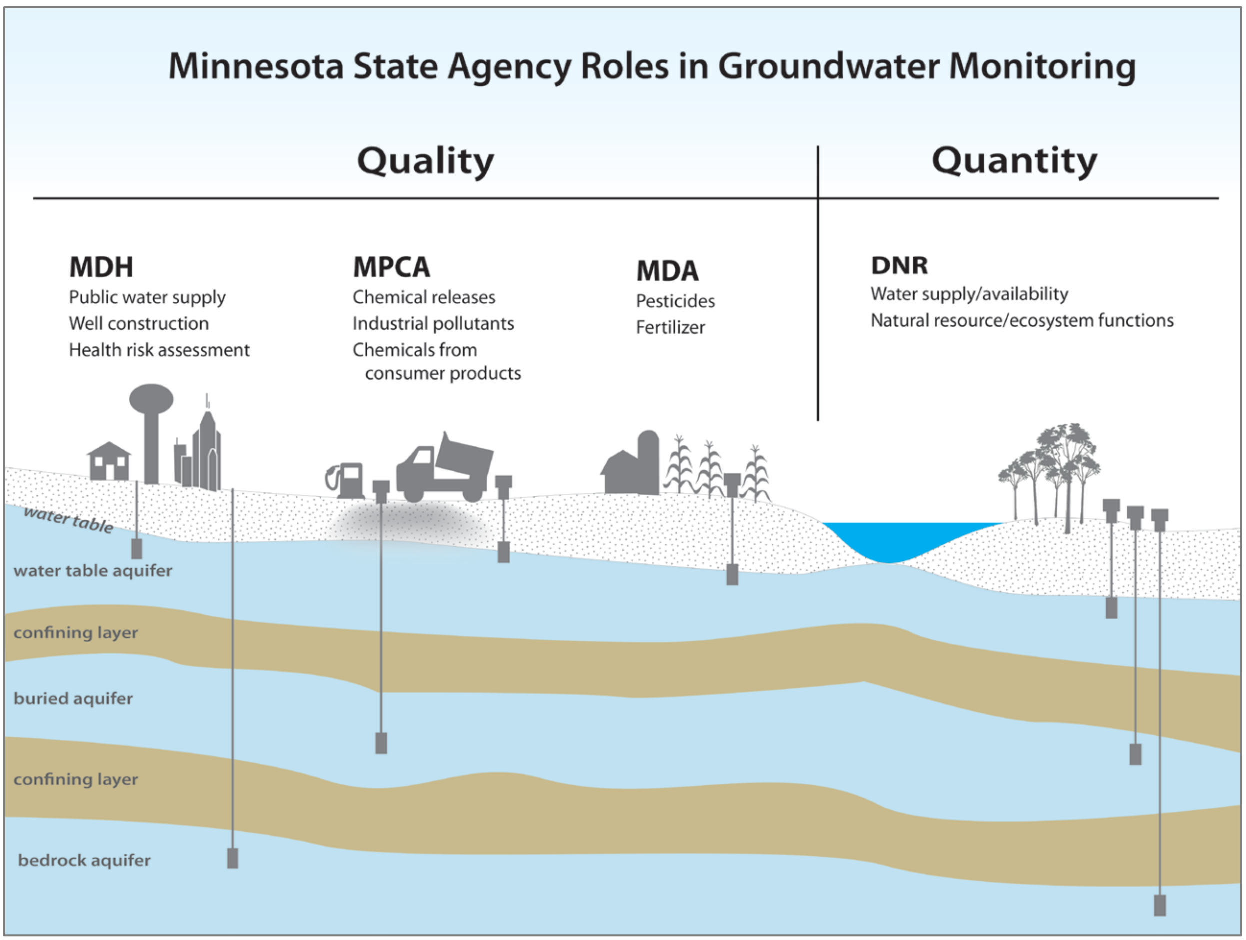

Figure 2. State agency roles in groundwater monitoring [Graphic courtesy of the Minnesota Department of Natural Resources].

Groundwater quality degradation concerns

Degraded groundwater quality can limit access to safe and reliable sources of drinking water for many Minnesotans who rely on groundwater as their primary source of drinking water. When groundwater becomes contaminated, public health concerns arise and significant costs can be incurred to monitor and treat contaminated water supplies. Of additional concern, contaminated groundwater can also contribute to the pollution of surface waters; especially in areas where there is karst geology or shallow sand and gravel aquifers that are closely connected to surface water.

A detailed review of the efforts to minimize and prevent the impacts of contaminants on groundwater quality is presented in the recently prepared Minnesota Environmental Quality Board's (EQB)report, Beyond the Status Quo: 2015 EQB Water Policy Report, found at the weblink: https://www.eqb.state.mn.us/beyond-status-quo-2015-eqb-water-policy-report. Appendix A of this report reviews the efforts of MPCA and MDA programs to control many of these contaminants.

Additional details for groundwater monitoring and contaminant remediation may also be found in MDA and MPCA publications at the following weblinks: http://www.mda.state.mn.us/chemicals/pesticides/maace.aspx, and in the Superfund Legislative Report at: http://www.pca.state.mn.us/index.php/view-document.html?gid=22362.

Strategies and recommendations for preventing groundwater contamination

This report recommends groundwater protection actions on two broad levels. First there are recommendations directed at individual contaminants for which protection efforts are underway in various stages of regulation and prevention. Second, the report recommends actions to help advance our understanding of Minnesota's complex and varied hydrogeology, and actions that continue building both governmental and private sector capability to protect groundwater.

For human-caused contaminants (nitrate, volatile organic compounds, chloride, pesticides, CECs, PFCs, and viruses) pollution prevention activities, remediation programs, permit regulations, monitoring, and numerous best management practices (BMPs) are utilized at both state and local levels to prevent and minimize groundwater contamination.

For naturally occurring contaminants that may be found at or above the drinking water standard (arsenic, manganese and radium), monitoring and identification of the aquifers and conditions where these contaminants occur is providing information which can be used to guide future well drilling, away from these sources of contaminants. Groundwater testing provides us with the information to decide if water treatment or blending is necessary to reduce contaminant concentrations below their health-based drinking water standards.

Nitrate/nitrogen

Description of the problem

In many areas, groundwater contamination from nitrate-nitrogen (nitrate) is a public health concern for those who rely on it for drinking water. Studies of groundwater quality in Minnesota over the last two decades have linked elevated nitrate concentrations to land uses where there are human-caused sources of nitrate in combination with vulnerable geology. The human health-based drinking water standard for nitrate is 10 milligrams per Liter (mg/L), sometimes referred to as 10 parts per million.

Most nitrate which enters groundwater comes from human caused sources such as animal manure, fertilizers used on agricultural crops, failing subsurface sewage treatment systems, fertilizers used at residences and commercially, and nitrous oxides from the combustion of coal and gas. With this array of sources, it is not surprising that nitrate is one of the most common contaminants of groundwater in Minnesota.

Monitoring

The MDA and MPCA have established water quality monitoring-well networks to test the shallower, more vulnerable groundwater in the state. These wells are typically less than 50 feet deep, and provide an early warning of the land use impacts from human activities. Results from this monitoring network frequently show a greater percentage of wells with higher concentrations of nitrate compared to private and public water supply wells, as discussed below.

The highest nitrate concentrations in these wells occur in shallow sand and gravel aquifers, and in the southeast karst area; underlying agricultural parts of the state. Most of the sand and gravel aquifers with nitrate concentrations that exceed the drinking water standard are located in the Central Sand Plains.

The MDA 2014 Water Quality Monitoring Report states "It is common throughout Minnesota agricultural areas to have shallow groundwater exceed the MDH Health Risk Limit (HRL) for nitrate-nitrogen.", and that 59% and 44% of the groundwater samples collected in the Central Sand Plains and east central regions, exceeded the drinking water standard for nitrate.

Private well monitoring networks

Monitoring of private drinking water wells in the southeast karst region of Minnesota found that nitrate exceeded human health standards in 7.6 % to 14.6 % of the wells tested between 2008 and 2012. Private well testing in the Central Sand Plains area of the state by the MDA found that nitrate exceeded human health standards in 4.6 % of the private wells tested.

A U. S. Geological Survey (USGS) study of nitrate in private wells in the glacial aquifer systems of the northern U. S. also found that just under 5% of private wells contained nitrate in excess of the drinking water standard, which is similar to the results cited above for the Central Sand Plains area of Minnesota (Warner & Arnold, 2010) .

The MDA recently started the Township Testing Program to test private wells in areas of the state with the greatest potential nitrate contamination, defined as areas with greater than 20% row crop agriculture and in vulnerable groundwater areas. Preliminary results from initial township testing in 2013-2014 found that 13% of the private wells tested exceeded the drinking water standard for nitrate.

Overall, these percentages of drinking water exceedances may seem relatively low; however, nitrate concentrations can be highly variable over short distances and the USGS notes that "Private wells are commonly located in rural parts of the country where large areas are fertilized. Nitrate is a concern in many of these rural areas because the residents rely on wells in the glacial aquifer system for drinking water and these wells are not routinely monitored for nitrate" (Warner & Arnold, 2010).

Public water supply well monitoring

The MDH reports that a growing number of public water systems in Minnesota are concerned about increasing nitrate levels in their source water and they must manage for nitrate contamination through various treatment options. These include: distributing bottled water to residents, managing land use, taking a well out of service, drilling a new well, connecting to a nearby public water system, blending higher-level nitrate water with lower-level nitrate water, and constructing reverse-osmosis water treatment plants.

Since 2008, the number of public water supply systems requiring nitrate treatment has increased from six to eight, and the number of people served by systems actively treating for nitrate has increased from approximately 15,000 to 50,000 people. Details are found in the web-link to the *MDH, Minnesota Drinking Water Annual Report for 2014,* at the end of the section.

At present, there are 27 community public water supply systems that conduct quarterly monitoring for elevated nitrate in their wells. Most of these are located in the same areas of the state where higher nitrate concentrations have been identified in the ambient and private well monitoring networks mentioned above. Some of the affected cities include: Park Rapids, Verndale, Cold Spring, Clear Lake, Becker, and Atwater, in the Central Sand Plains region; Hastings, Goodhue, Lewiston, Elgin, and Altura (in the southeast region); and Edgerton, Adrian, and the Lincoln-Pipestone Rural Water System (in the southwestern corner of the state).

What is being done

The MPCA and MDA manage a number of different programs that prevent and reduce nitrate impacts and partner with the MDH in source water protection efforts. To prevent water quality degradation MDA, MPCA, and MDH programs use a combination of voluntary and regulatory tools which include: discharge limits, permit requirements, environmental and technical reviews, source water protection, facility inspections, training, technical assistance, compliance and enforcement, guidance documents, fact sheets, and BMPs (some of which are described in the recommendations provided below).

Recommendations

Recommendations to prevent nitrate contamination of groundwater must focus on the major sources of human-caused nitrogen (fertilizer and manure) and the agricultural practices that can minimize the losses of nitrogen from these sources. The Minnesota Nitrogen Fertilizer Management Plan (NFMP) and the Minnesota Nutrient Reduction Strategy provide groundwater protection strategies that can serve as the basis for recommendations and actions to address nitrogen impacts on groundwater, which include the following:

- Promote the implementation of the four agronomic best management practices (BMPs) for nitrogen fertilizer and manure, which account for the right nitrogen rate, application timing, source (nitrogen fertilizer and manure) and placement, focusing on areas of the state where there are vulnerable aquifers and groundwater nitrate impacts. These BMPs are described in the 2015 NFMP and in the link to the nitrogen fertilizer BMPs (provided below). To ensure that nitrogen BMPs in the NFMP are implemented in the most groundwater-impacted areas, the MDA is working on developing a new rule to protect groundwater from nitrogen fertilizer sources, called the Nitrogen Fertilizer Rule. This rule, in combination with the nitrogen BMPs recommended in the NFMP, should be considered one of the main tools to help reduce nitrate contamination of our groundwater resources.
- Promote the use of targeted alternative management tools to reduce nitrogen inputs, which include: increasing the adoption of cover crops, growing perennial crops such as alfalfa, retiring land from production, conservation easement practices, grazing, alternative cropping varieties that require less nitrogen, and other new technologies. Detailed information on these practices can be found in the Minnesota Nutrient Reduction Strategy, NFMP and EQB's, Five-Year Assessment of Water Quality Degradation Trends and Prevention Efforts (cited below).
- Focus on nitrogen reduction efforts within source water protection areas (as administered by the MDH State Wellhead Program [Minn. R. 4720]).
- A Nitrogen Fertilizer Education and Promotion Team (NFEPT) has been convened to assist the MDA with the coordination of prevention activities and programs to promote BMPs and

alternative management tools in areas with vulnerable groundwater resources, such as wellhead protection areas, the Central Sand Plains area, and southeastern Minnesota's karst region.

- The success of the above recommendations is contingent upon the local participation of farmers, citizens, counties, cities, crop consultants, soil and water conservation districts (SWCD), and others. It is recommended that funding be provided for teams of experts to coordinate and implement the above recommendations within specific wellhead protection areas.

Information sources

MPCA, Minnesota Nutrient Reduction Strategy: https://www.pca.state.mn.us/sites/default/files/wq-s1-80.pdf

MPCA, Nitrogen in Minnesota Surface Waters Report: http://www.pca.state.mn.us/index.php/view-document.html?gid=19622

MPCA, Condition of Minnesota's Groundwater Report: http://www.pca.state.mn.us/index.php/view-document.html?gid=19743

MDA, Nitrogen fertilizer BMPs: http://www.mda.state.mn.us/nitrogenbmps

MDA, Nitrogen Fertilizer Rule: http://www.mda.state.mn.us/chemicals/fertilizers/nutrient-mgmt/nitrogenplan/mitigation/wrpr.aspx

MDA Webpage, Characterizing Nitrates in Private Drinking Water Wells:
http://www.mda.state.mn.us/en/protecting/cleanwaterfund/gwdwprotection/characterizingnitrates.aspx

MDA, Nitrogen Fertilizer Education and Promotion Team (NFEPT):
http://www.mda.state.mn.us/en/chemicals/fertilizers/nutrient-mgmt/nitrogenplan/prevention/nfept.aspx

MDA, Minnesota Nitrogen Fertilizer Management Plan (NFMP):
http://www.mda.state.mn.us/chemicals/fertilizers/nutrient-mgmt/nitrogenplan/draftplan.aspx.

MDA, 2014 Water Quality Monitoring Report:
http://www.mda.state.mn.us/chemicals/pesticides/~/media/Files/chemicals/maace/wqm2014rpt.pdfl

MDA, Township Testing Program initial results:
https://www.mda.state.mn.us/protecting/cleanwaterfund/gwdwprotection/~/media/Files/chemicals/nfmp/2015initialtestsumm.pdf

MDH, Nitrates in Drinking Water:
http://www.health.state.mn.us/divs/eh/hazardous/topics/sacnitrate.html

MDH, Minnesota Drinking Water Annual Report for 2014:
http://www.health.state.mn.us/divs/eh/water/com/dwar/report2014.pdf

MDH, Nitrate source water protection:
http://www.health.state.mn.us/divs/eh/water/swp/nitrate/index.html

EQB, Five-Year Assessment of Water Quality Degradation Trends and Prevention Efforts, Appendix A:
https://www.eqb.state.mn.us/beyond-status-quo-2015-eqb-water-policy-report

Volatile organic compounds (VOCs)

Description of the problem

VOCs are toxic chemicals that have contaminated groundwater at many sites, and have adversely-affected drinking water supplies and indoor air throughout the state. The largest contaminated sites are located in the Twin Cities Metropolitan Area (TCMA), but there are numerous small localized areas of groundwater contamination scattered across the state. VOCs are a broad group of organic chemicals that are contained in a variety of products, including fuel oils, gasoline, solvents, cleaners, degreasing agents, paints, inks, dyes, refrigerants, and pesticides. VOCs differ from other organic chemicals in that they easily evaporate into the air at normal temperatures. Recent work in Minnesota also has found that VOCs in the groundwater also can adversely affect the indoor air we breathe as well as our drinking water supplies. This phenomenon is called vapor intrusion, and it occurs when chemicals move from contaminated groundwater through the soil and into the air in the basements or foundations of buildings.

What is being done

Several MPCA programs work to prevent future VOC contamination in the groundwater. Leaking above and underground storage tanks, and improperly managed hazardous waste are well-known historic sources of VOC contamination to the groundwater. The MPCA's Tank Compliance and Assistance Program adopts regulations for how VOCs are stored and conducts inspections to ensure compliance with these regulations. The MPCA's Hazardous Waste, Pollution Prevention, and Small Business Assistance Programs help waste generators properly manage their hazardous waste through compliance with state and federal rules; licensing, education, and outreach activities. In addition, the Minnesota Technical Assistance Program (MnTAP) provides free and confidential technical assistance to businesses managing their hazardous wastes.

The MPCA also has many programs that clean up any VOC contamination that already is in Minnesota's groundwater. By the Governor's executive order, the MPCA is the lead agency to respond to most oil and hazardous substance spills in the state, such as chemical fires, train derailments, pipeline breaks, and tanker truck accidents. The agency's Emergency Response Program has on-call staff that respond to chemical spills 24 hours a day, 365 days a year. One of the nation's leading causes of groundwater pollution is leaks from petroleum storage tanks. The MPCA's Petroleum Remediation Program primarily works with responsible parties to evaluate and clean-up petroleum product spills in both the soil and groundwater.

Chemicals that were improperly disposed or spilled decades ago by long-extinct companies or parties are another cause of VOC contamination at many sites. The MPCA's Superfund Program identifies, investigates, and determines the appropriate cleanup plans for these abandoned or uncontrolled hazardous waste sites. The agency's Site Remediation and Redevelopment Program is conducting a large statewide vapor intrusion assessment. This project will evaluate whether vapor intrusion is a concern at the thousands of sites the agency has assessed for VOC contamination in the groundwater over the past few decades.

Old unlined landfills are yet another source of VOC contamination. To protect the state's groundwater from these sources of contamination, the Legislature established the Closed Landfill Program in 1994. This program properly closes, monitors, and maintains over 100 closed municipal sanitary landfills throughout the state.

MDH also plays a very important role in cleaning up VOC contamination. The agency develops and updates human health guidance for chemicals found in the groundwater. For example, in 2013-2014, MDH lowered the human health guidance for trichloroethylene and 1,1,1,2-tetrachloroethlyene (commonly known as PERC).

Recommendations

- MPCA programs that work to prevent and clean up VOC contamination must continue to receive sufficient funding to perform their current work and respond to several emerging issues, including the lowering of human health limits for VOCs and vapor intrusion.
- To provide clean drinking water and safe indoor air to Minnesotans, it is important to know the locations of current and historic sites contaminated with VOCs. All VOC data related to contaminated sites and general monitoring should reside in an electronic, central data management system; to make the VOC data available for plume mapping, risk assessment and water planning efforts, should funding become available.

Information sources

Information on the MPCA's cleanup programs can be found at:

Closed Landfill Program: https://www.pca.state.mn.us/waste/closed-landfill-program

Emergency Response Program: https://www.pca.state.mn.us/waste/emergency-response

Petroleum Remediation Program: https://www.pca.state.mn.us/waste/petroleum-remediation-program

MDH Human Health Guidance: http://www.health.state.mn.us/divs/eh/risk/guidance/index.html

Superfund Program Biennial Report: https://www.pca.state.mn.us/sites/default/files/lrc-s-1sy15.pdf

Vapor Intrusion: https://www.pca.state.mn.us/waste/vapor-intrusion

Chloride

Description of the problem

Chloride contamination is an emerging groundwater pollution problem that if left unchecked may adversely affect some of Minnesota's drinking water supplies in the future. Chloride is not believed to be very toxic to humans; however, high concentrations give water a salty taste that people dislike and do not want in their tap water. To minimize this taste problem, the EPA set a Secondary Maximum Contaminant Level (SMCL) for chloride of 250 mg/L for public drinking water supplies. SMCLs are not enforced by the EPA; this only is a guideline to assist public drinking water suppliers in managing their systems for aesthetic issues.

Monitoring conducted by the MPCA found that chloride concentrations are increasing in the groundwater in urban areas throughout the state, and the sand and gravel aquifers in the Twin Cities Metro Area (TCMA) generally contain the highest concentrations. The MPCA found that 27% of the wells sampled had concentrations exceeding the SMCL and concentrations as high as 8,900 mg/L were measured. Most of the wells with high chloride concentrations were shallow (less than 50 feet deep) monitoring wells.

Statistical analyses performed by the MPCA also found that chloride concentrations are increasing in a substantial percentage of the wells in its network. Over 30% of the wells analyzed in the 2013 MPCA report had statistically significant increasing chloride trends. These wells were located throughout the state, and concentrations increased by as much as 100 mg/L in a few of them. This analysis is repeated each year by the MPCA, and the 2015 analysis found that chloride concentrations also are increasing in some domestic wells that are at least 200 feet deep.

The major source of chloride to Minnesota's groundwater likely is salt from deicing chemicals. In the TCMA alone, about 349,000 tons of deicing chemicals are applied each year to melt ice from roadways, sidewalks, and parking lots, and the MPCA's monitoring also found that the chemical signature of the chloride measured in the groundwater was consistent with that of a deicing chemical.

Chloride use needs to decrease in order to reverse the high concentrations and increasing trends observed in the groundwater. Unlike many other common groundwater contaminants, chloride often is referred to as a "permanent pollutant" because it will not degrade in the environment. The only way to reduce chloride concentrations in the groundwater is to minimize its use.

What is being done

The MPCA prepared a draft Chloride Management Plan (CMP) that includes the framework to reduce chloride concentrations in both the state's ground and surface waters. The draft CMP contains a variety of BMPs that reduce salt use while maintaining safe conditions for the public. Salt still will continue to be used as the primary deicing chemical used in Minnesota since there currently is no environmentally safe or cost-effective alternative to melt ice. The chloride reduction strategy outlined in the draft plan uses a performance-based approach that does not have specific numerical requirements but focuses on implementing BMPs and tracking trends in chloride concentrations. The primary chloride reduction strategies recommended in the draft CMP include: 1) a shift to using more liquid deicing chemical products rather the granular ones, 2) improved physical snow and ice removal, 3) use of practices that prevent the formation of a bond between snow/ice and the pavement, 4) training for winter maintenance professionals, and 5) education for the public and elected officials.

The MPCA provides voluntary training on the BMPs for snow and ice control. Currently, a level I winter maintenance training on snow and ice control BMPs will be offered through January 2016. The agency would like to offer additional classes but cannot because the classes are funded by a federal grant which ends at this time. The MPCA also would like to offer a level II winter maintenance training course which would provide additional training to the winter maintenance professionals that are experienced with level 1 BMPs, and offer its training courses in alternate formats such as webinars to better accommodate participant schedules, especially the private applicators. Many local units of government and private applicators have had success with these BMPs. For example, the city of Prior Lake was able to reduce its salt use by 42%, even with a 7% increase in the amount of roadways to treat. Similarly, a private applicator in Minneapolis was able to reduce its salt usage by 50% while still providing the same level of safety.

The MPCA also developed a Winter Maintenance Assessment tool (WMAt) that can be used to document current practices, identify areas of improvement, and track progress with implementing BMPs. This is a free, easy-to-use web-based tool which also can help municipalities document chloride reductions as required in their separate storm sewer system permits beginning in 2016. The tool generates reports summarizing current and predicted BMPs sorted into advanced, standard, and remedial practices. It also can predict salt savings based on the industry's current salt savings research.

Feedback from stakeholders in Minnesota indicates that many private applicators over-apply salt due to litigation concerns. The state of New Hampshire has a limited liability law in place to alleviate these concerns (Law RSA 489-C, effective November 1, 2013). This law limits the liability of business owners who contract for snowplowing and deicing with applicators certified through the University of New Hampshire's Green SnowPro program.

The strategy outlined in the draft CMP for the TCMA uses ambient monitoring to demonstrate water quality improvements and compliance with standards after BMPs are put in place. Currently, the MPCA samples the wells in its monitoring network once a year for chloride and this basic monitoring must continue so the agency can track any changes in concentrations. There also are a few monitoring gaps that need to be filled to better inform the MPCA on the true extent of chloride contamination in the groundwater. Once-a-year sampling likely does not capture when chloride concentrations are highest. Limited monitoring conducted by the MPCA indicates that this likely occurs around the spring snowmelt period.

The MPCA is staffed to sample all of its wells during spring snowmelt, but is considering another cost-effective approach to obtain this information. This would involve installing continuously-recording specific conductance sensors in some of the MPCA's ambient groundwater monitoring wells as a surrogate measurement for chloride concentrations. In addition, the agency would like to install more deep wells to its monitoring network to track how far and deep the high chloride concentrations extend into the groundwater system. Currently, the MPCA's well network targets conditions near the water table for quick evaluation of trends in groundwater quality, but this does not yield much information on how concentrations are changing with depth.

Recommendations

- All deicing salt users should adopt the practices outlined in the MPCA's draft TCMA CMP (http://www.pca.state.mn.us/index.php/view-document.html?gid=22754) to protect the state's groundwater from chloride contamination.
- State law should change to limit liability for certified winter maintenance professionals, to enable them to use less salt without fear of litigation. A limited liability law also would encourage more private applicators to attend the voluntary snow and ice control training that is provided by the MPCA because the private applicators do not get paid to attend training and thus have less interest in getting their winter maintenance crews certified.
- A long-term source of funding is needed to train winter maintenance professionals on the various BMPs that can be used to prevent groundwater contamination as well as maintain safe driving and walking conditions during the winter. Long-term funding also would allow the MPCA to expand its training program.
- A continuous source of funding is necessary to keep the web-based WMAt up-to-date.
- MPCA should continue current groundwater monitoring and install some deeper monitoring wells alongside some of its shallow ones to evaluate the depth and extent of chloride migration from shallow aquifers.

Information sources

MPCA's 2013 Groundwater Condition Report

MPCA's draft Chloride Management Plan: https://www.pca.state.mn.us/sites/default/files/wq-iw11-06ff.pdf

New Hampshire Limited Liability Law: http://www.gencourt.state.nh.us/rsa/html/NHTOC/NHTOC-L-489-C.htm.

Pesticides

Description of the problem

Pesticides in drinking water may be harmful to human health, depending on how much is present, the length and frequency of exposure, and the toxicity of the specific pesticide. The MDA collects and analyzes water samples from its pesticide monitoring network in locations throughout the state to determine the identity, concentration, and frequency of detections of pesticides in Minnesota's groundwater resources.

Through monitoring shallow groundwater in agricultural areas, MDA sampling has found that commonly applied pesticides are frequently present in groundwater at detectable concentrations. The greatest number of pesticide detections occur in the more vulnerable groundwater areas of the State, which include the Central Sand Plains, east central, and southeastern monitoring regions.

Initial monitoring efforts by MDA in the mid-1980s found that the most frequently detected pesticides were atrazine and alachlor (both herbicides). In 2014, atrazine or its degradates were detected in approximately 25% of the samples collected; however, none of the atrazine concentrations exceeded drinking water limits.

The most commonly detected pesticide compound in 2014 was metolachlor ESA (a metolachlor degradate). The highest concentration measured for metolachlor or its degradates in 2014 was below the drinking water reference value. In addition, glyphosate, and its degradate AMPA, were analyzed in a small subset of groundwater samples and no detections were found. Overall, of the 37 different pesticides or degradates detected in groundwater across the State in 2014, none exceeded drinking water limits or other available drinking water benchmarks. Additional details related to pesticide detections, concentrations and time-trend analysis can be found in the MDA 2014 Water Quality Monitoring Report (cited below).

Recent research suggests potential concerns about a group of insecticides known as neonicotinoids for possible harm to various life stages of honey bees, native bees, as well as other pollinating insects. This concern led the Legislature to require MDA review neonicotinoid use in Minnesota. The 2014 review, provided in a link below titled "Neonicotinoids Use, Registration and Insect Pollinator Impacts in Minnesota", contains information on neonicotinoid risks, use and sales, mode of action, impacts, chemistry, and benefits.

Currently, MDA analyzes groundwater samples for six neonicotinoid pesticides including: acetamiprid, imidacloprid, thiamethoxam, clothianidin, dinotefuran and thiacloprid. To date, none of these compounds have been detected in urban groundwater samples. Acetamiprid, dinotefuran, and thiacloprid have not been detected in agricultural areas, while clothianidin, imidacloprid, and thiamethoxam have been detected in these areas. All detections have been below applicable groundwater reference values.

What is being done

The MDA is implementing the Pesticide Management Plan (PMP) for the prevention, evaluation and mitigation of pesticides, or their breakdown products, in groundwater and surface waters of the state. The PMP provides the MDA with a framework for outreach and education to agricultural stakeholders.

The PMP established a multi-stakeholder PMP Committee to annually review pesticide water quality data and provide comment to the Commissioner of Agriculture regarding the detection and concentration of pesticides in vulnerable aquifers, as well as the need for BMP development to minimize and prevent pesticide contamination of water resources. The PMP also established a Pesticide BMP Education and Promotion Team made up of state and local pesticide and water quality specialists, along with others interested in developing and delivering consistent messages to pesticide users about BMPs and water quality protection.

In 2004, the MDA developed core BMPs for all agricultural herbicides, as well as separate BMPs specific to the use of the common detection herbicides acetochlor, alachlor, atrazine, metolachlor and metribuzin. The acetochlor BMPs were revised in 2010 due, in part, to stream impairment designations for acetochlor in two southern Minnesota watersheds. One of the ways MDA is evaluating the adoption of BMPs is through biennial surveys, while BMP effectiveness is being evaluated through in-field studies and other methods.

The MDA also conducts special registration reviews of pesticides that might have specific concerns to use in Minnesota, including water quality protection. The scope of these special registration reviews varies depending on the potential education, outreach, and enforcement needs identified by the MDA. The MDA reviews new active ingredients recently approved by the EPA along with currently registered pesticides that have significant new uses or have undergone a major label change. At times, more in-depth reviews are necessary to provide stakeholders and the MDA Commissioner with more information about specific pesticide products and issues. Neonicotinoid insecticides are currently under review.

In the fall of 2014, the MDA began collecting samples for pesticide analysis in private wells where nitrate was detected in previous sampling efforts. The sampling is scheduled to continue through at least the summer of 2017, and the results will be reported on a regular basis. Preliminary data has shown pesticide detections above method reporting limits in 6 of the approximately 1,800 wells sampled in eight counties (Benton, Dakota, Morrison, Olmsted, Sherburne, Stearns, Wadena, and Washington) since September 2014. All detections were below Health Risk Limits.

The MDA collaborated with MDH to sample approximately 100 community supply wells for pesticide analysis in 2010 and 2015. This project tested community supply wells for over 133 pesticide compounds in 2015. The report for this project has yet to be published.

Recommendations

- Continue to implement the steps outlined in the PMP to monitor and evaluate pesticides in groundwater and drinking water supplies across the state, and promote pesticide-specific BMPs to prevent any deleterious effects of pesticides in groundwater.
- Continue program activities that cleanup agricultural chemical contamination sites.

Information sources

2014 Water Quality Monitoring Report:
http://www.mda.state.mn.us/~/media/Files/chemicals/maace/wqm2014rpt.pdf.

Acetochlor Surface Water Quality Impairments:
http://www.mda.state.mn.us/chemicals/pesticides/acetochlor1/acetochlor6.aspx).

Minnesota Pesticide Management Plan:
http://www.mda.state.mn.us/protecting/waterprotection/pmp.aspx.

Neonicotinoid Use, Registration and Insect Pollinator Impacts in Minnesota:
http://www.mda.state.mn.us/chemicals/pesticides/regs/~/media/Files/chemicals/reviews/scopingneonicsr.pdf.

Pesticide Lists: http://www.mda.state.mn.us/chemicals/pesticides/regs/pestprodreg.aspx.

Pesticide Sales and Use: http://www.mda.state.mn.us/chemicals/pesticides/pesticideuse.aspx).

Pesticide Water Quality Reports: http://www.mda.state.mn.us/chemicals/pesticides/maace.aspx.

Contaminants of emerging concern

Description of the problem

CECs are synthetic or naturally-occurring chemicals that have not been commonly monitored or regulated in the environment. The release of CECs into the groundwater is a particular concern because these chemicals may affect human or ecological health. Common classes of CECs include antibiotics, detergents, fire retardants, hormones, personal care products, and pharmaceuticals. These chemicals are not necessarily newly manufactured ones. In some cases, the release of these CECs into the environment has occurred for a long time, but laboratory techniques sensitive enough to measure them at environmentally relevant concentrations only were developed within the last decade.

What is being done

Several investigations have found CECs in Minnesota's groundwater. The majority of this monitoring has been conducted by the MPCA. The initial CEC groundwater monitoring, conducted in the early 2000s by the USGS, focused on wells in proximity to potential sources. In 2009, the MPCA broadened its CEC monitoring by adding CEC sampling to its ambient groundwater monitoring network. This monitoring targets shallow wells to provide an early warning of groundwater contamination, focusing on common urban land use settings. To date, the agency has sampled almost 250 wells in its monitoring network for over 200 different CECs. So far, 35 different chemicals have been detected and the measured concentrations generally have been low. The most detections and highest concentrations generally were found in shallow wells that were affected by the leachate from old, unlined landfills. No concentrations measured to date exceeded any established human health guidance; however, guidance has not yet been established for all of the CECs measured in the groundwater. Starting in 2013, the MPCA began to expand its monitoring to include other potential sources of CECs to the groundwater. From 2013-2015, the MPCA and the USGS sampled wells for CECs that were adjacent to areas where wastewater is discharged, including rapid infiltration basins and large subsurface sewage treatment systems. In 2015, the MPCA, in cooperation with the MDA, sampled 15 wells in agricultural areas for CECs.

The MDH's Drinking Water CEC program fills the need for developing human health guidance on CECs; helping determine whether any measured concentrations of CECs in our drinking water may pose a health risk. To date, about 40 human health guidance or screening values for CECs have been developed by the MDH's CEC Program.

Recommendations

- Continue to track CECs in the groundwater. The MPCA's ongoing CEC monitoring is the main source of information on unregulated contaminants in the groundwater, and this work should continue, to inform the state agencies on the presence of any new chemicals or trends that could harm drinking water.
- MDH should continue to develop human health guidance for these chemicals.
- MPCA should continue efforts to promote the proper disposal of unwanted or expired medications.

Information sources

First USGS CEC Assessment of the Groundwater: http://pubs.er.usgs.gov/publication/sir20045138

MDH CEC Program: http://www.health.state.mn.us/cec

MPCA Guidance on Managing Unwanted Medicines: https://www.pca.state.mn.us/living-green/managing-unwanted-medications

USGS 2014 CEC Report: http://pubs.usgs.gov/sir/2014/5096/pdf/sir2014-5096.pdf.

Perfluorochemicals (PFCs)

Description of the problem

PFCs are a family of synthetic chemicals that have been used for decades to make products that resist heat, oil, stains, grease, and water. The presence of PFC chemicals in the groundwater is problematic because these chemicals bioaccumulate and animal studies found that they adversely affect health. In Minnesota, PFCs are of particular interest because this is one of the few places in the nation where these chemicals are manufactured, plus the legal disposal of wastes generated by fluorochemical manufacturing several decades ago caused the contamination of some of the state's drinking water supplies and fish. In late 2003, the MPCA discovered PFCs in groundwater at and near four dump sites that received 3M waste, in: Oakdale, Woodbury, the 3M manufacturing facility in Cottage Grove, and the Washington County Landfill. Extensive clean-up has occurred at each of these sites.

What is being done

The manufacture of the most bioaccumulative PFCs has been phased out by many companies. Some companies, including 3M, stopped making PFCs with an eight-carbon chemistry over a decade ago. This voluntary phase-out, however, did not completely eliminate PFCs from the environment. There are other manufacturers of PFCs around the world that continue to make products with the eight-carbon PFC chemistry, and the reformulated chemicals still are used in some fire-fighting foams, lubricants, packaging, metal-plating, clothing, and other consumer and industrial products. Some of these chemicals break down into eight-carbon chemicals of concern.

Minnesota's groundwater also has been tested for PFCs. In 2004, the MPCA began sampling monitoring wells at the disposal sites and nearby private wells, and the MDH sampled city wells in Washington County to identify drinking-water supplies with PFCs. To date, most of the drinking water supplies located away from the eastern Twin Cities suburbs that have been tested have no detectable PFCs. Although perfluorobutanoic acid (PFBA) was detected in several wells, the concentrations were below levels of health concerns established by MDH. The MPCA also has tested the groundwater throughout the state for PFCs. This work found that PFBA often is detected in wells that are vulnerable to contamination but below levels of concern.

The MDH, MPCA, and 3M have worked with affected parties to provide safe drinking water by supplying alternative sources of water or assisting with water filtration to remove PFCs. Results over the past several years indicate the areas of groundwater contamination are not expanding and concentrations are not increasing.

Recommendations

- MPCA programs that work to clean up the PFC contamination should continue to receive sufficient funding to perform their work.

- The testing of groundwater throughout Minnesota should continue to evaluate potential exposure to PFCs through drinking water.
- The MDH should continue to develop and refine human health guidance for PFCs in drinking water.

Information sources

MPCA Perfluorochemicals Website: http://www.pca.state.mn.us/index.php/waste/waste-and-cleanup/cleanup/superfund/perfluorochemicals-pfc/perfluorochemicals-pfcs.html.

Perfluorochemicals Waste Site Summaries: https://www.pca.state.mn.us/waste/perfluorochemical-pfc-waste-sites.

Viruses

Description of the problem

Certain viruses have been associated with illnesses in groundwater; however, little is known about the presence of viruses in Minnesota groundwater and what it means for public health. National surveys have shown that approximately 30% of drinking water wells may be contaminated with human pathogenic viruses. Previous studies to examine occurrence of viruses in groundwater and drinking water in Minnesota are limited, and improved detection techniques are now available.

What is being done

The MDH is conducting a study to better understand viruses in drinking water. The objective is to determine how often viruses are found in Minnesota groundwater drinking water sources and manage the risk to public health. The Minnesota Legislature requested the study and funded it through the Clean Water Fund. The MDH will complete the study in May of 2016 and release a final report in 2017. It consists of two components; water monitoring and a community illness study. The monitoring component will occur in two phases. In Phase I MDH will sample randomly selected non-disinfecting groundwater supplies to determine how often viruses are present. In Phase II MDH will sample select sources to evaluate tools for predicting viruses. The community illness study asks participants in study communities keep a diary of symptoms and activities to link illness with the occurrence of viruses in water. More information on both components of the study can be found at the web link noted at the bottom of this section.

Recommendations

- Depending on the findings of the ongoing study noted above, it may be important to take a deeper look at some of factors that seem to correlate with virus occurrence in groundwater. It is too early to speculate what those might be at this time, but it would be helpful if the Minnesota Legislature and Clean Water Council were open to continued support of research in this arena.

Information source

http://www.health.state.mn.us/divs/eh/water/dwp_cwl/virus/index.html.

Arsenic

Description of the problem

Long-term exposure to arsenic from drinking water is a serious and widespread public health concern in Minnesota. Inorganic arsenic is classified as a known human carcinogen by the EPA, and exposure to this chemical can increase the risk of bladder, lung, skin, kidney, nasal passage, liver, and prostate cancer as well as cause nervous system problems, high blood pressure, and diabetes. The groundwater in many parts of Minnesota contains high enough arsenic concentrations to render the water unsafe for drinking. Research by the University of Minnesota found that about 14% of the sampled wells in the State have arsenic concentrations that exceed the EPA's Maximum Contaminant Level (MCL) of 10 ug/L (parts per billion). Wells with exceedances of the arsenic MCL are scattered across Minnesota; however, some parts of the State have a high percentage of wells with water that contains arsenic concentrations in excess of 10 ug/L. West-central and south-central Minnesota are two of these regions. In west-central Minnesota, approximately 50% of the 869 domestic drinking water wells sampled as part of MDH's Minnesota Arsenic Study had arsenic concentrations that exceeded safe levels.

Research has found that most of the arsenic in Minnesota's groundwater occurs naturally and does not result from spills or the improper disposal of chemicals. The State's soils and rocks naturally contain arsenic, and this arsenic can dissolve into groundwater under the right conditions. Research conducted in Minnesota has shown that groundwater with high arsenic concentrations tends to occur in sand and gravel aquifers that are located in a band from the northwestern corner of the state to the Iowa border in south-central Minnesota. All of these areas are covered by sediments that were deposited by an ancient glacier called the Des Moines Lobe. Researchers also have found that high arsenic concentrations also occur within specific zones in the sand and gravel aquifers. Wells where the screen is placed within 10 feet of a clay layer tend to have highest arsenic concentrations.

Many newly-drilled wells in the state still continue to have high arsenic concentrations despite what has been learned from this research. Since 2008, the state of Minnesota has required that water from new water supply wells be tested for arsenic. The data collected from this well testing have shown that 10% of the over 20,000 new wells drilled since this time have unsafe concentrations. For these wells, MDH recommends installing a treatment system or finding an alternate source of drinking water. Well drillers also report that arsenic concentrations can be drastically different from nearly identical wells installed on adjoining properties. In one instance, a driller reported that the arsenic concentration from one well they installed was an unsafe 12 ug/L, while a nearly identical well on the property next door had a safe concentration of 2 ug/L.

What is being done

The MDH currently is conducting a three-year study in cooperation with the USGS to determine whether the water sampling techniques used by the various well drillers influence the arsenic concentration measured in private wells. In this study, wells will be sampled several times after installation to see whether the groundwater chemistry changes due to the well construction process. The results from this study will be used to provide guidance to well contractors to reduce arsenic risks associated with drinking well water.

Recommendations

- State and local governments should continue to encourage Minnesotans to test any drinking water obtained from a private well at least once for arsenic. Groundwater contaminated with arsenic has no taste, odor, or color, and laboratory testing is the only way to know if a well contains this chemical.

- MDH's efforts to provide guidance to well drillers to minimize arsenic contamination in water supply wells should continue.
- MDH should continue to provide information on: 1) laboratories that private citizens can use to test water samples for arsenic and 2) water treatment systems that remove arsenic from water.

Information sources

MDH Arsenic Facts: https://apps.health.state.mn.us/mndata/arsenic_wells

MDH Arsenic Study: http://www.health.state.mn.us/divs/eh/hazardous/topics/arsenicstudy.pdf

MDH Lab Accreditation Program:
https://apps.health.state.mn.us/eldo/public/accreditedlabs/labsearch.seam

Radium

Description of the problem

Radium is a naturally-occurring radioactive metal produced by decay of geologically abundant uranium or thorium. Studies of radium in groundwater across many parts of North America and within Minnesota confirm that southern Minnesota is within a zone where radium is present at high levels. Public water systems monitor radium because ingesting it above the MCL of 5.0 picocuries per liter (pCi/L) may present increased cancer risk to humans (bone and blood cancers). The presence of radium in source water above the MCL adds expense to public water systems because of the need for treatment or blending. The health and economic difficulties that radium causes can be reduced by understanding factors that control its occurrence.

What is being done

The MDH investigated patterns of radium occurrence in two Cambrian sandstone drinking water aquifers (Mt. Simon and Jordan) beneath southern Minnesota to guide future well-drilling efforts away from radium-producing aquifers and to identify areas where treatment may be required to meet federal drinking water standards. The known radium distribution in several Minnesota aquifers is:

1. **Quaternary Aquifer.** Few available data points indicate a pattern of generally low radium, below the MCL.
2. **Prairie du Chien-Jordan Aquifer System.** Wells that exceed the radium MCL are located in Hennepin County, southern Ramsey County, and in a belt extending southward through Rice and northern Steele Counties.
3. **Tunnel City-Wonewoc Aquifer System.** Due to data scarcity, radium is unmapped. Few available data indicate radium is generally below the MCL.
4. **Mt. Simon Aquifer.** Radium generally approaches or exceeds the MCL, sometimes by a great margin.

Recommendation

- Additional assessment of the spatial distribution of radium in groundwater, to help identify people most at risk of exposure to radium in drinking water. The following aquifers are known to contain radium, but are incompletely assessed: Quaternary sand aquifers (statewide); St. Peter Aquifer (southeastern Minnesota); Tunnel City-Wonewoc Aquifer; and Sioux Quartzite Aquifer (southwestern Minnesota).
- Where the Mt. Simon Aquifer is used as a drinking water source, treatment for radium is recommended.

Information sources

http://www.health.state.mn.us/divs/eh/water/swp/radium/index.html.

http://www.health.state.mn.us/divs/eh/water/swp/radium/2010_radium.pdf.

Manganese

Description of the problem

Although manganese is essential for body functions, certain neurological health effects are positively correlated with drinking water manganese concentrations above 100 ug/L. Infants relying on powdered formula mixed with drinking water containing high levels of manganese are at highest risk. Naturally-occurring manganese concentrations in Minnesota groundwater vary by location and aquifer, commonly exceeding 1,000 ug/L in southwestern Minnesota while rarely exceeding 50 ug/L in southeastern Minnesota.

What is being done

The MDH developed tiered health risk guidance for manganese in drinking water: 300 ug/L for adults and children one year of age or older and 100 ug/L for infants. Manganese levels in public and private water supplies are not currently regulated and not required to be monitored. Potential manganese treatment methods include: carbon filtration; reverse osmosis; cation exchange or water softening; adsorption; oxidation; and filtration.

Recommendations

- Further study of neurological effects of exposure in infants and children exposed to low levels of manganese, and a comparison of the effects of drinking water versus dietary exposure.
- Establish correlation between ambient groundwater manganese concentrations and tap water manganese concentrations to determine typical exposure concentrations.
- Additional assessment of the spatial distribution of manganese in groundwater, to help identify people most at risk of exposure to manganese in drinking water.
- Evaluation of the effectiveness of manganese removal by water softeners and readily available pitcher or faucet filters.
- Target communication to private well owners about risks related to manganese in areas of the state with known elevated manganese levels.

Information source

Manganese in Minnesota's Ground waters (MDH was a major contributor):
http://www.mgwa.org/documents/whitepapers/01_manganese/Manganese_in_Minnesotas_Groundwaters.pdf.

Other key recommendations for groundwater protection

Mapping and modeling Minnesota's groundwater resources

Description of the problem

Governments, industries and individuals need access to accurate scientific information on Minnesota's groundwater resources to make informed decisions to protect groundwater and drinking water supplies.

What is being done

The Minnesota Geological Survey (MGS) and the MDNR are partnering in the County Geologic Atlas Program to develop maps and reports of the geology and groundwater resources of Minnesota counties. Documents include maps and reports of geology, groundwater, pollution sensitivity, and some special studies (e.g., the distribution of sand and gravel deposits, sinkholes, or other features of interest). As of 2015, 22 counties have been fully mapped, another 11 have completed geology maps, and 13 more are in progress or being updated. Several counties are updating their atlases to reflect new information from well-drilling logs.

County Geologic Atlases are used by governments in long-range planning efforts to protect and preserve groundwater, provide information for permitting, for source water protection and well sealing programs, for short-term emergency response to contaminant releases, and by businesses and citizens.

The MDNR is also consolidating maps of bedrock pollution sensitivity, near-surface pollution sensitivity, and water table information into state-wide coverages for easier use on groundwater issues that span county borders.

Additional tools are becoming available to predict groundwater recharge rates, through partnerships with the USGS. Groundwater modeling continues to advance, which helps groundwater managers and users understand how groundwater resources are affected by pumping in wellhead protection areas, near contaminated groundwater sites, and in irrigation settings.

A groundwater model for the TCMA (Metro Model 3) is currently being used to help counties and municipalities plan their current and future water use needs. In addition, an interagency groundwater modeling team has been developed to coordinate state agency efforts related to groundwater modeling and data evaluation.

Recommendations

- Continue to invest in the County Geologic Atlas program and groundwater modeling capabilities, so the best information on groundwater resources is available to water managers.
- Continue to develop, maintain and sample groundwater monitoring networks at MPCA, MDA and MDNR to assess conditions and trends, and to provide vital data for building predictive models for Minnesota.

Information sources

MDNR County Geologic Atlas Program:
http://www.dnr.state.mn.us/waters/groundwater_section/mapping/index.html.

Twin Cities Metropolitan Area Groundwater Flow Model:
http://metrocouncil.org/METC/files/59/595b5c07-58f9-40b7-9d82-0475f8279f98.pdf.

Understanding groundwater-surface water interactions

Description of the problem

Groundwater and surface water have typically been dealt with as separate water resources; however, in many hydrologic settings they are interconnected. Hydrologists have identified more and more examples of overuse or contamination of groundwater which has affected surface water resources. The areas of the state most vulnerable to these occurrences are found in the sand plain aquifers of central Minnesota, the fractured/solution-weathered karst bedrock of southeastern Minnesota, and in the altered farmland hydrology of irrigation and tiling. In these settings, contaminants from groundwater or surface water may be interchanged and affect the water quality of either water resource.

Little Rock Creek, a designated trout stream near Rice in central Minnesota, is one example. The stream is listed as impaired for lack of cold water fish expected to be there. A Clean Water Act-required study to identify the cause and possible fixes looked at 20 years of precipitation, groundwater level data, and increased groundwater pumping for irrigation between 1990 and 2009 using computer-assisted groundwater modeling. The study determined that increased irrigation pumping intercepts groundwater flow that normally would recharge the creek, reducing the volume of fresh, cool groundwater needed to support trout.

An extensive statewide nitrogen study completed in 2013 determined that nitrate-laden groundwater intercepted by field drain tile was conveying 37% of all nitrate discharged to Minnesota surface waters. Nitrate in groundwater discharging to surface water also is flagged as the driver of impairments in the Lake Pepin watershed restoration plan.

What is being done

State agencies and local authorities are recognizing that groundwater—surface water connections are important factors in protecting both surface and groundwater from contaminants.

The MDNR is addressing groundwater on several fronts with implications for surface and groundwater quality. The MDNR has established three initial GWMAs that are exhibiting groundwater and surface water problems attributed in part to over-pumping beyond sustainable recharge rates. These are the North and East Metro (including White Bear Lake) GWMA, the Straight River GWMA, and the Bonanza Valley GWMA. Other GWMAs may be added in the future.

The MPCA is now including groundwater review chapters in Watershed Reports produced under the 10-year intensive watershed monitoring program. An example is the Nemadji River Watershed Monitoring and Assessment Report in the link below.

The MDNR is also finalizing a report to the Legislature that includes recommendations for managing groundwater withdrawal aimed at long-term aquifer sustainability and preventing harm to surface water ecosystems. The MDNR's recommendations include some additional definitions, such as negative impact, ecosystem harm, and sustainable diversion limits, and its suggested approaches for setting protected flows and protection elevations to avoid harm. The MDNR's report also describes analytical tools that can effectively be used in Minnesota for this kind of work, and will suggest some broader revisions to statutes that would clarify the relationship of groundwater and surface water such that authorized appropriations meet the same criteria, regardless of source.

The MDNR and MPCA also are collaborating on the MDNR's Sentinel Lakes Program, with MPCA providing additional groundwater quality, temperature and elevation data from wells installed near designated Sentinel Lakes. This will help the agencies evaluate groundwater and lake quality changes that may result from increased irrigation pumping. Details can be found at the MDNR's Sentinel Lakes web-link provided below.

The MDH must also consider the impacts of surface waters which recharge groundwater being used for drinking water supplies within wellhead protection areas. Surface water contribution areas are delineated for nearly 20% of the wellhead protection areas statewide.

Recommendations

- Support continued advancement of groundwater–surface water interaction modeling capacity in state agencies, in partnership with the Minnesota Geological Survey, USGS, universities, and professional associations such as the Minnesota Ground Water Association. Encourage training of groundwater modeling professionals in colleges and universities.
- Recognize that groundwater contaminants have consequences both in underground waters and surface waters. Avoid compartmentalizing groundwater as separate from surface water. Incorporate groundwater data and predictive tools into surface water improvement efforts, and vice-versa when the opportunity exists.
- Continue and support the MDNR's growing efforts to manage groundwater withdrawals for sustainable supplies, groundwater quality, and surface water quality, including healthy aquatic life.
- Continue work on selected projects in areas with increasing groundwater withdrawals, including the Sentinel Lakes project and GWMAs, to monitor the effect of the withdrawals on groundwater quality and surface water quality.
- Continue inter-agency projects that are investigating the impact of irrigation pumping on vulnerable aquifers and surface waters, including the investigation of the Pinelands area northwest of Brainerd.
- Support enhanced monitoring efforts that help to better identify surface water connections to drinking water aquifers within Wellhead Protection Areas.
- Continue the coordinated state effort to integrate data management as led by the interagency Clean Water Fund team.

MDNR Groundwater Management Areas: http://www.dnr.state.mn.us/gwmp/areas.html.

MPCA 2013 Nitrogen Study: http://www.pca.state.mn.us/index.php/view-document.html?gid=19622.

Lake Pepin WRAPS: https://www.pca.state.mn.us/sites/default/files/wq-iw9-15n.pdf.

Little Rock Creek Watershed TMDL: https://www.pca.state.mn.us/sites/default/files/wq-iw8-09b.pdf.

MDNR Groundwater Thresholds Project: http://www.dnr.state.mn.us/gwmp/gw_thresholds/index.html.

Nemadji River Watershed Monitoring and Assessment Report: https://www.pca.state.mn.us/sites/default/files/wq-ws3-04010301b.pdf.

MDNR's Sentinel Lakes Weblink: http://www.dnr.state.mn.us/fisheries/slice/sentinel.html.

Groundwater planning, management, protection, and restoration

Description of the problem

Groundwater contamination is primarily the result of human activity on the land. The way we use our land is a key driver affecting groundwater quality and quantity. Appropriate land use practices by government, industry, agriculture, and property owners are central to having sustainable and drinkable groundwater resources for current and future Minnesotans.

When contaminants from old dumps and leaking tanks were detected in drinking water supplies in the late 1970s and early 1980s, Minnesota and the federal government launched extensive efforts to clean up the sources of contamination. Other laws followed, including the Minnesota Groundwater Protection Act in 1989, which established many important preventive requirements and assigned responsibilities to agencies with the necessary expertise. Some of these include groundwater monitoring, BMPs, health risk limits, protection of sensitive areas, and managing polluted groundwater, all with the goal of maintaining groundwater in its natural condition, free from degradation by human activities.

State law grants authority for adopting land use planning and controls to local government (i.e., counties, cities, and townships). While most local units of government exercise their authority to adopt local controls, the degree to which comprehensive planning considers groundwater and drinking water as a priority varies throughout the state, and the related authorities and tools available to local governmental units may be underutilized.

What's being done

The MDH has established wellhead protection areas and drinking water supply management areas to help protect the state's drinking water supplies. Details may be found through the link to the MDH Source Water Protection website, provided below.

A few county governments within the TCMA are revising groundwater management plans to account for population growth and increasing demand for available water, as are municipalities that have experienced contamination and shortages. The Metropolitan Council finalized a regional Master Water Supply Plan to assist communities with proactive, cost effective long term planning to ensure plentiful, safe, and affordable water. A water supply plan is required for all communities within the TCMA with a municipal water supply system (Minn. Stat., Sec. 103G.291). A link to the Plan is provided in the Information sources section below.

Furthermore, the Metropolitan Council is working on several water supply studies and projects, that include: 1) the University of Minnesota's Minnesota Technical Assistance Program to reduce industrial water use in the TCMA, 2) the North and east Metro potential for aquifer recharge and stormwater reuse, and several projects which evaluate groundwater resources within the TCMA. Details of these projects are provided in the link below.

The MDNR, for the Minnesota Association of SWCD, developed groundwater workshops held across the state in 2015, with assistance from state agency groundwater experts. It included a review of the State Geologic Atlas, groundwater/surface water interaction, pollution sensitivity, irrigation management, and the growing challenge of nitrate in groundwater. Evaluations of pre- and post-workshop knowledge and confidence among participants showed statistically significant improvement, and more workshops are anticipated in 2016. Details can be found in link below to the report "Groundwater Management: Capacity Assessment at the Local Level".

The University of Minnesota is conducting research and promoting increased use of vegetative cover and cover crops on agricultural lands to address environmental and agricultural concerns. Cover crops can increase nutrient and water holding capacity, and reduce soil erosion; all of which have the potential for environmental benefits in vulnerable groundwater settings. Additional details on these efforts can be found in the link below.

A new state and local groundwater protection effort began in 2015, called Groundwater Restoration and Protection Strategies (GRAPS), which aims to provide groundwater/drinking water information and management strategies on a watershed scale for incorporation into local water management plans. By considering ground and surface water together where practical, GRAPS will complement watershed restoration and protection strategies underway for surface waters with an aim to maximize available resources, improve efficiency, increase collaboration, and develop actions that benefit both ground and surface waters.

Recommendations

- Increase funding to support groundwater protection strategies at a local level. As legislative and media attention continue to focus on the state's water resources, local implementers will be expected to do more to protect key resources, like source water protection areas. Additional technical assistance and outreach is needed for local decision makers to fully utilize their authorities and tools in land use planning to help target and protect local groundwater and drinking water resources, and to encourage local landowners to adopt best practices.
- Continue to support the MDNR and SWCDs with groundwater workshops for local officials to continue building knowledge and capacity for groundwater protection in local land-use decisions.
- Support economically viable land-use practices that don't degrade groundwater quality.
- Support pre-development evaluation of the environmental impacts of large-scale forest land conversions to intensive crop and animal agriculture. Consider prohibitions and other protective restrictions on conversions to row-crop agriculture in forest areas vulnerable to contamination.
- MPCA should continue to develop and refine its watershed-specific groundwater information reports that are included in Watershed Monitoring Reports for each year's targeted watersheds, refine existing reports as new information becomes available, and make them easily accessible to other agencies and the public as stand-alone documents.
- Continue the GRAPS pilots with local authorities and stakeholders in two watersheds and evaluate effectiveness. Refine and improve the process, and look for action that benefits both groundwater and surface waters in these watersheds.
- The Interagency Groundwater and Drinking Water Team should continue its coordination and communication on groundwater issues in the executive branch agencies with specialized expertise in groundwater resources. Drinking water protection strategies should be a priority of this effort.
- Continue funding of University of Minnesota efforts to develop economically viable alternative crops and cover crops.
- Executive branch agencies should continue forward-looking collaborative work on groundwater stressors and solution strategies, including:
    - the effects of climate change on groundwater quality and quantity
    - climate change as a driver of long-term land-use changes, such as forest conversions to croplands and feedlots in areas with vulnerable aquifers and watersheds
    - water conservation, supply infrastructure and energy connections
    - re-use and re-infiltration of treated wastewater
    - Ongoing interagency coordination and coordination between Clean Water Act programs/activities and Safe Drinking Water Act programs/activities

Information sources

MDH Source Water Protection website: http://www.health.state.mn.us/divs/eh/water/swp/index.htm.

Groundwater Management: Capacity Assessment at the Local Level: http://files.dnr.state.mn.us/waters/groundwater_section/gw-management_report_122315.pdf.

Twin Cities Metropolitan Area Master Water Supply Plan: http://www.metrocouncil.org/Wastewater-Water/Publications-And-Resources/WATER-SUPPLY-PLANNING/MASTER-WATER-SUPPLY-PLAN-2015/Master-Water-Supply-Plan,-Chapters-1-8.aspx.

Metropolitan Council Studies, Projects & Workgroups

University of Minnesota, Forever Green Initiative: https://www.cfans.umn.edu/about/solutions/forever-green.