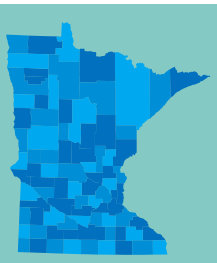
Chloride reduction

July 2024

Smart Salting Community Leaders Handbook

A Community leader's guide to the effects of chloride on the environment and infrastructure, actions steps, and policies that can help reduce salt pollution in the communities.

MINNESOTA POLLUTION CONTROL AGENCY



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Contents

An overview of this resource

Along with the Smart Salting for Community Leaders workshop, this handbook is divided into four main parts: first, it offers an overview of the problem of chloride pollution in Minnesota. Second, it describes possible solutions to this problem, followed by actionable steps community leaders can take and finally, a pledge for taking action.

Why community leaders? It's important to recognize that community leaders are from a diverse array of backgrounds and roles. No matter your role in the community, this handbook is meant to highlight how you can play an important part in reducing chloride pollution in your community.

As you review this resource, we invite you to reflect on your personal motivations for your chloride reduction work. Are you moved by a desire to serve your community, protect natural resources for future generations, or enact responsible change through budget and policy? Perhaps you have a different personal connection to this issue. All these motivations are relevant in the context of chloride reduction.

Defining the problem

Before addressing Minnesota's chloride issues, we must deepen our understanding of the problem. To do this, we will first review the basics of chloride and how it functions. We will examine the main sources of chloride in Minnesota, namely road maintenance, water softening activities, and fertilizers. Next, we will discover tools for determining the leading sources of chloride in one's community. We will then look at chloride's negative impacts on the environment, infrastructure, and the economy.

A closer look at chloride

Minnesota has a growing salty water problem that threatens its freshwater fish and insects. Chloride concentrations are rising across the state of Minnesota, a troubling development given chloride's impact: **it takes only one teaspoon of salt to permanently pollute five gallons of *water.*** Once in water, there is no feasible way to remove chloride and it is toxic to the fish, insects and plants living in our lakes, streams, and wetlands. Despite these challenges, community leaders can take meaningful action to reduce the impact of salt in their communities.

Salt vs. Chloride—which term works best?

When referring to salt in this handbook, we are referencing chemical compounds that contain a chloride ion. These compounds include

- sodium chloride (NaCl or rock salt)
- calcium chloride ($CaCl_2$)
- magnesium chloride ($MgCl_2$)
- potassium chloride (KCl or potash)

"Salt" and "chloride" are *often used interchangeably* when referring to this type of pollution.

From a chemistry viewpoint, chloride differs from other pollutants in that it is already in its ionic form. When chloride compounds are in water, they dissolve because the ions bond with polar water molecules, rather than with each other. Chloride has a strong affinity with water—once it is in water, the only way to separate the two is through reverse osmosis, which is an extremely costly and labor-intensive process. There is no natural way to break down chloride in the environment. For this reason, we call chloride a permanent pollutant.

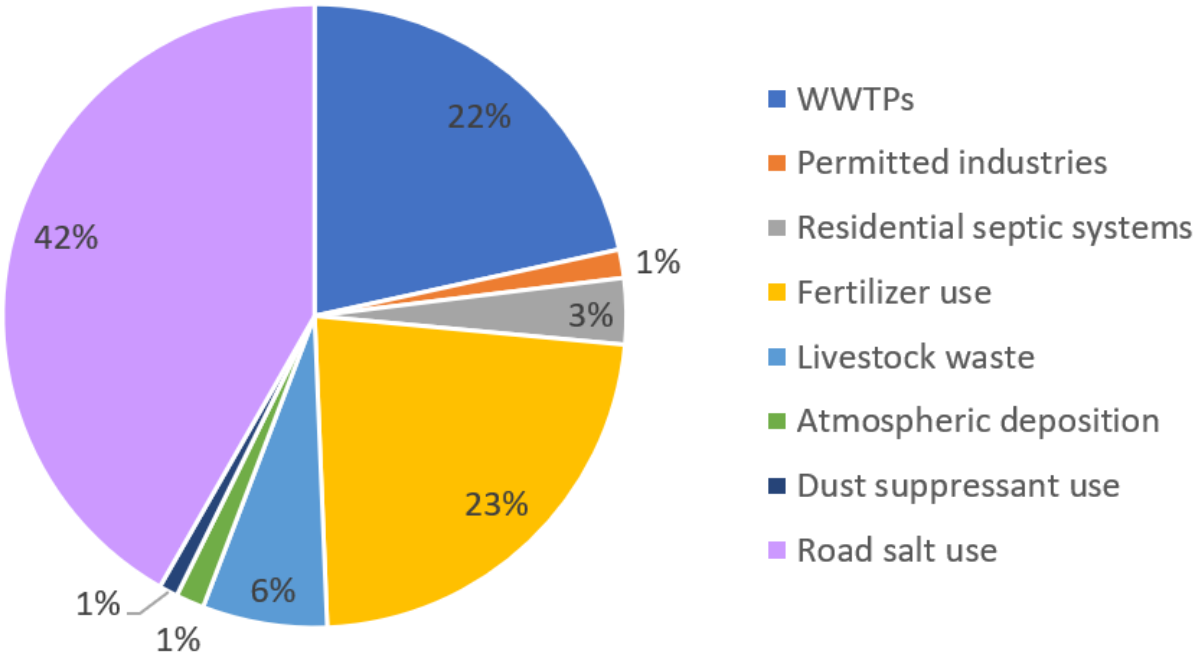
Sources of chloride in Minnesota

Chloride pollution in Minnesota's waters comes from three main sources:

- **Road maintenance**, which includes de-icing salt applied to roads, parking lots, and sidewalks, as well as dust suppressants.
- **Water softening activities**, whether from home water softeners or centralized systems.
- **Fertilizers**, whether applied to agricultural land or turf.

Currently, Minnesota's largest sources of chloride pollution are de-icing salts and water softener discharges to municipal wastewater treatment plants (WWTPs). These sources have already posed visible challenges, particularly in more populated areas.

Figure 1: Fractions of annual chloride contributions from major point and nonpoint sources for State of Minnesota (Overbo et al. 2019).



Road maintenance

De-icing salt

De-icing salt is the primary source of chloride in Minnesota. We use chloride-containing chemical compounds such as de-icing salts in winter maintenance because chloride lowers the freezing point of water. This melts pre-existing ice, and it can prevent the initial formation of ice. Sources of chloride in de-icing salts include roads, parking lots, driveways, sidewalks, and runoff from improperly stored de-icing salt. Each year in Minnesota, an estimated 403,600 tons of de-icing salt are applied to roads, parking lots, and sidewalks. More than 70 percent of that salt then mixes with stormwater and ultimately ends up in our lakes, rivers, and streams as well as our groundwater.

Dust suppressants

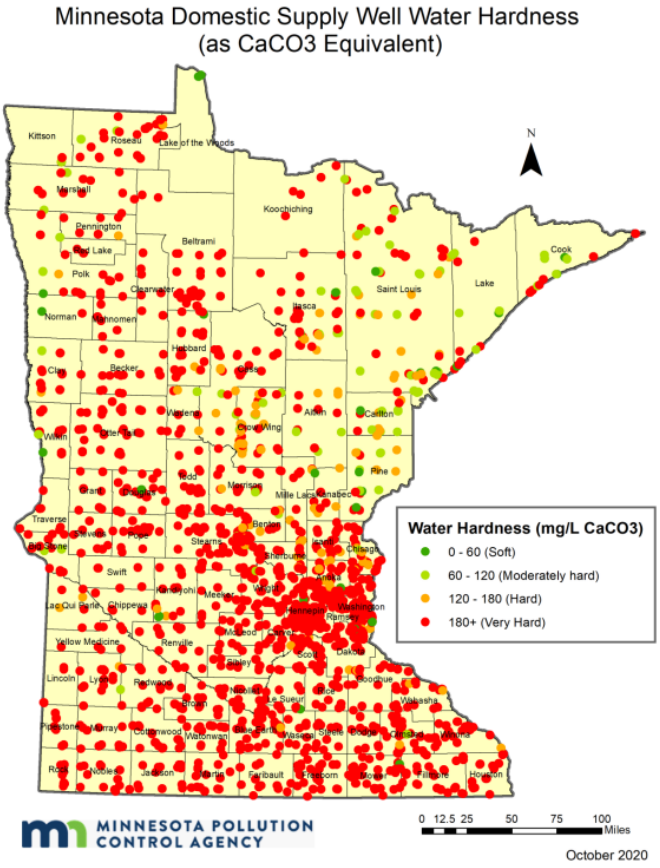
Dust suppressants are commonly applied to gravel roads one to two times during the summer months. These products, typically magnesium chloride or calcium chloride, play an important role in limiting exposure to air pollution. However, they also contain a high concentration of chloride. The fraction of chloride that washes off roadway surfaces after dust suppressant application can vary within the range of 20% to 70%. One study of 206 Colorado streams measured chloride levels at sites upstream and downstream of roads that received magnesium chloride as a dust suppressant treatment. Half of the streams measured had significantly higher downstream concentrations of chloride than upstream.

Water softening

The majority of Minnesota has hard to very hard groundwater, meaning it contains a high amount of minerals such as calcium and magnesium. Roughly 75% of Minnesotans rely on groundwater for drinking. With the high amount of minerals found in our drinking water, softening that water is often a preference because it removes the minerals that can build up on the insides of pipes, fixtures, and hot water heaters. Soft water may also lengthen the life of some appliances. For many Minnesotans, soft water is an expectation. Many people have in-home water softening equipment or receive water from a utility that uses centralized water softening methods to reduce the hardness of their water.

Chloride is a waste product of the water softening process. From a water softening unit, chloride is discharged into a septic system or municipal waste stream, which goes to a wastewater treatment plant. Chloride cannot be removed by typical treatment processes at a municipal wastewater treatment plant, so it enters the environment from both septic systems and wastewater treatment plants across the state.

Figure 2: Hardness values of drinking water supply wells in Minnesota.



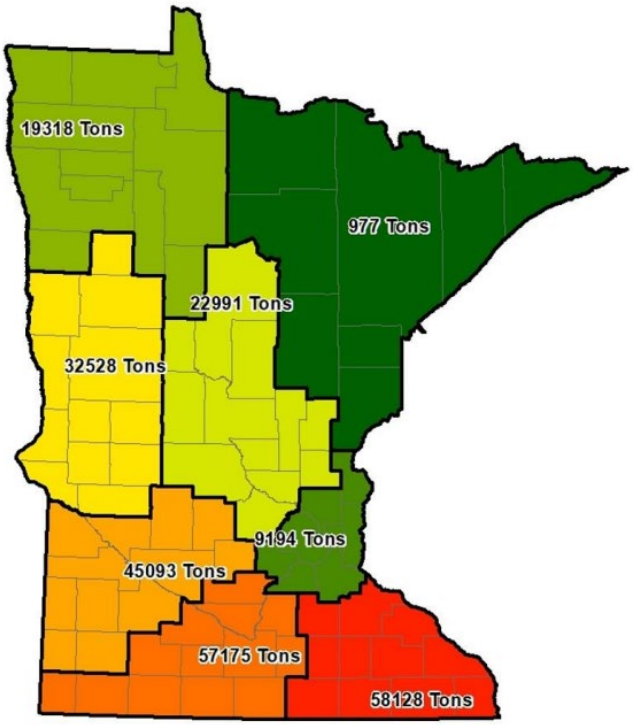
In a 2019 report, researchers at the University of Minnesota estimated that roughly 65% of all chloride that passes through wastewater treatment plants, or 136 thousand tons of chloride annually, comes from residential or commercial water softening processes. Depending on the community, this amount may be even higher.

Fertilizers

Chloride also appears as an ingredient in fertilizers for agriculture, ornamental plants and turfgrass, often in tandem with potassium. While potassium is naturally found in most soils, it is not always readily soluble for plants. To address this, potassium is often supplemented using a fertilizer. Potash (KCL) is the most commonly used fertilizer containing chloride. It is estimated that between 220,000 and 260,000 tons of chloride are applied to croplands per year across Minnesota as a component of certain fertilizers. Manure application also contributes to chloride pollution in Minnesota. Once these substances are applied to cropland, chlorides are transported to lakes and streams through surface runoff, as well as infiltration or seeping into shallow groundwater aquifers.

Although chloride-containing fertilizers for turfgrass and ornamental plants contribute a low portion of chloride in relation to Minnesota's other sources, these products are often used at high rates in developed areas that may already be at high risk of chloride pollution from de-icing activities. Similar to agricultural fertilizers, these substances are carried by rain directly to local lakes or streams. This is because our storm sewers drain to our waterbodies, not wastewater treatment plants. Thus, the substances applied on land can have a major impact on our waters.

Figure 3: Annual chloride (tons) estimated from potash (KCl) sales by district (Aicam 2020)



Chloride in your community

Chloride from winter de-icing activities may be the primary source of chloride in the state, but it is important to identify the primary source of chloride in your community.

The MPCA has created an online Smart Salting Tool to help organizations evaluate sources of chloride in their communities. Organizations can see and modify estimations of the amount of chloride from different sources in their community, including winter maintenance, dust suppressants, water softening, and fertilizers. The data can be updated if more exact measurements from these sources are available. The tool shares information about these sources as well as best management practices. It also allows for the creation of an action plan with detailed data on the key sources in one's community, as well as action steps and resources for reducing chloride from the identified sources.

Impacts of chloride pollution in Minnesota

Environment

Chloride is toxic to fish, plants, and insects that live in our lakes, streams, and wetlands, even at the relatively low concentration of 230 milligrams per liter (mg/L). That equates to 1 teaspoon of salt in 5 gallons of water. In Minnesota, we have a standard in place for chloride concentrations deemed too high for our freshwater fish and insects. That standard for us, which is also used by the United States Environmental Protection Agency (EPA), is 230 mg/L. When chloride exceeds this level, it has damaging effects on freshwater fish, insects, and even some plant species that are important to our ecosystems.

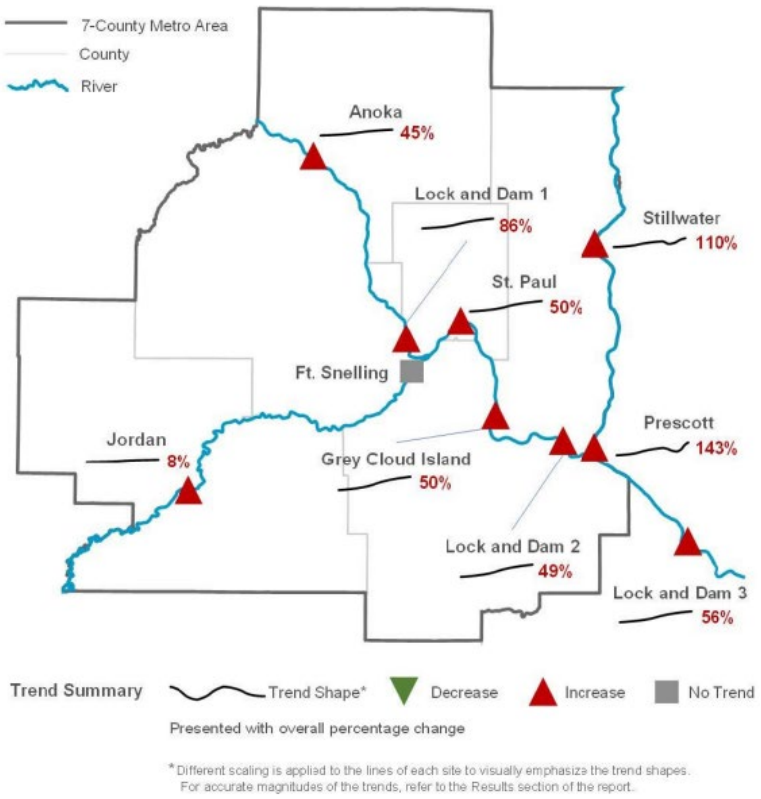
Amphibians exposed to de-icing salt are at risk of reduced growth, abnormalities, and lower survival rates—the permeable structure of their eggs puts them at particular risk of harm. Aquatic insects have been shown to experience developmental delays, physiological changes, altered food webs, and changes in predation pressures due to salt exposure. Immune response can also be compromised. Fish communities can experience reduced egg survival rates and stressed embryo development. Species native to Minnesota are particularly sensitive to chloride, which can in turn have a devastating impact on the ecosystems beloved for recreation or simply spending time in nature.

Chloride from de-icing products and wastewater treatment plants makes its way directly to surface waters such as lakes and streams. In addition to harming native species, chloride also disrupts the natural mixing processes of our lakes. This happens because chloride increases the density of water. The heavier salty water tends to collect at the bottom of the lake. This creates a difference in water density, impacting typical lake mixing patterns and potentially stopping them altogether. Changes to lake mixing patterns can inhibit the seasonal turnover process that normally occurs in Minnesota's lakes, leading to a lack of oxygen at lake bottoms and harming fish, insects, and plants.

Rivers are also impacted by rising chloride concentrations. A recent Metropolitan Council study found that chloride concentrations have significantly increased in Twin Cities rivers over the past 30 plus years, a trend that is expected to hold true for other areas of the state.

Figure 4: Chloride disrupts the natural mixing processes of our lakes. Photo courtesy USDA

Figure 5: Flow-Adjusted Chloride Concentration Trends in the Mississippi, Minnesota, and St. Croix Rivers, 1985-2015 (Metropolitan Council)



Groundwater occupies a precarious spot with chloride pollution, as 75% of Minnesotans rely on groundwater as their source of drinking water. While there is some natural occurrence of chloride in Minnesota's groundwater, these natural background levels are extremely low (1-10 mg/L) and well below risk levels. However, 2019 data from the MPCA shows that chloride in groundwater is increasing due to human activity: 40% of wells tested across the state are increasing in chloride. Higher groundwater chloride concentrations are typically found in the state's developed areas; 2/3 of wells with chloride concentrations exceeding the water quality standard were located in the Twin Cities Metro Area. This points to the influence of de-icing salt application on chloride levels in groundwater. However, here again it is important to remember that there is typically less chloride data available for water bodies outside the Twin Cities Metro Area.

Water bodies across the state undergo data collection over time to assess their health and the presence of various pollutants. When chloride concentrations exceed the state standard of 230 mg/L, the water is deemed impaired by chloride. When concentrations are within ten percent of that standard, the water body is classified as high-risk. Our most recent data on Minnesota's water bodies indicates that 68 water bodies are currently impaired by chloride, 14 of those were added in the 2024. An additional 75 water bodies are considered high-risk. 80% of these impaired and high-risk waterbodies are in the Twin Cities Metro Area, correlating with a greater road density and road salt usage. However, this trend also illustrates disparities in data sampling: much of the chloride data collected is from the Twin Cities Metro Area.

Figure 6: Chloride concentrations in ambient groundwater from sand and gravel aquifers (MPCA, 2020)

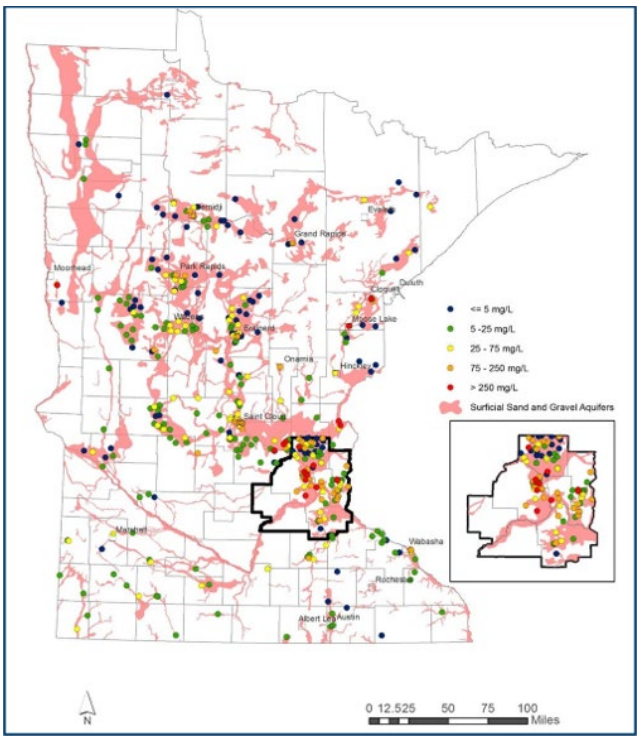
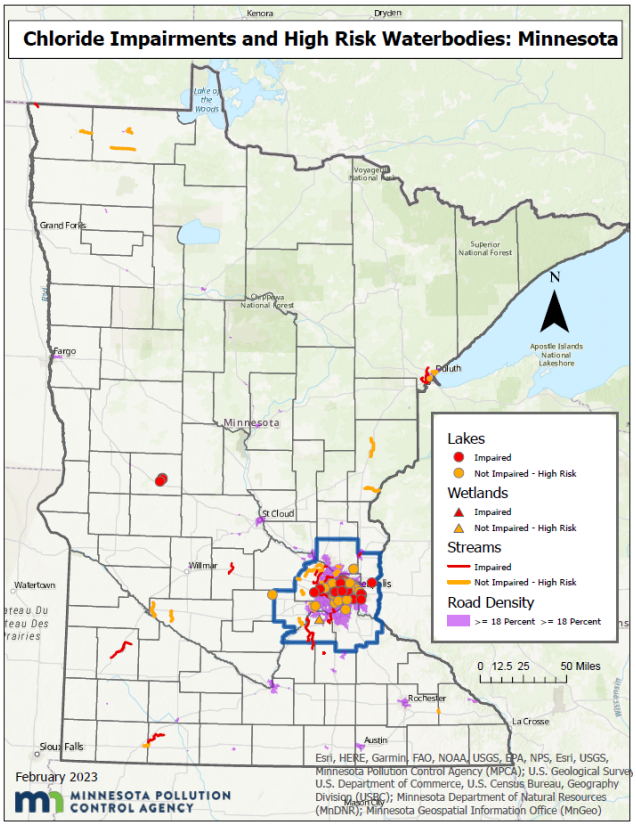
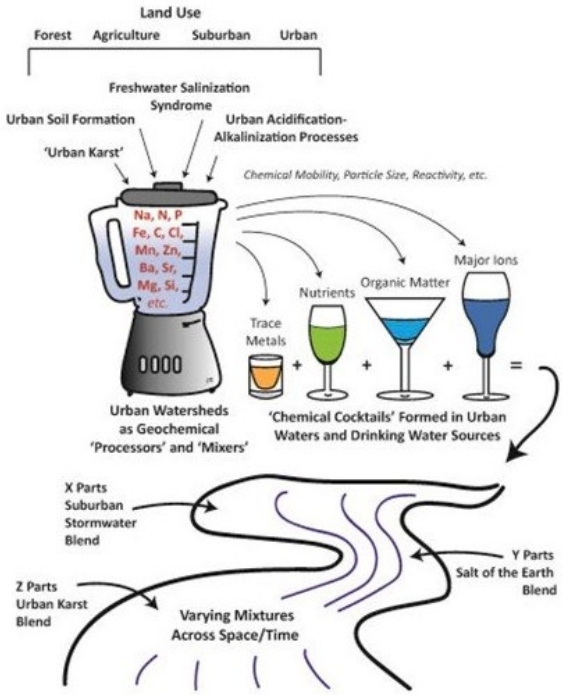


Figure 7: Chloride conditions in statewide Minnesota surface waters (MPCA, 2022)



Many of Minnesota's waters have never been tested for chloride, so these numbers only represent a portion of the whole picture.

Figure 8: How salts form chemical cocktails (Kaushal et al., 2020)



Salt can corrode metals and cause the release of heavy metals in drinking water systems, which also increases nutrient contamination and heavy metals in our streams, lakes, and wetlands. When these chemicals are released, they create a chemical cocktail with unknown toxic effects. Salts and the associated chemical cocktails build up in soils, surface water and groundwater, which is not easily remediated.

Infrastructure and vegetation

Due to its corrosive nature, chloride causes significant damage to buildings, road surfaces, bridges and reinforcing rods, and roadside vegetation. Salt applied to pavement also damages parking garages and underground utilities. Over time, these damages lead to compromised structural integrity, as well as increased maintenance and repair costs.

In addition, chloride can damage vehicles by corroding parts such as brake linings, frames, and bumpers. It can also accelerate rusting.

Figure 3: Witches' broom formation on tree

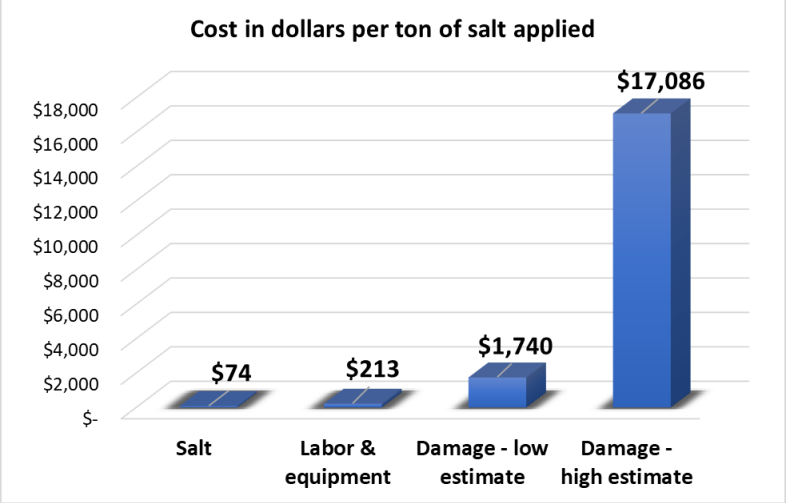
Plants near salted surfaces are at risk of severe damage or death from road salt spray and run-off. Many plants also suffer when drawing salty water up through their roots. Increased chloride levels in soil and direct salt spray can be seen through various indicators, including witches' brooms, which are atypical branch formations caused by high chloride levels. Furthermore, trees can die if they receive too much chloride runoff to their soil. Trees and plants surrounded by paved surfaces, such as downtown areas, are particularly susceptible to early die-off from nearby salt run-off. Many have seen the "vegetation burn" that is common in parking lots and sidewalks after snow melts—the characteristic dead yellow grass is often a direct result of salt spray. Costs for replacing dead grass, plants, and trees can add up quickly.

Finances

Chloride's costs far surpass its initial purchase and application. Salt damages ground-level building exteriors and interiors, walkways and sidewalks, steps, handrails, curbs, parking lots, vehicles, and vegetation. Salt that gets tracked indoors ruins entrance carpets and flooring. This means elevated costs, plus unanticipated maintenance and repairs for property managers and owners.

On a larger scale, salt damages concrete, roads, bridge surfaces, and parking garages. The corrosive nature of chloride ions leads salt to damage metal and concrete, weakening structures over time. Once chloride levels in water reach a certain threshold, lead and copper pipes can experience more corrosion, posing potential human health risks. According to a 2014 MPCA report (with rates adjusted for 2023 inflation), the total cost of infrastructure damage from one ton is salt is estimated to be between $2000-$17,000. The Minnesota Statewide Chloride Management Plan cites 2019 research from the Water Resources Center at the University of Minnesota (Overbo et al.) which estimates that 403,600 tons of de-icing salt are used each season statewide. In the Twin Cities Metro Area (TCMA), 249,100 tons of de-icing salt are used annually. The cost of salt alone amounts to about $18.4 million annually in the TCMA (249,100 tons of road salt x $74 per ton of salt). With the additional costs from damage to infrastructure, automobiles, and the environment, the "true" costs are much higher. If we multiply the 2014 MPCA study's low estimate of the financial damage from one ton of salt (adjusted for 2023 inflation) by the estimated 249,100 tons applied annually in the TCMA, we reach an approximate value of $433 million; the higher estimate values yield a potential annual damage with costs over $4.2 billion annually.

Figure 10: Sources: MPCA; 2014. The real cost of salt use for winter maintenance in the Twin Cities Metropolitan Area. Adjusted for inflation July of 2023



Reducing even a fraction of our salt use can save a significant amount of money. With cost estimates from 2019, the Minnesota Statewide Chloride Management Plan estimates that a 70% salt use reduction to Minnesota's 403,600 tons of de-icing salt would amount to between $290 million and $1 billion in financial savings.

Discovering solutions

Now that we have a better sense of the challenges we face with chloride and the effect it has already had on communities throughout Minnesota, we will present some of the solutions that are available to us. First, we will examine Smart Salting strategies for winter maintenance, including the MPCA's Smart Salting training program. We will look at tactics for reducing chloride from dust suppressants before addressing water softening and methods for reducing chloride from fertilizers.

Road maintenance

De-icing salt

Currently, there are no environmentally safe and cost-effective salt alternatives that are effective at melting ice on paved surfaces. The continued use of salt as a de-icing agent for public safety is to be expected, but we can use salt in smarter ways to reduce the harm it causes.

When we reference Smart Salting, we're referring to techniques that minimize environmental and economic impacts of chloride without compromising public safety and needs. Essentially, Smart Salting strategies do the following…

- Save on costs and time to improve efficiency.
- Still create safe surfaces.
- Protect water resources.

MPCA Smart Salting training and certification

In light of the complexities surrounding chloride use, the MPCA offers a training and certification program focused on Smart Salting. The MPCA's Smart Salting program helps improve operator effectiveness and reduce chloride pollution while keeping roads, parking lots, and sidewalks safe. Participating organizations have been able to reduce their salt use by 30 to 70%. The certification training has also been shown to prevent chloride contamination in bodies of water.

Figure 11: Training participants can earn a Smart Salting certification.

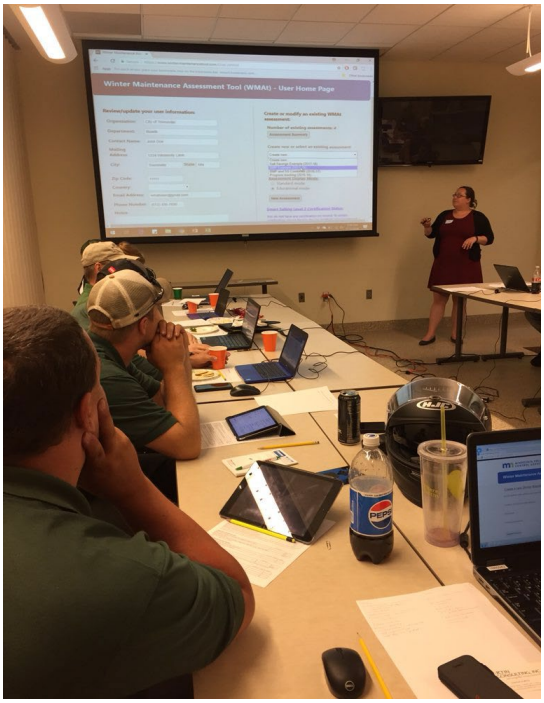
The MPCA offers level 1 and level 2 certifications. In level 1 certification training, individuals who manage snow and ice learn best practices to reduce their salt use while maintaining safety. Participants in the **Roads** and **Parking Lots/Sidewalks** trainings earn a five-year certification that can be renewed by attending another certification training and passing the test. The Roads class covers high and low speed snowplow operation, whereas the Parking Lot and Sidewalk training covers maintenance of private or public walkways, as well as parking lots and service roads.

Another level 1/individual certification offered by the MPCA is the Smart Salting for property management certification training, where **property managers**, business owners, those who hire winter maintenance professionals, and environmental professionals learn how to reduce damages caused by salt and save money while providing safe surfaces. They will also learn ways to encourage maintenance crews and staff to use more sustainable practices and the basics of snow and ice management tools.

Participants earn a three-year certification that they can renew by attending another certification training.

Organizations can earn Level 2/organizational certification by assessing their practices and associated salt use with the MPCA online **Smart Salting Tool**, then taking steps to minimize salt use. Organizations can obtain certification by assigning a representative to use the Smart Salting Tool independently or working through it at a MPCA Smart Salting level 2 training. Organizations earn a two-year certification that can be renewed by submitting the required assessments.

Figure 52: Level 2 Training participants learning to use the Smart Salting Tool



The MPCA is currently developing a Smart Salting for **Water Treatment Professionals** course. This will introduce chloride pollution issues into professional education and training for plumbers and water softening professionals. This course will focus on options for reducing and eliminating chloride from water softening systems.

The workshop that accompanies this handbook, Smart Salting for **Community Leaders**, is designed for city administrators, council members, environmental commissions, board members for housing associations or watershed districts, or other community leaders. If you know anyone who you think may be a good fit for this workshop, we invite you to share this opportunity with them.

You can learn more about the Smart Salting training program in this video, where winter maintenance professionals share how they've benefitted from these trainings. You can learn more about the Smart Salting program on the MPCA Smart Salting Training webpage. Upcoming trainings can be viewed on the MCPA Smart Salting events calendar.

Smart Salting Success Story: Mayo Clinic

As Ground Maintenance Supervisor for Mayo Clinic's Rochester campus, Nick Queensland was proud of his crew's accomplishments in terms of productivity and safety. However, he was bothered by the amount of salt applied to their paved surfaces in order to obtain these results. After the winter of 2017-2018, he began to research how he could maintain Mayo Clinic's excellent level of service while prioritizing salt reduction. He discovered the MPCA's Smart Salting training program.

- Fall 2018: grounds maintenance crews & leadership completed the MPCA's Smart Salting for Parking Lots and Sidewalks training.
- Post-training and certification: Queensland and his crew listed the methods their team could utilize to reduce salt use on Mayo's campus, focusing primarily on parking lot and roadway salting.
    - They calibrated their salt application equipment and found that knowing the rates of their spreaders proved to be an important tool—when they directed their contractors to apply salt, they could now specify a rate instead of having the contractors apply a heavy blanket of salt each time.
    - The crew incorporated liquid salt brine into their ice control toolkit, which allowed them to plow snow without needing to apply rock salt at all for several storms.
- Post-implementation of Smart Salting practices, the **Mayo Clinic was able to reduce their salt use by 60%** in a winter that received a record amount of snow and a normal amount of ice, all while keeping clients safe.
    - For Queensland, these efforts were well worth it for both the positive environmental impact and cost savings.

Smart Salting: The four Rs of winter road maintenance

The Smart Salting program features four Rs of winter maintenance: physical **removal** of snow and ice, using the **right amount** of salt, using salt in the **right conditions**, and selecting the **right product** for de-icing.

1. **Physical removal of snow and ice** is the most important tool we have in our toolkit when facing winter snow and ice. Early removal helps prevent snow from compacting, and it's the safest option for the environment and our infrastructure. The more snow and ice are removed manually, the less salt is needed, and the more effective what is used becomes.
    a. There are a variety of tools for removing snow physically. Whether you use a shovel, snow blower, snowplow, or ice scraper, it's best to get out there as early as possible to keep up with the storm. In taking this approach, salt may not even be needed.

Figure 6: Early manual removal of snow and ice is our safest option for the environment and infrastructure.

2. **Using the right amount of salt** is another key strategy for smarter salting. Oftentimes, people over-salt in efforts to speed up melting. It's important to note, however, that more salt does not mean more melting; each de-icing product is only able to melt a fixed amount of snow or ice. Ideally, we should scatter salt only where it's especially needed, such as on spots that are prone to icing over. There is no reason to put salt on bare pavement that has no ice, but unfortunately this is a common practice. (Note: some winter maintenance contractors are put under unreasonable pressure to over-salt due to employer expectations. Bare pavement policies often lead to unnecessary over-salting.)
    a. An easy way to approximate how much salt to use is remembering that one pound of salt (approximately one heaping 12-ounce coffee mug) can cover around 10 sidewalk squares, or one parking spot. This is equivalent to about 4 pounds of salt per 1,000 square feet.
3. **It's important to use salt in the right conditions.** Salt's effectiveness in melting ice is dependent on pavement temperature, not air temperature. Different ground surfaces have different temperatures, so a hand-held temperature sensor can be a great way to get an accurate reading of pavement temperature across varied surfaces. For winter maintenance professionals, pavement temperature is often measured using sensors on their trucks or using data from MnDOT's weather stations, which provide surface temperature measurements and other surface condition data.
    a. Colder pavement temperatures require more time for salt to work than warmer temperatures. 15 degrees Fahrenheit is an important point to remember—typical rock salt is not effective below this point. Below 0 degrees Fahrenheit, salt is not the best tool for managing ice. On these very cold days, sand is the best option for creating traction on icy spots.
4. **Using the right product** is key consideration, as certain types of salt are more effective than others in colder temperatures. Typical rock salt does not effectively melt ice below 15 degrees Fahrenheit. Magnesium chloride, potassium acetate, and calcium chloride are more effective at de-icing at lower temperatures compared to sodium chloride.

a. Note: There are currently no labeling requirements on de-icing salt, meaning companies are not required to list all the ingredients in their product or the percentages of ingredients used. Even when ingredients are listed, they do not need to be accurate, nor do any of the packaging claims. This leads to many producers attempting to present their product in an environmentally friendly light, even if this is untrue. Currently, there are not any confirmed products that are entirely safe for the environment, nor are there any products that are confirmed as safe for pets. There are no testing standards that could be used to support or deny these claims. It's important to know what the product is made up of in order to use it in the appropriate weather conditions—calling the manufacturer is one way to get a clearer picture of the product's true contents.

Dust suppressants

Dust suppressants are another important source of chloride in Minnesota. While these chloride-based products can help extend the lifespan of gravel roads and reduce air pollution, there are still ways to reduce the impact of chloride from these dust suppressants. Recommended practices include:

Figure 7: There are ways to reduce the impact of chloride from dust suppressants. Photo: Lars Plougmann

1. **Tracking application rates and locations.** Applying these products near surface waters (lakes, streams, wetlands), culverts, wells, or drainage tile inlets can accelerate the transfer of chloride to our waterbodies. Consider location when applying these products and note application rates.
2. **Reviewing appropriate level of service.** What application amount is expected for the area? Take steps to apply the right amount at the right frequency.
3. **Testing alternative dust suppressants without chloride.** What other products may be available for a similar purpose, but with reduced or no chloride?
4. **Educating crew and customers** about the long-term impacts of using chloride-based dust suppressants. As with the de-icing strategies we've examined, managing public expectation is a key step toward change. Sharing reasons behind making adaptations is an important way to keep community members informed, and crews need to know the reasons behind changing their approach, too.

Water softening

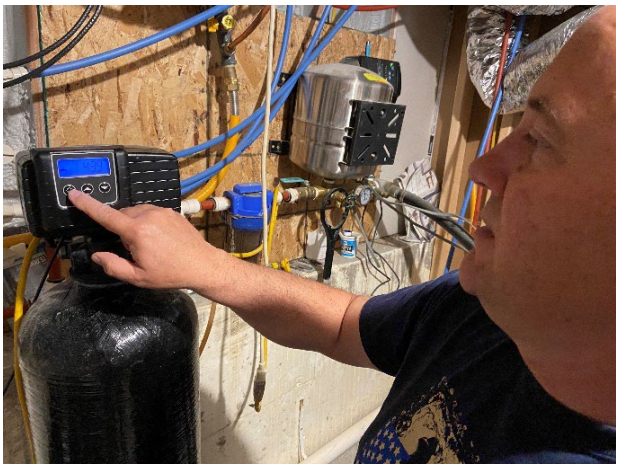
Next, we'll transition to Smart Salting solutions in water softening. We will first investigate what these practices look like in home water softening before examining options for centralized water softening.

Home water softening

One of Minnesota's ways of softening water is through residential ion exchange units, which produce a concentrated chloride discharge. To reduce their chloride impact from water softening, there are several steps users can take…

1. **Identifying the source of one's water** is an important first step. Is it from surface water, an aboveground source such as a river or lake, or is it from groundwater, such as an aquifer? Surface waters contain fewer minerals than groundwater, so it is naturally softer.
    a. Water softener users can determine the hardness of their water by checking consumer reports from their water provider. Private well owners can send water samples to a lab, or they can work with a local water softening professional to test their water's hardness.
2. **Understanding one's equipment** is crucial to this process of chloride reduction in water softening. Equipment type has a strong influence on chloride discharge—age and type can drastically change these impacts. Newer systems are more efficient than older ones, and on-demand water softeners have higher efficiency with salt usage than timer-based systems.
    a. Note: Checking if both indoor and outdoor water are softened can bring significant salt reductions. Softening only indoor water is one way to make substantial cuts to salt use.

Figure 8: Understanding one's equipment is crucial to chloride reduction in water softening. Photo: MPCA



3. **Maintaining water softening equipment** ensures efficiency and lower amounts of salt. Equipment should be regularly checked by professionals, who can ensure proper calibration and functioning. Oftentimes, water softeners are set by default to the highest setting (meaning the highest amount of chloride discharge), but depending on one's water hardness, this output may not be needed. A professional can help determine the best fit for one's needs.

Centralized water softening

Some municipalities have centralized water softening facilities that treat water before it is distributed to buildings. Many of these facilities use a combination of lime and soda ash to chemically remove minerals from water. Other communities have reverse osmosis softening facilities. Neither process requires the use of salt. As more communities learn about chloride's impacts and costs, many municipalities are installing non-chloride centralized softening facilities to reach chloride reduction goals. These adaptations can have a positive impact, but the startup costs can be high. Pages 28-29 features information on potential funding opportunities for communities interested in adapting their water softening facilities.

Water Softening Success Story: City of Morris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In Morris and other cities, solving a salty problem in municipal water

Kirsti Marohn Morris, Minn. March 12, 2019 9:00 a.m.

The wastewater treatment plant for the City of Morris discharges wastewater into the Pomme de Terre River, which discharged chloride concentrations that were consistently nearing 800 mg/L in recent years. The city was required to achieve a water quality standard of 400 mg/L by the end of 2020. To meet their NPDES permit limit for chloride, the City of Morris undertook a massive project to reduce their chloride.

Individual home water softeners were identified as the city's largest source of chloride. Over 90% of households in Morris use a water softener. To address this, the City of Morris began operating a new wastewater treatment plant in the spring of 2019. This plant uses a lime and soda ash-based system to centrally soften the city's municipal drinking water. The cost of this plant was $18 million, $12 million of which was provided through state aid.

In May of 2019, the City of Morris City Council voted to adopt an ordinance that would limit the discharge of briny wastewater from water softeners, minimizing the amount entering the municipal sanitary system from homes. In effect, this ordinance will restrict the use of older, timer-based water softeners, encouraging residents to have their softening systems inspected and reducing the amount of chloride from these systems.

Fertilizers

Agricultural fertilizers

The impacts of chloride from agricultural fertilizers vary by region. Across the state, potash, a chloride-based fertilizer, remains the main source of agricultural chloride, but manure also contributes to chloride concentrations. Agricultural practices involving chloride application need to meet the biological needs of plants and animals, so any adaptations must reduce chloride use without harming yields. Practices for reducing chloride from agricultural fertilizers include:

1. **Testing soils for potassium needs prior to fertilizing with KCL.** Furthermore, applying these fertilizers at agronomic rates can help reduce chloride's presence. These products may be needed at lower concentrations than what is presumed; testing soils allows for more certainty with application rates.
2. **Following suggested application rates** for potassium.
3. **Seeking chloride-free potassium options when feasible.**
4. **Developing best management practices for conserving potassium** that align with one's goals and the operation's needs. Practices such as leaving crop residues in place and accounting for all sources of potassium can reduce the need for applying additional potassium.
5. **Implementing best management practices for potassium application.** These practices may include balancing irrigation with demand and ensuring that any product is applied at the optimal time of year with respect to crop, soil type, temperature, precipitation, and weather.

Turfgrass and ornamental plant fertilizers

Maintenance practices for turfgrass and ornamental plants can have a significant impact on our waters, for better or for worse. As with agricultural fertilizers, many products intended for potassium supplementation also contain chloride, which washes into our streams and lakes with rain events. If a person has determined that the application of potassium is essential for their lawn or turfgrass, there are several steps one can take to address their application of chloride-containing fertilizers.

1. **Considering expectations around potassium fertilizer can inform future action.** What are your expectations for turfgrass quality? Do environmental considerations factor into your expectations? Using lower amounts of chloride-containing fertilizers can help protect our water resources.
2. **Testing one's soil** can inform the selection of products for one's property, from fertilizer ratio and type to frequency of application. The University of Minnesota's Soil Testing Laboratory provides low-cost soil testing that offers recommendations for fertilizer ratio, amount, and application instructions.
3. **Using less water** can minimize the fertilizer quantity that is needed. Excess watering or irrigation moves nutrients away from plant roots, increasing nutrient demand.
4. **Adapting fertilizer application processes** can impact the efficacy of fertilizer application. Calibrating equipment, applying at the right time of year, cleaning up spills, and following soil test recommendations can all ensure proper fertilizer application.
5. **Using a fertilizer with a non-chloride source of potassium** is another potential course of action. Beyond potash (KCl), there are other potassium fertilizers—while these products are typically more expensive, they are also often higher quality sources with a lesser likelihood of burning turf like potash.
6. **Soil conditions can be altered** to increase potassium's availability in the soil. Higher amounts of potassium can be released from soil minerals through a combination of practices, which may include amending soils with organic materials or restoring the activity of soil microbes.

Taking action as a community leader

Whether you're an elected official, part of a community municipality or watershed district, or a concerned member of the general public, you have an important role to play in enacting change. This section will shed light on policy recommendations and model ordinances, resources, and funding opportunities to equip you with tools to take meaningful action in your community. We will first discover actions tailored to road maintenance, before moving toward water softening actions.

Minnesota Statewide Chloride Management Plan

For those interested in extending their chloride familiarity and action beyond the scope of this handbook and workshop, the Statewide Chloride Management Plan can be a valuable resource. This document was released in 2020 by the MPCA and several partners to help government units, winter maintenance professionals, decision-makers, and others take action to protect Minnesota's waters from chloride pollution.

This management plan aims to serve as a guide for determining specific community priorities for chloride reduction. It is also meant to assist with determining your organization's role in slowing or preventing the trend of chloride pollution. Sections are tailored for different groups, including winter maintenance professionals, wastewater treatment facilities, and more.

The document offers potential policies and actions that can be considered for reducing salt use. This handbook will explore a few of these in more depth—these policy considerations are focused on state and community level implementation. These policy considerations are a compilation of suggestions and recommendations contributed by the MPCA and its stakeholders who assisted in the development of this management plan. We want to note, however, that the MPCA is not endorsing or actively promoting the policy changes outlined in the Chloride Management Plan. Instead, these proposed changes are meant to serve as ideas for organizations who may wish to implement similar ideas toward their chloride reduction goals.

Chloride reduction model ordinances

The MPCA has provided language that municipalities or other groups can utilize as they develop chloride reduction ordinances or policies in their communities. These were created by a team including city governments to offer language that can be easily incorporated into organizations' existing language.

These ordinances are offered as suggestions in the Chloride Management Plan, and they are accessible on the MPCA website. The model ordinance language focuses on four main areas presented in more depth below. A group or municipality should consider which of these ordinances is most appropriate for them based on their desired impact and their available resources. These ordinances can also be implemented as polices if you organization does not have authority to implement ordinances.

1. **Model ordinance 1: Occupational licensure for winter maintenance professionals.** This ordinance would require anyone who provides snow and ice services within their city limits to be Smart Salting trained and certified. Those engaging in the operation of a winter maintenance business would need to be in possession of current Smart Salting certification. A license could then be obtained upon approval from the director of public works, for example. From there, a city or township could publish a website list of all license holders.
    a. Something like this would be far from the first ordinance of its kind; in Minnesota, licensing requirements are already in place for a variety of professions that can cause harm if not performed with adequate regard for risk. For example, in Minnesota, certain tasks in the design, repair, maintenance, operation or inspection of septic systems can only be done by certified individuals. Pesticide applicators may not apply pesticides until they have a valid license. A licensure requirement for professionals who apply chloride would minimize potential harm to the environment, infrastructure, and financial resources.

Figure 16: Create an ordinance for certification of organizations doing salt application in your community.

    b. Policies in action: For organizations without an ordinance structure, licensure policies can be implemented. Examples of Minnesota organizations who have required Smart Salting certification for their winter maintenance professional staff and hired contractors as part of their policies include the City of Minneapolis, the University of Minnesota-Twin Cities, and Metro Transit. These are just some of the first to implement

this policy, many others have made this a standard hiring practice for snow and ice mangement services.

2. **Model ordinance 2: De-icer bulk storage facility regulations.** This ordinance would require any entity that stores bulk deicer within their city limits to follow the guidelines for proper salt storage. A group could add language to the ordinance to address additional storage-related issues such as facility siting, snow pile siting, and transfer of de-icing materials.
    a. This ordinance was specifically created to help MS4 permittees meet their permit requirement to have a regulatory mechanism in place that requires facilities in their jurisdiction to store salt properly. Utilizing this language is one way to ensure one's organization is well-equipped to meet permitting requirements.
    b. Other Smart Salting courses teach attendees how to properly store salt to prevent it from leeching into the environment. The MPCA also offers a Smart Salting Refresher course that specifically addresses salt storage.

What is an MS4?

This term refers to **municipal separate storm sewer systems**, or conveyances that are…

- Owned or operated by a public entity.
- Used for collecting stormwater.
- Not a combined sewer.
- Not part of a publicly owned treatment works.

MS4s in Minnesota must satisfy permitting requirements designed to reduce the amount of sediment and other pollutants entering state waters from stormwater systems.

Figure 9: Proper storage of de-icing materials is one requirement for MS4s. The MPCA offers a Smart Salting Refresher specifically for salt storage.

3. **Model ordinance 2: Land disturbance activities**. This ordinance would require the implementation of a chloride management plan for new and re-development projects, utilizing existing land use regulations. Furthermore, it would require the designation of a Smart Salting-certified applicator for these projects. Under this ordinance, an applicant for a permit for land-disturbing activity on property other than individual single-family home sites would need to provide a plan for post-construction chloride management on the site. At a minimum, this management plan would need to include 1) an individual designated as authorized to implement the chloride use plan, and 2) the designation of an MPCA Smart Salting-certified salt applicator engaged in the implementation of the site's chloride use plan.
    a. Ordinance in action: this ordinance has already been implemented by Nine Mile Creek Watershed District, as well as Riley-Purgatory Bluff Creek Watershed District.
    b. The Hennepin County Chloride Initiative (HCCI) has also developed winter maintenance and chloride management plan templates that can be used at the time

of land development or redevelopment permitting. These require or request the development of a winter maintenance plan from property management. There are currently three templates available on the MPCA Statewide chloride resources webpage, as well as a calculator that recommends which template best fits one's organization. This tool can be particularly helpful when beginning to develop a winter maintenance plan that follows Smart Salting techniques.

4. **Model ordinance 4: Parking lot, sidewalk, and private road sweeping requirements.** This ordinance would incorporate deicer sweeping requirements into existing off-street parking, sidewalk, and private roadway snow management requirements. This could be a new ordinance, or it could be incorporated into existing code language, if appropriate. Under this ordinance, property owners and occupants would need to follow ice and snow sweeping requirements immediately after a snow melt.

Figure 10: Ordinance 4 offers language for implementing a deicer sweeping requirement.

   a. Tip: Municipalities looking to implement this ordinance may want to specify the process for deicer removal. Some municipalities, for example, accept excess materials for disposal or reuse. Some require specific locations for landfill disposal.

   b. Ordinance in action: The City of Madison, WI has an ordinance whereby excess salt and chemical melting agents may not accumulate on sidewalks; they must be removed after snow or ice melt. If an inspector finds an owner has used an excessive amount of salt, the owner will be notified that they need to clear their sidewalk by a certain date. Failure to do so results in a fine.

Model contract for snow and ice management services

The City of Edina, guided by a diverse advisory committee of service providers, property managers, and environmental specialists, created a model contract for snow and ice management services, found on the MPCA Statewide chloride resources webpage. This model contract embraces Smart Salting practices while maintaining safety and reducing liability risk. This is a useful resource if your organization is interested in creating its own Smart Salting-friendly contract for winter maintenance services.

Model snow and ice management policy

The MPCA Statewide chloride resources website also offers a model snow and ice policy, a tool for cities and counties in the process of developing their own winter maintenance policies. A well-written snow and ice management policy is key for balancing public safety, equipment and material costs, and environmental impacts. The model policy has been developed to allow cities and counties to incorporate environmental considerations into their policies and operations to enable better management for liability risk.

Incentive approaches to encourage chloride reduction

Organizations may want to consider more incentive-based approaches as an alternative way to encourage chloride reduction in their communities. What might this look like in your community?

- Incentives in action: The City of Minneapolis has created a stormwater credit program whereby commercial properties can receive a credit for their stormwater utility fee by implementing certain practices. This could reduce their fee by up to 70%. All participating commercial properties must complete a chloride management plan. For this, a template is provided. A 30% reduction can be achieved by completing and implementing an advanced salt management plan that demonstrated the reduction or elimination of salt use from winter maintenance practices in applicable areas.

Further policy considerations in the Minnesota Statewide Chloride Management Plan

The Minnesota Statewide Chloride Management Plan offers further information on the proposed action steps above. In addition, it addresses the following policy concerns, which we invite you and your organization to consider.

De-icing policy considerations

1. **Development of liability protection legislation**. Developing limited liability language can protect Smart Salting-certified applicators using best management practices from slip and fall lawsuits.
2. **Advocacy for labeling accuracy**. There is need for the development of labeling requirements for de-icing products sold in Minnesota. Labeling requirements could include accuracy of ingredients, environmental and pet safety claims, potential negative impacts, and proper application.
3. **Encouragement of low-salt design practices**. This may include considering alternative pavement types that require lower or no salt for winter maintenance, as well as improved urban design for new construction and re-construction. Reducing impervious surfaces can reduce overall chloride use. These considerations could also spark more specific infrastructure changes, such as construction of narrower lanes, increased covered parking and walkway options, or the increase of public transit-oriented development.
4. **Establishment of salt recycling programs**. These programs can offer collection of residential deicers at the end of winter. Resident participation could be encouraged by offering a trade for a bag of mulch or compost, for example. Collected salt could then be added to a municipality's properly stored salt pile.

Figure 11: The Minnesota Statewide Chloride Management Plan offers an in-depth look at policy concerns, as well as further language that can be utilized to reach one's chloride reduction goals.

a. Program in action: In 2020, the City of Hopkins enacted a salt recycling program that allowed residents to leave their salt in a designated bin at Hopkins Public Works. Homeowners were able to free up storage space, and the city added that salt to the citywide deicing efforts.
b. Cities and Counties may consider an end of the season drop off program to private snow and ice contractors in their community who do not have proper summer storage for salt. This can help to prevent and overuse of salt at the end of the winter season events due to lack of year-round storage.

Water softening policy considerations

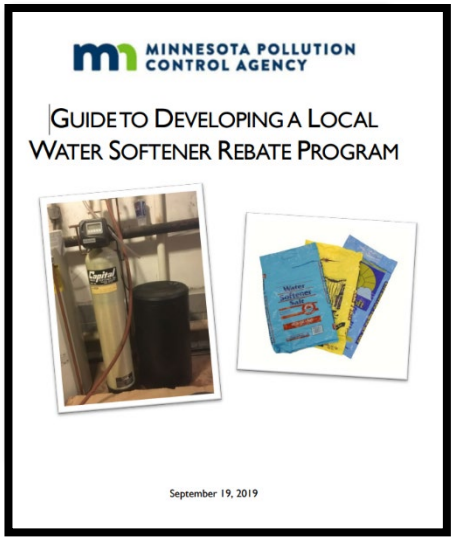
The Minnesota Statewide Chloride Management Plan contains policy considerations for chloride reduction in water softening practices. Below, some of these considerations are highlighted.

1. **Establishment of rebate programs**. Whether for residents or business, these programs could involve water treatment professionals in either the optimization of currently installed hardness reduction systems or the removal of individual home softening systems when appropriate.
2. **Establishment of cost share programs**. These programs would encourage home bypass of soft water for irrigation and drinking water. A cost share program could be used to facilitate the implementation of these plumbing changes.
3. **Establishment of ordinances or modification of plumbing codes**. A municipality or jurisdiction could require all new construction to install on-demand water softeners. Alternatively, plumbing codes could be updated to prohibit the installation of new timer-based water systems, allowing more homes to use on-demand water softeners that produce less chloride discharge.
4. **Provision of financial support and technical assistance**. Advocating for this support for municipalities can reduce chloride discharges and allow flexibility for how municipalities achieve chloride reductions.

Guide to developing a water softener rebate program

The MPCA has a guidance document on how to implement a local water softener rebate program. This is a general guide for city or watershed managers and staff who may be interested in developing a water softener rebate program in their jurisdiction. The guide presents an overview of key points to consider, as well as examples of how existing programs were implemented. Several cities have developed rebate programs that are currently underway with assistance from this guide.

Figure 12: MPCA guidance to implement a local water softener rebate program.



Water softening rebate programs in action:

- As part of their Chloride Reduction Grant funding from the MPCA, Bolton & Menk Inc. partnered with the Minnesota Water Quality Association to provide free water softening system optimizations, recommendations, and assistance with improvements or replacements in Altura, Avon, and Medina. In addition, they offered cost share funding for commercial, industrial, or other non-residential facilities.
- After the City of Marshall's Wastewater Treatment Facility was required by the MPCA to reduce the

discharge of chlorides into the Redwood River, the City of Marshall and Marshall Municipal Utilities (MUU) collaborated to discern which actions would produce their desired results. Their analysis determined that upgrading MMU's Water Treatment Plant to produce a softer water through a chloride-free soda ash and lime system was the most efficient method. This project has cut down on the amount of water softener salt needed by households and businesses alike. The City of Marshall partnered with Bolton & Menk Inc., a recipient of a Chloride Reduction Grant from the MPCA, to offer a rebate that helps Marshall residents cover the cost of replacing outdated water softeners or adjusting water softeners that remain functional.

Education and outreach

Each individual contributes to the attitudes and practices that have created a high and steadily growing volume of salt. To reverse this situation, each of us must contribute to changing attitudes and adapting practices to be more sustainable and less centered around salt. Residents form public policy, set the expectations our maintenance crews must meet, and use salt on their own properties through water softening and sidewalk salting. Engaging Minnesotans in this issue offers the best chance for mitigating salt use.

Just as we've seen that only one teaspoon of salt is needed to pollute five gallons of water, we can remember that every teaspoon of salt reduction protects five gallons of water from being polluted.

Figure 13: Even small reductions in salt use can make a big impact.

MPCA educational resources

The MPCA Statewide chloride resources webpage is home to a variety of chloride education and outreach resources, including tip sheets, posters, videos, and short courses for the general public, such as the City of Minneapolis's salt mini-course program.

Low salt, no salt Minnesota

The Hennepin County Chloride Initiative (HCCI) created a new outreach resource to assist local government units in their chloride reduction outreach to the private sector. Groups such as homeowner associations, property managers, and faith communities tend to make decisions about winter maintenance for large areas. From hiring contractors to influencing the salt practices these contractors use, these groups have a significant impact on the way chloride is used.

The Low Salt, No Salt Minnesota toolbox helps local government units deliver the program locally, increasing awareness of the issues surrounding chloride and providing support for private landowners who wish to reduce chloride pollution from their properties.

Izaak Walton League of America

The Izaak Walton League of America offers their Salt Watch program to Minnesota residents who want to participate in a citizen science chloride monitoring program. Volunteers receive a test kit that enables them to monitor chloride levels in their nearby streams, lakes, and wetlands. They report their results and the Izaak Walton league tracks this on their website and app. Volunteers are also encouraged to advocate for smarter salt use in their communities.

Participation in these efforts can be a great opportunity for interested community members to get involved in local chloride reduction efforts.

Assistance and funding opportunities

There are a variety of opportunities available to organizations looking to reduce their chloride use. Below is an overview of some of these options.

Minnesota GreenCorps Program

Minnesota GreenCorps is an environmentally focused AmeriCorps program coordinated by the MPCA. Government entities at the local, regional, state, and tribal level, nonprofits, and educational institutions across the state can be eligible to host a GreenCorps member. Members serve approximately 40 hours per week for an 11-month service term, with their service primarily in one of four areas: air pollutant reduction, community readiness and outreach, green infrastructure improvements, and waste reduction, recycling, and organics management.

Projects related to chloride reduction are a welcome part of the program, and current and past MN GreenCorps members have helped with chloride reduction projects across the state of Minnesota. Host site applications are typically open between January and March. You can learn more on the Minnesota GreenCorps webpage.

MN GreenCorps members in action: GreenCorps members serving with the City of Minneapolis developed a salt mini-course program to educate Minneapolis residents about the impacts of salt on the environment. The Salt mini-course is still in use today.

MPCA chloride reduction grant program

The MPCA has a grant program that assists communities with their projects related to chloride pollution reduction. Funding for these grants comes from Clean Water, Land and Legacy Amendment Funding. The hope is to decrease salt use or eliminate it entirely, and these funds can be a critical step toward reaching these goals. For updates on grant information and application timelines, subscribe to the Smart Salting program newsletter. You can also visit the MPCA grants and loans webpage to learn more.

MPCA clean water partnership loans

With a borrowing limit of $1.25 million, this loan could be a good fit for organizations looking to develop chloride reduction projects, whether that involves developing ordinances, education and outreach resources, or purchasing efficient winter maintenance materials tools such as liquid brine equipment. More information can be found on the MPCA Clean Water Partnership loans webpage.

MPCA small business environmental improvement loans

Smaller businesses may want to consider looking into these loans, which are tailored for organizations with fewer than 100 full-time employees, an after-tax profit of less than $500,000, and a demonstrated ability to repay the loan. More detail about eligible expenses, borrowing limits, and terms and conditions can be found on the Small Buisiness environmental assistance webpage. Because this would permit investing in cost-saving equipment and technology and ultimately using less salt, this loan and its larger counterpart above can yield big savings.

The Minnesota Board of Water and Soil Resources (BWSR) Clean Water Fund Grants

BWSR Clean Water Fund Grants provide funding to local units of government to deliver soil and water conservation services to their communities. These funds can support and increase local capacity to implement programs that protect Minnesota's water. You can learn more about these grants on BWSR's Clean Water Fund webpage.

Reflect and pledge to take action

Starting now, we can work together to reduce chloride. We can engage in and encourage Smart Salting practices, just as we can advocate for policy change. What steps make the most sense for you and your organization? We invite you to consider the Action Pledge below, identify actionable steps you can take, and share with others in your organization and community.

MPCA Smart Salting for Community Leaders:

Action pledge

Level 1

- ☐ Your attendance in the Smart Salting for Community Leaders workshop, coupled with reviewing this handbook, are great first steps! Check off the actions you feel that you've completed.
- ☐ Deepen your understanding of chloride. What are the impacts of chloride on the environment, infrastructure, and finances? How do constituents contribute?
- ☐ Participate in the workshop and complete the survey.
- ☐ Understand options for reducing chloride use.

Level 2

After attending the workshop, consider how you want to continue your chloride reduction efforts. What actions are relevant and realistic for you and/or your organization? Select at least one action.

- ☐ Raise community awareness of the harmful effects of chloride through education and outreach for local residents, winter maintenance staff, community leaders, and businesses.
- ☐ Conduct a chloride source assessment to determine source(s) of chloride in your community.
- ☐ Create a local chloride reduction plan.
- ☐ Require local entities to hire Smart Salting-certified winter maintenance contractors on their owned or leased properties.
- ☐ Partner with the MPCA to offer Smart Salting training and certification for local private and public winter maintenance professionals each winter.

Level 3

Are you ready to commit to change? How might you and/or your organization be most effective? Select at least three actions.

Policy advocacy and change

- ☐ Require that contractors for snow and ice management services within your community have MPCA Smart Salting certification.
- ☐ Implement an ordinance that requires all salt and sand piles to be properly stored (inside a covered shed, building or container is best) and on an impermeable surface.
- ☐ Advocate for accurate labeling on deicers, similar to those for pesticides or food products.
- ☐ Consider requirements for updated water softening at the point of sale for homes and buildings.

- ☐ Consider recommendations for development or redevelopment projects to have a percentage of hard surfaces that a) do not require salt (i.e. heated) or b) require much less salt.
- ☐ Consult the Minnesota Statewide Chloride Management Plan and select action steps that align with your organization's goals.

Training and outreach

- ☐ Educate civic leaders on the benefits and importance of reducing chloride.
- ☐ Share the benefits of smarter salt use with constituents.
- ☐ Encourage local businesses and public buildings to reduce salt use through improved insurance benefits and liability protection.
- ☐ Provide homeowners and small businesses a measuring cup type salt scooper at the salt point of sale to raise awareness of smart salting quantities.
- ☐ Host yearly certification trainings for local winter maintenance professionals, encourage use of the Smart Salting Tool, and track progress of best management practices implemented.

Program and project development

- ☐ Monitor local surface waters for chloride concentrations to track trends, measure progress, and understand chloride's movement through the watershed.
- ☐ Develop an incentive-based program for chloride reduction strategies.
- ☐ Coordinate end-of-winter excess salt drop-off locations for private contractors.
- ☐ Implement a rebate program for residents to install on-demand water softeners and remove old, inefficient water softeners.
- ☐ Work to reduce chloride use in agricultural and ornamental fertilizers.
- ☐ For GreenStep Cities & Tribal Nations participants, complete steps under Best Practice Action 6: Reduce de-icing and dust suppressant salt use to prevent surface water and groundwater pollution.
- ☐ Evaluate dust control practices and look for non-chloride options.

Thank you for working to protect Minnesota's water resources!

Resources and further reading

The following resources offer a more in-depth look at chloride issues, as well as opportunities for continued learning.

The 2020 Statewide Chloride Management Plan is available on the Minnesota Pollution Control Agency's website.

To learn more about the Minnesota Pollution Control Agency's Smart Salting program, you can visit the MPCA Smart Salting Training webpage, view or register for upcoming workshops and trainings, and access the Smart Salting Tool. This video offers an overview of the Smart Salting trainings, as well as testimonials from winter maintenance professionals who have been certified. You can also consult the manuals from our other trainings:

Smart Salting for Property Management Manual

Smart Salting for Parking Lots & Sidewalks Manual

Smart Salting for Roads Manual

MWMO Manual for Turfgrass Maintenance (see also the MPCA webpage for turf grass maintenance training)

The following studies offer an in-depth look at recent research surrounding chloride in the Midwest:

Overbo A., Heger S., Kyser S., Asleson B., Gulliver J. 2019. Chloride Contributions from Water Softeners and Other Domestic, Commercial, Industrial, and Agricultural Sources to Minnesota Waters. Ph.D. Thesis, Saint Paul, MN: University of Minnesota.

Stefan, H., Novotny, E., Sander, A., and Mohseni, O. 2008. Study of Environmental Effects of Deicing Salt on Water Quality in the Twin Cities Metropolitan Area, Minnesota. Minnesota Department of Transportation. Report No. MN/RC 2008-42.