SUMMARY NOTES OF THE JANUARY 31, 2024, MEETING OF THE TECHNICAL ADVISORY COMMITTEE FOR *A CHLORIDE IMPACT STUDY FOR THE SOUTHEASTERN WISCONSIN REGION*

INTRODUCTION

The January 31, 2024, meeting of the Technical Advisory Committee (TAC) for *A Chloride Impact Study for the Southeastern Wisconsin Region* (Study) was convened online at 10:01 a.m. The meeting was called to order by Committee Chairman Thomas M. Grisa, Director of Public Works, City of Brookfield. Mr. Grisa welcomed the attendees to the meeting. Attendance was taken using the online software.

Members Present

Thomas M. Grisa, Chairman.....Director, Department of Public Works, City of Brookfield
Laura K. Herrick, Secretary ..... Chief Environmental Engineer, SEWRPC
Mandy Bonneville..... Deputy Director/County Conservationist, Walworth County Land Use and Resource Management Department
Karl E. Buck.....Community Planner, FHWA Wisconsin Division
Brian Cater.....Interim Director of Public Works/City Engineer, City of Kenosha
Cody Churchill.....Winter Maintenance Engineer, Wisconsin Department of Transportation
Steven R. Corsi ..... Research Hydrologist, Chemistry, U.S. Geological Survey
David J. Hart .....Hydrogeologist, WGNHS
Bryan D. Hartsook ..... Natural Resources Basin Supervisor, Wisconsin Department of Natural Resources
Craig Helker..... Water Resources Biologist, WDNR
Samantha J. Katt .....Urban Stormwater Specialist, Wisconsin Department of Natural Resources
Matthew T. Magruder .....Environmental Research Manager, Milwaukee Metropolitan Sewerage District
Cheryl Nenn..... Riverkeeper, Milwaukee Riverkeeper
Neal T. O'Reilly.....Director, Conservation and Environmental Science Program, UWM
Charles J. Paradis ..... Assistant Professor, Department of Geosciences UWM
Scott Schmidt.....Chief Public Works Officer/County Surveyor, Washington County Highway Department
Kurt Sprangers ..... Engineer in Charge, Environmental Engineering Section, Department of Public Works, City of Milwaukee
David Strifling..... Director, Water Law and Policy Initiative, Marquette University Law School
Michael Wieser.....Director, Engineering and Public Works, City of Cedarburg

Guests and Staff Present

Joseph E. Boxhorn .....Principal Planner, SEWRPC
Karin M. Hollister..... Principal Engineer, SEWRPC
James M. Mahoney .....Engineer, SEWRPC
Nicklaus J. Neureuther.....Specialist, SEWRPC
Mitchell T. Olds..... Water Resources Specialist, Milwaukee Metropolitan Sewerage District
Aaron W. Owens.....Senior Planner, SEWRPC
Justin P. Poinsatte ..... Principal Specialist, SEWRPC
Michael Timm.....Milwaukee Water Stories Program Manager, Reflo Milwaukee

Mr. Grisa welcomed everyone to the meeting. Ms. Herrick introduced the presenters and the agenda for the meeting to review Chapters 3 and 5 of SEWRPC Technical Report No. 62 *Impacts of Chloride on the Natural and Built Environment.*

[Secretary's Note: The agenda for this meeting is attached herein as Exhibit A.]

REVIEW OF THE SUMMARY NOTES FROM THE NOVEMBER 10, 2023, TECHNICAL ADVISORY COMMITTEE MEETING

At Ms. Herrick's request, Mr. Boxhorn reviewed the summary notes from the November 10, 2023, TAC meeting. He highlighted the fourth and fifth paragraphs on page 3 of the summary notes, explaining that in order to resolve the discussion regarding the efficacy of permeable and pervious pavement at eliminating the need to apply deicing chemicals, Commission staff contacted four units of local government that had experience with permeable and pervious pavement. He noted that based on their responses, any definitive statements about the effectiveness of permeable and pervious pavements in reducing chloride use were removed from the text.

TAC members offered no questions or comments on the review of the Summary Notes.

Mr. Boxhorn stated that he would review drafts of Chapters 3 and 5 of Technical Report No. 62. He explained that the TAC reviewed Chapters 1, 2, and 4 at its April 26, 2023, meeting. Mr. Boxhorn noted that he and former SEWRPC senior engineer Zijia Li were the principal authors of this report and that the figures were drafted by SEWRPC senior graphic designer Megan Deau and former SEWRPC administrative assistant Alexa Carzoli.

REVIEW OF PRELIMINARY DRAFT CHAPTER 3, "IMPACTS OF CHLORIDE ON BIOLOGICAL SYSTEMS," OF SEWRPC TECHNICAL REPORT NO. 62, *IMPACTS OF CHLORIDE ON THE NATURAL AND BUILT ENVIRONMENT*

Mr. Boxhorn stated that TR-62 is a review of the scientific and technical literature regarding impacts of chloride. He noted that the impacts may be caused by chloride, the cation associated with chloride, or salinity in general. He added that studies differ in how chloride is measured. Mr. Boxhorn explained that some studies report a concentration or mass of chloride, while others may report specific conductance or salinity. He noted that when the results of a study were summarized in the chapters, he followed the practice of the study being described.

Mr. Boxhorn began the review of draft Chapter 3 and noted that this chapter examines impacts on biological systems, including individual organisms, biological communities, and ecosystems. He indicated that the chapter reports chloride impact results on about 200 species of organisms. Mr. Boxhorn added that 57 percent of these species are found in Wisconsin and another 27 percent belong to genera found in Wisconsin. He noted that this is a tiny fraction of species in both Wisconsin and the rest of the world.

Mr. Boxhorn next summarized the sections of draft Chapter 3 that discuss toxicity. He defined acute and chronic toxicity and discussed factors that affect chloride toxicity, Wisconsin's water quality standards for chloride, and waterbodies in southeastern Wisconsin that exceed these standards. He noted that Appendix B presents the data from the literature on acute toxicity of chloride salts. TAC members offered no questions or comments on the discussion of toxicity.

Mr. Boxhorn summarized the sections of draft Chapter 3 that discuss the impacts of chloride on different types of organisms. He stated that these impacts are the results of toxic effects; however, he did not frame it this way in the text. Mr. Boxhorn explained that many different endpoints and effects are used to examine chronic toxicity and that this precluded being able to construct a table summarizing these impacts.

Mr. Timm asked what species of fish is shown in the picture showing reduced growth of fish due to exposure to road salt. Mr. Boxhorn replied that the picture is from a study conducted in Bill Hintz's laboratory at the University of Toledo.

[Secretary's Note: The fish shown are young rainbow trout (*Oncorhynchus mykiss*).]

Ms. Nenn asked whether there was any data on chloride impacts on freshwater mussels. Mr. Boxhorn responded that information on mussels is included in the section on impacts on macroinvertebrates. He added that he was unable to find any information on impacts of chloride on lizards or snakes. Members of the TAC offered no further questions or comments on the sections describing impacts of chloride on individual organisms.

Mr. Boxhorn summarized the section of draft Chapter 3 that discusses the impacts of chloride on biological communities. He noted that several impacts have been reported at thresholds well below the Wisconsin chronic toxicity water quality criteria of 395 milligrams per liter (mg/l) and the U.S. Environmental Protection Agency (USEPA) recommended chronic criteria of 230 mg/l and that this raised the question of whether current standards are adequately protective of aquatic communities. He noted that changing this might require USEPA to reexamine how it derives toxicity standards for the protection of aquatic life.

Ms. Nenn commented that organisms in streams are simultaneously impacted by multiple pollutants and stressors, some of which could be interacting with chloride. She noted that testing stream sites for compliance with the chronic toxicity criterion is difficult. She explained that this requires volunteers from her organization to sample the site on four consecutive days. She added that because of this we are probably underestimating the number of sites at which chloride concentrations exceed this standard. Mr. Boxhorn agreed. He explained that this is one of the reasons that Commission staff developed regression models for estimating chloride concentration from the level of specific conductance. He added that this effort would be discussed at the next TAC meeting on draft *TR-64 Regression Analysis of Specific Conductance and Chloride Concentrations.*

Mr. Boxhorn summarized the section of draft Chapter 3 that discusses the impacts of chloride on ecosystems. He noted that impacts on nutrient cycling were discussed in Chapter 2, so this section focuses on energy flow through ecosystems.

Mr. Corsi commented that he has observed elevated concentrations of chloride in streams that have persisted for periods of one to a few months. He asked whether we considered what would be found if these studies considered longer-term exposures rather than the results of toxicity tests that lasted for two to seven days. Mr. Boxhorn replied that the Chapter does review some long-term studies which examined impacts on organisms. He noted that these studies were not framed in terms of toxicity, but the impacts were clearly toxic effects.

Mr. Corsi commented that the way that water quality standards for chloride are developed might need to be reconsidered to account for instances of long-term exposure. Mr. Boxhorn agreed and explained that he examined the 1988 USEPA document that developed their recommended chloride criteria and the 1982 USEPA document that set forth the methodology for developing these types of water quality criteria. He noted that these documents assumed that chronic toxicity tests represented longer-term impacts and that a criterion that was developed for a four-day period would be protective for longer periods. Mr. Boxhorn commented that he is not sure that this is necessarily true and that he is still studying the calculations and how these criteria were developed.

Ms. Nenn commented that chloride concentrations in samples collected by the Milwaukee Metropolitan Sewerage District from Honey Creek in summer 2021 exceeded the acute toxicity standard. She added that exceedances have been detected in other streams as well. Mr. Boxhorn replied that he is not surprised that exceedances are occurring in Honey Creek. He noted that as part of the development of the watershed-based municipal stormwater discharge permit for the Menomonee River watershed, Commission staff used

a regression model developed by Mr. Corsi to estimate chloride concentrations from continuous measurements of specific conductance taken in this stream. Mr. Boxhorn noted that there were several periods during which estimated chloride concentrations in Honey Creek exceeded 1,400 mg/l, including one that lasted for 19 days. He added that TR-63 will examine chloride conditions in waterbodies of the Region.

Members of the TAC offered no further questions or comments on draft Chapter 3.

REVIEW OF SEWRPC PRELIMINARY DRAFT CHAPTER 5, "IMPACTS OF CHLORIDE ON HUMANS AND HUMAN ACTIVITIES," OF SEWRPC TECHNICAL REPORT NO. 62, *IMPACTS OF CHLORIDE ON THE NATURAL AND BUILT ENVIRONMENT*

Mr. Boxhorn next reviewed draft Chapter 5 and explained that the chapter examines health effects to humans and some other ways in which chloride may affect human activities. He noted that some health effects have been linked to sodium, which is the most common cation associated with chloride.

Mr. Grisa commented that the basis of using deicing salts on roads is to promote human health by reducing injuries and deaths due to traffic accidents. He suggested that a discussion of this be included in the text. Mr. Boxhorn agreed and noted that a section could be added to Chapter 5 discussing this benefit. Mr. O'Reilly asked whether the U.S. Department of Transportation has information on the reduction of accidents related to road salt use. Mr. Boxhorn replied that he will look into this and also discuss this with staff from the Commission's Transportation Division to see whether they are aware of any studies. Ms. Herrick asked Mr. Churchill whether the Wisconsin Department of Transportation had any information of reductions in accident rates due to road salt application. Mr. Churchill replied that he was not aware of any data related to this question.

Mr. Magruder suggested that a discussion of benefits of chloride use also include slip and fall accidents. Mr. Boxhorn replied that he would research this.

> [Secretary's Note: A section was added to Chapter 5 on the beneficial effects of chloride use to humans. This section discusses four topics: reduction of traffic accidents due to use of chloride deicers, reductions in slip and fall accidents due to chloride deicers, benefits of water softening, and the agricultural benefits of potassium chloride fertilizers. This section is included herein as Exhibit B.]

Mr. O'Reilly commented that building managers and other staff at the University of Wisconsin-Milwaukee have reported that windows on buildings near roads acquire a film from salt spray, increasing the cost of window cleaning in the spring. He noted that he has no cost data on this.

TAC members offered no further discussion on draft TR-62.

NEXT STEPS FOR THE PLAN

Mr. Boxhorn stated that staff will take comments on TR-62 until March 1, 2024. He added that they can be submitted through the Chloride Study webpage at www.sewrpc.org/chloridestudy or directly to him through email at jboxhorn@sewrpc.org.

Ms. Herrick reviewed the next steps for the Study. Work will continue with research and report writing, developing regression and loading analyses, and gathering information on state-of-the-art practices. She

stated that she anticipates that the next TAC meeting will be in April 2024 and consist of review of TR-64 which documents the development of regression models for estimating chloride concentrations from levels of specific conductance. She indicated that meeting presentations and summary notes along with draft chapters will be posted on the SEWRPC project website at www.sewrpc.org/chloridestudy.

ADJOURNMENT

There being no further business, the meeting was adjourned by unanimous consent at 11:42 a.m.

Respectfully submitted,

Laura Herrick
Recording Secretary

COMMENTS RECEIVED BY EMAIL PRIOR TO THE JANUARY 31, 2024, MEETING OF THE TECHNICAL ADVISORY COMMITTEE

On January 31, 2024, Commission staff received an email from Craig Helker, Water Resources Biologist, Wisconsin Department of Natural Resources, with comments on Chapter 3.

Mr. Helker commented that the discussion in the last paragraph of page 9 and the first paragraph of page 10 was confusing.

[Secretary's Note: The last sentence of the last paragraph on page 9 was revised to read (Revised or added text is shown in bold font. Normal font will be used in the Chapter):

"At the highest temperature tested, the LC50 chloride concentrations

represented between 3 and 27 percent of the concentrations at the temperatures where each species showed maximum tolerance**, indicating that the toxicity of chloride had increased substantially with the increase in temperature**."

The last sentence of the first paragraph on page 10 was revised to read:

"The amount of decrease is consistent with a general pattern observed in the acute toxicity of many substances in which an 18°F increase in temperature often leads to a two-to-four-fold reduction in the LC50, **conforming to a general pattern in which the toxicity of many substances increases substantially with increases in temperature.**"]

Mr. Helker suggested adding the ranges of hardness common in southeastern Wisconsin waterbodies to the discussion of the effects of hardness on the toxicity of chloride on pages 11-12.

[Secretary's Note: The following paragraph was added after the first full paragraph on page 12:

"Many waterbodies in southeastern Wisconsin contain hard water. For example, a study of water quality in six watersheds of the Region found that average hardness ranged from 253 mg/l as calcium carbonated ($CaCO_3$) in the Kinnickinnic River to 374 mg/l as $CaCO_3$ in the Root River.[*]"

"* *SEWRPC Technical Report No. 37*, Water Quality Conditions and Sources of Pollution in the Greater Milwaukee Watersheds, *November 2007."*]

Relative to the reference to submerged, rooted aquatic plants on page 29, Mr. Helker noted that coontail does not root, per se, and suggested using a different example.

[Secretary's Note: The reference to coontail (*Ceratophyllum demersum*) in the fourth sentence of the second paragraph on page 29 was changed to eelgrass (*Vallisneria americana*).]

Mr. Helker suggested that the differences between the results observed in *Potamogeton* species versus *Ranunculus circinatus* in the last paragraph on page 31 may reflect differences between the two genera.

[Secretary's Note: The following sentence was added to the end of the last paragraph of page 31:

"The differences in the results between the *Potamogeton* species and *R. circinatus* may reflect differences in the sensitivities of these two genera to this concentration of chloride."]

In reference to the discussion of macroinvertebrate strategies for dealing with salinity in the first full paragraph on page 43, Mr. Helker suggested emphasizing the fact that salt marsh mosquitoes are brackish water species.

[Secretary's Note: The third sentence of the first full paragraph on page 43 was revised to read:

"Some macroinvertebrate species such as salt marsh mosquitoes **which inhabit brackish water environments**, are capable of this, but many others lack this ability."]

Mr. Helker suggested changing reference to the Asian Clam to freshwater golden clam, as that is the common name for this organism that is currently used by the Wisconsin Department of Natural Resources.

[Secretary's Note: References to Asian clam were changed to freshwater golden clam throughout the Chapter and Appendix B.]

ATTACHMENTS

Exhibit A – Meeting Agenda (271466)
Exhibit B – Benefits of Chloride Use Section for TR-62 Chapter 5 (271885)

#271791 – TR-62 SUMMARY NOTES CHLORIDE TAC-January 31, 2024
200-1100
LKH/JEB
2/7/24, 3/6/24

Exhibit A

Southeastern Wisconsin Regional Planning Commission

Notice of Meeting and Agenda

TECHNICAL ADVISORY COMMITTEE FOR
A CHLORIDE IMPACT STUDY FOR THE SOUTHEASTERN WISCONSIN REGION

DATE: Wednesday January 31, 2024

TIME: 10:00 am to Noon

TEAMS LINK:
Join on your computer, mobile app or room device
Click here to join the meeting
Meeting ID: 215 060 441 167
Passcode: ddsupM

AGENDA:

1. Roll call

2. Review of summary notes from the November 10, 2023, TAC meeting

3. Review preliminary draft **SEWRPC Technical Report No. 62, Impacts of Chloride on the Natural and Built Environment**
    a. Chapter 3 – Impacts of Chloride on Biological Systems
    b. Chapter 5 – Impacts of Chloride on Humans and Human Activities
    c. Appendices

4. Next steps

5. Adjourn

Laura K. Herrick
Chief Environmental Engineer

The summary notes and preliminary draft chapters can be found on the Study webpage at www.sewrpc.org/chloridestudy

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1/4/24

Exhibit B

#271885 – TR-62 (Chloride Study Impacts) Chapter 5 - Insert
200-1100
LKH/JEB
2/14/24, 3/6/24

SEWRPC Technical Report No. 62

IMPACTS OF CHLORIDE ON THE NATURAL AND BUILT ENVIRONMENT

Chapter 5

IMPACTS OF CHLORIDE ON HUMANS AND HUMAN ACTIVITIES

5.2 BENEFITS OF CHLORIDE SALT USE TO HUMANS

The use of chloride salts provides several benefits to humans. These include improving traffic safety, improving the safety of pedestrians, reducing the infrastructure problems associated with hard water, and improving crop production. This section describes several benefits of chloride use.

Traffic Safety

Road and weather conditions during winter present challenges to motorists. Weather events, including heavy snow as the most severe condition, can reduce traffic volumes by up to 44 percent, reduce average speeds by up to 40 percent, reduce road capacity by up to 30 percent, and increase travel time delays by up to 50 percent.[1] Snow-, slush-, and ice-covered roads can produce hazardous driving conditions which can lead to accidents that cause deaths, injuries, and property damage. Snow, slush, and ice reduce friction between the pavement and vehicle tires, making safe operation of the vehicle more difficult. This hazard can be compounded by at least two issues. First, ice is not always visible to motorists, nor is it uniformly distributed on pavement. Second, snowstorms affect driver behavior leading to lower speeds and more variable speeds, which increases the risk of accidents occurring.[2]

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[1] *U.S. Federal Highway Administration,* How Do Weather Events Impact Roads?, *2018.*

[2] *X. Qin, D.A. Noyce, C. Lee, and J.R. Kinar, "Snowstorm Event-Based Crash Analysis,"* Transportation Research Record, Journal of the Transportation Research Board*, 1,948(1):135-141, 2006.*

In 2021, there were 24,234 traffic accidents reported on roads in Wisconsin that were covered by snow, slush, and/or ice.[3] These accidents represented about 19 percent of the traffic accidents that occurred in the State that year. In 45 of these accidents at least one person was killed, and in another 3,655 of these accidents at least one person was injured.

Winter weather and the presence of snow, slush, and ice on roads can increase the rates at which accidents occur. A comparison of crash rates in the State of Washington found that the frequency of traffic accidents in the presence of snow was about five times the frequency of accidents under clear conditions.[4] This study also found that about twelve times the number of accidents occurred in Washington during the month of January than occurred during the month of July.

The response to winter weather can affect the likelihood that accidents will occur. A study that investigated the impact of snowstorms on Wisconsin State Trunk Highways found that a large percentage of accidents that occur during a snowstorm happen during the initial stages of the storm.[5] The authors attributed this to the fact that winter maintenance activities have not begun during the early stages of a storm. This study also found that during later stages of a snowstorm, a greater percentage of accidents occurred on local roads than on State highways. They may reflect that these roads receive different levels of winter maintenance.

Some studies have attempted to evaluate the effects of applying chemical deicers to roads on accident rates during snowstorms. One such study documented accident rates before and after winter road maintenance operations began during winter storm events over a four-year period in Germany.[6] This study examined over 4,700 accidents that occurred on about 400 miles of roads in rural and suburban areas. It analyzed hourly accident rates in the 12 hours before and after application of deicing salt began. During

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[3] *Wisconsin Department of Transportation, "2021 Crash Facts," www.content.dot.wi.gov/content/crashfacts/2021/index.html, accessed February 9, 2024.*

[4] *L.C. Goodwin,* Best Practices for Road Weather Management, *U.S. Federal Highway Administration Report No. FHWA-OP-03-081, 2003.*

[5] *Qin et al. 2006,* op. cit.

[6] *H. Hanke and C. Levin,* Influence of Winter Road Maintenance on Traffic Safety and Transport Efficiency, *Darmstadt Technical University, Darmstadt, Germany, 1988, in German described in D. Kuemmel and R. Hanbali,* Accident Analysis of Ice Control Operations*, Department of Civil, Construction, and Environmental Engineering, Marquette University, Milwaukee, Wisconsin, June 1, 1992.*

the 12-hour period prior to salt spreading, traffic accident rates ranged between about 2.8 and 16.7 accidents per motor vehicle miles traveled (MVMT), averaging about 9.6 accidents per MVMT over the period. In the 12 hours following salt application accident rates ranged between about 1.9 and 4.0 accidents per MVMT, averaging about 2.7 accidents per MVMT.

A second study used similar methods to examine the effectiveness of deicer application on reducing accidents on two-lane highways and freeways in nine counties in the States of Illinois, Minnesota, New York, and Wisconsin during the winter of 1990-1991.[7] On two-lane highways, this study compared the rates of accidents in the four hours before and after salt application began. It found that salt application reduced the rates of all accidents on two-lane roads during the four hours following salt application by about 87 percent. After deicing the accidents resulting in at least one injury and accidents with property damage were reduced by 88 percent and 85 percent, respectively. The study also found that salt application reduced the average cost of an accident by about 10 percent. This study also compared the rates of accidents on freeways in the two hours before and after salt application began. It found that salt application reduced the rates of all accidents on freeways during the two hours following salt application by about 78 percent. After deicing the freeway accidents resulting in at least one injury and accidents with property damage were reduced by 85 percent and 56 percent, respectively. The study also found that salt application reduced the average cost of a freeway accident by about 30 percent. The study cost-benefit analysis concluded that salt application on two-lane highways provides $6.50 of benefit for every $1.00 spent. Similarly, the study found that salt application on freeways provides $3.50 for every $1.00 spent. Note that an additional cost-benefit analysis of road salting is provided in Chapter 4 of this Report.

Subsequent research has criticized the before and after comparison methodology used in the studies described in the previous two paragraphs for not controlling for factors that could potentially confound the results.[8] A third study constructed a computer model based on a road surface condition index. This model controlled for factors such as weather, road geometry, and traffic. This study found that road salt application could reduce the number of accidents by between 20 and 85 percent, depending on the existing conditions when salt is applied and the degree of improvement in road conditions following salt application.

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[7] *Kuemmel and Hanbali 1992,* op. cit.

[8] *L. Fu and T. Usman,* Safety Impacts of Using Deicing Salt*, Department of Civil and Environmental Engineering, University of Waterloo, Waterloo, Ontario, Canada, 2014.*

This study also conducted a before and after comparison similar to the comparisons made in the studies previously described.[9] This comparison was conducted using finer scale methods that allowed the authors to separate the effects of only salting on accident rates from those of salting combined with snow plowing. The comparisons also examined a wider range of highway types than in the previous studies. This study found that salting alone led to a 51 percent reduction in accident rates. Salting combined with snow plowing led to a 65 percent reduction in accident rates. The authors stated that these reduction magnitudes should be interpreted cautiously because this type of comparison lacks controls for factors such as visibility, traffic volume, traffic speed, and wind speed. While they were confident that winter road maintenance activities had reduced accident rates, they were less confident about the magnitude of the reductions.

In conclusion, the results of all of these studies indicate that that the use of deicing salts as part of winter road maintenance provides benefits to humans by reducing the number of traffic accidents and the fatalities, injuries, and property damage caused by such accidents. The magnitude of this benefit is difficult to determine, both because it is hard to separate the effects of salting from those of other winter road maintenance activities such as snow plowing and how numerous other factors such as type of road, traffic volume, traffic speed, and visibility affect accident rates.

Slip and Fall Prevention

The use of chloride-based deicers can help to prevent slip and fall accidents. Accumulation of snow and ice on surfaces like sidewalks, parking lots, steps, and ramps make walking difficult. This can lead to greater risk of slip and fall accidents that can result in injuries. A study of seasonal variations in fall-related hospital emergency department visits found that the number of such visits was higher during the winter than during other seasons.[10] Studies have also found that a higher risk of fall injuries occurs immediately after periods of snowfall and freezing rain.[11]

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[9] Ibid.

[10] *R.S. Kakara, B.L. Moreland, Y.K. Haddad, I. Shakya, and G. Bergen, "Seasonal Variation in Fall-Related Emergency Department Visits by Location of Fall—United States, 2015,"* Journal of Safety Research*, 79:38-44, 2021*.

[11] *A.N. Dey, P. Hicks, S. Benoit, and J.I. Tokars, "Automated Monitoring of Clusters of Falls Associated with Severe Winter Weather Using the BioSense System,"* Injury Prevention*, 16:403-407, 2010; K. Gevitz, R. Madera, C. Newbern, J. Lojo, and C.C. Johnson, "Risk of Fall-Related Injury Due to Adverse Weather Events, Philadelphia, Pennsylvania, 2006-2011,"* Public Health Report*, 132(1 Supplement): 53S-58S, 2017; J.F. Bobb, K.K. Ho, R.W. Yeh, L. Harrington, A. Zai, K.P. Liao, and F. Dominici, "Time-Course of Cause-Specific Hospital Admissions During Snowstorms: An Analysis of Electronic Medical Records from Major Hospitals in Boston, Massachusetts,"* American Journal of Epidemiology*, 185:283-294, 2017*.

The presence of snow and/or ice is a major factor contributing to slip and fall accidents. A study examining fall accidents among 40 postal delivery workers in the United Kingdom found that about 40 percent of these accidents involved snow and another 30 percent involved ice.[12] A follow up to this study examined fall accident data among 1,734 postal delivery workers over a two-year period.[13] This study found that the most common event initiating a fall was a foot slipping, with about 46 percent of these slips occurring on ice. The study also found that slipping accidents tended to be clustered on single days where heavy snowfall or ice made conditions particularly hazardous. In addition, over 90 percent of the employees whose falls were investigated mentioned that snow or ice was one of the contributing factors.

Adults aged 65 years and older are particularly vulnerable to slip and fall injuries. In 2018 in the United States, fall-related injuries led to about three million hospital emergency department visits, over 950,000 hospital admissions, and about 32,000 deaths among older adults.[14] Not all of these fall-related injuries were caused by snow and ice conditions. Further examination of the data showed that about 72 percent of these injuries occurred indoors with the remaining 28 percent occurring outdoors.[15] This suggests that the presence of snow and ice was probably still a factor in a substantial number of falls among older adults.

Application of deicing chemicals can reduce the risk of slip and fall accidents by reducing ice buildup on surfaces. Proper application of deicing salts is discussed in an accompanying technical report.[16]

Water Softening

Hardness of water is caused by dissolved minerals, especially dissolved ions of calcium and magnesium. Groundwater in most of the Southeastern Wisconsin Region is either hard or very hard, with hardness of

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[12] *R.A. Haslam and T.A. Bentley, "Follow-Up Investigations of Slip, Trip, and Fall Accidents among Postal Delivery Workers,"* Safety Science*, 32:33-47, 1999.*

[13] *T.A. Bentley and R.A. Haslam, "Slip, Trip, and Fall Accidents Occurring during the Delivery of Mail,"* Ergonomics*, 41:1,859-1,872, 1998; T.A. Bentley and R.A. Haslam, "Identification of Risk Factors and Countermeasures for Slip, Trip, and Fall Accidents During the Delivery of Mail,"* Applied Ergonomics*, 32:127-134, 2001.*

[14] *B. Moreland, R. Kakara, and A. Henry, "Trends in Nonfatal Falls and Fall-Related Injuries among Adults Aged ≥ 65 Years—United States, 2012-2018,"* Morbidity and Mortality Weekly Report*, 69:875-881, 2020.*

[15] *B.L. Moreland, R. Kakara, Y.K. Haddad, I. Shakya, and G. Bergen, "A Descriptive Analysis of Older Adult Falls that Resulted in Emergency Department Visits in the United States, 2015,"* American Journal of Lifestyle Medicine*, 15:590-597, 2020.*

[16] *SEWRPC Technical Report No. 66,* State of the Art in Chloride Management*, in preparation.*

shallow groundwater in much of the Region being greater than 180 milligrams per liter as calcium carbonate.[17] This can lead to problems as much of the Region uses groundwater as a source of water supply.

Several problems are associated with the use of hard water. Hard water can lead to formation of lime scales that have damaging effects on plumbing and appliances.[18] Scale can clog pipes, reducing water flow. An example of this is shown in Figure 5.1. Scale can also reduce the efficiency of boilers and water heaters, sometimes by as much as 50 percent.[19] Appliances such as washing machines and dishwashers can also be damaged by scale. Mineral deposits from hard water can damage chrome fixtures. These impacts from hard water can increase the costs of operating water heaters and other appliances and can ultimately shorten their useful lives, leading to early replacement and the associated costs.

The calcium and magnesium ions in hard water also reduce the effectiveness of soaps, detergents, and other cleaning agents. This can require the use of more detergent to achieve clean conditions as compared to what could be achieved using soft water. For example, one study of laundry detergents found that powdered detergents performed significantly worse in hard water than in soft water.[20] Bringing clothing washed in hard water to the same level of cleanliness as was achieved in soft water required the use of 10 to 30 percent more detergent, which increases the cost of cleaning. Cleaning using hard water can also lead to problems such as the formation of films on dishes, glasses, and sinks, and dingy looking clothing.

In homes and businesses, hard water is often treated by point of entry ion exchange water softeners. These softeners capture calcium and magnesium ions on an ion exchange resin and release sodium to the water. The resin is periodically recharged by passing a sodium chloride brine through the softener which results in a waste stream containing chloride ions. Proper calibration and use of water softeners and potential alternatives to ion exchange methods for softening are discussed in an accompanying technical report.[21]

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[17] *SEWRPC Technical Report No. 37,* Groundwater Resources of Southeastern Wisconsin*, June 2002.*

[18] *A.J. Heidekamp and A.T. Lemley,* Water Bulletin: Hard Water, *Cornell University Cooperative Extension, April 2005.*

[19] *U.S. Department of Energy, "Reasons Every Home Should Have a Water Softener," www.energy.gov/energysaver/articles/reasons-every-home-should-have-water-softener. September 13, 2023, accessed February 6, 2024.*

[20] *B.A. Cameron, "Detergent Considerations for Consumers: How Much Extra Detergent is Required?"* Journal of Extension*, 49(4):4RIB6, 2011.*

[21] *SEWRPC Technical Report No. 66,* op. cit.

Crop Growth

Chloride salts are used as fertilizers for plant growth. As discussed in Chapter 3 of this report, chloride is an essential micronutrient for plants. Chloride deficiency can occur when soils contain very low levels of chlorides. Soils commonly contain about 20,000 parts per million (ppm) potassium. Most of this is unavailable to plants because it is bound in the crystalline structure of minerals in the soil. Weathering of these minerals can release potassium, but this occurs too slowly to supply the needs of crops.[22] As a result, potassium fertilizers are often applied to agricultural fields. Potassium chloride, also known as muriate of potash, is the most commonly used potassium fertilizer.[23] Alternatives to the use of potassium chloride are discussed in an accompanying technical report.[24] The use of potassium chloride fertilizer adds about 0.9 pound of chloride to soil for every pound of potassium added.[25]

The symptoms of chloride deficiency vary among different plants. In wheat this deficiency appears as random spots of yellowing on leaves.[26] Crops experiencing chloride deficiency have been reported in the States of Kansas and Montana[27] but not in Wisconsin.[28]

Potassium chloride is commonly applied to agricultural lands because potassium is an essential macronutrient for plants. Shortages of potassium in soils can markedly reduce crop yields.[29] Shortages of

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[22] *E.E. Schulte and K.A. Kelling,* Understanding Plant Nutrients: Soil and Applied Potassium*, University of Wisconsin Extension Fact Sheet A2521, no date*

[23] *E.E. Schulte, L.M. Walsh, K.A. Kelling, L.G. Bundy, W.L. Bland, R.P. Wolkowski, J.B. Peters, and S.J. Sturgul,* Management of Wisconsin Soils (fifth edition)*, University of Wisconsin-Extension, 2005.*

[24] *SEWRPC Technical Report No. 66,* op. cit.

[25] *E.E. Schulte,* Understanding Plant Nutrients: Soil and Applied Chlorine, *University of Wisconsin-Extension Fact Sheet A3556, 1999.*

[26] *R.E. Lamond, and D.F. Leikam,* Chloride in Kansas: Plant, Soil, and Fertilizer Considerations*, Kansas State University, December 2002.*

[27] Ibid.

[28] *Schulte 1999,* op. cit.

[29] *K.A. Kelling, L.G. Bundy, S.M. Combs, and J.B. Peters,* Optimum Soil Test Levels, *University of Wisconsin-Extension R-11-99-2M-100, 1999.*

potassium can also reduce crop quality. For example, insufficient potassium in soils reduce the percentage of legumes occurring in pasture plants.[30]

Potassium has several roles in plant nutrition.[31] It is important in the movement of water, nutrients, and carbohydrates through plants. In corn, potassium helps prevent breakage of corn stalks below the ear.[32] The overall effects of potassium on plant growth include:

- Increased root growth
- Improved drought resistance
- Reduced water loss and wilting
- Increased plant protein contents
- Retardation of some crop diseases

The symptoms of potassium deficiency vary among species of plants.[33] On field crops, this deficiency appears as yellowing or scorching on the margins of older leaves. On other crops, it may appear as whitish-gray spots on the outer margins of recently matured and older leaves. As the deficiency increases, leaves may turn completely yellow or drop off the plant. Examples of plants suffering from potassium deficiency are shown in Figure 5.2.

Plant requirements for potassium vary among species.[34] Corn, soybeans, and small grains have relatively low potassium requirements. Alfalfa, beans, clovers, wheat, and some other field crops have intermediate

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[30] *K. Barnett, T. Cadwallader, R. Halopka, M. Bendixen, and N. Schneider, "Potassium Fertilizer Management of Pastures,"* Graziers Notebook, *5(2):1-6, 2011.*

[31] *University of Minnesota Extension, "Potassium for Crop Production," extension.umn.edu/phosphorus-and-potassium/potassium-crop-production, accessed February 6, 2024.*

[32] *Kelling et al. 1999,* op. cit.

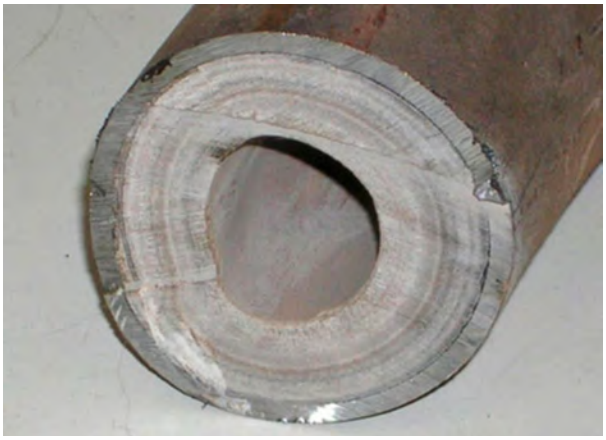
[33] *Schulte and Kelling nd,* op.cit.

[34] *C.A.M. Laboski and J.B. Peters,* Nutrient Allocation Guidelines for Field, Vegetable, and Fruit Crops in Wisconsin, *University of Wisconsin-Extension, 2012.*

needs. Tomatoes, peppers, and leafy greens have relatively high needs. Potatoes have very high needs. Potassium is removed from agricultural fields in the harvest portions of crops. When optimum amounts of potassium for the intended crop and yield are present in the soil, only enough potassium fertilizer should be applied to replace the amount of potassium removed through harvesting.[35]

[35] Ibid.

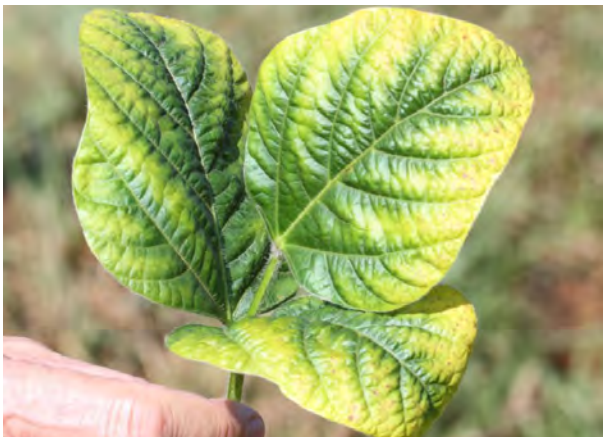
Figure: 5.1
Scale Build-up in a Water Pipe



Source: Wikimedia User Alexander Yurievich Lebedev

Figure 5.2
Symptoms of Potassium Deficiency in Crop Plants

Soybean



Cabbage

Source: Wikimedia Commons User Alan D. Manson