Freshwater Salinization Within La Crosse County Waters: Current Status, Consequences and Solutions

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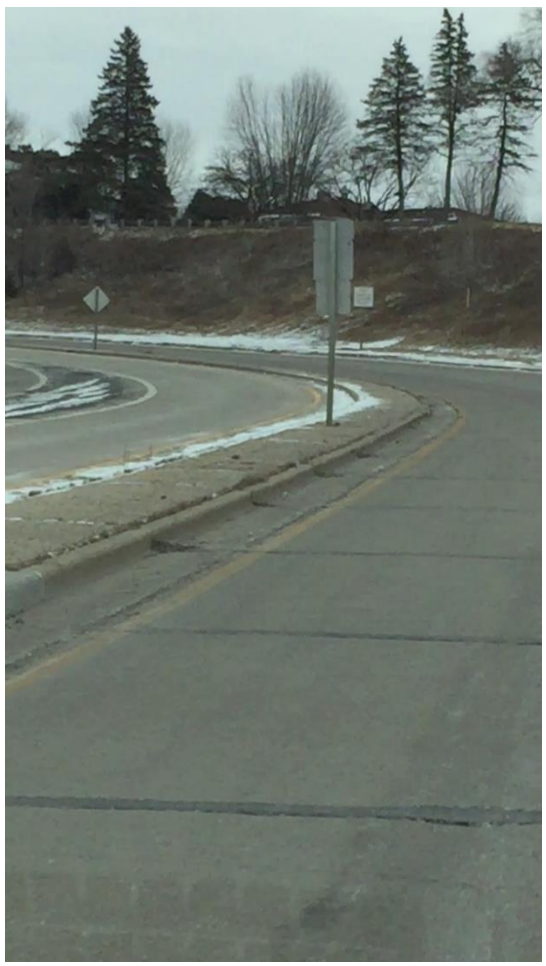

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Introduction

Salinization occurs when mineral salts, dominated by chloride, are loaded to surface waters. The salinization of freshwater has become a major ecological problem in recent decades due to anthropogenic activities that add salts to the environment. Natural background levels of chloride are driven by the weathering of rock and are typically very low in unimpacted freshwaters. Chloride budgets developed for states in the northern United States typically list de-icing salts as, by far, the major source of chloride, followed by potassium chloride fertilizer use and water softening equipment (Overbo et al. 2019). Urban environments have been linked to increased chloride concentration due to the increase in impervious surfaces in urban settings and the use of deicing salts on those surfaces (Corsi et al. 2015).

Freshwater organisms can differ widely in the level of salinity they can tolerate. Many species of fish, invertebrates, plants and amphibians are highly sensitive to elevated chloride concentration (Kefford et al. 2016). Elevated chloride concentrations can lead to an overall reduction of ecological integrity and biodiversity in aquatic ecosystems (Canedo-Arguelles et al. 2013). Currently, thousands of North American rivers and lakes are at significant risk for salinization over the long term (Dugan et al. 2017; Kaushal et al. 2018).

The pace of freshwater salinization has resulted in increased attention directed toward chloride in recent years. The term "freshwater salinization syndrome" has become popular in the scientific literature and is used to describe a suite of symptoms that range from ecosystem degradation to infrastructure corrosion (Kaushal et al. 2018). Chloride is also of concern for drinking water systems. Corrosion related to elevated chloride can result in corrosion of lead and copper drinking water lines creating contaminated drinking water (Stets et al. 2018). Elevated chloride has also been shown to interfere with lake mixing and turnover processes (Novotny et al. 2008). Very high chloride concentration has been shown to result in reduced zooplankton abundance, causing a trophic cascade that resulted in elevated phytoplankton abundance (Jones et al. 2017). Excessive use of salt has been linked to groundwater contamination (Kincaid and Findlay 2009). Other work has pointed to the inadequacy of current regulations to protect freshwater ecosystems from salinization and its negative consequences (Schuler et al. 2009).

Chloride in Wisconsin surface waters continues to increase on an annual basis. All 43 of the Wisconsin Department of Natural Resources Long Term Trend River water quality sites are indicating increasing chloride concentrations. Most sites are indicating 1-4% annual increase in chloride, with some sites increasing >10% annually. This trend is consistent with trends in the northern United States that have indicated a doubling of chloride concentration in recent decades (Corsi et al. 2015). Chloride accounts for 3% of impaired water pollutant listings in Wisconsin. More than half of these listings were added in the 2016 and 2018 reporting cycle and are in the Milwaukee Area. It is becoming clear that the current pattern in salt usage is unsustainable and there is a strong desire for communities in western Wisconsin to act before impaired waters listings begin to occur.

The Wisconsin chloride standards are set to protect aquatic life from chronic (long-term) and acute (short-term) toxicity. The Wisconsin criterion for chronic toxicity is 395 mg/L and 757 mg/L for acute toxicity. Chloride levels may be assessed at any time during the year because the aquatic community may be detrimentally impacted regardless of season; however, levels tend to be highest after snow melts. A waterbody is considered impaired for chronic toxicity if a 4-day average of the daily maximum values taken from 4 consecutive days exceeds the chronic criterion more than once in a three-year period. For acute toxicity, a waterbody is considered impaired if the daily maximum exceeds the acute criterion more than once in a three-year period. The USEPA criteria indicates that freshwater organisms should not be affected unacceptably if the four-day average of dissolved chloride, when associated with sodium, does not exceed 230 mg/L (chronic) more than once every three years on average and if the one-hour average concentration does not exceed 860 mg/L (acute) more than once every three years on average.

Elevated sodium concentration in surface and groundwater is also becoming problematic. Most deicing salts are typically applied as sodium chloride resulting in elevated sodium in addition to chloride. Present EPA guidance states that individuals on salt restricted diets should not drink water with sodium concentration >20 mg/L (US EPA 2003). Currently, many wells throughout the state are above this level with many more at risk of exceeding this level in the coming years. In recent decades, wells in the City of Onalaska and City of La Crosse have begun to exceed 20 mg/L sodium (WI DNR Sanitary Survey Reports- La Crosse and Onalaska 2017). One well site in La Crosse with elevated sodium (>70 mg/L) is associated with a former deicing salt pile that wasn't covered in a timely enough fashion in the past. The elevated chloride associated with this well resulted in the La Crosse Brewery having to install an interceptor well to ensure low sodium source water.

This monitoring project was designed to answer the following questions: 1) What is the status of chloride and sodium concentration in surface waters within La Crosse County? 2) How do current chloride concentrations compare to established chloride toxicity standards? 3) How does the concentration of these parameters change on a seasonal basis? This project will establish an important data baseline that can be used for future comparison. Initiatives designed to reduce chloride loading to the environment are proposed (e.g., conversion to brine road salting and conversion to more efficient water softening systems). This dataset provides a measuring stick to document the efficacy of these management changes.

Methods

Water samples were collected at twenty sites within La Crosse County, WI (Figures 1 and 2). Samples were collected 0.2m below the water surface. Most sampling sites were collected in stream with waders, while bridge site samples were collected using a clean sampling bucket following two rinses. Samples were collected quarterly

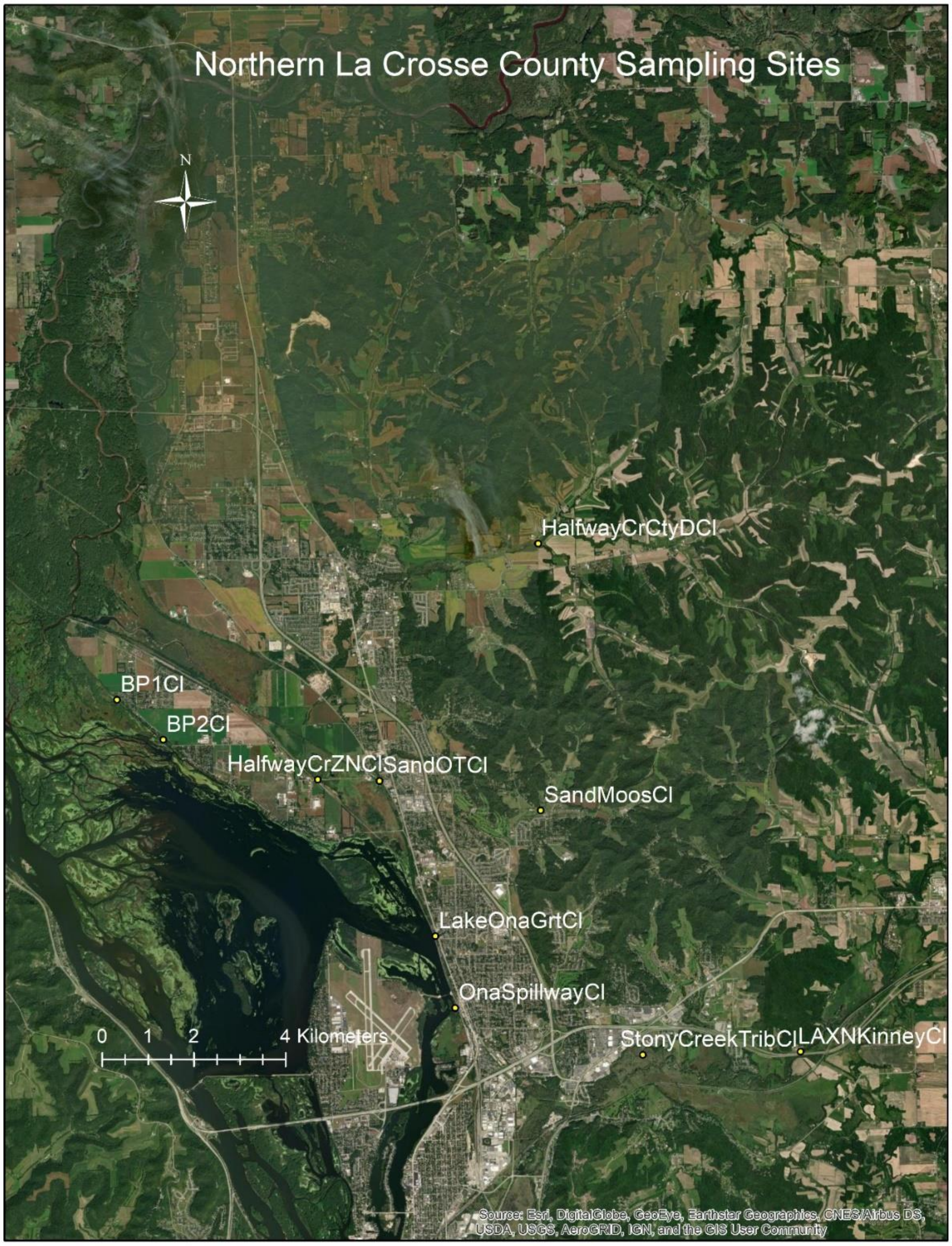

Figure 1: Northern La Crosse County sampling sites.

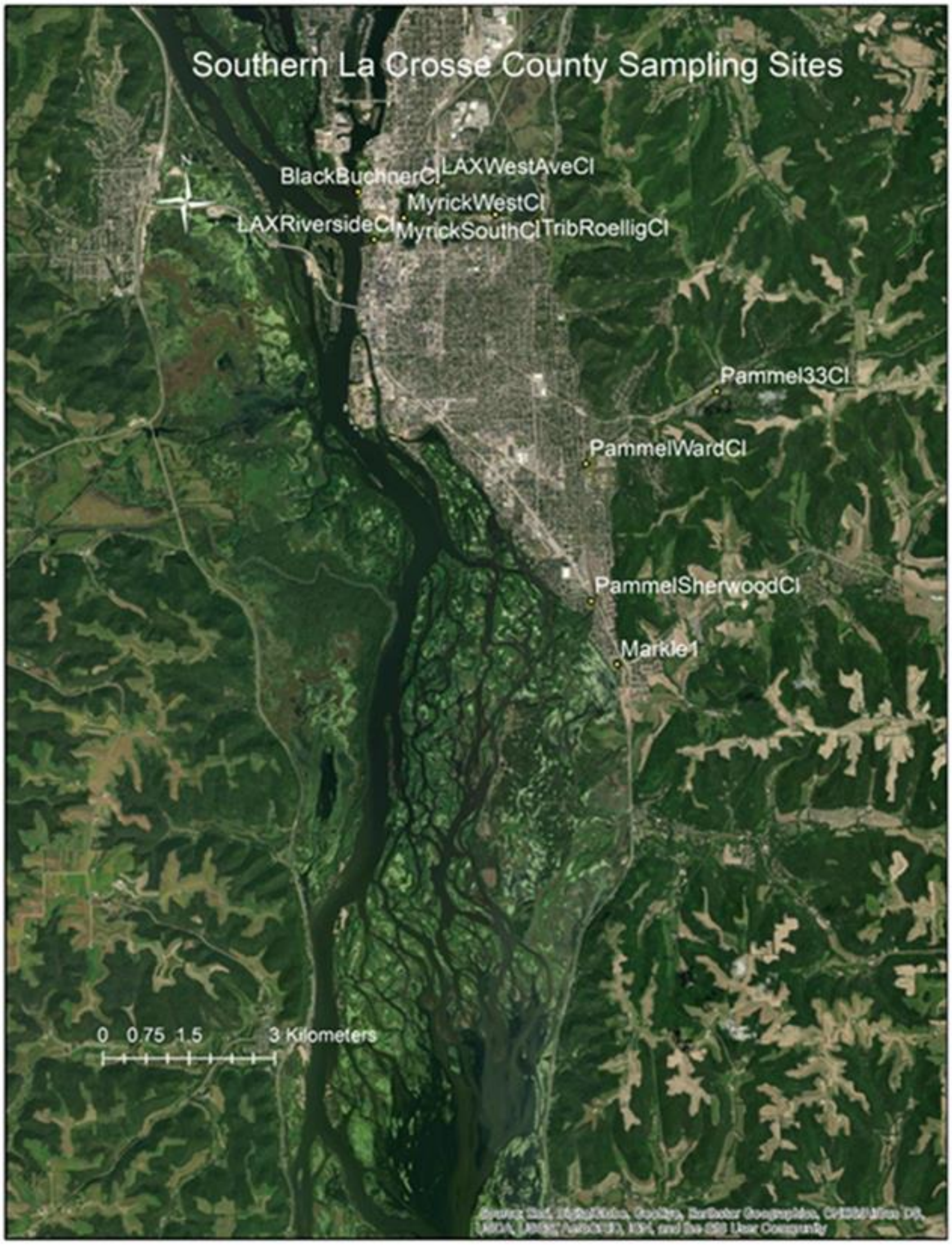

Figure 2: Southern La Crosse County sampling sites.

with the first sample collection occurring July 2020 (also-October 2020; January 2021; April 2021). Two additional sampling events occurred during the winter months and were timed to coincide with days above freezing to document melt of accumulated snow. The February melt off sampling event occurred during a period of significant snow melt while the early-March sampling event occurred during a period which snowpack prior to the thaw was minimal. Samples were collected, stored on ice, refrigerated and shipped to the Wisconsin State Lab of Hygiene (Madison, WI) the following day for analysis. All six sampling events were analyzed for chloride, while the July and January quarterly samples were also analyzed for sodium to develop a relationship between chloride and sodium (Figure 3). The water data were analyzed in relation to land use utilizing the Wiscland2 land cover dataset. The most explanatory land cover variables were developed land, high intensity (areas with 50% or greater impervious cover of man-made materials) and developed land, low intensity (areas with 25% or greater solid impervious cover of man-made materials, but less than 50%). Both developed land metrics were summed together into a total developed land metric for analysis. Linear regression was used for the land cover analysis. Data were analyzed by sampling site and season using SigmaPlot (version 11) and compared with Wisconsin and US EPA acute and chronic toxicity values.

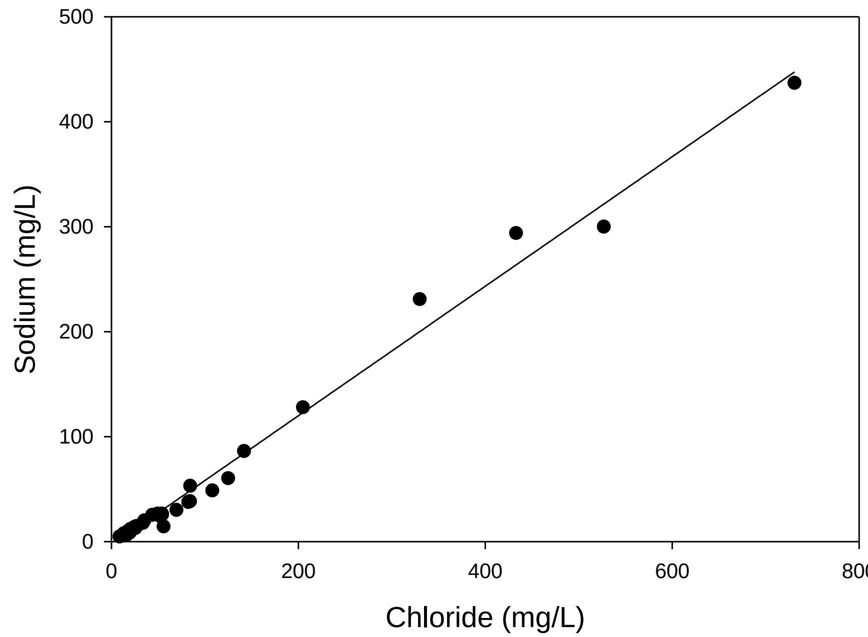

Figure 3: Relationship between chloride and sodium during the July 2020 and January 2021 sampling events (R^2=0.9898).

Monthly data from the Wisconsin DNR Long Term River monitoring site on the Mississippi River at Lock and Dam 9 (Lynxville, WI) were also analyzed. Data were analyzed using linear regression and Mann-Whitney Rank Sum tests to assess chloride seasonality and trends at this site from 1982-2020.

Results and Discussion

Chloride samples collected quarterly indicated the highest concentrations during winter, followed by spring, fall and summer (Figure 4). Exceedances of Wisconsin and EPA chronic toxicity were common during the winter months and to a lesser degree during spring. Sodium samples were higher during January than July with frequent exceedances of US EPA recommended drinking water recommendation for people on

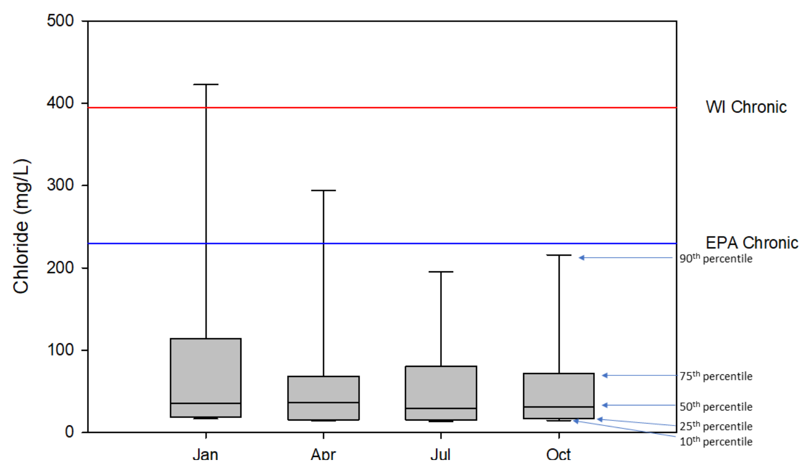

Figure 4: Quarterly La Crosse County chloride data from 2020-2021. Boxplots represent the 10th, 25th, 50th, 75th and 90th percentiles. The red and blue lines represent the Wisconsin (395 mg/l) and US EPA (230 mg/L) chronic toxicity values.

salt restricted diets (< 20 mg/L sodium; Figure 5).

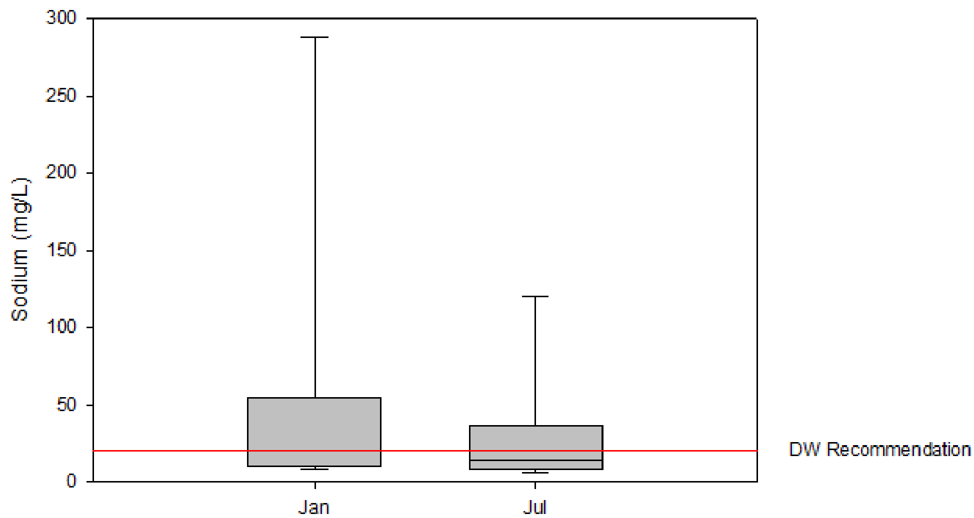

Figure 5: La Crosse County January 2020 and July 2021 sodium data. Boxplots represent the 10th, 25th, 50th, 75th and 90th percentiles. The red line represents the US EPA (< 20 mg/L) drinking water recommendation for people on a salt restricted diet.

Analysis of the quarterly chloride data revealed a wide range of concentrations throughout the county with numerous exceedances of WI and USEPA chronic toxicity criteria (Figure 6). Quarterly sodium data revealed a similarly wide range of conditions throughout the county (Figure 7).

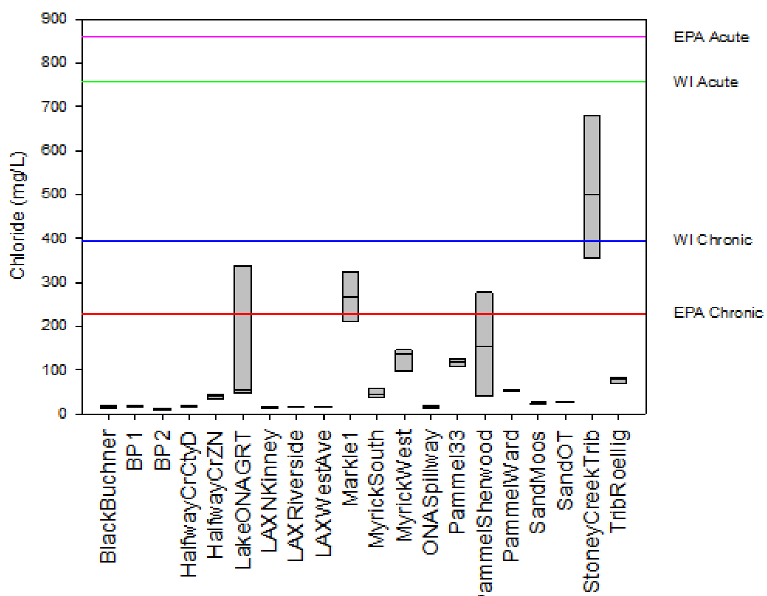

Figure 6: Quarterly La Crosse County chloride data from 2020-2021. Boxplots represent the 25th, 50th and 75th percentiles. The lines represent the Wisconsin (395 and 757 mg/l) and US EPA (230 and 860 mg/L) chronic and acute toxicity values.

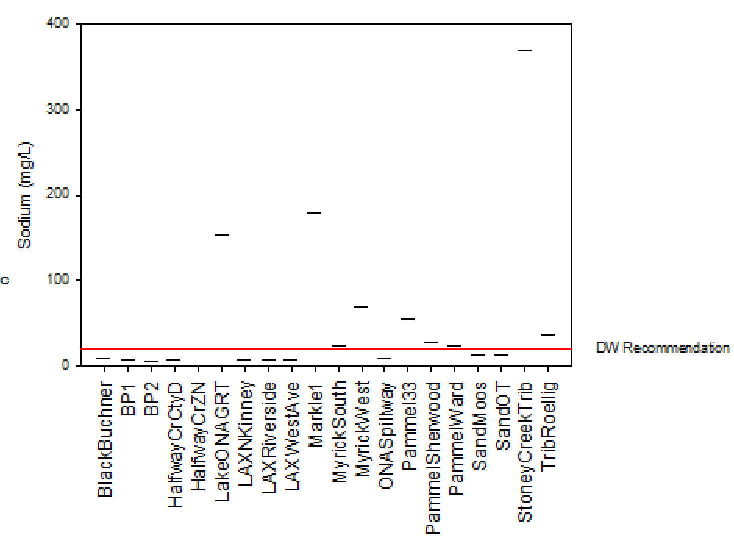

Figure 7: La Crosse County January 2020 and July 2021 sodium data. Black lines represent the median. The red line represents the US EPA (<20 mg/L) drinking water recommendation for people on a salt restricted diet.

Winter chloride data also revealed a wide range of concentrations throughout the county with numerous exceedances of WI and USEPA chronic and acute toxicity criteria (Figure 8). Of these three winter sampling events, two were designed to capture melt off events resulting in values that are likely higher than typical winter conditions. Of the 120 total study samples from all six sampling events:

- 10.83% exceeded US EPA chronic toxicity criteria (> 230 mg/L Cl)
- 7.5% exceeded Wisconsin chronic toxicity criteria (> 395 mg/L Cl)
- 3.33% exceeded Wisconsin acute toxicity criteria (> 757 mg/L Cl)
- 3.33% exceeded US EPA acute toxicity criteria (> 860 mg/L Cl)

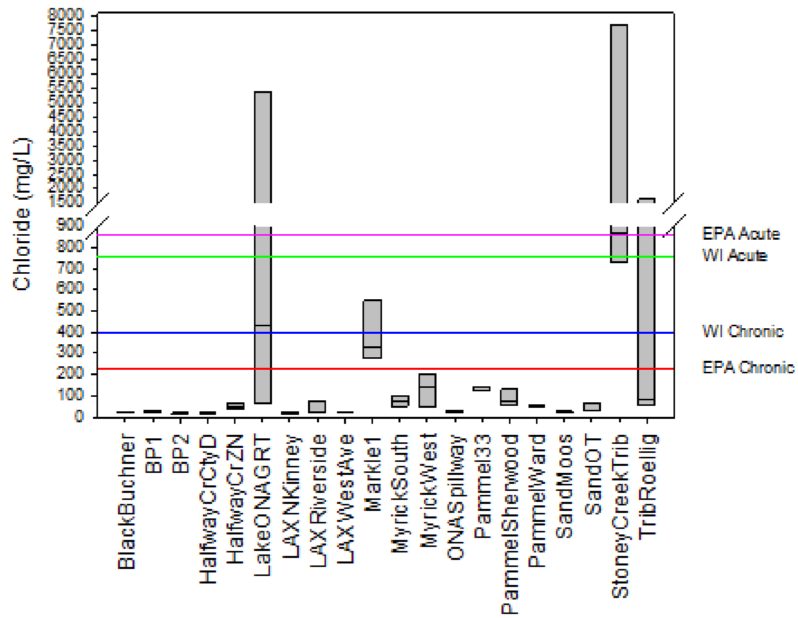

Figure 8: Winter La Crosse County chloride data from 2021. Boxplots represent the 25th, 50th and 75th percentiles. The lines represent the Wisconsin (395 and 757 mg/l) and US EPA (230 and 860 mg/L) chronic and acute toxicity values.

All four of the study samples greater than the WI acute toxicity standard were collected during the winter months and were located near stormwater outfalls. The TribRoellig site (Millers Creek in La Crosse; 1630 mg/L Cl on 2/22/21), LakeONAGRT (a wetland with City of Onalaska stormwater sources; 5360 mg/L Cl on 2/22/21) and StoneyCreekTrib (a first order stream that empties to the La Crosse River with a major stormwater outfall; 7680 mg/L Cl on 2/22/21) were the most elevated samples collected during the study. Other sites with elevated values (Markle1, MyrickWest, MyrickSouth and Pammel Creek) were in the City of La Crosse and were downstream of stormwater outfalls.

A statistically significant relationship between the total percentage of developed land and quarterly median chloride concentration was observed (Figure 9). A stronger relationship was observed between the total percentage of developed

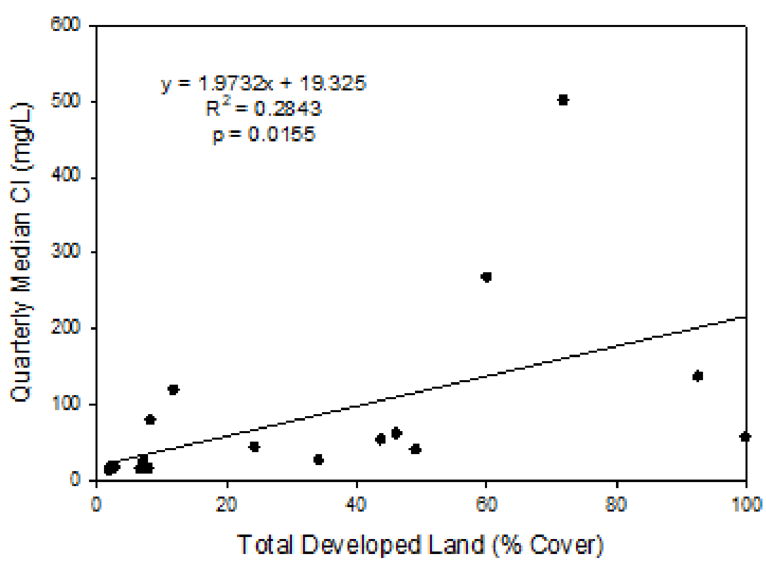

Figure 9: Relationship between total developed land cover and median chloride concentration during the four quarterly sampling events in La Crosse County.

land and winter median chloride concentration (Figure 10). The strong winter relationship highlights winter deicing salt as a dominant source of chloride to surface waters within La Crosse County. Sites at the base of sloped roadways

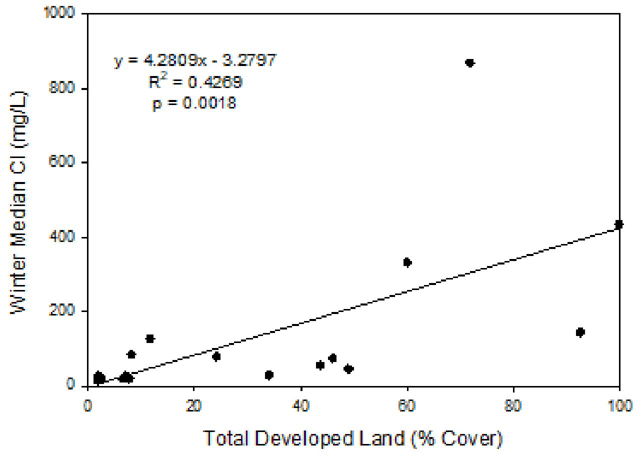

Figure 10: Relationship between total developed land cover and median winter chloride concentration during the three winter sampling events in La Crosse County.

(Markle1 and Pammel33) tended to show median concentrations greater than the trendline, suggesting the influence of heavy road salt use in these areas to keep sloped roads clear of ice. The StoneyCreekTrib site was an unusually high outlier suggesting there may be factors beyond deicing salts that may be influencing this area. Further investigation of this watershed should be conducted to ensure illicit discharge (e.g., backflushing of water softener brine into the stormwater system) isn't occurring at locations within this watershed.

Analysis of data from the Wisconsin DNR Long Term River monitoring site on the Mississippi River at Lock and Dam 9 (Lynxville, WI) revealed a statistically significant increase between 1982 and 2020 (Figure 11). A 66% increase in chloride was observed between 1982 and 2020. Analysis by season of the chloride data at Lynxville revealed statistically higher chloride during the most recent period (2003-2020) when compared with an earlier time period (1982-1998) for all four seasons using a Mann-Whitney rank sum test (Figure 12). Similar to the data collected in La Crosse County, winter chloride values were the highest, followed by spring, fall and summer (Figure 13).

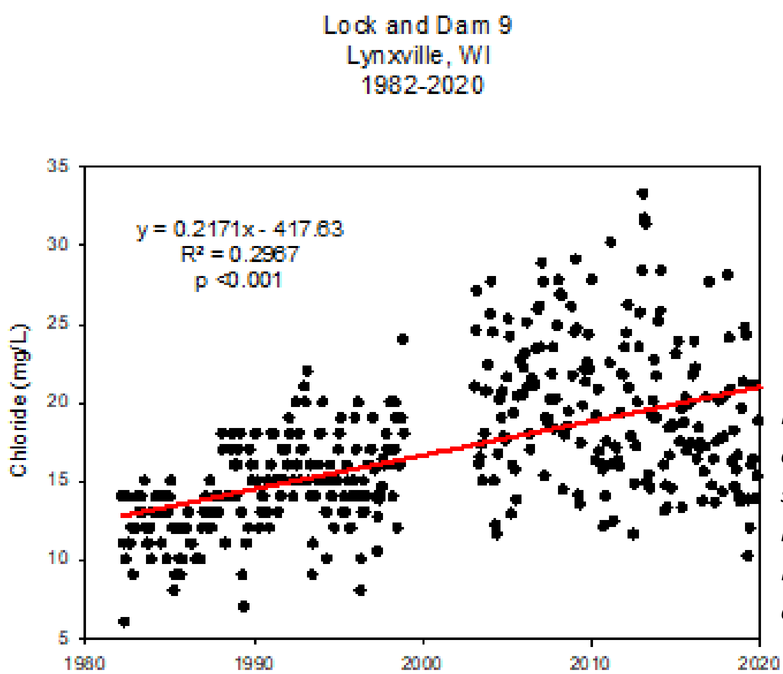

Figure 11: Chloride data from 1982-2020 collected at the Long-Term River Monitoring site at Lynxville, WI. The red line is the linear regression result for the time period. Regression statistics and level of significance are presented.

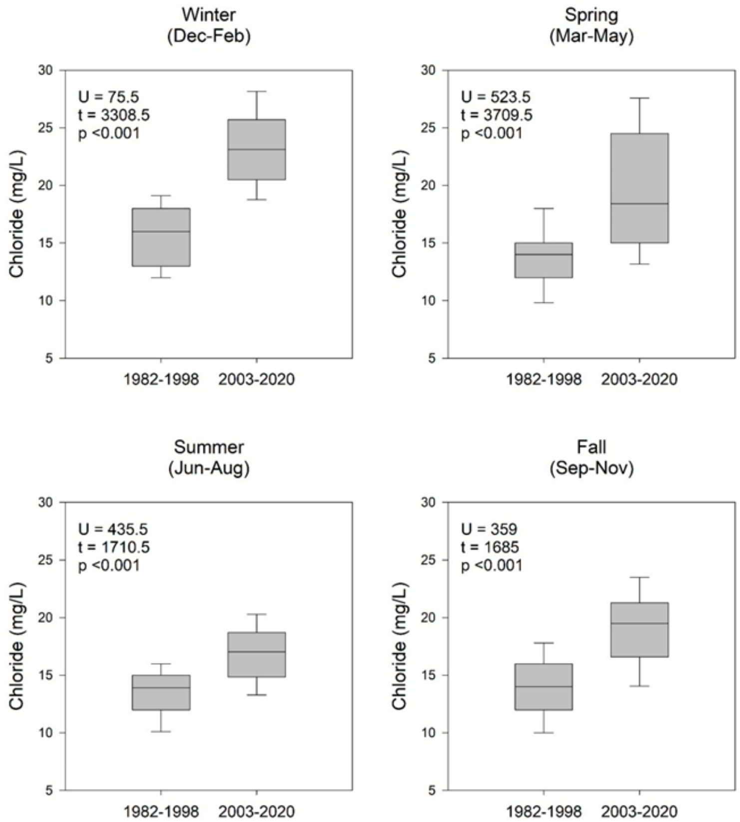

Figure 12: Chloride concentration by season at Lock and Dam 9 during the 1982-1998 and 2003-2020 time periods. The Mann-Whitney rank sum test statistics are presented for each season. Boxplots represent the 10th, 25th, 50th, 75th and 90th percentiles.

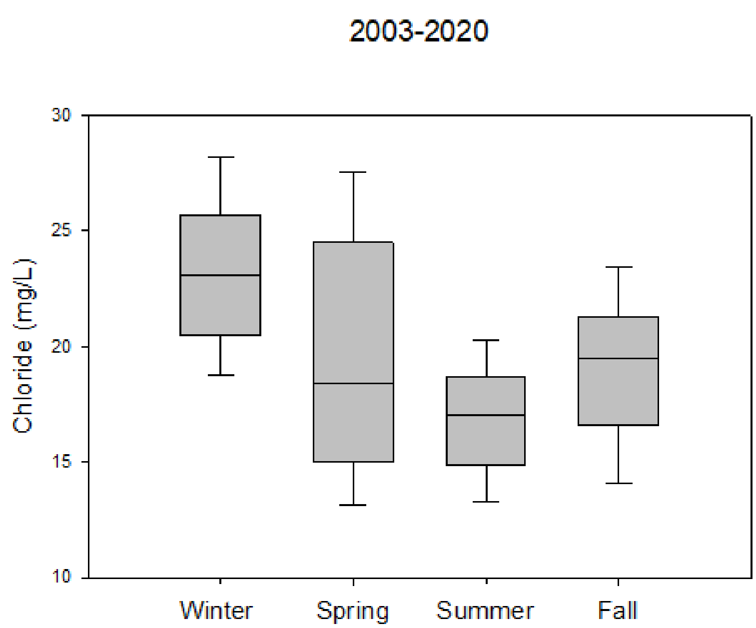

Figure 13: Chloride concentration by season at Lock and Dam 9 from 2003-2020. Boxplots represent the 10th, 25th, 50th, 75th and 90th percentiles.

The data from this study highlight the degree to which La Crosse County is on an unsustainable path regarding chloride and sodium use. Many sites routinely exceed toxicity guidance put forth by Wisconsin and USEPA. This is notable when considering that La Crosse County is only a partially urban county, with the mid-sized city of La Crosse (pop. 52,000) as its main population center. It is also important to note that many of the watersheds from this study are tied into regional wastewater plants, so a sizeable fraction of human salt additions via water softening equipment aren't fully captured in these results. Actions will need to be taken to reduce chloride concentration statewide and within waters of the county to prevent the addition of waters to the Wisconsin Impaired Waters listing in the coming years. Actions that could help to alleviate the salinization of La Crosse County waters in order of importance based on the WI DNR Chloride Workgroup rankings include:

1. Make the switch away from the use of rock salt as a deicer and move toward the increased use of liquid brine deicing systems that use less salt.
2. Ensure proper calibration of salt application equipment.
3. Implement a salt training program for commercial applicators on the benefits of reducing salt use. Offer legal liability protection in exchange for completion of this training.
4. Increase participation in salt training programs for county highway and public facilities managers (e.g., wisaltwise.com).
5. Ensure plowing instead of simply salting during minor snow events of less than two inches.
6. Ensure municipal and commercial salt stockpiles remain covered to prevent leaching during precipitation.
7. Upgrade water softening systems to more modern units that use less or no salt.
8. Educate the public and commercial salt applicators regarding the importance of reducing or eliminating salt as a deicer on parking lots, driveways and sidewalks.
9. Educate the public about the consequences of elevated chloride and sodium levels to aquatic resources and human health.
10. Ensure placement of plowed snow away from waterways.
11. Implement centralized water softening systems where possible.
12. Implement rebate program for upgrades to more efficient water softeners (e.g., Lake Geneva, WI).
13. Emphasize that prevention is the only viable option to reduce salt.

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