Liquid anti-icing in winter maintenance of parking lots reduces chloride inputs to the environment

1. Introduction

In cold regions worldwide, road salt (mostly sodium chloride (NaCl), also known as rock salt) is applied to roads to melt snow and ice to promote safe driving conditions. In Canada, reported road salt application to roads and highways ranged from 2.15 to 4.97 million tonnes from 2004 to 2019 (Environment and Climate Change Canada, 2023). This doesn’t include privately managed salt application to parking lots, where rates are not well reported (Fu et al., 2013), and are likely much higher than the rates used on roads (Lembcke et al., 2017). In some watersheds, salt applied to parking lots can comprise up to 50 % of total salt applied (New Hampshire DES, 2008).

Because of high road salt usage, chloride concentrations of freshwater ecosystems in cold climates are increasing (Albright, 2005; Ledford et al., 2016; Mazumder et al., 2021; Perera et al., 2009; Wallace and Biastoch, 2016). High chloride concentrations have wide-ranging negative impacts on aquatic and terrestrial ecosystems which is why road salts containing chloride are considered a toxic substance in Canada.

With no cost-effective ways of removing chloride once it has entered the environment, the adoption of management practices resulting in lower application rates is still the best option. The use of liquid ice melting products (i.e., brine) is a leading best management practice (Van Seters, 2022). They are typically used in two ways: (1) pre-treating/pre-wetting rock salt for de-icing or anti-icing or (2) as-is for anti-icing. De-icing refers to the application of material after the event, usually after the surface has been plowed. Anti-icing refers to the application of material prior to the event to prevent snow and ice from forming a bond with the pavement (Blackburn et al., 1994; Kahl, 2004; Ketcham et al., 1996). In pre-treating/pre-wetting a liquid de-icer is sprayed onto dry rock salt in order to coat it, either while it is stockpiled (pre-treating) or as it is being dispersed from the vehicle (pre-wetting).

NaCl brine is the most common and affordable liquid ice melting product, however, brines with a beet juice additive have been increasing in popularity because of their lower chloride content and ability to work at colder temperatures. Since they contain organic material, they’re often seen as being more environmentally friendly, however, research suggests they also have negative environmental impacts (Gillis et al., 2021).

The goal of this study was to quantify the amount of chloride that can be saved by combining liquid anti-icing with rock salt de-icing compared to rock salt de-icing alone, to maintain a parking lot over the winter. We tested both traditional NaCl brine and an NaCl brine with a beet juice additive (beet brine).

2. Methodology

We used nine parking lots in Mississauga, Ontario ranging from 8,157 m^2 to 23,704 m^2 in the study (Figure 1). All are located within 1 km of one another, so there were no significant differences in weather condition among the nine lots.

Figure 1: Map of nine study parking lots in Mississauga, Ontario. Group A lots are shown in red, group B lots are shown in blue, and group C lots are shown in green. Numbers represent unique parking lot identifiers.

The parking lots were grouped into three groups of three. For each of the three winters of the study (2019/20, 2020/21, 2021/22), each group of parking lots was assigned one of three winter maintenance tactics: (1) optional anti-icing and de-icing with pre-treated rock salt (rock salt only); (2) anti-icing with NaCl brine and de-icing with pre-treated rock salt (NaCl brine + rock salt); or (3) or anti-icing with beet brine and de-icing with pre-treated rock salt (beet brine + rock salt). All rock salt applied was pre-treated with a beet juice product. The rock salt only tactic is our control and reflects typical business-as-usual practices among winter maintenance contractors, while the liquid anti-icing tactics reflect best management practices.

For each weather event each parking lot received one or more applications of NaCl brine, beet brine, and/or rock salt. For example, during one event, parking lot 1 received one application of beet brine (875 L) during anti-icing and one application of rock salt (0.75 tonnes) during de-icing. The total mass of chloride applied to the parking lot for this and all events includes the chloride in both the anti-icing and de-icing products.

3. Results

Over the three seasons we collected data for 29 events; 10 during the 2019/20 season, 11 during the 2020/21 season, and seven during the 2021/22 season.

Meteorological conditions varied over the three study seasons. All three seasons had temperatures slightly milder than normal, although the 2021/22 season had a colder daily minimum. The 2019/20 and 2021/22 seasons were wetter than normal with more total precipitation and total snowfall, although in 2019/20 that snowfall was concentrated over fewer days. The 2020/21 season was slightly drier than normal; however, total snowfall was close to the normal.

Most of the chloride that was applied came from the rock salt that was applied as de-icer, rather than the liquid applied during anti-icing. The chloride in liquid anti-icing products makes up roughly 30 % of the total chloride applied across all events for which liquid anti-icing was used (Figure 2). Therefore, the main benefit of using liquid anti-icers comes from the reduced rock salt application rates required for de-icing afterwards.

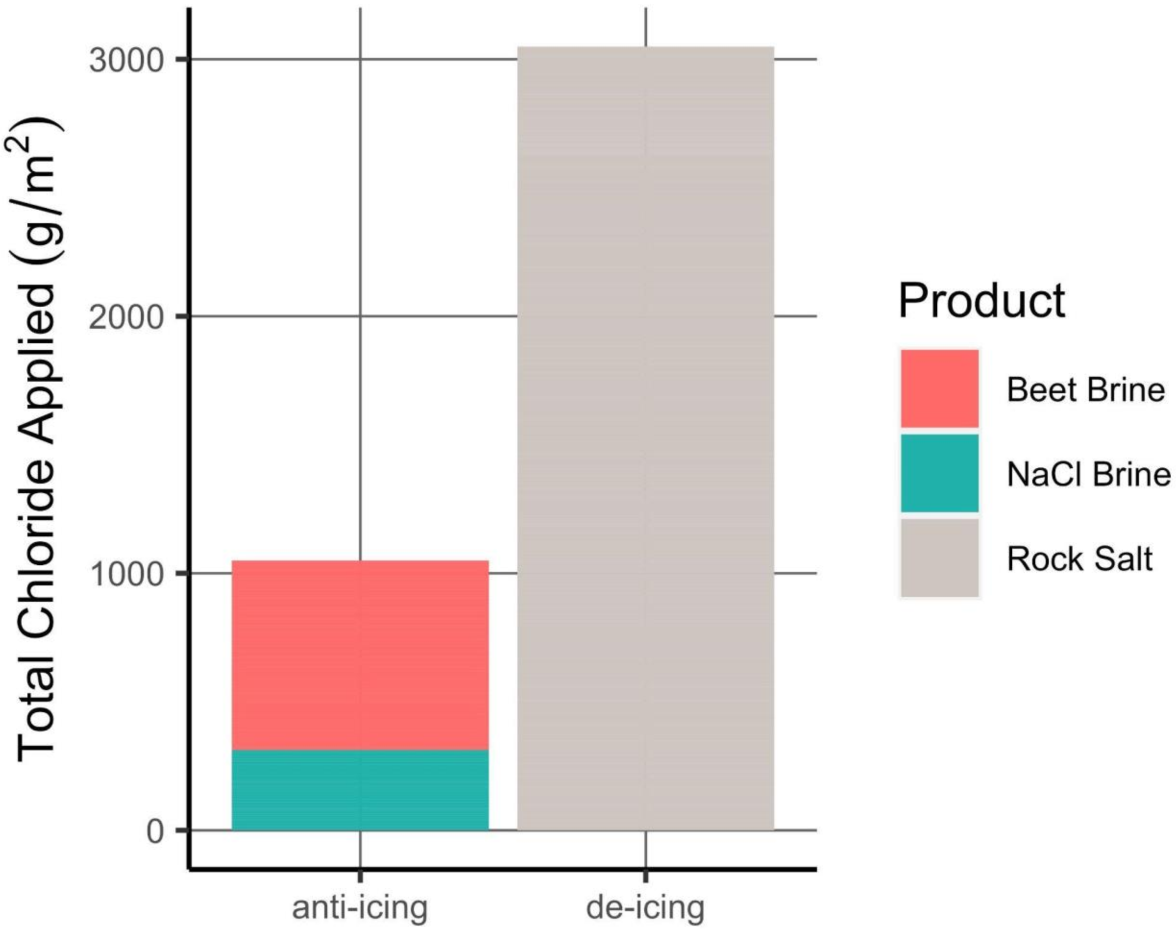

Figure 2: Total chloride applied during anti-icing and de-icing for events where liquid anti-icing (either with beet brine or NaCl brine) was used.

We calculated the relative percent difference (RPD) in chloride application rates between either of the two liquid anti-icing treatments and rock salt only. In 24 out of 26 events, parking lots receiving liquid anti-icing required a lower overall chloride application rate for the event than parking lots receiving rock salt only (Figure 3). Events 12 and 16 are the only ones where rock salt only resulted in the lower chloride application rate. During event 12 the contractor noted that the brine truck operator used significantly more liquid than was intended (i.e., a staff training issue) and during event 16 the forecasted snow did not end up fully materializing, so more liquid anti-icer was used than was ultimately necessary. However, parking lots receiving only rock salt for this event received rock salt as de-icer in response to actual weather conditions.

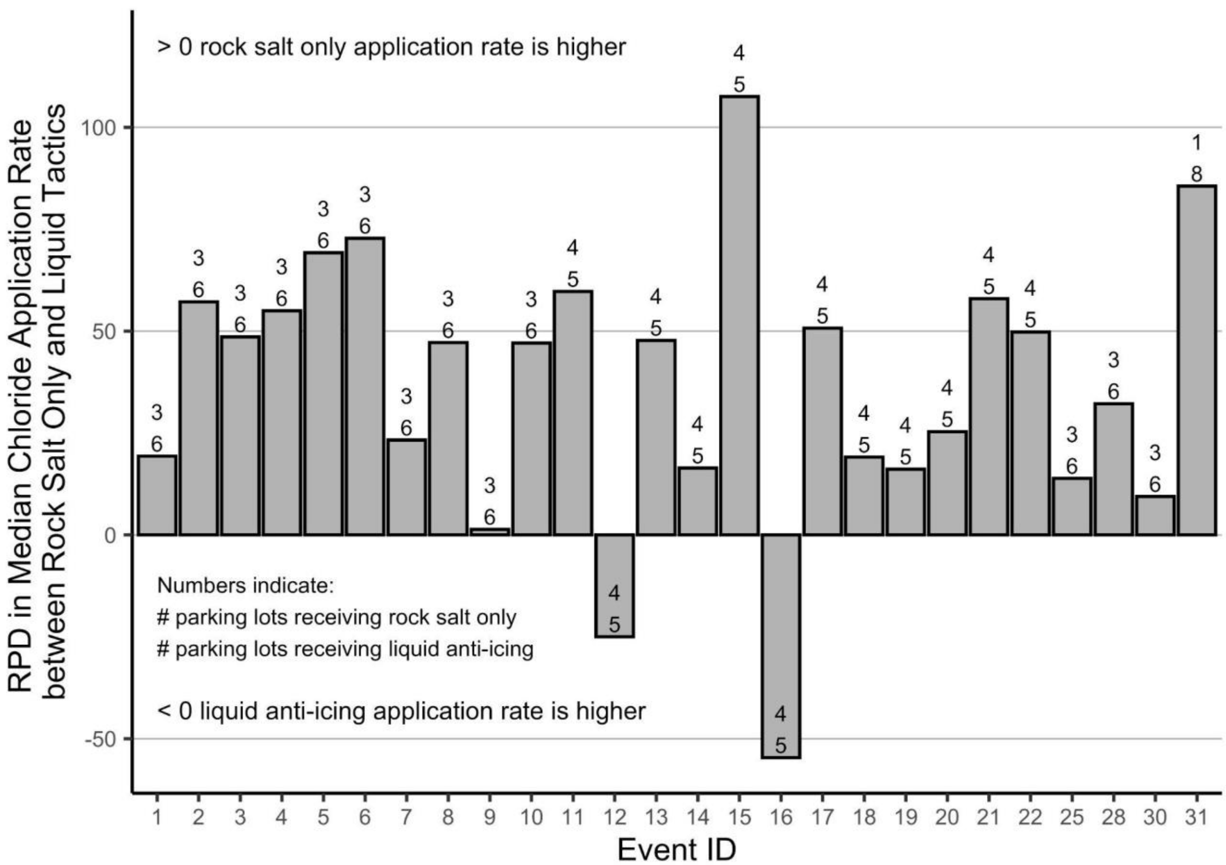

Figure 3: Relative percent difference (RPD) in median chloride application rate between liquid anti-icing and rock salt only.

Additionally, we calculated the RPD between the two different liquid anti-icing products: NaCl brine, and beet brine. In 10 out of 11 events, parking lots receiving beet brine required a lower overall chloride application rate for the event than parking lots receiving NaCl brine (Figure 4). During event 3, the only event where beet brine resulted in a higher application rate, client complaints at two of the three parking lots receiving beet brine resulted in additional rock salt applications.

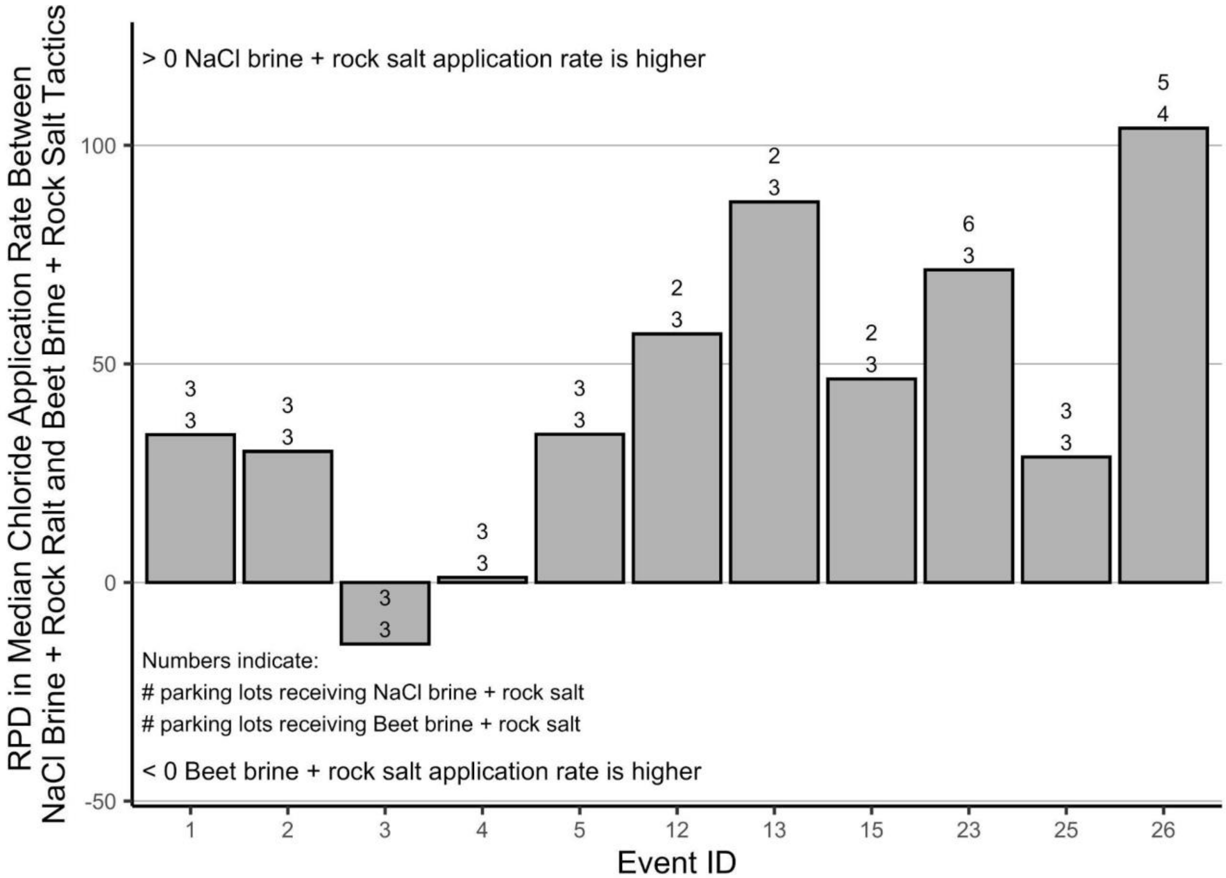

Figure 4: Relative percent difference (RPD) in chloride application rate between NaCl brine and beet brine.

4. Conclusions

We found that liquid anti-icing consistently resulted in lower total chloride application, reducing chloride input on average by 28 %. The addition of an agricultural by-product, in this case beet juice, further reduced chloride application, resulting in an average of 32 % less chloride input to the environment than with NaCl brine.

Anti-icing with a beet juice-based brine may reduce chloride inputs to the environment, however, the impacts of this (and other) organic material(s) on receiving environments are not as well understood as the impacts of chloride. Research has found beet juice byproducts and beet brines to be toxic to freshwater mussels (Gillis et al., 2021), however, further research into concentrations of these products in receiving environments and their toxicity to aquatic life at those concentrations is needed. While we found that the addition of beet juice to an NaCl anti-icer can reduce total chloride input for an event by 32 %, the trade-off between the environmental impacts of chloride and organic materials must be weighed. However, liquid anti-icing, regardless of the product, is likely to be highly beneficial for reducing chloride concentrations in receiving waters.

Adopting best management practices including liquid anti-icing presents several challenges to winter maintenance contractors who must balance customer satisfaction and legal liability with environmental protection. Liability protection for winter maintenance contractors such as that adopted by the state of New Hampshire in the United States (NH Rev Stat § 508:22(2016)) may incentivize the adoption of best management practices. This limited liability protection model makes it less risky for contractors to adopt novel practices, such as liquid anti-icing, while managing their insurance costs.

References

Albright, M., 2005. Changes in Water Quality in an Urban Stream Following the Use of Organically Derived Deicing Products. Lake Reserv. Manag. 21, 119–124. https://doi.org/10.1080/07438140509354419

Blackburn, R.R., McGrane, E.J., Chappelow, C.C., Harwood, D.W., Fleege, E.J., 1994. Development of Anti-Icing Technology. Washington, DC.

Environment and Climate Change Canada, 2023. Review of Progress : Code of Practice for the Environmental Management of Road Salts 2014 to 2019. Gatineau, Quebec, Canada.

Fu, L., Omer, R., Liaqat, Z., 2013. A Survey of Current State of Practice for Winter Maintenance of Parking Lots and Sidewalks. Transp. Res. Board 92nd Annu. Meet.

Gillis, P.L., Salerno, J., Bennett, C.J., Kudla, Y., Smith, M., 2021. The Relative Toxicity of Road Salt Alternatives to Freshwater Mussels; Examining the Potential Risk of Eco-Friendly De-icing Products to Sensitive Aquatic Species. ACS ES&T Water 1, 1628–1636. https://doi.org/10.1021/acsestwater.1c00096

Kahl, S., 2004. Agrigultural By-Products for Anti-Icing and Deicing Use in Michigan: Summary, in: Sixth International Symposium on Snow Removal and Ice Control Technology. https://doi.org/10.17226/17602

Ketcham, S.A., Minsk, L.D., Blackburn, R.R., Fleege, E.J., 1996. MANUAL OF PRACTICE FOR AN EFFECTIVE ANTI-ICING PROGRAM: A Guide for Highway Winter Maintenance Personnel. Hanover, New Hampshire.

Ledford, S.H., Lautz, L.K., Stella, J.C., 2016. Hydrogeologic Processes Impacting Storage, Fate, and Transport of Chloride from Road Salt in Urban Riparian Aquifers. Environ. Sci. Technol. 50, 4979–4988. https://doi.org/10.1021/acs.est.6b00402

Lembcke, D., Thompson, B., Read, K., Betts, A., Singaraja, D., 2017. Reducing road salt application by considering winter maintenance needs in parking lot design. J. Green Build. 12, 1–12. https://doi.org/10.3992/1943-4618.12.2.1

Mazumder, B., Wellen, C., Kaltenecker, G., Sorichetti, R.J., Oswald, C.J., 2021. Trends and legacy of freshwater salinization: Untangling over 50 years of stream chloride monitoring. Environ. Res. Lett. 16. https://doi.org/10.1088/1748-9326/ac1817

New Hampshire DES, 2008. Total Maximum Daily Load (TMDL) Study For Waterbodies in the Vicinity of the I-93 Corridor from Massachusetts to Manchester, NH: Policy-Porcupine Brook in Salem and Windham, NH. Source.

Perera, N., Gharabaghi, B., Noehammer, P., 2009. Stream chloride monitoring program of city of Toronto: Implications of road salt application. Water Qual. Res. J. Canada 44, 132–140. https://doi.org/10.2166/wqrj.2009.014

Van Seters, T., 2022. Review of Snow and Ice Control Practices on Parking Lots and Walkways. Ontario.

Wallace, A.M., Biastoch, R.G., 2016. Detecting changes in the benthic invertebrate community in response to increasing chloride in streams in Toronto, Canada. Freshw. Sci. 35, 353–363. https://doi.org/10.1086/685297