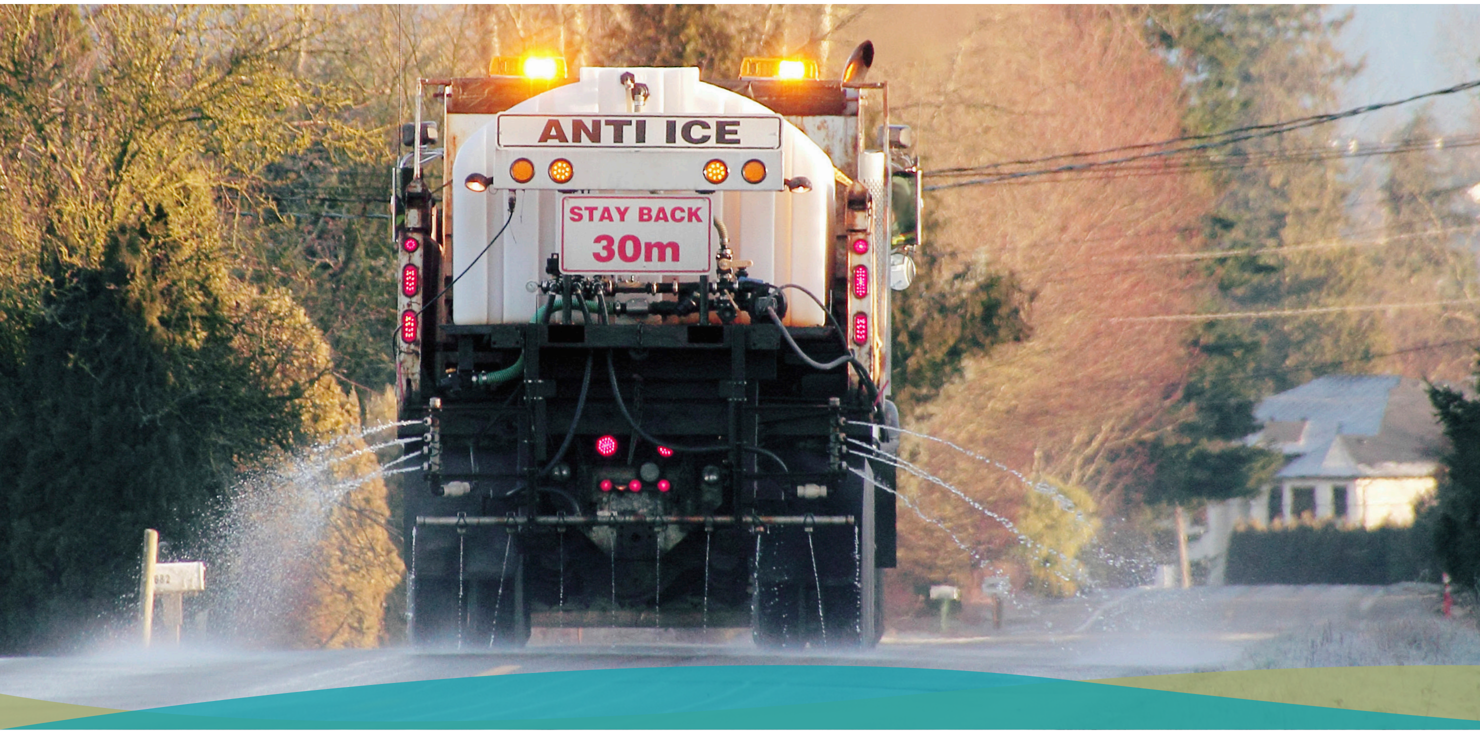
Evaluation of Organic Anti-icing Materials for Winter Maintenance

TECHNICAL BRIEF

Salt Management



Approximately five million tonnes of road salts are applied in Canada every year. Road salts have been shown over years of use to reduce accidents, injury and mortality associated with icy and snowy conditions. However, the salts also pollute groundwater, damage roadside vegetation, alter the hydrologic properties of soils, and drain into streams and lakes where they pose a threat to aquatic ecosystems. Salt is also a significant factor contributing to the corrosion of bridges, buildings and vehicles, resulting in substantially higher maintenance costs.

In 2001, following a comprehensive review of scientific literature on the effects of road salts on the environment, Environment Canada and Health Canada recommended that road salts be considered 'toxic' under section 64 of the Canadian Environmental Protection Act (EC and HC, 2001).

The practice of anti-icing, in which liquid brine solutions are applied to paved surfaces before or at the onset of winter storms to help prevent ice and snow from bonding to the surface, has been shown to significantly reduce the quantity of salt needed to remove compacted snow and ice after storms. New liquid organic and semi-organic alternatives with low chloride content have become available but lack independent data on performance at different application rates. This study compares the performance of liquid road salt (brine) to three types of organic/semi-organic alternatives applied on a university parking lot in Waterloo, Ontario. Products are evaluated as anti-icers (applied pre-snowfall) based on the coefficient of friction (CoF). The results indicate that in general, anti-icing treatments improved friction levels by 10-40% relative to a control without any application of anti-icers. Despite containing less chloride, the organic and semi-organic products performed as well as traditional sodium chloride brine at similar application rates. It was also found that an application rate as low as 3L/1000 ft^2 was sufficient for parking lot snow and ice management, which is 25% less than the current practice of applying 4L/1000 ft^2. Although organic anti-icers contributed less chloride into receiving streams, they contain higher concentrations of nutrients and organic content, which may limit their applicability in some contexts.

INTRODUCTION

A large quantity of road salt is applied to paved surfaces every year to protect humans against the hazards of snow and ice. Salt applied as part of a de-icing or anti-icing strategy lowers the freezing point of water allowing snow and ice to melt at cold temperatures. De-icing is a reactive strategy as the product is applied on top of the snow layer following a snow event. This method is popular due to the flexibility of the product application time window (Ketcham, 1996), but uses nearly five times as much salt as would be required for anti-icing (NCHRP-577, 2007). The proactive anti-icing strategy is carried out prior to snowfall to suppress the freezing point of snow and prevent bond formation between the snow and the pavement. As a result, post snowfall plowing requires less effort and is more effective, as long as pavement temperatures do not fall below the minimum temperature at which the product operates.

The overall objective of this study, conducted by researchers from the University of Waterloo (Hosseini et al., 2014), was to evaluate and compare the capacity of three organic and semi-organic anti-icing liquids and conventional sodium chloride brine to improve pavement friction relative to an untreated control. The study also presents independent analysis of the chemical composition of the tested products and assesses the influence of external factors on product performance.

Figure 1. Study site map of Lot C parking lot at the University of Waterloo where the salt study was conducted (© OpenStreetMap contributors)

Figure 2. Clockwise from top left: NaCl Brine, Fusion 2350, SnowMelt, Caliber M1000.

STUDY SITE

The study was conducted at the University of Waterloo, Ontario, Canada in Parking Lot C, which covers approximately 25, 540 m^2 (6.31 acres) consisting of 900 parking stalls and eight driveways. The surface is paved with asphalt that was in good condition, and the area is drained by catchbasins and sewers. Tests were conducted over several snow events. For each snow event, several 3 x 6 meter parking stalls were selected maintaining consistency in pavement type, initial snow type, and initial snow depth. The pavements were cordoned off from vehicular traffic for field tests.

APPROACH

Anti-icing products were selected based on the following considerations: percentage of organics in product, performance of product at low temperatures, product availability, and price. The following products were selected for field tests: Fusion 2350, Snowmelt, and Caliber M1000 (Figure 2). Performance of products was compared to that of a standard sodium chloride (NaCl) brine and a control without any product applied (Table 1). Snowmelt was the only product formulated from 100% organics. Its semi-organic form (30:70 Snowmelt to brine) referred to as Diluted Snowmelt was also tested.

Table 1.Products selected for field tests, their compositions, effective temperature and cost.

Trade Name	Composition*	Effective Temperature	Cost ($/L)**
Brine	23% NaCl, 77% water	-7°C	0.15
Fusion 2350	12% NaCl, 50% degraded beet juice, 38% P/U*	-27°C	0.3
Snowmelt	15-20% Glycerine, 10-20% Polyether polymer, 3-8% Lactic acid, 2-4% Sorbitol, 1-3% Acetic acid, 1-2% 1,2 – Butanediol (balanced with water)	-20 to - 40°C	0.29
Caliber M1000	27%MgCl, 6% Carbohydrate, 67% water and P/U***	-29°C	0.4

* Compositions listed are as reported by supplier or in literature/material information sheet

** Unit prices are general quotes from supplier

*** P/U: Proprietary/Unknown

Separate plots were used for anti-icing and control (no product applied) treatments. All products were applied in liquid form with a sprayer prior to snowfall based on weather forecasts. Careful attention was given to maintain consistency in the amount of product applied between sites and between products. Once the products were applied and snowfall had ended, the snow was removed from both control and anti-icing sites with either a plow truck or a shovel (depending on snowfall depth) and the friction of the sites were evaluated using a T2GO friction tester. The T2GO calculates the Coefficient of Friction (CoF), a physical measure of the resistance between the road surface and vehicle tires or shoes. Anti-icing solutions should have weakened the bond between the snow pack and the pavement making snow removal more effective and improving friction over the control sites.

Field tests were conducted in a manner that simulated real world parking lot maintenance procedures. Tests were generally started at or before 7 am and three different application rates of 3, 6, and 9 L/1000L ft^2 were tested for each product. The tested rates cover standard application rates of between 3 and 10L/1000 ft^2 used on various paved surfaces. The most common application rate used for parking lots is 4L/ 1000 ft^2. To understand the impact of environmental variables on product performance, the following variables were measured at fixed time intervals after application: precipitation depth, air temperature, pavement temperature, snow type and snow depth. A multiple linear regression was conducted to determine which of these variables significantly affect the CoF.

FINDINGS

The 2013-2014 winter season had 20 light snow events (less than 2 cm), 10 medium events (2 to 5 cm) and 5 heavy events (more than 5 cm). Limited by weather forecasting accuracy and the requirement of a bare pavement for product application, anti-icing tests were conducted on 15 of these events. A total of 213 anti-icing tests were conducted over the course of the study. The pavement surface

Figure 3. (a) Measurement of environmental variables (pavement temperature),(b) application of anti-icing product, and (c) friction testing with T2GO to acquire CoF.

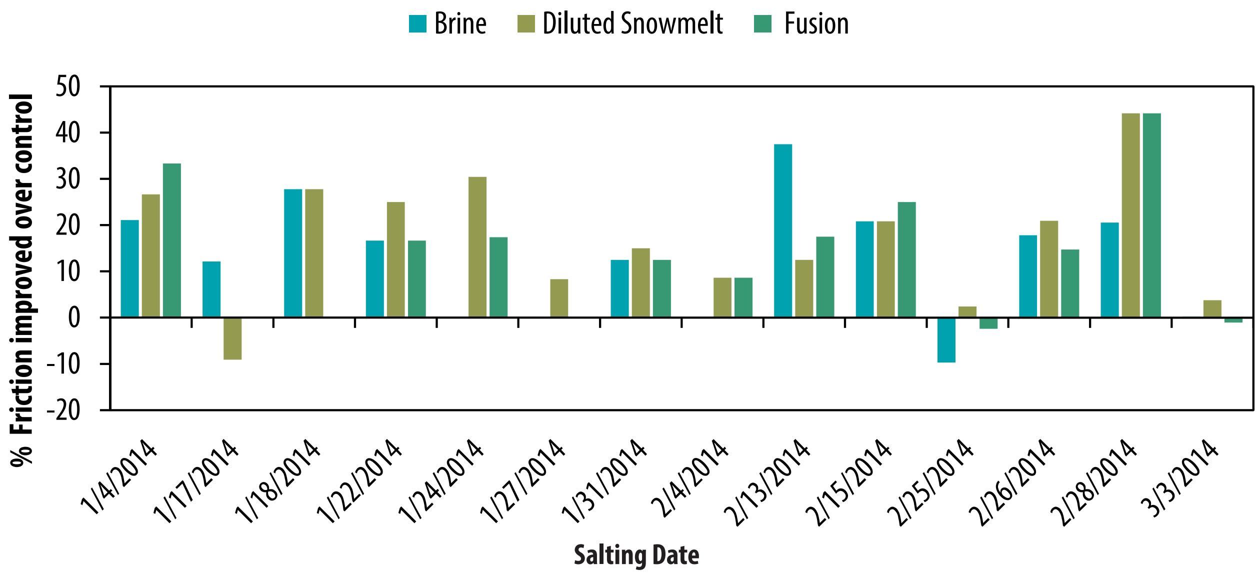


Figure 4. Percent friction improvement at anti-icing sites with application of brine, diluted Snowmelt, and fusion over the control treatment, for an application rate of 3L/1000 ft^2.

temperatures ranged between -15 to 1°C and average event based air temperatures ranged between -22 and -2°C.

Pavement friction improved considerably after applying anti-icing products. Figure 4 shows the improvement in the Coefficient of Friction (CoF) relative to the control sites (no product applied) by three anti-icing products (Brine, Diluted Snowmelt, Fusion) at an application rate of 3L/1000 ft^2. Sites where anti-icers were applied had up to 40% higher CoFs than the control sites. T-tests confirmed a significant difference ($p < 0.05$) between CoF values of control and anti-icing sites with Brine, Diluted Snowmelt, Snowmelt, Fusion and Caliber M1000. The few test days (Jan 17th, Feb 25th, and Mar 3rd) that showed anti-icing sites having lower CoFs than control sites had several environmental factors in common: snow cover depth less than 2 cm with no additional snow accumulation between plowing and friction testing, loose/very loose snowpack with low density, pavement temperatures around -7 °C (+/- 2°C) and air temperatures that were lower than the pavement temperatures. Under these conditions, it is likely that the anti-icers melted the snow, but colder air temperatures penetrated the shallow low density snow cover and caused the melted snow to refreeze.

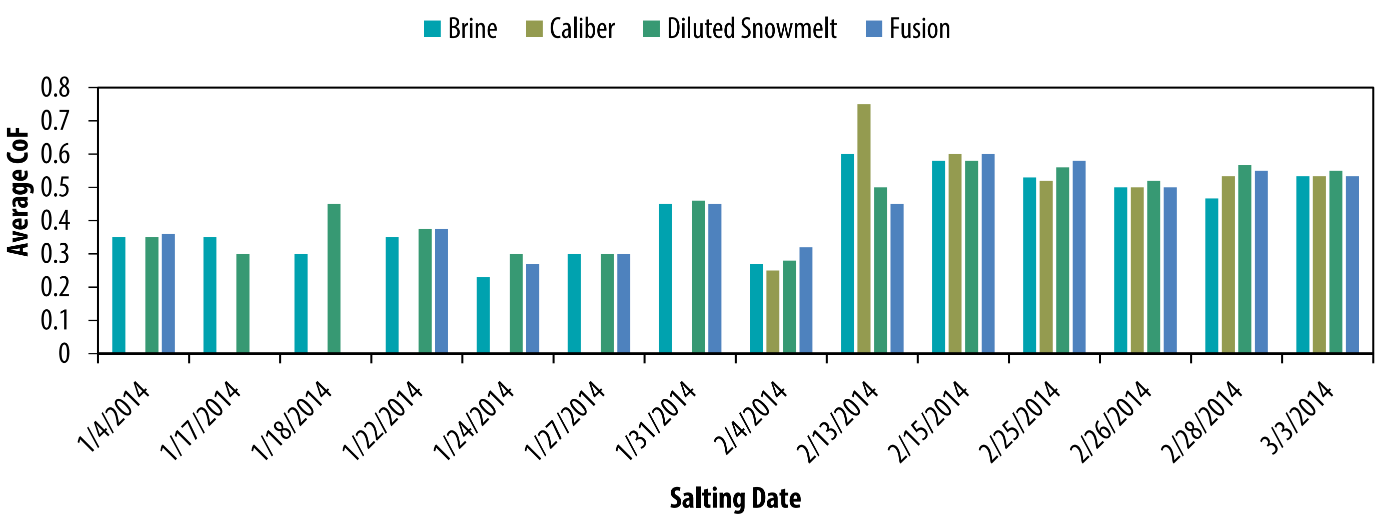


Figure 5. Average CoF for Brine, Caliber, Diluted Snowmelt, and Fusion sites. Caliber was added late in season on 2/4/2014 and Snowmelt was not used due to limited data points.

As temperatures continue to drop below -7 °C, the anti-icers were less effective or diluted and the refrozen layers resisted the effects of plowing, resulting in lower CoFs than control sites. Although vendors state that the effective temperature of the Fusion anti-icer is up to -27 ° C (Table 1), this may only be true when it is used as a pre-wetting agent for solid de – icers.

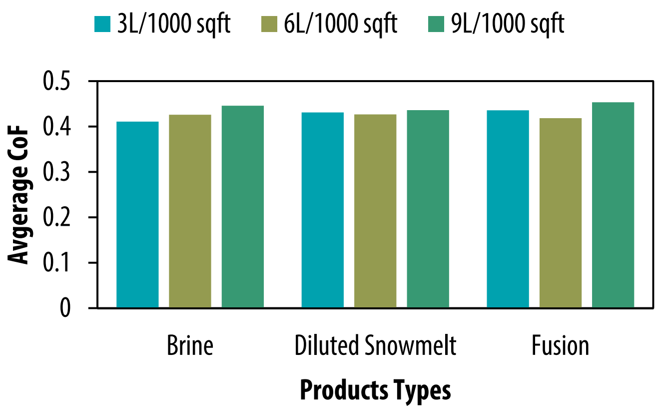


Figure 6. Effect of application rate on average CoF for Brine, Diluted Snowmelt and Fusion.

The performance of alternative salts did not differ significantly from standard sodium chloride brine, or from each other. Average CoFs of brine and alternative anti-icers (Caliber, Diluted Snowmelt, and Fusion) compared in a one way ANOVA showed that there was no significant difference in performance among the different anti-icers or between anti-icers and brine ($p > 0.05$)(Figure 5). Therefore, within the temperature ranges tested, the organic alternatives were at least as effective as brine.

Application rates of 6 and 9L/1000 ft^2 showed no significant improvement over 3L/1000 ft^2. Brine suppliers generally recommend that products be applied at a rate of 4L/1000 ft^2 on parking lots. However, in this study, reducing the application rate to 3L/ 1000 ft^2 did not have a significant effect on the CoF, even though there was a 25% reduction in the product being applied (Figure 6).

Mixing Snowmelt with Brine (30 : 70 Snowmelt to Brine) did not improve performance. At an application rate of 3L/1000 ft^2, diluting concentrated Snowmelt with Brine (30:70 Snowmelt to Brine) did not improve its performance (Figure 7). While this mix helps to reduce the cost per application, using the undiluted 100% organic Snowmelt product mitigates the harmful effects that chloride salts would have on the environment, without sacrificing performance.

The effect of external factors on CoF varies among anti-icer products. Friction levels decreased with decreasing pavement temperatures for NaCl brine and Caliber products because these products lose their effectiveness at temperatures below -7 to -10°C. Diluted Snowmelt and Fusion sites were not significantly impacted by the pavement temperature, while Snowmelt sites had a significant negative relationship (i.e. CoF of Snowmelt sites increased with decreasing temperatures) (Table 2). Snow amount negatively impacted CoF regardless of which anti-icer was used, due primarily to dilution of the anti-icer, but the effect was only statistically significant on brine sites. Under the categorization of wet and dry snow, brine and Caliber were found to be more effective under dry snow conditions, whereas the other three anti-icers were not significantly affected by snow type. None of the anti-icers significantly affected the CoF by the application rates tested (3,6,9L/1000ft^2), which suggests that the lowest rate (3L/1000ft^2) should be adopted for anti-icing.

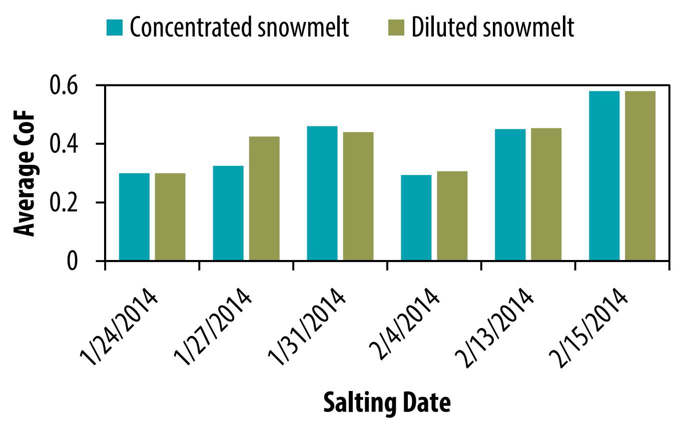


Figure 7. Comparison of average CoF between Concentrated and Diluted Snowmelt on different test days.

Moreover, when considering factors such as application rate, pavement temperature, snow amount and snow type, NaCl brine sites were the most influenced by external factors while Diluted Snowmelt and Fusion were the least impacted. Pavement temperature and snow type appeared to have a greater effect on the CoF of a site than application rate and snow amount.

Since anti-icers will ultimately find their way into the soil, groundwater and/or surface water, the chemical composition of selected products should be carefully considered prior to use. Table 3 shows the ingredient concentrations of metals, nutrients and organic carbon in each of the products tested in this study. Not surprisingly, traditional NaCl brines contained high

Table 2.Mulitple regression analysis on factors that may affect anti-icing performance. Statistically significant ($p<0.05$) coefficients are shaded.

Variable		Brine (N=44)	Diluted Snowmelt (N=44)	Fusion (N=38)	Snowmelt (N=16)	Caliber M1000 (N=20)
R^2		0.31	0.09	0.12	0.71	0.57
Intercept	Coeff.	29.812	15.895	27.883	6.354	31.666
	P-Value	0.011	0.124	0.011	0.415	0.102
Application Rate	Coeff.	1.375	0.024	0.433	0.640	-1.581
	P-Value	0.247	0.982	0.688	0.444	0.324
Pavement Temp	Coeff.	3.107	0.167	0.887	-2.064	8.025
	P-Value	0.001	0.837	0.262	0.002	0.005
Snow Amount	Coeff.	-6.653	-3.109	-3.034	-1.231	-4.370
	P-Value	0.006	0.148	0.136	0.330	0.420
Snow Type	Coeff.	13.992	8.225	-4.005	-2.456	54.744
	P-Value	0.099	0.282	0.642	0.672	0.000

levels of sodium and chloride. The highest chloride levels, however, were found in the Caliber M1000 anti-icer. Fusion 2350 had lower chloride and sodium levels than traditional brines, but higher levels of nitrogen (primarily as total kjeldahl nitrogen) and phosphorus.

The highest phosphorus levels were found in the SnowMelt anti-icer. The organic products also had higher levels of organic carbon, which can result in higher biological oxygen demand in surface waters if the organic matter is oxidizable and biologically degradable.

Table 3. Concentration of selected water quality variables in product samples. Average concentrations in stormwater runoff are simulated based on a winter melt event with 5 cm of snow accumulation and no plowing.

		Sample Concentration					Hypothetical Runoff Concentration*					
Water Quality Variable	Units	NaCl Brine	Snow Melt	DilutedS now Melt	Fusion 2350	Caliber M1000	NaCl Brine	Snow Melt	Diluted Snow Melt	Fusion 2350	Caliber M1000	Receiving Water Guidelines
Chloride	mg/L	145500	1425	109200	111000	230400	285.85	2.80	214.54	218.07	452.65	120
Sodium	mg/L	117000	100800	112500	85800	2028	229.86	198.04	221.02	168.57	3.98	--
Magnesium	mg/L	53.10	3.00	33.90	80.40	96300	0.10	0.01	0.07	0.16	189.19	--
Copper	mg/L	0.00	0.00	0.00	6.24	0.00	0.00	0.00	0.00	0.01	0.00	0.005
Iron	mg/L	2.22	57.60	18.24	21.12	1.56	0.00	0.11	0.04	0.04	0.00	0.30
Lead	mg/L	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.005
Chromium	mg/L	0.00	0.72	0.24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	--
Zinc	mg/L	0.04	6.00	1.86	4.80	0.04	0.00	0.01	0.00	0.01	0.00	0.02
Total Organic Carbon	mg/L	27	237000	67200	71400	25380	0.05	465.62	132.02	140.28	49.86	--
Total Nitrogen	mg/L	17.34	1122	294.60	5100	28.98	0.03	2.20	0.58	10.02	0.06	--
Nitrate+Nitrate-N	mg/L	3.27	741.00	251.70	134.70	1.86	0.01	1.46	0.49	0.26	0.00	2.90
Phosphate	mg/L	0.11	78.60	24	2.97	0.44	0.00	0.15	0.05	0.01	0.00	--
Total Phosphorus	mg/L	2.22	112.20	34.20	54.00	0.23	0.00	0.22	0.07	0.11	0.00	0.03

* Runoff concentration is calculated based on an application rate of 3 L/1000 square feet, assuming dilution from 5 cm of snowmelt over the area of application. Accumulated snow was converted to water at a ratio of 10:1. Hence, 5 cm of snow was calculated to have a water equivalent of 5 mm.

To assess the potential effect of pollutants in anti-icers on surface waters, sample concentrations were converted to runoff concentrations by conservatively assuming that only 5 cm of snow fell, and that anti-icers were applied at a rate of 3 L per 1000 ft^2. All of the snow was assumed to have melted without plowing. During this hypothetical event, all of the products except the undiluted Snow-Melt anti-icer exhibited concentrations exceeding the receiving water guideline for chloride (120 mg/ L). Both organic products had elevated levels of phosphorus, suggesting that these products may not be well suited to streams or water bodies that are sensitive to nutrients. Concentrations of metals were generally very low in all products.

It should be noted that this analysis is limited by the specific context it attempts to simulate. In areas where snow melt drains to road side ditches, or where plowed snow is removed and transported to a snow disposal site, the risks of nutrient release to water ways may be considerably lower. Likewise, there may be less concern about potential impacts if stormwater from the area where organic brines are applied is treated by an appropriate stormwater BMP.

CONCLUSIONS

This study compared the friction performance of traditional chloride and organic/semi-organic anti-icing products to a control without treatment. The major findings are as follows:

- In general, using anti-icers resulted in a gain of friction of between 10-40% over the control sites, regardless of the product used.
- Performance of organic alternatives were not significantly different ($p<0.05$) from chloride based salts. Although organic alternatives cost more than traditional chloride based brines, they have a lower impact on the environment and reduce corrosion of infrastructure.
- Performance did not improve when more product was applied, which suggests that products can be effectively applied at the lowest application of 3L/1000ft^2.
- Environmental parameters had varying effects on the performance of different anti-icing products. Traditional brines formulated from sodium or magnesium chloride, worked less effectively at temperatures below – 7^0C. All anti-icers tested were less effective for wet snow and heavy snowfall conditions.
- Analysis of product samples showed that organic anti-icers had lower chloride and sodium levels, but contained higher levels of nutrients and organic carbon, which in some cases may lead to elevated BOD and/or nutrient levels in receiving waters. Caution should be exercised in areas draining to nutrient sensitive waters.

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