Anti-icing and Pre-wetting: Improved Methods for Winter Highway Maintenance in North America

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ABSTRACT

In recent years, anti-icing and pre-wetting practices have been gradually accepted and adopted by the North American highway agencies. One of the greatest challenges of implementing these practices has been the misunderstanding of the benefits and outcomes of their use. Members of the general public and organized groups such as trucking associations have been critical of these strategies, which may be a result of insufficient information, limited understanding and speculation. Therefore, research is needed to synthesize the information on these strategies in an objective manner.

Through a project with the Pacific Northwest Snowfighters Association, the authors synthesized information obtained from a literature review and agency surveys on the advantages and disadvantages of anti-icing and pre-wetting for winter highway maintenance. Concerns discussed include: driver safety, human health, environmental stewardship, corrosion, costs, etc.

The research indicates that compared with traditional methods for snow and ice control, anti-icing and pre-wetting lead to decreased applications of chemical products, reduced use of abrasives, decreased maintenance costs, improved roadway friction, and lower accident rates. Anti-icing has been recognized as a pro-active approach to winter driver safety. Pre-wetting has shown to increase the performance of solid chemicals or abrasives and their longevity on the roadway surface, thereby reducing the amount of materials required.

The information in this paper will benefit maintenance agencies and transportation officials who seek to fully understand the benefits derived from improved winter maintenance technologies, identify areas for improvement within their own jurisdiction, and learn about related experiences from other agencies.

BACKGROUND

In the northern states and Canada, transportation agencies face a difficult challenge to keep roadways open and safe during heavy snowfall, low visibility, and icy conditions. Each winter, large amounts of solid and liquid chemicals, along with abrasives, are applied onto the roadways to keep roads clear of ice and snow. The widely used chemicals include: sodium chloride, calcium chloride, magnesium chloride, potassium acetate, calcium magnesium acetate, and agricultural byproducts. They can melt ice and snow by lowering the freezing point of the snow-salt mixture.

Winter highway maintenance practices in North America have traditionally been based on reactive strategies where the launch of maintenance operations relied on signs of snow and ice accumulation. After snowfall, the *de-icing* process uses granular materials that penetrate accumulated snow and ice in order to break the bond that has formed with the roadway. Once the bond is broken, the layer of snow and ice can be easily removed by mechanical means such as snowplows. In addition, through *sanding* operations, abrasives such as sand are applied onto the roadways to provide temporary traction in slippery conditions. Such reactive strategies are generally reliable and well understood.

One concern regarding reactive maintenance practices is the increased potential for accidents and injuries due to poor road conditions while maintenance crews are being deployed. Another problem with reactive practices is the quantity of materials and labor hours needed to maintain the level of service for winter roadways.

However, in the past decade or so, an improved approach termed *anti-icing* has been adopted by winter maintenance personnel, which is the early application of chemicals to help prevent black ice and prevent or weaken the bond between ice and the roadway surface. While it is possible and appropriate under certain circumstances to use solid chemicals for anti-icing, liquids are more commonly used. Another innovative practice in winter road maintenance is termed *pre-wetting*, i.e., the addition of a liquid chemical to an abrasive or solid chemical before it is applied to the road. The pre-wetting of solids is performed either at the stockpile or at the spreader.

As improved maintenance strategies, anti-icing and pre-wetting are seeing increased implementation in North America. One of the greatest challenges of the implementation has been the misunderstanding of the benefits and outcomes of their use. Members of the general public and organized groups such as trucking associations have been critical of these strategies, which may be a result of insufficient information, limited understanding and speculation. Therefore, research is needed to synthesize the information on these strategies in an objective manner.

Through a project with the Pacific Northwest Snowfighters Association (PNS), the authors at the Western Transportation Institute at Montana State University (WTI) synthesized information obtained from a literature review and agency surveys on the advantages and disadvantages of anti-icing and pre-wetting for winter highway maintenance. Concerns discussed include: driver safety, human health, environmental stewardship, corrosion, costs, etc.

METHODOLOGY

This paper summarizes up-to-date information regarding the practices of anti-icing and pre-wetting for winter maintenance in North America, gathered through a literature review and a questionnaire to the snow and ice control community followed by phone interviews.

The questionnaire was sent as an email attachment to maintenance professionals in eighteen state departments of transportation and two Canadian provincial ministries of transportation, including the six participating PNS states (and provinces) and twelve states involved with the Federal Highway Administration Test and Evaluation Project #28. The contact list was developed by the project's advisory committee, and included maintenance managers, directors, superintendents, and engineers.

Fifteen of the twenty contacted professionals agreed to participate in the questionnaire, including: Alaska, Alberta, British Columbia, Colorado, Idaho, Minnesota, Missouri, Montana, Nevada, New York, Oregon, Vermont, Washington, Wisconsin, and Wyoming. Upon confirmation of participation, maintenance professionals were given a week to review the questionnaire and gather any needed information at which time an interview was scheduled. All interviews and responses to the questionnaire were completed by April 2005. With only one contact per state or province, the results presented herein are reflective upon the opinions of the interviewee, and are not necessarily representative of the entire state or province.

The questionnaire focused on the current state of practice for winter road maintenance as well as any advantages or disadvantages experienced while implementing anti-icing or pre-wetting strategies. It also addressed concerns associated with winter maintenance practices such as driver safety, human health, environmental stewardship, vehicular and infrastructure corrosion, and costs.

DISCUSSION

Why Winter Highway Maintenance Planning and Management Is Needed

Snow and ice control methods allow maintenance agencies to keep the road system safe, mobile, and productive, striving to ensure that:

- Traveler safety is maximized by the reduction of vehicular accidents and associated fatalities and injuries;
- Merchandise and services can arrive to their destinations throughout the winter;
- Emergency service vehicles can continue to provide timely response and assistance;
- Travelers can access winter recreation activities and support the local tourist economy; and
- Daily routines are uninterrupted.

It has been shown that repeated applications of winter maintenance chemicals and abrasives may adversely affect the surrounding vegetation, water bodies, aquatic biota, and wildlife (*1*,*2*). Expert opinions indicate that the environmental impacts of abrasives are generally a much greater concern than those of chemicals (*3*). However, winter maintenance chemicals may cause corrosion of and damage to pre-stressed or normally reinforced concrete structures, steel bridges, motor vehicles, and paved surfaces (*4*).

Snow and ice control operations call for agencies to strike the right balance among their multiple objectives including: traveler safety, environmental stewardship, infrastructure preservation, and economics during winter seasons. By examining alternatives to conventional snow and ice control strategies and applying improved technologies, maintenance agencies have been able to reduce costs, labor hours and material usage while providing safe roadways and minimizing environmental and corrosion impacts. The ultimate goal is *to deliver the right amount of materials in the right place at the right time*.

New advancements in science and engineering, specifically, reliable weather forecasting and new equipment and materials, are making it possible for highway agencies to implement improved snow and ice control strategies that benefit the public and help minimize the effects of winter weather on roadway surfaces.

For instance, anti-icing introduces a proactive concept for maintaining winter roads because it treats potential conditions before problems arise, thus giving maintenance crews an advantage when fighting winter storms. The roads remain wet and slushy longer and return to *bare pavement* conditions earlier when anti-iced. As a proactive strategy, successful use of anti-icing chemicals requires application immediately prior to a storm, and thus entails accurate weather forecast. When applied correctly, anti-icing can reduce plowing time and decrease the quantity of chemicals used (*5*).

Snow and Ice Control Operations: Benefits and Concerns

Investing in clear roads is essential and beneficial to the public and the economy. Winter maintenance activities offer such direct benefits to the public as fewer accidents, improved mobility, and reduced travel costs. A study found that "failure to get snowplows out and salt on the roads during a single day of a winter storm costs almost three times more in lost wages than the total annual costs for snowfighting" (*6*).

For the public, all maintenance activities decrease the potential for accidents and increase the ability to travel. Improved maintenance strategies, however, have lowered accident rates even further. Colorado has seen a 14% decrease in snow and ice related crashes during a twelve-year study involving advanced maintenance strategies on the interstate system in the Denver metro area (*7*).

While providing improved driving conditions, chemical products and abrasives used have the potential to harm the surrounding environment. Studies have shown vegetative damage and die-off near roadways due to salt spray and runoff. It has also been shown that water quality may be affected, at least temporarily, in areas utilizing chemicals and abrasives for snow and ice control.

Abrasives may also become particulate matter and contribute to poor air quality. Particles smaller than 10 microns (0.01mm) in diameter, known as PM-10, may become suspended in the air and lead to air quality issues, especially in urban settings, which is a primary reason behind passage of the U.S. Clean Air Act (*9*). Inhaled particulate matter may increase breathing difficulties for sensitive populations causing respiratory damage and possibly lung cancer.

Another concern of winter maintenance products is corrosion to both motor vehicles and the highway infrastructure. For motor vehicles, corrosion from winter maintenance chemicals is generally cosmetic, however, brake linings, frames, bumpers, and tailpipes may also show signs of corrosion related to these products. Potential damages to the highway infrastructure include concrete deterioration due to corrosion of the reinforced steel, surface deterioration known as scaling, and degradation of the concrete matrix. Large span supported structures, steel bridges, and even parking garages are susceptible to corrosion derived from winter maintenance chemicals. It is difficult, however, to determine the extent of damages caused by winter maintenance chemicals.

Prevention of future problems requires adopting design practices for corrosion prevention, utilizing non-corrosive, environmentally friendly chemical products, and minimizing material usage while maximizing performance. In order to reduce costs and improve levels-of-service, it

is important that individual maintenance agencies improve their snow and ice control strategies and tactics and implement a quality assurance program for snow and ice control products.

PNS has become a recognized pioneer in establishing and standardizing chemical products for snow and ice control, and numerous states and provinces outside the Pacific Northwest have adopted the PNS specifications. The members of the PNS are the transportation agencies in the states of Washington, Oregon, Montana, Idaho, Colorado, and British Columbia. Throughout this analysis, for comparison, results will be presented in two categories: 1. PNS States (and Provinces), and 2. Non-PNS States.

Winter Highway Maintenance Practices in North America: A Snapshot

The U.S. spends over $2.3 billion annually on snow and ice control operations (*8*). The states of Colorado, Idaho, Montana, Oregon and Washington are part of the PNS association and comprise 5% of this expense at approximately $114 million (estimates based on the questionnaire results).

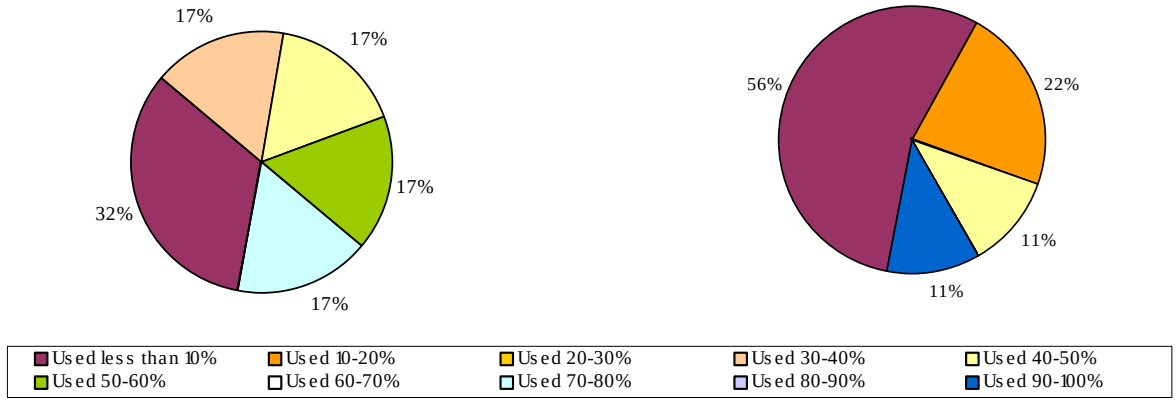

FIGURE 1 Percent roadways using anti-icing: (left) PNS states, (right) non-PNS states

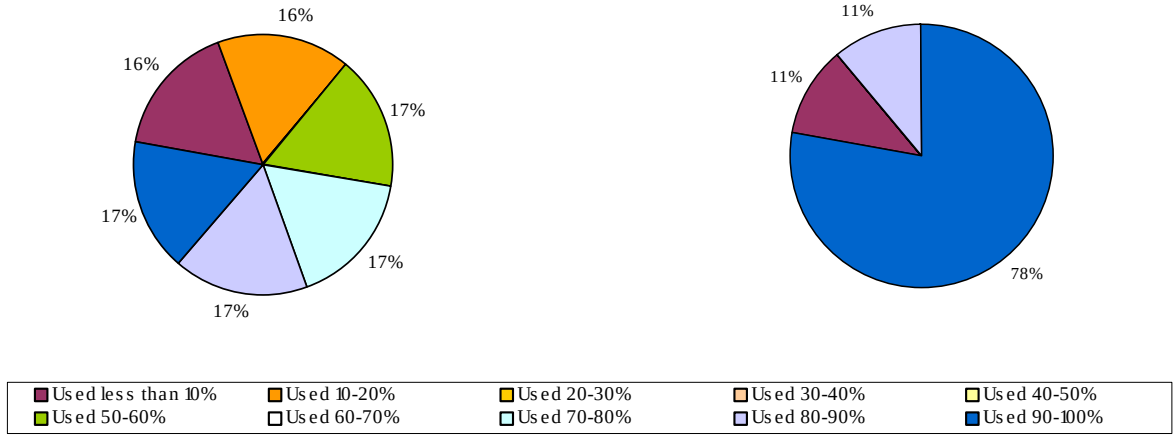

FIGURE 2 Percent roadways using de-icing: (left) PNS states, (right) non-PNS states

Traditionally, winter highway maintenance was heavily reliant on snowplowing, sanding and de-icing. Through this research, it was apparent that these traditional means of snow and ice control are all still heavily utilized today.

When asked "What do you see as the best method for maintaining safe winter driving conditions", all respondents stated that a combination of all available tools was best. As a follow-up question, professionals were asked "what percentages of your roadway use anti-icing,

de-icing, snowplowing and sanding". It was found that on average of the fifteen states, snowplowing was used 92% of the time, sanding – 75% of the time, de-icing – 76% of the time, and anti-icing – 29% of the time. FIGURES 1 - 4 show the percentage of agencies in the PNS and non-PNS states that use these practices, ranging from less than 10% of the time to 100% of the time.

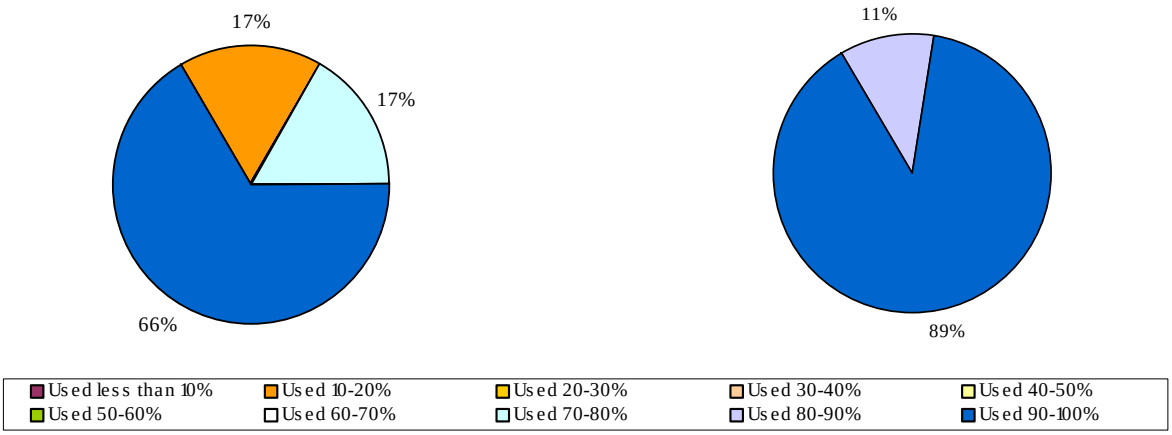

FIGURE 3 Percent roadways using snowplowing: (left) PNS states, (right) non-PNS states

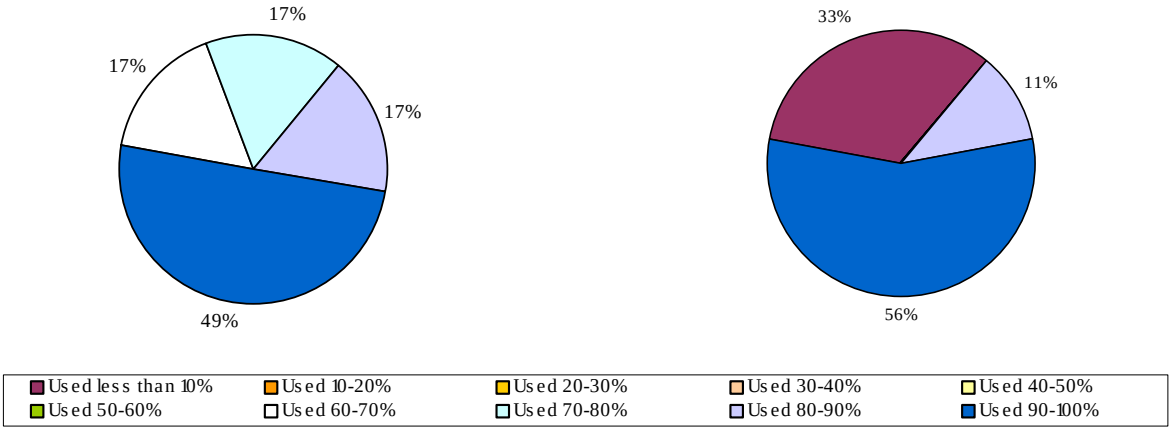

FIGURE 4 Percent roadways using sanding: (left) PNS states, (right) non-PNS states

Anti-icing and Pre-wetting: Improved Methods for Winter Highway Maintenance

Anti-icing and pre-wetting are maintenance methods that are improving the way agencies across North America manage roadway surfaces during inclement winter weather. The majority of agencies from both PNS and non-PNS states have had 5-10 years of experience with pre-wetting, whereas the difference in experience with anti-icing was far greater. Fifty percent of PNS states had more than 10 years of experience with ant-icing, whereas none of the non-PNS states falls into this category. The differences in experience levels between the two groups of agencies implementing these improved tactics are shown in FIGURES 5 - 8.

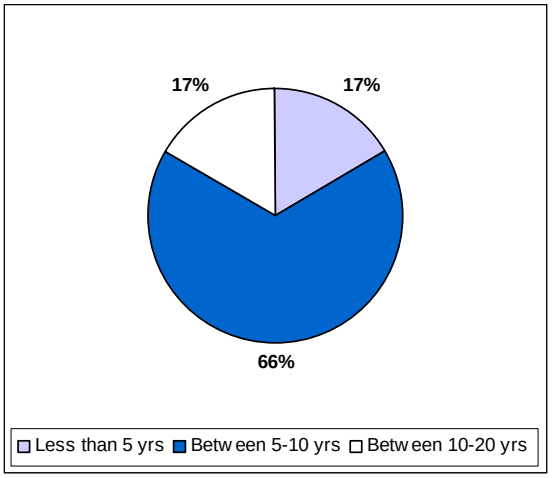

FIGURE 5 Years of experience with pre-wetting – PNS states

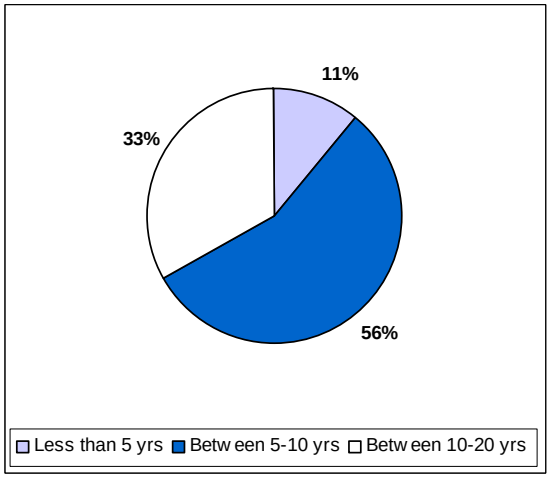

FIGURE 6 Years of experience with pre-wetting – non-PNS states

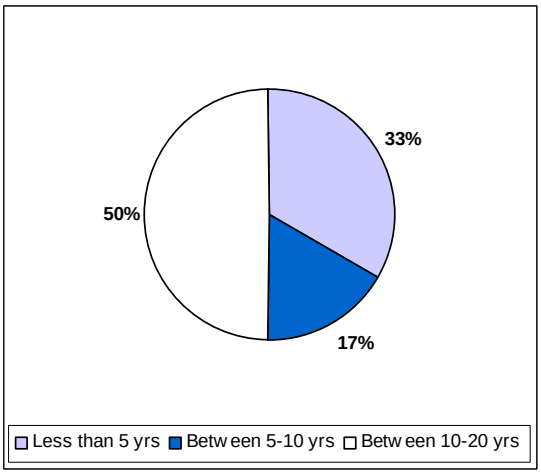

FIGURE 7 Years of experience with anti-icing – PNS states

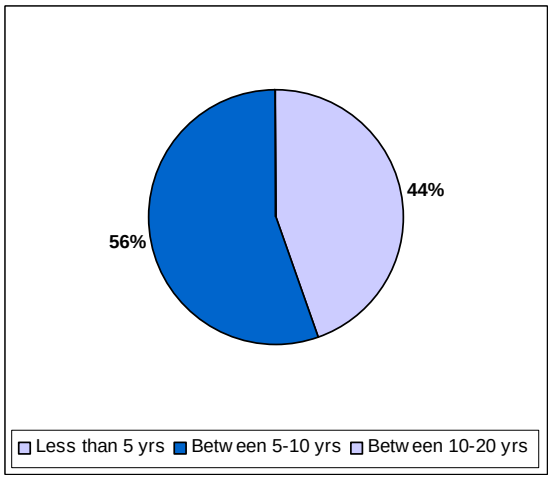

FIGURE 8 Years of experience with anti-icing – non-PNS states

Both anti-icing and pre-wetting are efficient means of winter maintenance and have been found to decrease maintenance costs while reducing the vulnerability of the highway system to winter weather. In Washington State, the implementation of anti-icing in the North Central Region has resulted in improved level-of-service at the same cost as previous maintenance practices (*10*). Other benefits include: improved winter driving safety, reduced environmental impacts, reduced human health impacts, and reduced corrosion effects.

Interviewed experts agree that roads have increased traction more of the time when anti-icing and pre-wetting have been utilized. When asked "Have the practices of anti-icing and pre-wetting improved roadway safety for your jurisdiction", the answer was unanimously positive.

Overall, maintenance agencies are confident that pre-wetting strategies significantly improve material retention and speed up the melting process. Pre-wet abrasives will refreeze quickly to the road surface and create a sandpaper-type surface, which can cut abrasive use by 50% in cold temperatures (*9*). If warm, chemicals can accelerate break-up of snow pack while providing a traction aid to the public (*9*).

While pre-wetting is a useful technique in fighting snow and ice pack and for use in areas with high winds, the best way to keep roadways safe is to be proactive and implement anti-icing techniques ahead of a winter storm event. In many conditions, anti-icing eliminates the need for abrasives because it eliminates the cause for slipperiness (*9*). In Montana, benefits of this proactive strategy were witnessed during a winter storm that hit State Route 200 in December of 2000. The crew responsible for the Plains section used anti-icing techniques whereas the Thompson Falls crew implemented pre-wetting techniques. Of the two sections, the Plains section achieved bare pavement conditions while the Thompson Falls section remained snow packed, suggesting the success of anti-icing (*11*).

Idaho has also seen the benefits of anti-icing. On US 12, once anti-icing was implemented, accidents were reduced by 83% each year compared to years before the start of the pilot program (*12*).

Environmentally, anti-icing and pre-wetting help reduce chemical and sand levels in waterways and particulate matter in the air. Both practices reduce the total amount of materials needed, which helps reduce negative environmental impacts. When asked "Are there environmental benefits offered by the practices of anti-icing and pre-wetting", most agencies believed so but such benefits are hard to monitor. When asked "Have the practices of anti-icing and pre-wetting significantly reduced your application rate of chemicals or sand", some managers indicated a reduction of 20-30% for sanding applications and about 10% for chemical applications.

Concerns regarding human health and the use of chemicals and abrasives on winter roads are generally mild. In addition, agencies have found that through anti-icing and pre-wetting, they were able to reduce material usage and thus reduce potential health risks. Most agencies surveyed have experienced contamination due to winter maintenance chemicals in some form, but felt that anti-icing and pre-wetting reduce chances of reoccurrences. Survey responses are included in TABLE 1.

TABLE 1. Survey Responses Regarding Environmental Concerns

Environmental Concerns	AL	AB	BC*	CO*	ID*	MN	MO	MT*	NV	NY	OR*	VT	WA*	WI	WY
Claims	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	No	No	No	Yes	No
Groundwater Contamination	X	X	X	X						X				X	
Soils and Vegetation		X	X					X	X					X	
Air Particulates				X					X						
Beneficial	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes

*Current PNS Association Participating Members

Corrosion related to winter maintenance chemicals is a great concern to motorists as well as state Departments and Provincial Ministries of Transportation. Most questionnaire respondents felt that corrosion was minimal with a few complaints of cosmetic corrosion on vehicles. In one instance, an allegation was made by the power authorities, claiming that the use of magnesium chloride was corroding wires and short-circuiting some of the hydropower lines. Some agencies responded that corrosion to maintenance vehicles was high when lots of salt was used, but with the use of liquid chemicals, there is less corrosion to the body of a truck and more on the wiring. Very few agencies, however, linked winter maintenance practices to the infrastructure damage.

In examining economics related to snow and ice control, all costs should be considered such as material costs, labor hours, cleanup and repair, vehicle damage, travel delays associated

with winter road closures and construction, human health and litigation. While some of these numbers are difficult to estimate, all are important in balancing the equation to determine the best management practices.

Materials and labor hours are two categories that are easily estimated, however, not all agencies separate costs in terms of practice. Instead, they may only report a lump sum, which raises a problem when trying to differentiate whether or not anti-icing and pre-wetting are economical. However, both practices may reduce labor hours and materials while providing a safer roadway, leading to the assumption of cost savings.

The research indicates that agencies see cost savings derived from anti-icing and pre-wetting practices for snow and ice control. Overall, agencies felt that they were able to apply less material and clear the roads faster without the need for overtime. One agency reported that "trucks are off and parked 20% faster than the ones not using liquid" (*13*). It should be noted that economic benefits was not the number one reason for a switch in maintenance practices, but more for the improved level-of-service and safety for motorists.

Constraints Associated with Improved Technologies

Constraints of implementing anti-icing or pre-wetting generally relate to the lack of equipment or training. While most agencies agree that these practices are extremely beneficial for the driving public and the environment, one respondent commented that it was difficult to implement and execute these practices in a methodical manner. On the contrary, participating PNS members overcame this kind of problem years ago. Following are some of the identified constraints associated with anti-icing and pre-wetting.

Anti-icing:

- Training and management,
- Equipment costs,
- Reliance on accurate weather forecasts,
- Casual slipperiness effect,
- Material handling, and
- Public perception

Pre-wetting:

- Training and management,
- Equipment costs,
- Material handling, and
- Public perception

It should be noted that not all conditions warrant the use of anti-icing. Under some climatic conditions such as high wind and very cold temperatures, anti-icing should be avoided (*14*, *15*, and *16*).

CONCLUDING REMARKS

Anti-icing and pre-wetting offer many benefits and have great potential in changing the way maintenance agencies approach snow and ice control. Anti-icing and pre-wetting both present a viable option in reducing materials applied to roadways and maintenance costs while providing

safer traveling conditions. Both practices also lead to less corrosion and environmental impacts due to snow and ice control operations.

Materials chosen for anti-icing and pre-wetting are often similar to those used for de-icing. However, improved application techniques allow agencies to achieve safer roadways sooner with less material. By implementing anti-icing and pre-wetting, fewer chemicals and abrasives have a chance to enter soil, waterways and the atmosphere.

Compared with traditional methods for snow and ice control, anti-icing and pre-wetting lead to decreased applications of chemical products, reduced use of abrasives, decreased maintenance costs, improved roadway friction, and lower accident rates. Anti-icing has been recognized as a pro-active approach to winter driver safety. Pre-wetting has shown to increase the performance of solid chemicals or abrasives and their longevity on the roadway surface, thereby reducing the amount of materials required.

Areas for improvement may include, but not limited to: better products and equipment for snow and ice control, better weather forecasting, better deployment and utilization of road weather information systems (RWIS), and most importantly, more training. Understanding the fundamental concepts behind the anti-icing and pre-wetting practices would allow agencies to use them correctly. Training and good management practices would help agencies select the best tools available for the specific combination of site, traffic and climatic conditions, including conventional snow and ice control methods.

Surveyed agencies felt that the use of anti-icing and pre-wetting techniques would become more widespread in the next five to ten years. For anti-icing, its widespread use will be possible with an improved RWIS network and reliable, site-specific local weather forecasts (such as those provided by the Weather Operations Program at the Utah Department of Transportation). A less desirable option is termed *just-in-time anti-icing*, which is suitable for agencies without access to reliable weather forecasts (such as the Montana Department of Transportation). This requires maintenance agencies to watch for visual signs that a weather event is approaching such as moisture and temperature drops, at which time, crews will begin deploying anti-icing trucks.

Agencies should continue to implement these improved practices for winter highway maintenance and further tailor the techniques to meet their localized needs. A better understanding of these practices is expected in both fundamental science and engineering aspects, as implementation is increased and additional research is performed.

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