Roadsalt and Winter Maintenance

for

British Columbia Municipalities

Best Management Practices

to

Protect Water Quality

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GLOSSARY OF TERMS

Anti-icing —The application of a chemical freezing point depressant to a roadway prior to precipitation events so as to prevent the bonding of snow and ice to the road surface. Mechanical snow and ice removal usually follows the precipitation event.

Best Management Practices (BMP's) —A practical design, construction, operational procedure or maintenance method, which helps prevent, reduce or correct water pollution.

Brine —A concentrated solution of a salt in water. Usually applied to a saturated solution of sodium chloride.

De-icing —The application of a chemical freezing point depressant to snow and ice that are bonded to paved roadways for the purpose of melting the snow or ice, thereby ensuring safe driving conditions.

NPS (Non-Point Source) Pollution —This is caused by the release of pollutants from widespread and diffuse sources, many of them unidentified and unregulated, associated primarily with land use and development.

Pre-wetting—The addition of water or a de-icing solution to roadsalt or sand before, or during, application to the road.

Roadsalt —The terms 'roadsalt' and 'salt' refer solely to sodium chloride, or rock salt, the most commonly used de-icing chemical.

Spalling—This is the process where the surface of concrete flakes-off in small chips.

Winter maintenance —Public works or highways operations that keep roads clear of snow and ice.

PREFACE

This document is one of a series that deals with non-point source (NPS) pollution problems in British Columbia by proposing BMP's to eliminate or reduce such pollution. It provides guidance and information to local governments and road maintenance contractors concerning BMP's that minimize the impact of roadsalt on roadside vegetation, transportation corridor infrastructure, surface water and ground water.

Public safety is the first priority and must not be sacrificed for more economical winter maintenance procedures. However, the cumulative effect on public safety over the lifetimes of the individuals, which includes contamination of drinking water supplies and corrosion of road infrastructure and vehicles, must be considered. This document recommends cost-effective ways to reduce roadsalt and de-icer damage to infrastructure, vegetation and water resources without compromising public safety.

It is intended for public works departments and local environment committees which supervise or advise on the winter maintenance of roads and streets within municipal jurisdiction. The intention is to supplement, not replace, the current British Columbia Ministry of Transportation and Highways accepted practices which are documented in a technical maintenance manual (BC MOTH, 1995). Refer to this manual, which may already be used in some municipalities, for specific operational details.

this document contains Best Management Practices to help mitigate Non-point Source Pollution problems in British Columbia

SUMMARY

there are alternatives to common roadsalt which are more effective and less damaging to water supplies

the total cost to society should be considered, not just the capital cost of the roadsalt

This document reviews measures that British Columbia Municipalities can use to reduce the pollution of the environment by roadsalt and de-icers without compromising road safety. These include a reduction in salt use by following application guidelines, replacement of some salt with sand or ploughing. Pre-wetting the salt or sand/salt mixture can make it more effective thus reducing the amount that needs to be used. Advanced equipment such as special snow ploughs, remote monitors, automated de-icer sprays, infra-red pavement temperature monitors, spreaders and pavement friction monitoring devices can also reduce salt use. Anti-icing techniques and materials can also be used.

There are alternatives to roadsalt which are more effective and less damaging to water the environment but their costs are significantly higher. However, the total cost to society should be considered, not just the capital cost of the roadsalt. One can also use alternative winter maintenance practices. Changes in driver behaviour and expectations would reduce the need for as much salt and maintenance if dry, bare roads were not expected. Changing snow dumping practices to eliminate dumping in sensitive areas would reduce the environmental damage caused by what salt was still required. Eliminating some contaminants in roadsalt would reduce the harmful effects of roadsalt use.

There is a list of roadsalt and winter maintenance web sites in section 5.1.

1. INTRODUCTION

In British Columbia, each municipality determines its own winter road maintenance operations, which, for many communities, relies heavily on the use of salt as a road and street de-icer. This BMP document attempts to provide guidance to BC communities so that they are better able to protect their natural resources and quality of living without compromising the level of winter maintenance services. Because road safety remains the top priority when looking at measures that reduce the flow of roadsalt into the environment, this document focuses on examples of successful, cost-effective initiatives that do not compromise safety. This document also provides technical information, resources and guidance to encourage and facilitate development of effective local plans to reduce the impact of roadsalt.

Case studies elsewhere demonstrate that levels of service need not suffer due to changes or reductions in application of roadsalt. Following these selected BMP's, local governments may notice significant savings in addition to environmental benefits. There are already many municipalities in British Columbia that have advanced winter maintenance programs and employ many of the measures outlined in this document. They are an excellent resource for other communities that are working to establish more conscientious winter maintenance practices.

this document focuses on examples of successful, cost-effective initiatives that do not compromise safety

Winter maintenance is an indispensable operation that provides safe winter driving conditions for BC residents. The goal is fewer accidents and thus lower repair costs for automobiles, and reduced medical and job loss costs for people. There are a variety of tools used to clear roadways of snow and ice; plowing and road salting are only the primary ones.

it is widely recognized that the ever-increasing use of salt to maintain clear roadways is not without costly consequences

Since the early 1950s, roadsalt has been applied extensively in North America (14 million tons in the USA in 1996) to de-ice roads for the purpose of providing safe and convenient driving conditions. Over time, the use of roadsalt has become commonplace; the amount used in British Columbia increased rapidly. There was about a 40 percent increase through the 1980s (Bedford, 1992).

In the 1970s, it became widely recognized that the ever-increasing use of salt to maintain clear roadways is not without costly consequences. Damage due to roadsalt on roadside vegetation, wildlife, soil, road surfaces, bridges and automobiles, as well as the contamination of surface and drinking water, have generated concern about the use of roadsalt for de-icing.

In parts of Canada and the United States, groundwater has been contaminated to the degree that it is no longer potable and some lakes have suffered environmental impacts.

The transfer of roadsalt and other de-icers from delivery trucks to the storage facility, and from the storage facility to the spreader trucks, may be of more environmental concern than the actual storage of the roadsalt. Groundwater in Heffley Creek, BC (just north of Kamloops) was contaminated in 1994 by spillage during handling and storage at a salt storage facility. Salt and sand was stored in front of the storage facility and not under cover on an impervious surface. The incident demonstrated that communities in BC are susceptible to water quality degradation as a result of roadsalt. Generally, the spillage which may occur while transferring the salt to and from the storage piles is of more environmental concern than long term storage, when a proper storage facility has been constructed. This spillage must be cleaned up immediately to prevent chronic contamination of the local area.

The initial cost of roadsalt is low compared to most alternative treatments; however, studies indicate that the real cost of applying roadsalt is much higher than the capital cost of the material. The USEPA reports that the actual annual cost of salt-related damage approaches 15 times the cost of purchasing and applying the roadsalt. This is due to damage to roads, vehicles, bridge decks and superstructures, water supplies and vegetation. This cost must be weighed against the cost of property damage and personal injuries resulting from slippery roads which result in higher accident rates.

A further cost to consider is legal suits arising from injuries occurring due to roads not being maintained to an acceptable standard.

communities in BC are susceptible to water quality degradation as a result of roadsalt

the actual annual cost of salt-related damage approaches 15 times the cost of purchasing and applying the roadsalt

2. BACKGROUND

2.1 ROADSALT: WHAT IS IT?

Conventional roadsalt is primarily common table salt (sodium chloride or NaCl). Because of this, it is rarely viewed as potentially toxic or harmful. In reality, roadsalt can be very damaging to the environment. Roadsalt can have serious impacts on water quality and specific BMP's have evolved to protect water resources. In addition, a number of other chemicals are often added to roadsalt to depress the freezing point, reduce the corrosion of vehicles and structures and prevent the roadsalt from caking or clumping so that it may be readily spread; roadsalt usually contains various impurities as well.

roadsalt can have serious impacts on water quality

Environment Canada has included roadsalt and other de-icers in their second Priority Assessment List of potential toxic substances under the *Canadian Environmental Protection Act*.

Roadsalt is typically mined as the ore halite and transported to various stockpiles from which it is distributed for use as a de-icing chemical.

Roadsalt acts by lowering the freezing point of water. NaCl is effective down to about -7 °C and $CaCl_2$ will still work several degrees lower but $CaCl_2$ costs more. When the salt crystals are dissolved by moisture, the brine formed is then able to melt or dissolve crystals of snow and ice, thereby clearing the roadway for traffic. However, the effects of the sodium chloride solution do not end there.

2.2 IMPACTS ON WATER QUALITY AND THE ENVIRONMENT

The sodium chloride brine and solids enter the surrounding environment in runoff, spray, aerosols and dust from traffic, deposition from ploughing and snow removal. Negative impacts can include damage to vegetation, soils and wildlife, contamination of surface and ground water (including drinking water supplies) and corrosion of metals, concrete and other materials. This document is concerned principally with the impact of roadsalt on water quality and other impacts are not discussed. However, if less roadsalt is used the effects on soils, vegetation and animals will also be reduced.

Recent studies in southern Ontario showed that only about 45% of the applied roadsalt runs off; the rest contaminates shallow aquifers. Considering the past and present rate of roadsalt application in Ontario, groundwater will soon be contaminated with sodium and chloride beyond safe levels. Since there is a lag period before the salt shows up in groundwater, the problem with contaminated drinking water will continue to get worse before it gets better, even if road salting stops.

groundwater will soon be contaminated with sodium and chloride beyond safe levels

The accepted chloride level in drinking water is around 250 mg/L as set by the USEPA and the Ontario Ministry of Environment. Pore waters from the unsaturated zone adjacent to Metropolitan Toronto Highways had measured chloride levels of 14,000 mg/L in 1987 (Pilon and Howard, 1987).

sodium is highly soluble and a proportion of it may end up in groundwater or surface water

chloride migrates through soils and accumulates in underground water supplies

Mass balance and steady state calculations, based on current application rates in Ontario and measured loss rates, indicate chloride will reach 400 mg/L and sodium 250 mg/L (Howard *et al*, 1993). Ultimately the salt will start to show up in the Great Lakes (Howard *et al*, 1993; Toronto-1995). There are no similar studies available for British Columbia.

Sodium is highly soluble and a proportion of it may end up in groundwater or surface water.

Sodium ions may bind to soil particles in roadside soils causing other ions, often heavy metals, to be released into the water in place of sodium. This exchange typically causes harmful changes to soil structure and properties.

High concentrations of sodium in the soil and water may be toxic to plants. High concentrations of sodium in the human diet may lead to many conditions such as hypertension, cardiovascular disease, metabolic disorders, renal diseases and cirrhosis of the liver. However, water would become unpalatable to most people before these conditions would arise.

Sodium may also alter the pH of the surface water; Na^+ ion exchange releases H^+ ions from the soil thereby making the water more acidic. Changes in pH have been known to greatly exaggerate the effects of certain ambient toxic substances upon aquatic life.

Chloride is prone to migrate through soils and accumulate in underground water supplies.

Chloride is relatively unreactive, but has been known to contribute to density stratification, as a component of dissolved salt in small lakes, preventing the ecologically important seasonal lake overturn. Chloride tends to be somewhat less toxic to animals and plants than sodium. However, too much chloride makes water unpalatable and eventually unfit to drink. There are abundant examples of extensive drinking water contamination resulting from applying sodium chloride to roads. In the United States, Massachusetts and New Hampshire in particular, the costly replacement and/or abandonment of wells due to chloride contamination has occurred often enough that, in many cases, applying salt to roads has been discontinued in problem areas (Chollar, 1996; Minsk *et al*, no date).

A survey of wells near Ottawa, Ontario in 1979 showed that levels of chloride resulting from nearby application of salt to the roads exceeded the Ontario Ministry of Environment public water supply criterion (Minsk *et al*, no date). In British Columbia, the community of Heffley Creek suffered severe drinking water contamination from stored roadsalt and individual wells had the quality of their water impaired.

there are abundant examples of extensive drinking water contamination resulting from applying sodium chloride to roads—in BC the major documented problem arose from improper salt storage and handling rather than from application

roadsalt containing iron cyanide as an anti-caking agent should not be used

Cyanide is highly soluble and will contaminate surface waters. It is also prone to migrate through soils and accumulate in underground water supplies.

Iron cyanide may be added to roadsalt as an anti-caking agent at levels reaching at least 45 mg total cyanide per 1000 kg of roadsalt. Roadsalt containing iron cyanide (ferrocyanide or ferricyanide) as an anti-caking agent should not be used. There are other environmentally safe replacements for iron cyanide. This cyanide content may not be labelled or it may be called 'yellow prussiate of soda'. UV light breaks down the chemical bond releasing free cyanide.

British Columbia is a large and diverse province. There are significant differences in regional and site-specific climate, biology, geology and geography which are important in determining the impact of de-icing chemicals. For example, soil composition, drainage patterns, moisture content, timing and both total quantity of salt applied as well as the concentration of salt per km are a few characteristics recognized as important in determining the sensitivity of an area to salt damage. Because the impact of roadsalt is so site-specific, it is very difficult to make broad recommendations for all British Columbia municipalities.

2.3 LOCAL CONCERNS

Some characteristics that often pre-dispose an area to potential water quality impairment from roadsalt include regularly salted roadways in association with:

—highly permeable soils (low clay content) with low to moderate overall precipitation that may allow salt to filter into aquifer waters, but not enough rainfall to flush the salt through the soil or aquifer,

—shallow or poorly designed wells, and.

—high gradient slopes over impermeable soils that drain directly into low volume, slow moving water bodies.

Often, as was the case in Heffley Creek's 1994 water contamination, water quality degradation due to roadsalt goes unnoticed for years until the problem is relatively severe. Each community should examine its potential susceptibility to environmental damage from de-icing chemicals and implement winter maintenance strategies that will protect their resources.

each community should examine its potential susceptibility to environmental damage from de-icing chemicals and implement winter maintenance strategies that will protect their resources

3. MINIMIZING THE IMPACT OF ROADSALT ON WATER QUALITY

In British Columbia, several coastal lakes are known to have had their normal calcium and carbonate dominated chemical equilibria altered such that sodium and chloride are now the dominant ions (Warrington, 1998). One lake is on the highway between Terrace and Kitimat and another between Port Alberni and Long Beach. These are lakes adjacent to highways with snow and ice problems which happen to have convenient scenic pullouts along the lakeshore where snow, containing salt, was pushed over the bank during removal operations or else roadside snow and salt simply ran directly into the lake during the spring thaw.

the source of the Heffley Creek groundwater contamination was inadequate salt handling and storage

The source of the Heffley Creek groundwater contamination was inadequate salt handling and storage outside the storage facility that had been releasing salt into the soil for years. Heffley Creek residents were supplied with bottled drinking water, suffered damage to gardens and other vegetation and may also have suffered damage to water filtering systems, pipes and fixtures as a result of this contamination. The total remediation cost of the contamination was about $2,000,000 which included land purchases and construction of a new salt storage facility.

Supplying drinking water, sealing a gravel pit, upgrading the water supply and testing and monitoring, came to $635,000. While normal roadsalt application operations would not be expected to cause contamination at the levels observed in Heffley Creek, the incident demonstrates that communities in British Columbia are susceptible to water quality degradation as a result of improper salt storage and application. Since salt application, roadway area, and traffic volume all continue to increase, it is prudent to take steps to protect water resources by preventing impacts rather than attempting remedial measures later.

Nine strategies to reduce or eliminate the risk to water quality caused by roadsalt are discussed below. These are:

- modify snow dumping practices,
- reduce salt use,
- use pre-wetting,
- use modern metering equipment,
- practice anti-icing,
- use alternatives to salt,
- carry out alternative maintenance practices,
- change driver behaviour and expectations and
- eliminate contaminants in the roadsalt.

3.1 REDUCE SALT USE

The State of West Virginia uses 100,000 to 140,000 tons of roadsalt, or more, in an average to severe winter. They may have up to 73,000 tons stockpiled at any one time. This salt costs them an average of $35.00 ton; it is the cheapest (capital cost) deicing material available.

communities in British Columbia are susceptible to water quality degradation as a result of improper salt storage and application

the simplest way to mitigate the environmental impact of roadsalt is to reduce the amount of salt applied

In the USA highway deicing accounted for 60% (20 million tons) of the 31.5 million tons of NaCl used in 1994. No other use exceeded 10% (WVDOT, 1997). Similar data is not available for British Columbia but these examples give an idea of the magnitude of roadsalt use. In addition to improved salt storage and handling, the simplest way to reduce the environmental impact of roadsalt is to reduce the amount of salt applied.

Follow application guidelines

In many cases, applying less salt is practical without compromising road safety. Without specific guidelines, operators desiring to do the best possible job of clearing a roadway may err on the side of caution and apply too much roadsalt. To prevent over-application, established amounts of salt per unit area for specific temperature ranges and timing, with respect to snowfalls, should be calculated. Crews should be well trained to adhere to the standards and ensure that application rates are consistent. There should be regular reviews and adjustments to the materials and amounts applied as conditions dictate. These measures alone have been shown to reduce salting and sanding by as much as 30 percent (Michigan, 1996). Reducing the proportion of salt added to sand helps too.

Consider sanding

Another means of reducing the amount of roadsalt is to rely more on sand as an abrasive. Good judgement is required when using abrasives; they may cause more environmental problems than they solve.

It depends on the abrasive used and what effect it has on infrastructure, air quality, and watercourses.

Rely on ploughing

Ploughing snow is more economical than melting it with chemicals (Lawson, 1995). In general, mechanical removal should be used in preference to salting where both methods are shown to be equally effective, economical and practical.

Table 1 is taken from the British Columbia Ministry of Transportation and Highways, Maintenance Services Manual, and provides minimum roadsalt application rates to be used by winter maintenance contractors. These rates can be used as a basis for comparison with local salt use rates.

3.2 PRE-WETTING SALT

Applying water or some de-icing solution to roadsalt and/or sand before, or during, application is a process known as pre-wetting (Gustafson, 1992). The liquid coats the particles and, upon contact with the roadway surface, the salt or sand embeds itself in the ice or snow (Bodnarchuck *et al*, 1994).

Pre-wetting has a capital cost which must be weighed against the environmental costs of not using this more efficient process. Pre-wetting decreases the amount of roadsalt or sand required without decreases in levels of service. However, the increased costs due to pre-wetting and the decreased cost of using less salt and sand may not be equal

pre-wetting decreases the amount of roadsalt or sand required without decreases in levels of service

Table 1. Roadsalt Application Rates.

Application	Description	Application Rate
A light application	surface temperature near freezing with light snow or sleet, or to prevent Black Ice	60 kilograms per two-lane kilometre (about 1/20 cubic metre)
B average application	early in day with surface temperature -4° Celsius and rising; conditions: snow, sleet or freezing rain	85 kilograms per two-lane kilometre (about 1/14 cubic metre)
C heavy application	early in day with surface temperature -4° Celsius and stable or -6° Celsius and temperature rising or late in day with surface temperature -4° Celsius and rising accumulation of packed snow or ice on highway surfaces	130 kilograms per two lane kilometre (about 1/9 cubic metre)

The services manual contains other useful information, and should be consulted. Details about the manual can be found in the Information Resources section of this document.

Experiments in 1993 and 1994 by the British Columbia Ministry of Transportation and Highways in pre-wetting salt with calcium chloride ($CaCl_2$) and magnesium chloride ($MgCl_2$) brines resulted in large reductions (as much as 53% in one instance) in total de-icing chemical applications (Bodnarchuck *et al*, 1994). The sand is also embedded in the snow and ice and does not get washed or blown off the road surface. This means that less roadsalt and sand needs to be applied to achieve the same effect, resulting in less runoff. Smaller sand particles are used, resulting in less vehicle paint and windshield damage. These results may justify the extra capital cost.

A variety of liquids may be used for pre-wetting roadsalt. These include sodium chloride, calcium chloride, magnesium chloride, potassium acetate, and calcium magnesium acetate in brine solutions. Water can also be an effective pre-wetting agent provided that the temperature is relatively high.

Each solution has different properties and may behave differently due to the chemical characteristics and the method of pre-wetting employed (for more detailed information, see the document FHWA-Effective Anti-icing Program under the heading On-line References in the Information Resources section of this document).

pre-wetting does not necessarily require large and expensive equipment

Pre-wetting does not necessarily require large and expensive equipment purchases. There are three basic techniques of pre-wetting.

savings in salt, time and money can be significant

- injecting a pre-wetting chemical into a material stockpile in specific amounts,

- spraying the liquid into a full spreader or into the solid chemical as it is being loaded, and

- wetting the material with a spray system as it is spread (Ketcham *et al*, 1996).

The Information Resources section of this document identifies documents that provide instruction on how to modify trucks, spreaders, and garages to facilitate pre-wetting. While there is an initial investment in time, experimentation and training required, the eventual savings in salt, time and money can be significant.

The following are some of the benefits and concerns associated with pre-wetting:

- The melting action of salt is sped up by the additional moisture, especially when the snow is cold and dry.

- The wet particles tend to adhere to the pavement surface or embed themselves in the ice or snow. This results in less waste due to scattering so less roadsalt can be used and also results in improved vehicle traction.

- The effective temperature range of roadsalt can be increased by pre-wetting with calcium chloride ($CaCl_2$) and/or magnesium chloride ($MgCl_2$).

It is important to note, however, that like NaCl, these other compounds contain chloride. Therefore, the total volume of de-icers applied should decrease to offset the additional chloride from the pre-wetting solution.

- Roadsalt that is pre-wetted with calcium chloride ($CaCl_2$) tends to retain moisture and remain on the roadway longer than NaCl in its own brine. This may result in less total roadsalt being applied since less frequent applications are required.

3.3 ADVANCED EQUIPMENT

The technology and equipment used in winter maintenance operations is advancing continually. There are an enormous variety of tools that can be used to increase efficiency and safety and to reduce costs. Some of these tools are discussed below:

Special snow ploughs

Several specialized snow ploughs are available that are effective for removing specific types of snow and ice and for operating under different road, highway and street conditions (O'Doherty, 1992). Some examples of different ploughs are:

—one-way front ploughs,
—reversible ploughs,
—four-way articulated ploughs,
—deformable moldboard ploughs,
—underbody ploughs, and
—side wings (Ketcham *et al*, 1996; Michigan, 1996).

Materials used for blade edges include synthetic polymers, rubber, steel and carbide inserts. According to the Washington State Department of Transportation, polymer edges are useful for removing slush (Ketcham *et al*, 1996) from streets and highways. It is therefore only necessary to reduce packed snow to slush, rather than fully melt it, which requires only half as much salt (Ketcham *et al*, 1996; Kuusela *et al*, 1992).

However, this environmentally beneficial reduction in the amount of roadsalt used has an economic cost since a second pass is required to remove the slush. There are also snowplough scoops designed to make snow plough operations more efficient. Note that ploughing *after* de-icing salt has been applied to snow and ice results in the deposition of salt off the roadway. This is both a considerable waste of salt and a potential threat to the environment which is not always avoidable.

Remote monitors

These transmit information about roadway conditions and thus may facilitate timely and appropriate winter maintenance measures.

Such monitors are only a component of an integrated road (or street) weather information system. In addition to real-time pavement temperature, dew point, humidity, air temperature, wind velocity and direction and the amount of de-icing chemical on the pavement; they may have processing and display capacities to assist maintenance managers choose the best maintenance measures (Chollar, 1996; Ketcham *et al*, 1996). Such integrated systems are used by highway and urban maintenance staff alike (Minsk *et al*, no date; Nevada, 1995).

Pavement temperature monitors

These are very useful and much less expensive than fully integrated remote monitors.

Pavement temperature is the main factor in the formation, development and breaking of a bond between fallen or compacted precipitation and the road surface as well as the effectiveness of chemical treatment (Ketcham *et al*, 1996).

Remote monitors that lie beneath the road surface can indicate pavement temperatures in particular trouble spots, near or on a bridge for instance, so that action can be taken immediately when there is the risk of dangerous conditions. It is even feasible to have speed limits over bridges regulated by automated road condition monitors. Thermisters are used in several locations in British Columbia.

speed limits over bridges can be regulated by automated road condition monitors

an efficient and precise spreading mechanism is one very effective way to mitigate the impact of roadsalt on the environment

Automatic de-icer spray systems

These are available for trouble spots such as bridge decks; a high pressure nozzle and sprayer are embedded in the roadway itself and activated remotely or automatically when sensors indicate there is a need (Minsk *et al*, no date).

Infra red pavement temperature monitors

These can be fitted to trucks so maintenance supervisors can determine the most efficient rate of de-icer or abrasive application required (Lawson, 1995).

Spreaders

These and other application mechanisms are one of the most fundamental pieces of winter maintenance technology with regard to de-icing chemicals. They can range from somebody in the back of a pickup with a shovel and some salt, to a state-of-the-art spreader truck with tanks for liquid de-icing chemicals, automatic speed regulated application and various other technologies. The range in capital cost is, of course, equally broad. Having an efficient and precise spreading mechanism is one very effective way to mitigate the impact of roadsalt on the environment. An even distribution of salt, applied at a consistent, pre-determined rate, with minimal scattering of salt particles cuts down dramatically on the amount of material applied. Special spreaders also allow for the implementation of liquid de-icer, anti-icing and pre-wetting applications which, themselves, can be very effective means of reducing roadsalt application.

Highway authorities in Finland report that a *liquid* roadsalt solution allows for 50 to 75 percent reductions in roadsalt application over granular roadsalt, because of application accuracy (Kuusela *et al*, 1992). Each community should examine its own needs and consider the most effective device for their own de-icing operations. Future savings in materials, wages, and community-wide salt damage should be considered when comparing the cost of various spreaders.

Pavement friction monitoring devices

These can be used to determine precisely how slippery the roadway is. Such a device attaches to a vehicle and measures the friction coefficient of the road surface. The operator can then make an informed decision as to whether application of roadsalt is needed.

3.4 ANTI-ICING

The term anti-icing is one that has emerged relatively recently to describe a new approach to winter maintenance that differs from traditional de-icing methods. Anti-icing is the timely application of chemical freezing point depressants to roadways before snow and ice accumulate. This prevents the formation of a bond between slippery snow and ice and the roadway, thereby facilitating mechanical removal (Ketcham *et al*, 1996). Anti-icing allows for a very high level of traffic safety at low cost and significantly reduces the amount of roadsalt used.

anti-icing allows for a very high level of traffic safety at low cost and significantly reduces the amount of roadsalt used

Salt is no longer applied in quantities required to melt downward through a heavy layer of snow and ice. Because the required amount of de-icer is reduced, it then becomes feasible to use more expensive and more specific chemical alternatives to roadsalt.

to use anti-icing techniques, a winter maintenance operation may only need minor adjustments

Many of the winter maintenance tools described earlier, such as special ploughs and weather information systems are components of anti-icing programs. Anti-icing consists of preventative winter maintenance measures that may vary depending on climatic, roadway and traffic conditions as well as timing. This practice requires the use of considerable judgement and experience, the methodical use of available information, and the ability to promptly coordinate and mobilize operations (Ketcham *et al*, 1996).

To use anti-icing techniques, a winter maintenance operation may only need minor adjustments. Often, it is discovered that anti-icing is being practiced without it being recognized as such. Some of the more effective anti-icing tools include liquid anti-icing chemicals (liquid de-icers) and accurate local weather information. In some areas these techniques alone are sufficient to eliminate, or greatly reduce, the use of roadsalt. Liquid spreading mechanisms can be constructed at relatively low cost.

These tools, along with experience of local road conditions, may be enough to achieve goals like improved roadway conditions, fewer working hours per week for winter maintenance operators and reduced impact on the environment (Keep *et al*, 1995).

An essential component for a successful anti-icing program is operator training. Winter maintenance experts in North America and Europe alike stress the importance of training for anti-icing. Operators must have a good understanding of what the options available to them will achieve and use a systematic approach. Standards and calibration charts are important parts of an anti-icing operation but are ineffective without an operator who is aware of their function and impact. Operator training is one benefit of inter-community exchanges of information and resources that can be especially valuable. There are also consultants who may be contracted to educate crews and managers about anti-icing practices.

an essential component for a successful anti-icing program is operator training

The above material only summarizes some basic information on anti-icing. Further independent research on the topic is recommended. For references see the Information Resources section of this document.

3.5 ALTERNATIVES TO SODIUM CHLORIDE

Several freezing point depressants are available for road de-icing as alternatives to NaCl.

the actual annual cost of salt related damage approaches 15 times the cost of purchasing and applying the roadsalt

Their efficiency as de-icers, and their relative effects on the environment need to be reviewed on an individual basis.

The initial cost of NaCl is quite low compared to most alternatives, but studies have indicated that the real cost of applying roadsalt is much higher than the initial cost. The US Environmental Protection Agency reported that the actual annual cost of salt related damage for 1976 was 15 times the cost of purchasing and applying the roadsalt (D'Itri *et al*, 1992).

Figures for the full cost of applying roadsalt in BC are not available, but they are likely similar and substantial. The high actual cost of salt damage has not been enough to dissuade most agencies in North America from using salt. However, the Washington State and Oregon State Departments of Transportation have eliminated or vastly reduced sodium chloride in their winter maintenance programs because of the high overall costs associated with its use (Keep *et al*, 1995). They have used anti-icing strategies, including the application of calcium magnesium acetate as the principal freezing point depressant.

Calcium Chloride ($CaCl_2$) is a more effective de-icer at lower temperatures than sodium chloride (NaCl). It attracts moisture and tends to stay on the road surface longer than NaCl (Trotta, 1988). A brine is commonly used for pre-wetting. $CaCl_2$ has the same problems with chloride activity, and is more costly, than NaCl.

Calcium Magnesium Acetate has a low environmental impact but can contribute to biochemical oxygen demand (BOD) in small bodies of surface water. It is an effective agent for anti-icing (Keep *et al*, 1995) although a little less effective as a de-icer than NaCl. The main reason it is not more widely used is its high purchase cost relative to NaCl.

Magnesium Chloride ($MgCl_2$), like $CaCl_2$, is also a more effective de-icer at lower temperatures than sodium chloride (NaCl). It also attracts moisture and tends to stay on the road surface longer than NaCl. Brines are commonly used for pre-wetting. $MgCl_2$ has the same problems with chloride activity, and is somewhat more costly, than NaCl.

Potassium Acetate is used as a base for several commercial chloride-free liquid de-icer formulations. The reputed advantages include low corrosion, relatively high performance and low environmental impact. The cost is high.

Potassium Chloride (KCl) is similar to calcium and magnesium chlorides. It is also a more effective de-icer at lower temperatures than sodium chloride (NaCl), is hygroscopic (attracts moisture), and tends to stay on the road surface longer than NaCl. Brines are commonly used for pre-wetting. KCl has the same problems with chloride activity, and is somewhat more costly, than the more common NaCl.

brines are commonly used for pre-wetting

there are alternatives to roadsalt available that cause less environmental damage

Sodium Salts of Carboxylic Acids are mixtures of the sodium salts of fatty acids with low molecular weight, such as sodium formate, and have demonstrated de-icing properties comparable to sodium chloride. Such chemicals can be used to reduce the amount of chloride released in winter maintenance operations, but sodium would still be an issue. Such chemicals are still largely under development. Their use should be carefully controlled.

Urea is not as effective as NaCl but is less corrosive. It has less effect on soil and vegetation than NaCl but promotes algal growth and biochemical oxygen demand (BOD) in surface waters. Urea is used at airports to avoid corrosion of aircraft.

There are various liquid and solid formulations of these chemicals. Each winter maintenance operation must determine the best choice for its own program. There are alternatives to roadsalt available that cause less environmental damage and more are being developed. Regular reviews of products available in the market and discussion with other communities regarding alternative de-icers are recommended. MOTH constantly carries out reviews and analyses of de-icers. Capital cost is usually the major problem with use of such materials.

3.6 ALTERNATIVE WINTER MAINTENANCE PRACTICES

There are alternative ways to reduce impact of roadsalt to the environment.

While simply modifying existing winter maintenance practices slightly is one technique, there are some other measures that can be applied. A few such measures are listed below.

1. Education of road maintenance staff to reduce the quantities of salt used and to prevent the unnecessary use of salt.

2. Limiting salt application to specific areas that need it the most such as steep inclines, bus routes and main thoroughfares.

3. Establishment of buffer zones and filter strips on the sides of roadways to prevent direct spray and runoff from reaching sensitive surface waters and vegetation.

4. Construction of drainage systems that direct salt laden runoff away from sensitive areas. When local groundwater quality is a concern, catchbasins, drainpipes, lined ditches, and impervious berms beneath the roadside are all effective for directing salt away from the problem areas. This is more cost-effective in urban areas.

5. Identification of salt-sensitive areas, ecosystems, waterbodies and aquifers which require special reductions in the application of salt on relevant stretches of roadway. Alternative chemicals, more efficient use of salt, reliance on abrasives and changes to the road surface are possible means of achieving such a reduction.

education of road maintenance staff can reduce the quantities of salt used

3.7 CHANGING DRIVER BEHAVIOUR

One measure which would allow for vast reductions in winter maintenance would be to increase public awareness of the potentially harmful effects of de-icing chemicals on the environment and to secure the public's cooperation in reducing the need for application of salt on roads by lowering speed limits under icy conditions. In some places where the environment is very sensitive to human activity and important to the public, lower speed limits and other driving restrictions have been imposed.

In Japan, commuters drive more slowly in the winter months and use special soft rubber winter tires that grip the road surface almost as well as studded tires (Minsk *et al*, no date). In parts of the Netherlands where drinking water quality is an issue, speed limits are sometimes controlled by road conditions and the public does not expect to drive the same speed all year round (Leppänen, 1996). Anti-lock brakes on vehicles will also help, to some extent, to reduce accidents on ice and snow.

3.8 SNOW DUMPING

In many cases, particularly in cities, snow cannot be pushed off the road-side, but must be picked up and dumped somewhere. Where to dump large quantities of snow has always been a problem. In many places it has been dumped into water, rivers and lakes, which gets rid of it effectively.

However, when it is scraped off the streets, snow includes salt, sand, organics, metals and debris and these contaminants are of concern (Table 2). If snow is left on the streets to melt and runs into storm sewers much of this material ends up in the rivers, although some solids do settle out in retention basins where these exist. If the snow is piled on empty lots the solids are removed but much of the soluble salts will eventually find their way into groundwater or surface waters. There is no fully satisfactory solution, but there are some compromises which lessen the impacts to water and sediment quality. These include:

—do not dump snow from roads into lakes, ponds, swamps or other standing water bodies.

—do not dump snow from roads in small community streams-dump it only in large rivers with a high dilution flow.

—snow dumped in high flow rivers should be mostly fresh new snow with low concentrations of salt, sand, sediment or other contaminants.

—contaminated snow (snow which has been on the road for some time and has been salted or sanded) should be dumped on non-porous land and allowed to melt. The land should be situated such that there will be no overland flow of the melt water into water courses.

—the same location should not be used continuously over many years where the soil conditions could lead to groundwater contamination.

snow includes salt, sand, organics, metals and debris when it is scraped off the streets

3.9 CONTAMINANTS IN ROADSALT

do not assume roadsalt is just NaCl

Roadsalt may contain a number of contaminants, some deliberately added and others incidental. The source of roadsalt used should be analysed to make sure it has no harmful materials in it. Anti-caking compounds are sometimes added and some of these contain cyanide which is very toxic and should be avoided. Do not assume roadsalt is just NaCl; the commercial grade used for roadsalt is impure and will contain contaminants, some of which may be toxic. However, apart from the cyanide the concentrations are generally too low to be of concern.

When large purchases of roadsalt are going to be made, insist on an analysis of the product first. Testing by MOTH over the years indicates that the normal mixture supplied is about 99% NaCl and only 1% contaminants, mostly soil particles.

Table 2 gives some contaminants in snow removed from roads in Toronto. Not all of these contaminants resulted from roadsalt application. With the obvious exception of the chlorides, most came from the roads and the cars themselves and after normal dilutions of 10:1 or 20:1 would not constitute a water quality problem.

Table 2. Contaminants in Snow Removed from Toronto Roads.

Parameter	mg/L concentration	lb./ton of snow
total solids	10500	21
chlorides	2250	4.4
total lead	9.8	0.02
total iron	41.5	0.08
total phosphorus	2.4	0.005
BOD	57	0.114

based on 5 samples of Toronto street snow.

The concentrations of all these contaminants exceed the BC water quality criteria for aquatic life; undiluted melted snow would not meet water quality guidelines to support aquatic life.

groundwater contamination by roadsalt was caused by runoff and infiltration of NaCl from salt storage piles

4. SALT STORAGE FACILITIES

Roadsalt was often stored in piles near the stretch of road where experience indicated it would be needed. Often there were neither floor nor roof provided for the piles. Historically, groundwater contamination by roadsalt was caused by runoff and infiltration of NaCl from these salt storage piles.

A properly constructed storage facility, and transfer procedures which avoid spillage, should virtually eliminate the risk to water quality from roadsalt storage facilities.

For further information see the document on salt storage by the BC Ministry of Transportation and Highways (Buchanan, 1996) and a more general reference document on road maintenance (BC MOTH, 1995); both can be found in the Information Resources section that follows.

The following page contains a list of suggestions for building and maintaining salt storage facilities to help minimize the risk of water quality impairment.

- Locate the site well away from populated areas, wells, groundwater sources and surface waters.

- Construct a permanent roof, impervious to precipitation.

- Drain storage site runoff via tiled ditches or pipes to a collection area, preferably a specially designed sump area.

- Install a plastic liner beneath the storage and loading areas to ensure that spilled salt does not migrate through the soil and into near-by groundwater.

- Keep the loading areas clear of spilled or scattered salt.

- Make the floor out of high quality concrete: air-entrained and sealed to prevent spalling, or cover the concrete floor in asphalt.

- Ensure that the floor or pad has a slope between 2 and 5 percent to allow any moisture to drain into the collection sump.

- For very small and temporary sites that do not warrant a structure, keep the salt, or salt/sand mixture covered with a waterproof material to prevent runoff and store it on waterproof ground sheets to prevent runoff and absorption of moisture from the ground.

5. INFORMATION RESOURCES

There are many publications on the application of salt to roads and general winter maintenance. An Internet search using key words such as deicing, de-icing, anti-icing, road salt, roadsalt, salt, snow and ice will likely get results for those looking for more or new information on the topic. It is also useful to inquire at MOTH yards directly as they often have the resources and information to answer questions.

The Internet may give additional contacts, examples of research and operational programs, and other useful information. Some website addresses that contain information and links to other sites on roadsalt are listed below. Other uncited publications of special interest are listed as well. Remember that internet sites are ephemeral and will quickly become dated.

5.1 ON-LINE REFERENCES

http://www.dot.gov/ (US Department of Transportation)

http://www.engr.orst.edu/~taekrtha/trans.html
(Transportation Links)

http://www.fhwa.dot.gov/reports/mopeap/eapcov.htm
(FHWA-Effective Anti-icing Program)

http://www.fhwa.dot.gov/reports/mopeap/mop0296a.htm#eap23 (FHWA-Effective Anti-icing Program)

http://www.hend.com/shrp/publications.htm (Anti-Icing Study Completed. Focus: Jan. 1996, p. 7, Fed. Highway Admin.)

http://www.history.rochester.edu/class/roadsalt/home.htm (Effects of roadsalt in Toronto).

http://www.odin.com/winter.htm (Winter Road Maintenance Home Page)

http://www.ota.fhwa.dot.gov/ (Highway Technet, the on-line highway technology resource of the US Federal Highway Administration)

http://www.saltinstitute.org/2.html (Salt Institute)

http://www.saltinstitute.org/39.html (Proper Salt Storage, Salt Institute)

http://www.state.wv.us/wvdot/wvdotctr/drive/winter/saltfax.htm (West Virginia Department of Transport, Winter Driving, Road Salt).

http://www.tfhrc.gov/pubrds/winter96/p96w2 (Public Roads On-line Winter 1996)

http://www.usroads.com/journals/rmj/9702/rm970202.htm (prewetting with salt brine, Iowa)

http://www.usroads.com/journals/rmj/9702/rm970201.htm (anti-icing testing, FHWA)

http://www.usroads.com/journals/p/rmj/9712/rm971202.htm (using salt and sand, Wisconsin)

http://www.wnet.gov.edmonton.ab.ca/ (Welcome to Winternet)

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