Article 139

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Rating Deicing Agents: Road Salt Stands Firm

Watershed managers frequently wonder if there are any practical alternatives to the use of road salt for keeping roads free of ice in the winter. Others are concerned about the impact of chlorides on downstream water quality or on adjacent plants. A Michigan study suggests that despite the development of alternatives, road salt (primarily sodium chloride, NaCl) generally remains a competitive choice based on environmental, infrastructural, and cost factors.

Most northern states have traditionally employed road salt as a primary chemical deicer (Table 1) and sand as an abrasive (for better traction). Although sodium chloride is an inexpensive and effective choice, concerns are frequently raised about its potential negative impacts—particularly from chloride—on human health, the environment, highway infrastructure, and vehicles (see Table 2). Alternate deicing agents are not free of controversy either. For example, some localities employ urea to protect critical infrastructure (such as bridges or airports) from corrosion due to chlorides. Application of urea, however, may increase nutrient loading of waterways. In an era of ever-decreasing budgets, cost is an important factor that will often determine the type of deicer to be used. Lastly, and most importantly, highway departments must be confident that a given deicing agent will provide safe roads in winter driving conditions.

To respond to these concerns, the Michigan Department of Transportation (MDOT) analyzed the comparative performance, environmental impacts, and costs of six deicing agents: road salt (sodium chloride, the most common deicer in Michigan); calcium magnesium acetate (CMA); CMS-B (also known as Motech, a patented product containing primarily potassium chloride and derived as a by-product of beet processing); CG-90 Surface Saver (a patented corrosion-inhibiting salt); calcium chloride; and Verglimit (a patented concrete road surface containing calcium chloride pellets). Sand was also included in the evaluation. The primary components of the selected deicing agents were also compared (Table 3). In addition, MDOT briefly evaluated ethylene glycol, urea, and methanol. Due to their poor performance, environmental and human health effects, or high cost, these three agents were dropped from consideration as practical deicing alternatives.

As might be expected, each deicer has a different combination of performance, costs, and impacts. This suggests that different deicers may be appropriate for different climatic regimes in the country. None of the seven deicers was considered to possess widespread adverse environmental threats; however, they can exert site-specific impacts depending on the deicing agent's runoff concentration. Impacts may be significant for many threatened and endangered species which are already stressed and habitat-limited, small streams and lakes, water supplies, and wetlands and swales. A comparison of the potential impacts of the seven deicing agents (Table 4) can help users choose the deicer(s) most suitable for a particular area.

Table 1: Typical Elemental Composition of Two Road salt Samples (Biesboer and Jacobson, 1994)

Element	Concentration (ppm)
Sodium (Na)	349,714.0
Chlorine (Cl)	539,259.0
Calcium (Ca)	4,573.5
Potassium (K)	187.5
Iron (Fe)	73.9
Magnesium (Mg)	55.7
Aluminum (Al)	27.7
Lead (Pb)	6.7
Phosphorus (P)	4.6
Manganese (Mn)	3.1
Copper (Cu)	2.0
Zinc (Zn)	1.9
Nickel (Ni)	1.7
Chromium (Cr)	1.1
Cadmium (Cd)	0.4

Note: concentrations are typically diluted by one to three orders of magnitude in urban stormwater and streams. Elemental nitrogen was not analyzed.

The study also compared the effectiveness of deicing agents with respect to minimum activation temperatures, corrosion, and estimated cost (Figure 1). Unfortunately, environmental costs are difficult to quantify and are not included. One of the deicing agents, CMS-B, is a new product, and only limited data is available on its performance and cost.

The study did identify some potential alternatives to the use of sodium chloride. For example, calcium chloride applied in pellet or liquid form could be the most attractive deicer for areas where fast melting is a priority. It also causes less corrosion and is only 10 to 15% more expensive per road mile than road salt. Verglimit contains calcium chloride, but has relatively low deicing ability—a result of its significantly lower concentration of the salt and tendency to absorb water, rendering it largely ineffective at lower temperatures.

In regions where the environmental and corrosive effects of deicers are important management issues, CMA may be the preferred choice. However, CMA only works above 23°F, has less deicing ability, and is the most expensive option (Figure 1).

Road salt will probably continue to be an attractive deicing agent because of its high deicing ability, utility at low temperatures, and low cost. The report suggests that corrosive effects from road salt can and have been reduced through design and material modifications to both road structures and vehicles over the past several years. Such developments may make road salt even more attractive as a deicing agent. Consequently, management measures should be taken to minimize runoff containing road salt and other deicing agents into sensitive environmental areas (Table 5) . It is important to remember, however, that the study specifically analyzed the usefulness of deicing agents in Michigan; as a result, other regions may wish to evaluate agents in the context of their particular floral, faunal, infrastructural, and economic conditions.

—RLO

References

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Massachusetts Audubon Society. *A Low-Salt Diet for the Roads.* Public Service Information Sheet 12. Lincoln, MA.

Michigan Department of Transportation. 1993. *The Use of Selected Deicing Materials on Michigan Roads: Environmental and Economic Impacts.* Lansing, MI. Prep. by Public Sector Consultants, Inc.

Table 2: Some Impacts of Road Salt (MDOT, 1993)

- Contamination of drinking water supplies
- Corrosion of automobiles (50% of automobile corrosion is due to road salt, although this number is declining due to the increased use of corrosion-resistant materials in vehicles)
- Corrosion of bridges and other infrastructure
- Damage to vegetation within 50 ft. of roadside
- Temporary reduction in soil microbes, followed by summer recovery
- Sensitivity of various deciduous trees (see Technical Note 56)
- Attraction of deer to salts on roadways, increasing the risk of accidents
- Stratification of small lakes, hindering seasonal turnover
- Secondary components (3-5% of road salt composition) include N, P, and metals in concentrations exceeding those in natural waters

Table 3: Primary Components of Selected Deicing Materials (MDOT, 1993)

Deicing Material	Primary components*	Chloride as fraction of total mass
Calcium magnesium acetate (CMA)	Ca, Mg, $C_2H_3O_2$	0%
Calcium chloride	Ca, Cl	>57%
Calcium chloride (Verglimit)	Ca, Cl	2.2 to 4.8%
Sodium chloride (road salt)	Na, Cl	~58%
Corrosion inhibitor (CG-90 Surface Saver)	Na, Cl and Mg, Cl	46% 17%
Potassium chloride (CMS-B/Motech)	K, Cl	Unknown
Sand	Si, O	0%

* Ca = calcium; Mg = magnesium; $C_2H_3O_2$ = acetate; Cl = chloride; Na = sodium; K= potassium; Si = silicon.

Table 4: Impacts of Selected Deicer Components and Products on the Environment (MDOT, 1993)						
	Sodium Chloride (NaCl)	Potassium Chloride (KCl)	Calcium Chloride ($CaCl_2$)	CG-90 Surface Saver	CMA ($CaMgC_2H_3O_2$)	Sand (SiO_2)
Soils	Cl complexes release heavy metals; Na can break down soil structure and decrease permeability	K can exchange with heavy metals, releasing them into the environment	Ca can exchange with heavy metals, increase soil aeration and permeability	Same as NaCl; Mg can exchange with heavy metals	Ca and Mg can exchange with heavy metal	Gradually will accumulate on soil
Vegetation	Salt spray/splash can cause leaf scorch and browning or dieback of new plant growth up to 50' from road; osmotic stress can result from salt uptake; grass more tolerant than trees and woody plants				Little effect	Accumulates on and around low vegation
Groundwater	Mobile Na and Cl ions readily reach groundwater, and concentration levels can increase in areas of low flow temporarily during spring thaws. K, Ca, and Mg can release heavy metals from soil					No known effect
Surface Water	Can cause density stratification in small lakes having closed basins, potentially leading to anoxia in lake bottoms; often contain nitrogen, phosphorus, and trace metals as impurities, often in concentrations greater than 5 ppm				Depletes dissolved O_2 in small lakes and streams when degrading	No known effect
Aquatic Biota	Little effect in large or flowing bodies at current road salting amounts; small streams that are end points for runoff can receive harmful concentrations of Cl; Cl from NaCl generally not toxic until it reaches levels of 1,000-36,000 ppm; Cl from KCl may be more toxic; eutrophication from phosphorus in CG-90 can cause species shifts				Can cause oxygen depletion	Particles to stream bottoms degrade habitat

Table 5: Suggestions to Help Reduce Excessive Deicing Agents (Particularly Road Salt)Rrunoff (Nonpoint Source News-Notes, 1995; MA Audubon Society, and VT Agency of Transportation, 1993)

Storage

- Salt storage piles should be completely covered and handled on impervious surfaces.
- Runoff should be contained in an appropriate area.
- Spills should be cleaned up after loading operations. The material may be directed to a sandpile or returned to salt piles.

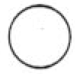
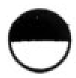
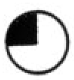
Application

- Instead of applying deicers at the same rate on high- and low-volume roads, control measures should be tailored to conditions.
- Trucks should be equipped with ground-speed sensors that automatically control the spread rate of the material.
- Drivers and handlers of road salt should attend training programs to improve efficiency and reduce losses.
- Drivers should avoid plowing snow from treated surfaces into piles or near frozen ponds, lakes, or wetlands.

Additional Suggestions:

- Identify ecosystems such as wetlands that may be sensitive to salt.
- Use calcium chloride and CMA, which are more costly than sodium chloride but may be less environmentally harmful to sensitive ecosystems.
- Apply sand to help traction and reduce salt. However, excessive sanding is an additional expense and poses sedimentation problems.
- To avoid overapplication and excessive expense, choose deicing agents which perform most efficiently according to pavement temperature.
- Monitor the deicer market, which changes as new products are developed, existing ones are developed more cheaply, and more is learned about their application and effects. While the purchase price of road salt alternatives is usually high, their full cost may actually be lower when the cost of contaminated water supplies, corroded vehicles and highways, and roadside vegetation loss is considered.
- Use stormwater practices, such as buffer zones, to further protect sensitive areas.

Figure 1: Comparison of Deicers' Effectiveness and Cost (MDOT, 1993)

	Deicing ability	Corrosion protection	Minimum effective temperature *(from lab tests)*	Material costs per ton	Total direct cost per E-mile *
Sodium chloride			12°F (-11°C)	$20 - 40	$12,741 - 13,818
Calcium chloride			-20°F (-29°C)	$200	$13,953-15,057 plus storage and equipment costs
Calcium magnesium acetate			23°F (-5°C)	$650 - 675	$25,915 - 32,637
CG-90 Surface Saver		 **	1°F (-17°C)	$185	$11,861-12,296
Verglimit			25°F (-4°C)	$109 - 145 (3X cost of regular asphalt overlay)	Not available †
CMS-B	Unknown	Unknown	-10°F (-23°C)	$0.40 - 0.50 / gal.	Not available
Sand			Not available	$5	$9,508 - 10,215 (Road salt / sand mixture)

* Unless otherwise noted, direct cost includes procurement of materials, personnel, corrosion, storage, and equipment. An e-mile, or "equivalent mile," is one mile of 24-foot-wide (two-land) road surface.

** Questions have been raised about the longevity of CG-90 Surface Saver's corrosion protection.

† Verglimit is also a road surface; therefore it offers more than deicing alone, making its costs difficult to compare with other deicers.