

The Future of Deicing Salt in North America

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ABSTRACT

Historical growth in the use of deicing salt in North America correlates with increases in highway mileage resulting from construction of the interstate highway system and improvements in other roadways. Use of deicing salt increased steadily between 1947 and 1979, but has remained relatively stable since 1979, fluctuating with the frequency and severity of precipitation in the snow belt. Demand for deicing salt in the U.S. originates with highway users because of expectations and need for continued driving mobility and safety during hazardous winter weather. As a result of this demand, bare pavement policy has been the norm throughout most snow belt winter maintenance jurisdictions. Although reduced mobility in the absence of a bare pavement policy is obvious, recent studies have shown that accident rates increase under conditions of snow, sleet or freezing rain.

As a result of broadly stated environmental concerns about sodium chloride, the salt industry faces several external threats. Legislative efforts have been initiated to ban, reduce and control the use of sodium chloride as a deicer; alternative deicers have been developed and strongly promoted; and regulatory efforts have been directed toward limiting the maximum allowable levels of sodium in sources of drinking water. Countering these threats are factors that have reduced the potential effects of sodium chloride in the environment. During recent years, great strides have been made in automobile and infrastructure corrosion resistance. Highway design takes into consideration the need to divert deicing runoff to less environmentally sensitive areas, and selection of salt resistant plant species can minimize damage to roadside vegetation. Health concerns about sodium in drinking water have been reduced because of confirmation that only a small percentage of the population is salt sensitive. Training programs directed toward the sensible use of salt have been successful in demonstrating that salt can be stored safely and used effectively with minimal harm to the environment.

INTRODUCTION

Rock salt is the principal highway deicer used in North America. Its ability to effectively and economically ensure bare pavement under severe snow and ice conditions has contributed to highway safety and the high level of winter mobility enjoyed throughout snow belt regions of North America. As the use of salt increased from the late 1940s through the mid 1970s, concerns about potential environmental and health related effects grew into a general belief that any increase in sodium or chloride in the natural environment is inherently detrimental. As a result, initiatives were launched during the past two decades to restrict the use of deicing salt and to reduce dietary consumption of salt for alleged health reasons.

During that time, the use of deicing salt has been assailed from virtually every direction. Considerable effort and money has been expended in the search for an ideal, environmentally benign deicer. Much of this effort has been misdirected. Data exist showing

that sodium chloride can be used as an integral part of winter maintenance programs without undue harm to the environment, motor vehicles, infrastructure or human health. In spite of widespread negative publicity, sodium chloride continues to be the only low cost, effective deicer available in sufficient quantity to assure safe driving conditions and mobility throughout the North American snow belt during the winter season.

The purpose of this paper is to examine environmental and health concerns, initiatives that would limit the use of sodium chloride as a deicer, and to dispel the notion that judicious and proper use of sodium chloride represents a potential threat to society and the environment. In fact, the opposite is true. The benefits of sodium chloride for accident reduction have long been intuitively known and now are being documented by studies. Programs supported by the salt industry, through the Salt Institute, are encouraging more effective use and environmentally sound storage of salt, and there is

firm evidence that the natural environment can tolerate varying levels of sodium chloride without distress.

A BRIEF HISTORY OF DEICING WITH SALT

Sodium chloride deicer has provided safe driving conditions in North America for much of this century. Coons and Harris (1940) refer to the use of common salt for snow and ice control during the 1930s, and salt was used to prevent freezing of abrasives prior to its use as a primary deicer.

Following World War II, consumer demand increased the number of automobiles, the trucking industry expanded and the use of sodium chloride as a highway deicer began a period of strong growth. Between 1940 and 1960, the amount of salt used for deicing grew from 149,000 to 2.1 million tonnes (Mt). U.S. Bureau of Mines records indicate that deicing salt use peaked at 10.2 Mt in 1972. According to data summarized by Morse (1985), the amount of salt used for deicing has leveled off at about 9.0 Mt per year. Annual fluctuations are due to variations in severity of winter weather conditions.

CORROSION, THE ENVIRONMENT AND POTENTIAL HEALTH EFFECTS

Concerns about the use and storage of sodium chloride as a deicer fall into three categories. (1) Damage to motor vehicles and infrastructure such as highways, bridges, parking structures and other concrete and steel structures; (2) potentially harmful effects on the natural environment; (3) potentially harmful effects on human health due to elevated levels of sodium in sources of drinking water.

Corrosion

The chloride ion is chemically aggressive. Historically, damage to steel reinforced concrete structures and motor vehicles is well documented. In areas where deicing salt is used or stored some of this damage can be attributed to the use of sodium chloride and other deicers. However, progress has been made in design, construction and production techniques to protect these structures from corrosion.

Corrosion of reinforcing steel in concrete has been sharply reduced by using high quality, air entrained concrete with adequate depth of cover and epoxy coating on reinforcing steel. Cathodic protection used in conjunction with bridge rehabilitation is well documented and strongly supported by the U.S. Federal Highway Administration as the best means of protection for bridge decks. Improvements in design, materials, coatings, metal forming technology and

production methods have extended the corrosion-free life of motor vehicles. Most automobile manufacturers offer some form of extended perforation-free warranties on new automobiles.

Environment

The effect of sodium chloride on the environment is a complex matter that is often over-simplified. Adverse effects of salt on flora and fauna and uses of ground and surface waters depend on several factors. Concentration of sodium and chloride ions, placement in the environment, rates of atmospheric precipitation, and susceptibility of various organisms to harm. The concept that environmental harm is inevitable merely because sodium chloride is used as a deicer is unsubstantiated.

Sodium and chloride ions occur naturally in most waters. Van der Leeden et al. (1990) gives levels of sodium in finished public water supplies across the U.S. as 1.1 to 198 mg/l and levels of chloride as 0 to 572 mg/l. Welty et al., (1986) report over 400 mg/l of sodium in drinking water in Gila Bend, Arizona.

Aquatic species exhibit highly variable tolerances for concentrations of chlorides in their natural habitats. For example, the U.S. Environmental Protection Agency (Quality Criteria For Water 1986) refers to studies on fresh water species of fish demonstrating a broad range of survival rates in waters containing up to 10,000 mg/l dissolved solids and limited survival at levels of 15,000 to 20,000 mg/l dissolved solids.

Chloride levels in streams adjacent to highways where salt is used tend to disperse or dilute rapidly downstream from the point of application. Helz (1986) studied potential build-up of sodium and chloride in the Chesapeake Bay due to the use of deicing salt on Maryland highways. He reported that natural estuarine circulation of water from the Atlantic Ocean carries 400 Mt of dissolved solids each month during winter into the Maryland portion of the Chesapeake Bay. This compares with an estimated 800,000 t of sodium chloride entering the same portion of the Bay from the three major rivers. According to Helz, chloride levels in these three rivers were "very similar to the North American average." Dilution of sodium chloride downstream from a source minimizes otherwise potentially harmful effects. The author also said that sodium and chloride ions are "derived from weathering, precipitation, dry deposition of marine aerosols, sewage treatment plant discharges and other sources in addition to highway runoff."

Hsu (1984) measured sodium and chloride accumulation in roadside soils between 1973 and 1982. She found that sodium ions tended to accumulate

with the application of road salt within forty feet of the highway but showed little increase beyond that distance. At distances of twenty and forty feet the highest values of soil sodium encountered were 68.3 and 70.8 mg/l respectively, "far below exchangeable sodium levels that are considered damaging" to soil. Chloride ions leached out of the soil and did not show any build-up.

Demers and Sage (1990) found increases in chloride levels in four streams receiving runoff from a New York highway where deicing salt was used. Chloride concentrations were "31 times higher" in downstream samples compared with upstream samples. However, numerical values were relatively low. The highest levels of chloride ranged between 5.83 and 32.80 mg/l. Mean chloride concentrations 50 m downstream in all four streams varied between 1.70 and 17.05 mg/l. While higher than upstream values of less than 1.5 mg/l, there is absolutely no evidence that chloride levels in this range are detrimental to aquatic life.

Benoit and Stephan (1988) in developing water quality criteria for chloride, determined that acute sensitivities for aquatic organisms to chloride "ranged from 1,470 mg/l for *Daphnia pulex* to 11,940 mg/l for the American eel." Chronic sensitivities for *Daphnia pulex*, rainbow trout and fathead minnow were, respectively, 372, 923 and 433 mg/l. In fact, available data indicated that chlorides of potassium, calcium and magnesium are "more toxic to fresh water species than sodium chloride." The study area included a 160 ha lake into which the four streams discharged. Chloride concentration at a depth of 2 m was 1.50 mg/l and at 18 m was 3.69 mg/l. The authors interpreted this difference as density stratification, but the numerical concentration of chloride was very low and not harmful to aquatic life.

Resource Concepts (1990) looked extensively at injury to trees in the lake Tahoe area of Nevada and California. Of approximately 152,000 trees in a zone 31 m in both directions from the pavement edges, fewer than 14% were believed affected by salt while nearly 29% were damaged by insects, disease, drought and other factors not related to salt. The degree of salt influence decreased rapidly as distance from the highway increased, and the authors affirmed that resistance of trees to salt varies with species. The study also noted other factors affecting the degree of salt damage, such as drought conditions, soil type and steepness of the slope adjacent to the highway.

Most species of vegetation can tolerate some level of salinity in soil and water. The U.S. Department of Agriculture's Handbook Number 60 (1954) classified irrigation waters into four salinity hazard categories

based on conductivity; low, medium, high and very high. Categories were separated at 250, 750, and 2,250 micromhos/cm, which can be converted to approximately 175, 525 and 1,575 mg/l of dissolved solids. Longenecker and Lyerly (1974) used the same classification and confirmed that virtually all crops and soils can withstand a certain degree of water salinity.

Potential damage to roadside environments by sodium chloride is site specific. Highway design is an effective way to ensure that any damage is minimized. Drainage systems can be designed to divert runoff to less environmentally sensitive areas. Salt tolerant trees and shrubs located an appropriate distance from the pavement edge can be used with landscape designs, limiting environmental disturbance created by the highway corridor.

Health effects

Health concerns about sodium chloride are the result of fears that elevated levels of sodium in drinking water can aggravate or cause hypertension in the general population. This contention is not supported by fact. There is evidence that these health concerns are highly exaggerated and most people are not effected by sodium in drinking water.

The U.S. Environmental Protection Agency in its National Primary Drinking Water Regulations (1985) decided not to regulate sodium in drinking water. Their decision was based on two important facts. First, the amount of sodium ingested with an average intake of two liters of water per day is very small in comparison with other sources of dietary sodium. Second, EPA did not find enough evidence linking sodium in drinking water to hypertension in the general population to merit regulation. Subsequently, sodium was removed entirely from EPA's Priority List of Substances (1991) being tracked for possible future regulation.

The Agency summarized its rationale for not regulating sodium by stating: "Persons on (severely) restricted sodium diets may have an intake restricted from 500 to 1,000 mg/day sodium. The portion ingested with water must be compensated by reduced levels in food ingested so that the total does not exceed the allowable intake. Using certain assumptions of water intake, two liters per day, and sodium content of food, it has been calculated that for very restricted sodium diets, 20 mg/l in water would be the maximum."

The 20 mg/l value was suggested by the American Heart Association during the early seventies. It was not intended as a maximum contaminant level for sodium in drinking water. Its sole purpose was to serve as a guideline in American Heart Association

diet booklets for patients on severely restricted sodium diets. The booklets recommended that "if the water supply contains more than 20 milligrams of sodium per quart of water it would be necessary to use distilled water." (M. Winston, pers. commun., 1977).

A mounting volume of evidence demonstrates that only salt sensitive hypertensives, approximately 5-10% of the population, benefit from sodium restriction. Those individuals who can benefit from sodium restriction will do so only on rigid, medically-supervised diets. Healthy persons have an enormous tolerance for salt intakes far in excess of the body's metabolic needs, and as noted, a very small amount of total dietary sodium intake is associated with drinking water.

Salt storage

Many environmental problems attributed to deicing salt are the result of improper storage of deicing salt. During the past 30 years, cases of elevated levels of sodium chloride in drinking water have been reported. Water wells associated with these complaints usually were located very near salt storage piles lacking proper cover or other engineering controls, or were within drainage systems of major highways where deicing salt had been applied.

Runoff from salt storage sites can be effectively controlled with an appropriate form of cover or engineering controls and good operating procedures. Guidelines for proper salt storage, such as the Salt Institute's *Salt Storage Handbook* (1990), have been available since 1972 and are used by many agencies responsible for winter maintenance.

THREATS TO THE CONTINUED USE OF SODIUM CHLORIDE

External threats to the use of sodium chloride as a deicer fall into two broad categories. First, legislative and regulatory activities that would either restrict the use of deicing salt or impose higher costs on the industry relative to non-salt deicers, and second, the promotion of non-salt, chemical deicers as non-corrosive, environmentally benign replacements for sodium chloride.

Legislative and regulatory activities

Legislative actions that bear directly on the use of sodium chloride, such as salt bans or restrictions have been least successful. The Salt Institute (1988) reported eight incidents of complete salt bans between 1970 and 1986 and numerous cases of salt restrictions or attempted salt bans. In all eight cases where salt was banned, the bans were lifted during

the same winter season in which they were enacted, in some cases within a matter of days or weeks.

Other forms of regulation, while not directly restricting the use of salt, can have an indirect effect by limiting the levels of sodium and/or chloride in drinking water sources. For example, several states have groundwater discharge guidelines for sodium. Massachusetts and Vermont have a 20 mg/l maximum contaminant level (MCL) for sodium in drinking water requiring notification of health professionals when exceeded. These restrictions are based primarily on concerns about sodium and health, even though in 1985 the U.S. Environmental Protection Agency decided against regulating sodium in drinking water. State regulations are encouraged to some degree by the U.S. Food and Drug Administration's continuing recommendation that all individuals reduce their dietary sodium intake.

The National Secondary Drinking Water Standards include a secondary maximum contaminant level (SMCL) for chloride of 250 mg/l. Van der Leeden et al., (1990) note that this limit is based primarily on aesthetic qualities that affect public acceptance of drinking water. The U.S. Environmental Protection Agency in Quality Criteria for Water (1986) cites a survey by Bruvald et al., of 29 California water systems where consumers rated as excellent, good and unacceptable waters containing, respectively, nearly 400, 750 and 1,300 mg/l dissolved solids. A survey by Lockhart et al., (1955) on taste thresholds for chloride in drinking water indicates that the range for detecting a "salty taste" varies between 120 and 1,200 mg/l chloride.

Other regulations that could affect the use of sodium chloride as a deicer are currently in the rule-making process. For example, the Environmental Protection Agency's proposed storm water NPDES General Permit requirements (1991) may increase the cost of storing deicing salt because of language that could require all salt piles to be placed under rigid cover. The salt industry is actively opposing this portion of the proposed rule because other engineering controls and good management practices can achieve similar results.

The Agency is also attempting to develop by negotiation regulations covering a broad definition of mining wastes. EPA's concern appears to be with the metal mining segment of the industry and not specifically with rock salt mining. However, preliminary indications are that these regulations may be very broad in scope with the potential to affect the salt mining industry.

Proposed and future rule-making by the Mine Safety and Health Administration could have significant cost impact on the U.S. salt industry. Although

generally supportive of much of MSHA's rule-making agenda, the salt mining industry is concerned that proposals on exposure to nitrogen dioxide and salt dust are overly restrictive and could significantly increase costs of mining salt. MSHA recently provided advance notice of its proposed diesel emission standard for metal and nonmetal mines. This proposal could restrict the use of diesel equipment in salt mines. The Salt Institute plays an active role in all regulatory rule-making activity affecting the salt industry by providing useful information to regulatory agencies throughout North America.

Alternative, non-salt deicers

A number of non-salt, alternative deicers have been tested during the past two decades. Most either have not performed well as highway deicers, are cost prohibitive for widespread use on highways or raise their own environmental questions. Minsk (1987) lists eleven substances with properties that provide deicing action. Magnesium acetate, calcium acetate, sodium chloride, calcium chloride, magnesium chloride, lithium chloride, methyl alcohol, ethyl alcohol, urea, ethylene glycol and sodium formate. Several of these products, in addition to sodium chloride, are currently used in specific applications. All are several times more costly than rock salt and most, with the exception of calcium magnesium acetate and sodium formate, have little, if any, environmental advantage.

Calcium magnesium acetate

Calcium magnesium acetate (CMA), the most popular non-salt alternative, is widely promoted as an environmentally benign, non-corrosive alternative to rock salt for highway deicing. Most studies indicate that CMA is less corrosive and less of an environmental threat than sodium chloride. However, three factors become apparent in virtually all tests carried out with CMA. It works slower and more is needed to provide levels of deicing comparable to sodium chloride. It works "differently" than salt and has some undesirable material handling characteristics. And, CMA is not environmentally "free." It has characteristics that raise concerns about its environmental fate.

Gidley (1991), while concluding that CMA is an effective deicer, reported that 1.7 times more CMA than salt is required and that it works slower than salt and does not dissolve as quickly. He also noted that although CMA changes the consistency of snowpack for easier plowing, it "does not penetrate snow or ice all the way to the pavement as rapidly as salt." Gidley also found that because of differences in physical properties CMA requires more storage

space than salt, a significant cost where large quantities are used.

DeFoe (1989) found CMA to be somewhat less effective than rock salt, even when applied at "over twice the rate at which salt is applied." Manning and Crowder (1989) estimated the optimum rate for applying CMA to be between 1.4 and 1.7 times that of rock salt. Turner and Harris (1990) confirm that CMA "does work as a deicer, but has different deicing mechanisms from salt." Rather than forming brine, CMA changes snow into an "oatmeal" consistency and "the shape of CMA is a serious drawback" causing it to bounce off the pavement surface. According to the authors, CMA has problems with dust so that "even with dust masks, CMA irritates eyes and dries throats."

Many cost benefit analyses comparing sodium chloride to alternative, non-salt deicers tend to attribute a majority of corrosion and other damage costs solely to the use of sodium chloride as a deicer. In fact, sodium chloride is not the only source of chloride in the environment. Complete elimination of sodium chloride as a deicer, if feasible, would not eliminate all chloride from the environment. For example, the natural environment of coastal areas throughout the world is recognized as being as corrosive as snow belt regions where deicing salt is used.

Cost benefit comparisons between sodium chloride and non-salt alternatives such as CMA, nearly always include the assumption that the non-salt alternative has no environmental cost. In contrast, environmental costs are added to the cost of sodium chloride to arrive at a "total" cost far higher than the cost of the product. The comparison is often inaccurate and misleading because alternative, non-salt deicers such as CMA, are neither environmentally nor operationally "free." The complete elimination of sodium chloride and exclusive use of an alternative deicer will not eliminate reduce environmental corrosion.

The high cost of CMA must be considered on its own. During the winter season of 1981/1982 and 1982/1983, (Salt Institute Statistical Report Analysis 1991), average annual quantities of salt used as reported by state highway agencies in Illinois and Michigan were 204,255 and 284,141 t respectively. An example of \$27 per t for rock salt, delivered, can be used as a basis for cost comparison. Delivered costs for rock salt can be obtained from media reports and appear realistic, based on the average value for bulk rock salt of \$15.96 per t f.o.b. plant reported by Kostick (1991). Using \$716 per t for CMA and a conservative application rate factor of 1.4 times more CMA than salt, a comparison of the total cost of using all salt or all CMA for each of the two states can be approximated.

Illinois

Salt: 204,000 t at \$28 per t = \$5.7 million

CMA: 286,000 t at \$716 per t = \$204.8 million

Michigan

Salt: 284,000 t at \$28 per t = \$8.0 million

CMA: 397,616 t at \$716 per t = \$285.0 million

According to the Salt Institute Statistical Report Analysis (1991), both winter seasons were about 13% below average for total U.S. sales of deicing salt during the twelve year period ending June 1989. The extraordinary high cost of using CMA, 35 times more than the cost of rock salt, does not include additional storage, spreading equipment and other handling costs associated with its use.

Several environmental questions about CMA were raised in NCHRP Report 305 (1988). The report suggested "possible oxygen depletion due to CMA addition to (surface) water." This phenomenon was found in both laboratory and field tests. Laboratory tests also indicated that CMA has the "potential to release certain trace metal (iron, aluminum, zinc, and copper) preexisting in soils." Another concern raised by the NCHRP report was that of "phosphorous enrichment of surface waters by CMA produced from agricultural wastes containing this nutrient."

Rea and LaPerriere (1986) found low dissolved oxygen conditions in a small pond at concentrations of 24 mg/l CMA. They recommended additional research to determine the environmental fate. The widely promoted view that CMA is environmentally benign has not been established.

Turner and Harris (1990) expressed concern and recommended further study on (1) potential increases in water hardness caused by bacterial decomposition of CMA into calcium and magnesium; (2) the potential for causing "eutrophication of receiving waters" or algae blooms; (3) mobilization of heavy metals in soils; and (4) "bacteria blooms" resulting in dissolved oxygen depletion due to bacteria feeding on the acetate. The authors note on page 18 of their report that "CMA is more of a concern for surface water quality than salt" and that CMA levels in water must be less than 10 mg/l to maintain safe levels of dissolved oxygen.

The most authoritative comparison of sodium chloride and calcium magnesium acetate was recently completed for the U.S. Federal Highway Administration by the Transportation Research Board's Committee on Comparative Costs of Rock Salt and CMA (1991). The study found that "the use of CMA as a general replacement for salt is unlikely and probably unwarranted." Among the major findings reported were that sodium chloride is a low priced, easily applied, reliable ice-melter that "is

likely to continue to be the predominant highway deicer for years to come." The committee said that continuing advances in corrosion protection have controlled many costs associated with the use of sodium chloride. The report confirms that CMA is less effective than salt and does not always perform as well under a variety of conditions. Because of these factors, CMA's widespread use "could present significant operational difficulties to highway agencies." The committee said that roadside environments are unique and must be considered on a case by case basis. "(F)or all potential (CMA) use situations, however, consideration must be given to other means of reducing salt costs, such as protection from corrosion, modification of highway drainage, improvement of deicer application techniques, and more vigilant salt management."

This important study affirms the role for sodium chloride in winter maintenance, shows that effective use and continuing technological advancements mitigate effects on the environment and infrastructure, and demonstrates conclusively that the economic benefits of sodium chloride outweigh any perceived disadvantages.

FACTORS ENCOURAGING THE CONTINUED USE OF SODIUM CHLORIDE

Sodium chloride is the most economical, effective and readily available deicer currently available. Concerns about potential effects of sodium chloride on the environment must be balanced with the need for highway safety and mobility. There are a number of positive factors that will encourage its continued use as the principal deicer.

Accident reduction

One of the problems associated with determining the cost-benefit ratio of sodium chloride as a deicer has been a lack of data showing reductions in accident and injury costs as a result of its use. Some authorities concluded such benefits did not exist. However, Belangie (1979) examined delays, speed reduction, volume changes and accident rates as a function of weather in three U.S. states. He found that accident rates, injury rates and property damage increased as pavement conditions deteriorated from dry to wet to snow-packed.

Hanke and Levin (1988) examined four highway maintenance centers over four time intervals in non-urban areas of central Europe. They were able to determine the total number of accidents, injuries and amount of property damage. They obtained detailed information on snow fighting activities in-

cluding timing, weather and quantities of salt spread. The authors found that 10–15% of all personal-injury accidents are related to "winter road conditions and unadjusted driver behavior." Accident rates fell to 2.6 from 9.5 accidents per million vehicle kilometers following the application of deicing salt, and the accident cost rate fell to 62 from 358 Deutsch Marks per accident, a drop of 83%. The authors concluded, based on these data, that 2,500 injuries, including 1,000 fatalities or severe injuries are prevented by salt spreading in non-urban areas. Total cost savings in the first hour after salting for all benefits, including time, operating and fuel costs were 340 million Deutsch Marks.

Research based on the method used by Hanke and Levin is currently in progress at Marquette University in the U.S. Researchers are examining hourly accident rates immediately before and after application of deicing salt. They are using data from fifty test sites totalling 550 miles in four states in the U.S. Detailed traffic analyses were performed to arrive at estimates of hourly vehicle miles of travel twelve hours before and twelve hours after each weather event on each test section. The study will determine the direct benefits of accident reduction due to salt application. Although not available at time of writing, the results of this study will be published during 1992, and are expected to confirm the conclusions reached by Hanke and Levin.

Strategic Highway Research Program

The Strategic Highway Research Program, or SHRP, is in the midst of a multi-year technological development program. Research currently in progress will provide usable methods and procedures for direct application by highway agencies to improve all aspects of highway performance. Winter maintenance research included in this program will assure continued improvements in corrosion resistance of highway structures and more effective use of sodium chloride. These efforts will have far reaching, future benefits, and the SHRP program affirms that sodium chloride can continue to be a major factor in winter maintenance programs.

Enhanced salt deicers

Interest in high cost, alternative, non-salt deicers during recent years has provided an incentive for North American salt producers to develop proprietary, corrosion inhibited, sodium chloride-based deicers. These enhanced salt products contain corrosion inhibitors that significantly lessen the effect of the chloride ion on steel. Enhanced salt deicers are marketed by the major North American salt pro-

ducers. They have undergone a large number of laboratory tests showing that they are less corrosive than sodium chloride. Successful field testing has been carried out during the past several years in a number of states. Although more expensive than rock salt, these products cost far less than the most widely promoted non-salt deicer, calcium magnesium acetate.

Sensible salting

Winter maintenance agencies throughout North America have been successful in efforts to apply deicing salt in minimum quantities necessary to maintain safe driving conditions. One such successful effort is the Salt Institute's Sensible Salting Program (1989). This program was introduced in 1972 to help public agencies control and even reduce the amount of salt used for deicing. Training seminars emphasize the importance of proper salt storage, good equipment and proper calibration and maintenance of spreading equipment. The program shows that effective deicing can be maintained, even by using less salt, without reducing the level of service and presenting unexpected hazards for motorists.

The Salt Institute's Excellence in Storage program encourages proper storage practices by conferring awards to snow and ice control agencies with outstanding salt storage facilities. One of the objectives of this program is to encourage construction of sound storage facilities with exemplary operating practices to minimize environmental concerns.

Salt Institute programs are directed at the relatively smaller storage piles found at governmental agency highway salt storage facilities. However, North American salt producers are vitally concerned with improving their own larger production and distribution facility storage sites. Many of these stockpiles are of such a size that structural cover of the type recommended for agency piles is infeasible. Flexible cover, runoff collection systems and good manufacturing practices can and do provide effective environmental protection for areas adjacent to salt storage sites.

North American salt producers are strongly supportive of and actively participate in Salt Institute efforts to promote sensible salting and proper storage practices. Salt Institute member-companies are currently developing a means of environmental self-regulation of their storage facilities. This action reaffirms their commitment to sound environmental policies that will minimize the impact of large salt storage facilities on the environment and will lessen the degree to which federal or state regulation of these sites will be required.

CONCLUSIONS

Because there are currently no cost effective alternatives to sodium chloride, reliance on its ability to maintain safe driving conditions will continue. As more and better defenses against the chloride ion are incorporated into motor vehicles, bridges, highways and other concrete structures, there will be correspondingly more appreciation of sodium chloride's economy and superior performance. Because of successful efforts by governmental agencies to minimize quantities, the use of sodium chloride and its addition to the natural environment has stabilized and will likely not increase significantly in the foreseeable future. These factors, along with the fact that sodium in drinking water is not an important health risk for most individuals should reduce negative pressures on the use of sodium chloride as a deicer.

Enhanced salt deicers, at a far lower cost than non-salt alternatives, will play an increasingly important role in areas where non-corrosive deicers are required. Environmental concerns related to the use of sodium chloride will not likely disappear entirely. However, recognition that environmental systems are able to manage levels of sodium chloride above amounts present in the natural environment, along with proactive steps by the salt industry to assure environmentally sound storage and sensible application practices should continue to alleviate many of those concerns. Present day social and economic systems are vitally dependent on safe, mobile highway transportation systems, even during severe winter weather, and North America will continue to rely on sodium chloride as the primary "deicer of choice."

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