Special Report 235

Highway Deicing

Comparing Salt and Calcium Magnesium Acetate

Committee on the Comparative Costs of Rock Salt and Calcium Magnesium Acetate (CMA) for Highway Deicing

Transportation Research Board
National Research Council
Washington, D.C. 1991

Transportation Research Board Special Report 235

Subscriber Categories
IB energy and environment
IC transportation law
IIIC maintenance

Transportation Research Board publications are available by ordering directly from TRB. They may also be obtained on a regular basis through organizational or individual affiliation with TRB; affiliates or library subscribers are eligible for substantial discounts. For further information, write to the Transportation Research Board, National Research Council, 2101 Constitution Avenue, N.W., Washington, D.C. 20418.

Printed in the United States of America

NOTICE: The project that is the subject of this report was approved by the Governing Board of the National Research Council, whose members are drawn from the councils of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine. The members of the committee responsible for the report were chosen for their special competencies and with regard for appropriate balance.

This report has been reviewed by a group other than the authors according to the procedures approved by a Report Review Committee consisting of the members of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine.

This report was sponsored by the Federal Highway Administration, U.S. Department of Transportation.

Library of Congress Cataloging-in-Publication Data

Highway deicing : comparing salt and calcium magnesium acetate /
Committee on the Comparative Costs of Rock Salt and Calcium
Magnesium Acetate (CMA) for Highway Deicing.
p. cm.—(Special report, ISSN 0360-859X ; 235)
ISBN 0-309-05123-1
1. Roads—United States—Snow and ice control—Costs. 2. Roads—
Snow and ice control—Environmental aspects—United States.
3. Deicing chemicals—costs. 4. Calcium magnesium acetate.
5. Salt. I. National Research Council (U.S.). Committee on the
Comparative Costs of Rock Salt and Calcium Magnesium Acetate (CMA)
for Highway Deicing. II. Series: Special report (National Research
Council (U.S.). Transportation Research Board) ; 235.
TE220.5.H54 1991
625.7'63—dc20 91-41654
CIP

Cover design: Diane L. Ross

Committee on the Comparative Costs of Rock Salt and Calcium Magnesium Acetate (CMA) for Highway Deicing

JOHN J. HENRY, *Chairman*, Pennsylvania Transportation Institute, The Pennsylvania State University, University Park
ROBERT BABOIAN, Texas Instruments, Inc., Attleboro, Massachusetts
JAMES W. DUNLEAVY, Oakland County Road Commission, Waterford, Michigan
DONALD N. GEOFFROY, New York State Department of Transportation, Albany
JEFFREY L. GIDLEY, California Department of Transportation, Sacramento
RICHARD R. HORNER, University of Washington, Seattle
MAURICE A. LARSON, Iowa State University, Ames
DAVID G. MANNING, Ontario Ministry of Transportation, Downsview
PATRICK S. MCCARTHY, Purdue University, West Lafayette, Indiana
L. LEE PIEPHO, General Motors Corporation, Milford, Michigan
SAMUEL J. POLLOCK, Massachusetts Department of Public Works, Wellesley Hills
DELLA M. ROY, The Pennsylvania State University, University Park
DONALD L. WISE, Northeastern University, Boston, Massachusetts
RONALD L. ZOOK, Ohio Department of Transportation, Columbus

Liaison Representatives

CLAYTON ORMSBY, Federal Highway Administration, U.S. Department of Transportation
L. DAVID MINSK, Strategic Highway Research Program, National Research Council
CRAWFORD F. JENCKS, Transportation Research Board
FRANK N. LISLE, Transportation Research Board

Transportation Research Board Staff

ROBERT E. SKINNER, JR., Director for Special Projects
THOMAS R. MENZIES, Project Manager
NANCY A. ACKERMAN, Director of Publications
NORMAN SOLOMON, Assistant Editor

Consultants

CHARLES R. GOLDMAN
JOHN E. REUTER

Preface

Deicing chemicals, along with plowing and sanding, are important tools for highway snow and ice control. For many years, however, it has been widely acknowledged that the most popular deicing chemical, sodium chloride or common road salt, has many unintended and often costly side effects. The last major efforts to estimate the true cost of salt were conducted 10 to 20 years ago. Today, however, many of the findings from these studies are no longer accurate, because knowledge and understanding of salt's adverse effects have increased and, in some cases, significant steps have been taken to help control them. Unfortunately, the lack of more up-to-date cost information has contributed to confusion over the benefits and savings that might be achieved by using less harmful but higher-priced alternatives to salt that have been developed in recent years, such as calcium magnesium acetate (CMA).

Recognizing this need, Congress called on the U.S. Department of Transportation (DOT) to sponsor a study examining the total cost of salt and CMA, including the direct cost of application and indirect costs to the environment, infrastructure, and motor vehicles. The National Academy of Sciences was identified as an organization to conduct the study.' The National Research Council, which is the principal operating arm of the Academy, appointed a special study committee under the auspices of the Transportation Research Board (TRB) and the leadership of John J. Henry, Director of the Pennsylvania Transportation Institute at The Pennsylvania State University. Committee members are experts in chemistry, materials science, economics, environmental science, and highway engineering, operations, and maintenance.

Congress requested that the study examine the full economic costs of using salt and CMA for highway deicing. In sponsoring the study, the Federal Highway Administration (FHWA) of DOT asked TRB to examine each deicer for both general deicing and selective uses, such as in environmentally sensitive areas and on corrosion-prone bridges. In approving the project, the TRB Executive Committee requested that the study committee also consider and comment on other promising deicing alternatives to salt and CMA when appropriate.

Much of the report focuses on defining the true cost of salt, which is the most popular deicer and the standard of comparison for most other deicing products. After reviewing the evidence, the committee estimated many of salt's costs in monetary terms, but often had to rely on a combination of sparse quantitative data, simplified assumptions, and its own expert judgment to do so. In some cases, however, a lack of sufficient information prevented even rough approximations of cost.

Although the committee debated whether to assign monetary values to environmental damages, it did not for the following reasons: (a) the environmental effects of salt vary widely by location; (b) not enough information is available to determine the extent of environmental damage, even in nonmonetary terms (e.g., number of trees harmed); and (c) the valuation of environmental damage is highly subjective. Nevertheless, the committee did present several hypothetical environmental cases in Chapter 4 that contain estimates of the monetary costs involved in correcting or mitigating environmental damage from road salt. Although these cases are not representative of all highways on which salt is applied, they illustrate the potential scale of environmental costs attributable to salt use, and they are indicative of the kinds of data and analyses that are needed to estimate the nationwide environmental costs of road salt in monetary terms.

In considering CMA, the committee summarized what is known about its field performance, compatibility with highway and automotive materials; environmental impacts, and production technologies and price. This task was complicated by the relatively small quantities of CMA used to date. Although the congressional request for the study focused on salt and CMA, at the outset of the study the committee hoped to include other deicing treatments (e.g., salt substitutes and additives) in its investigation. Whereas some references to other treatments are included in the report, the committee found too few independent analyses of them (many of which are proprietary commercial products) to draw conclusions. Salt, on the other hand, has been heavily researched, and CMA has been subjected to numerous government-sponsored evaluations. As a result, the committee focused on these two products.

The committee stopped short of recommending that CMA be used in specific situations, because such conclusions can be reached only after in-depth consideration of local circumstances and all other deicing treatments and mitigation measures available. Instead, the main purpose of the report is to provide general background information and reference material for highway agencies that may be unfamiliar with CMA, as well as those trying to get a better handle on the overall cost of their salting programs.

The final report of the committee was reviewed by an independent group of reviewers in accordance with National Research Council report review procedures.

ACKNOWLEDGMENTS

Thomas R. Menzies managed the study and prepared the final report under the guidance of the committee and the overall supervision of Robert E. Skinner, Jr., Director for Special Projects. Charles R. Goldman and John E. Reuter, consultants, wrote a commissioned paper on the effects of road salt on the environment, which formed the basis for Chapter 4. Richard D. Thomas of the National Research Council's Board on Environmental Studies and Toxicology briefed the committee on the health effects of salt in drinking water and, along with Catherine E. Woteki and Paul R. Thomas of the Food and Nutrition Board, critically reviewed Chapter 5. Joseph W. Loper analyzed computer tapes of the National Bridge Inventory file for Chapter 3. Crawford F. Jencks, Frank N. Lisle, L. David Minsk, and W. Clayton Ormsby, FHWA's technical representative, commented on drafts of the report and provided helpful technical information during committee meetings and throughout the course of the study.

Special appreciation is expressed to Marguerite E. Schneider and Frances E. Holland for typing drafts of the manuscript and providing administrative support.

Contents

Executive Summary

Each year about $1.5 billion is spent on highway snow- and ice-control programs in the United States. Apart from plowing, the most important element of these programs is chemical deicing, which represents about one-third of winter maintenance expenditures. Chemical deicing provides important public mobility and safety benefits by rapidly and reliably providing more driveable and less hazardous road conditions during the winter months. The benefits are difficult to quantify but are widely acknowledged to be valuable to society.

Sodium chloride, or common road salt, is by far the most popular chemical deicer, because it is reliable, inexpensive, and easy to handle, store, and apply. Since 1970, highway agencies have applied an average of approximately 10 million tons of road salt each winter. Over the years, however, the widespread use of salt has been linked with many indirect costs, including damage to motor vehicles, infrastructure, and the environment. Recognizing these drawbacks, in 1980 the Federal Highway Administration identified calcium magnesium acetate (CMA) as a possible replacement for salt. Since its discovery, CMA has been the subject of many laboratory and field studies to determine its deicing performance, environmental acceptability, and compatibility with automotive and highway materials. Results have been promising, but the most significant impediment to its use has been its price, which is more than 20 times that of salt.

The commercial availability of CMA and continued concerns about the indirect costs of salting have underscored the need for more information on the total cost of deicing. Recognizing this need, in 1988 Congress requested a study comparing the true costs of salt and CMA, including direct application costs and indirect costs to the environment, human health, motor vehicles, and infrastructure. A special committee of the Transportation Research Board carried out the study. The committee focused most of its efforts on determining the true cost of salting, which was last estimated 15 years ago for the Environmental Protection Agency. In addition, the committee reviewed what is known about CMA as a deicer and identified major cost and use issues that need to be addressed when CMA is considered as a replacement for salt.

ROAD SALT DAMAGES AND COSTS

The main side effects, or indirect costs, of salting are (a) motor vehicle and infrastructure damage, (b) degradation of the environment along the roadside, and (c) sodium infiltration of drinking water.

Motor Vehicle and Infrastructure Costs

Salt damages motor vehicles and infrastructure primarily because of its corrosive effects on metals. The chloride ions in salt disrupt natural protective films on metal surfaces and increase the conductivity of water, which induces and accelerates corrosion. By far the most costly damage is to motor vehicles, followed by bridges and parking structures. Less obvious side effects, which collectively may be significant, include damage to concrete pavements, underground utilities, and roadside objects.

Motor Vehicles

During the 1960s and 1970s, the increased use of sodium chloride for highway deicing, combined with acid precipitation from atmospheric pollutants, sea spray in coastal areas, and the use of calcium chloride for low-temperature deicing and dust control, resulted in widespread corrosion in vehicles throughout the Northeast and Midwest. Besides affecting the appearance of vehicles, corrosion affected the structural condition and function of critical vehicle parts, such as brake linings, floor panels, and frame and bumper systems.

Automobile manufacturers have made gradual advances in reducing corrosion during the past 20 years by improving vehicle designs, materials, and manufacturing processes. It is anticipated that these advances will continue to reduce the incidence and severity of corrosion. During the past decade, these advances have led to the virtual elimination of salt-induced structural and functional corrosion, and cosmetic corrosion has been greatly reduced. Today the most clearly identifiable cost of road salt is the more expensive corrosion-resistant materials and coatings used in new cars and trucks. Altogether, corrosion protection features that are directly related to road salt have increased the cost of manufacturing new vehicles by approximately $1.9 billion to $3.9 billion per year.

Besides bearing the expense of this protection, motorists in salt-using regions also spend additional time and money trying to prevent persistent cosmetic corrosion, for example, by more frequent car washing and careful touching up of paint damage caused by stone chips and minor accidents. Only limited data are available to estimate the cost of this additional maintenance and any losses in vehicle appearance and value due to cosmetic corrosion that persists. The committee believes that a plausible range for this cost is $1 billion to $2 billion per year, but that the cost will continue to decline during the next 10 years because of continued progress in corrosion prevention.

Bridges

Among the components of highway infrastructure, road salt is most clearly damaging to bridge decks. The chloride ions in salt penetrate concrete and cause reinforcing steel bars (rebars) to rust, resulting in cracking and fragmenting of the surrounding concrete. Though this damage seldom compromises the structural integrity of a properly maintained deck, it can cause extensive potholing of the deck surface, which can seriously degrade deck ride quality.

During the past 30 years in the Northeast and Midwest, road salt has caused more premature bridge deck deterioration than any other factor. After decades of salting, thousands of older decks are critically contaminated with chloride and will continue to deteriorate whether salt or noncorrosive deicers are used. Repair and restoration of these contaminated decks as they become deficient is likely to be a major, and largely unavoidable, expense for many years. Accordingly, an urgent concern is to protect newer decks that are not already contaminated. New construction techniques and materials have been developed in recent years that promise to reduce both the incidence and severity of deck damage. Most decks built in the past 10 to 20 years in snowbelt states are equipped with some type of protection. During the next 10 years, the total cost of installing these protections during the construction of new decks and repairing the portion of currently sound decks that become damaged by continued salting will be about $125 million to $325 million per year.

Bridge components other than concrete decks that are vulnerable to salt-induced damage include reinforced concrete supports (e.g., beams), steel structural supports, bearings, and joint devices. Damage to these components, which is caused by salt leaking from the deck and salt splash and spray from adjacent roadways, is generally less extensive than deck damage but is often more difficult and expensive to repair and protect against. Although the information available to quantify these costs is limited, the committee believes that collectively they are as large as deck costs and, as a rough approximation, fall within the same range, $125 million to $325 million per year.

Parking Garages

There are about 5,000 large, multilevel parking garages in the Northeast and Midwest. During the past 20 years, hundreds have become contaminated and seriously damaged by salt dropped from parked cars. The process is similar to that of bridge decks; salt intrusion causes the reinforcing steel to rust, in turn causing cracking and fragmenting of surrounding concrete. Like bridge decks, many older parking garages are critically contaminated with salt and will need to be repaired or demolished regardless of future salt use. Accordingly, an urgent concern is protecting newer garages not already contaminated with chloride. Most new parking garages are equipped with some type of protection against corrosion, which should reduce damage in the future. During the next 10 years, the total cost of installing these protections and restoring garages that become damaged by continued salting will be roughly $75 million to $175 million per year.

Other Infrastructure

Other infrastructure components affected by road salt include nonbridge highway components, such as reinforced concrete pavements and roadside hardware (e.g., signposts and light stands); objects buried under or alongside highways, such as utility lines, pipelines, and steel storage tanks; and some nonhighway objects near salt-treated roads, such as bronze monuments. For many of these items, repair and maintenance requirements due to corrosion (from numerous sources) and other sources of damage are serious problems with large annual costs. Available data, however, are insufficient to isolate the incremental effect of road salt on this much broader set of infrastructure costs.

Summary

The committee's estimates of annual salt costs associated with motor vehicles and infrastructure are summarized in Table ES-1. The reliability of these estimates varies, and some cost items are not quantified because of inadequate information. Summation of the more reliable cost estimates, for which supporting data are relatively dependable, suggests a minimum vehicle- and infrastructure-related

TABLE ES-1 SUMMARY OF ANNUAL COSTS FOR MOTOR VEHICLES AND INFRASTRUCTURE FROM CONTINUED SALTING

Cost Item	Annual Cost ($ millions)
Category I (Data Reliable and Complete)	
Motor vehicle corrosion protection	1,900–3,900
Bridge decks	125–325
Parking structures	75–175
Total	2,100–4,400
Category II (Estimates Based on Committee Judgment)	
Motor vehicle corrosion damage	1,000–2,000[a]
Bridge nondeck components	125–325
Other highway components	100[b]
Total[c]	1,200–2,400
Category III (No Reliable Data Available)	
Roadside objects	N.A.
Underground objects	N.A.
User costs[d]	N.A.

NOTE: N.A. = not available.
[a] From an illustration in Chapter 3 of the potential magnitude of these costs if car buyers in salt-using states are willing to spend an additional $125 to $250 per new car (the cost of existing salt protection) to eliminate persistent cosmetic corrosion.
[b] Cost totals less than $100 million, assuming it is an order of magnitude smaller than total bridge costs.
[c] Rounded to nearest $100 million.
[d] Examples include user costs associated with salt damage and repair to bridge decks and parking garages.

cost ranging from approximately \$2 billion to \$4.5 billion per year. Inclusion of other cost items that are based heavily on committee judgment provides a more complete, although less precise, cost estimate ranging from approximately \$3.5 billion to \$7 billion per year.

Among the cost items omitted from these estimates because of insufficient information are damage to roadside objects, corrosion of underground materials and structures, and costs incurred by motorists who are inconvenienced by bridge and parking garage damage and repair work. These costs are difficult to quantify but are potentially significant in specific situations.

Environment

During the past three decades, hundreds of reports have been written documenting the effects of road salt on the environment. The literature clearly indicates that the effects can be significant but depend on a wide range of factors unique to each site. Most frequently reported in the literature are damage to roadside vegetation, soil, and surface water.

Vegetation

Roadside trees and other vegetation can be injured by salt through changes in soil chemistry and splash and spray on foliage, shoots, and branches. The primary concern is excessive exposure to chloride. The symptoms of chloride injury are similar to those of drought: inhibited growth, browning and falling leaves and needles, and sometimes dying limbs and premature plant death. The extent of damage varies greatly by location and depends on factors such as degree of salt use, topography, precipitation, drainage, weather conditions, and vegetation cover and species. Damage is most likely to occur along downsloping roadsides (which result in greater salt runoff and allow salt spray to reach treetops) along primary highways, because high speeds and traffic volumes are associated with greater salt use and salt spray.

Highway agencies in states in which public concern about vegetation damage is greatest report that 5 to 10 percent of the roadside trees (those within 100 ft of the pavement edge) along some sections of salt-treated primary highways exhibit signs of salt-related decline. In general, they report less significant damage on secondary highways and that common roadside shrubs and grasses tend to tolerate salt better than do trees.

Soil

Salt's effect on soil is usually confined to 15 ft of the pavement edge. The primary concern is long-term sodium accumulation, which can adversely affect soil structure characteristics. Specifically, sodium accumulation can increase soil density and reduce permeability, moisture retention, and fertility, which affect plant growth and erosion control. However, whether salt has a cumulative effect depends on local conditions, such as soil type, precipitation, and topography.

Surface Water

Salt's effects on surface water are confined mainly to small streams running adjacent to heavily salted highways. Although small receiving lakes and ponds can be affected, few such incidents have been reported in the literature. In general, salt loadings in larger rivers and lakes are diluted because of high water volumes. In extreme cases, high and persistent chloride concentrations in roadside streams can harm fish and other stream life. The complexity of stream environments and the absence of detailed data make it difficult to characterize and quantify possible adverse effects on a national basis.

Summary

In summary, each report of salt damage to the environment must be reviewed in the light of prevailing conditions at the particular site; hence, reliable nationwide estimates of environmental damage and resultant costs are not possible. Though such evaluations have been attempted in the past, they were not intended, nor are they accurate enough, to compare the overall cost of salt with that of alternatives. Meaningful estimates of environmental damage can only be accomplished on a case-by-case basis by evaluating local circumstances in depth. Even when environmental damage can be quantified for a specific site, a monetary value can be difficult to assign and highly subjective. Estimates of remediation costs—such as the expense of removing and replacing an injured tree—provide some cost perspective, but they may be inaccurate or incomplete because they do not reflect the value of the injured tree to society or other indirect costs, such as diminished roadside aesthetics and secondary effects on the roadside ecosystem.

Drinking Water

Road salt can enter drinking water supplies by migrating through soil into groundwater or by runoff and drainage directly into surface water. In general, only wells or reservoirs close to salt-treated highways or salt storage facilities are susceptible to salt infiltration. Susceptibility depends on many factors, such as salting intensity, soil type, climate, topography, and water volume and dilution. Sources of salt in drinking water other than road salt include natural brines and salt deposits, industrial and agricultural chemicals, and water treatment and softening processes.

During the past 30 years, communities in several states, primarily in the Northeast, have reported higher sodium and chloride concentrations in private wells and public water supplies that have been linked to road salt. Many of these problems resulted from improper salt storage. Most of the more egregious salt storage problems are being corrected. Some communities report salt concentrations in water supplies due to highway runoff, although such concentrations are seldom as high as those associated with improper salt storage.

The discovery of higher salt concentrations in drinking water due to road salt has raised concerns about possible adverse effects on public health. Salt is a source of dietary sodium. Excess dietary sodium has been negatively associated with health primarily because of concerns related to hypertension, or high blood pressure. Typically, drinking water and all other beverages combined account for less than 5 percent of daily sodium intake. Because of the normally minor contribution of drinking water to sodium intake, no federal standards have been established for salt (i.e., sodium or chloride) concentrations in water supplies.

Efforts to mitigate the amount of salt in drinking water vary from state to state and by community. Common measures include modifying highway drainage, relocating private wells, upgrading salt storage facilities, and reducing salting activity in the vicinity of public water supplies. Nationally, about $10 million is spent on mitigation each year by state and local governments, mostly in the Northeast and Midwest.

CMA

Since 1980, numerous laboratory and field studies have been conducted to evaluate CMA's field performance, likely impacts on the environment and human health, compatibility with automotive and highway materials, and prospective production technologies and market price. Findings from published reports of CMA field evaluations and interviews with current CMA users indicate the following:

- Field experience: To date, CMA has had limited use, which complicates efforts to determine its likely performance under a wide range of conditions. In the selective and experimental situations in which it has been used, it has often performed acceptably, although generally not in the same manner and not quite as effectively or consistently as salt. Compared with salt, it is slower acting and less effective at lower temperatures [below −5°C (23°F)] and in freezing rain, drier snowstorms, and light traffic. The timing of application is more critical than for salt. If application is delayed, its deicing performance is notably reduced. CMA is usually applied in greater quantities (by weight) than is salt—usually by 20 percent or more—though specific quantities vary by storm and user. Because of its lower density and greater volume requirements, CMA may require substantially more truck capacity and enclosed storage space (60 percent or more) than salt, especially for more general use.
- Health and environmental effects: Research findings to date indicate that CMA is likely to have no adverse effects on human health and few negative environmental effects. Because it is biodegradable and exhibits poor mobility in soils, it is less likely than salt to reach groundwater. In preliminary environmental evaluations, the potential for CMA to extract heavy metals from roadside soils was identified; however, results from follow-up studies have not indicated this effect. CMA has exhibited negligible adverse effects on common roadside vegetation and is apparently safe for use near most aquatic environments, although the effect of heavy CMA treatments near some small, poorly flushed, or poorly diluted ponds and streams may require monitoring and further study. These findings may not apply to CMA derived from some alternative feedstocks, such as municipal solid waste, which may introduce contaminants that alter its known environmental effects or create new ones.
- Compatibility with motor vehicles: CMA is more compatible with most automotive materials and components than is salt. Vir-

tually all automotive metals, plastics, coatings, parts, and components tested in laboratory experiments have exhibited fewer negative reactions when exposed to CMA than when exposed to salt. The potential for CMA spray to adhere to vehicle windshields and body parts, which has been reported by some field users, would probably require further study before more widespread use.

- Compatibility with highway and bridge materials: Laboratory tests indicate that CMA is less detrimental than salt to common highway materials, including those used for paving, road marking, and highway construction. CMA is much less corrosive than salt to exposed steel and other metals commonly used on bridges for applications such as joints, gutters, railings, and beams. Recent findings also indicate that CMA is less corrosive than salt to rebars in new concrete and does not accelerate corrosion of rebars in older, chloride-contaminated concrete. However, there is insufficient evidence to determine whether CMA reduces the rate of corrosion in concrete that is already contaminated with chloride, which is the condition of many older bridges in the Northeast and Midwest.
- Production technologies and price: CMA is manufactured by reacting dolomitic lime with acetic acid, which is CMA's chief cost component. The only CMA on the market is manufactured by using acetic acid derived from natural gas. It is priced between $600 and $700 per ton delivered. Alternative, lower-cost production technologies are being investigated. Given the uncertain prospects of these technologies and the long-term schedules required to introduce new manufacturing processes, prices on the order of $600 to $700 per ton are the only reasonable projections that can be made now.

CMA COST AND USE ISSUES

Cost issues related to both the general and selective use of CMA were reviewed by the committee.

General CMA Use

The committee believes that the use of CMA as a more general replacement for salt is unlikely and unwarranted. Widespread use of CMA would probably reduce corrosion of some motor vehicles and infrastructure components that are poorly protected and not already contaminated by salt. However, its widespread use would have little effect on the corrosion of many older, salt-contaminated infrastructure components or on many other costs related to corrosion prevention. Even in the absence of road salt, the continued corrosivity of the highway environment due to atmospheric pollution (acid precipitation), the continued use of other chloride chemicals (such as calcium chloride for low-temperature deicing and dust control), and salt spray in coastal regions would make much of this corrosion protection necessary. In addition, because salt's environmental impacts are site specific, it is not clear that widespread use of CMA would result in significant environmental savings that could not be achieved by less expensive, targeted mitigation measures (which might include selective CMA treatments).

If a moderate- or large-scale conversion to CMA were made, highway agencies would learn how to use CMA more effectively and efficiently—for example, by modifying equipment and adopting spreading, handling, and storage practices better suited to CMA. Nevertheless, such a conversion would have far-reaching effects on winter maintenance budgets and operations, both during the initial conversion and in the long term. Given CMA's higher price and greater volume requirements—which would be likely to require substantially more storage space, spreading equipment, and manpower—expenditures on deicing material would increase by 20- to 30-fold, and winter maintenance budgets would increase by a factor of five. In practice, because CMA is slower acting than salt and does not always perform as well in light traffic, freezing rain, and dry and cold storm conditions, its widespread use could present significant operational difficulties to highway agencies. In particular, the need to apply CMA early during a storm cycle could pose problems for highway agencies without enough manpower and equipment to provide early coverage on all highways.

Selective CMA Use

Currently, CMA is used selectively and in limited quantities, primarily in environmentally sensitive areas and on new (uncontaminated) corrosion-prone structures and highway sections. On the basis of existing information about CMA's deicing performance and cost, the committee believes that such selective applications are likely to be the principal uses for CMA in the future. CMA's cost-effectiveness in such situations can only be determined on a case-by-case basis, after considering the relative costs of CMA, salt, alternative deicing materials, and other measures to mitigate salt's adverse effects. This is especially true for environmentally sensitive areas, because each roadside has a unique environment and valuations of environmental damage vary by location. For all potential 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.

OUTLOOK FOR REDUCING DEICING COSTS

More than 20 years after the adverse side effects of road salt first came to light, the total cost of salting continues to be high. During this period, however, major achievements in corrosion protection have helped control many costs and are expected to continue to do so. Carefully designed and located salt storage facilities and better-managed salting programs should help reduce environmental damage and water contamination.

In all likelihood, sodium chloride, or common salt, will continue to be the predominant highway deicer for many years. Highway agencies and private industry continue to refine and seek new ways to prevent and treat salt's adverse effects, for example, by improving corrosion protection and developing new corrosion repair methods. Likewise, research continues aimed at reducing salt use by developing anti-icing technology (e.g., chemicals for pretreating roadways to prevent ice formation), improving salt application techniques, and exploring alternatives to salt besides CMA. CMA is therefore one of many options available to highway agencies to mitigate salt's adverse effects, and its use and acceptance is likely to depend in large part on the progress made in other mitigation areas.