Table 2. Recommended plantings where the ROW is not constrained.

Botanical Name	Common Name	Maximum Height at Maturity (cm)	Number of Rows	Distance Between Rows (cm)	Spacing in Rows (cm)
Juniperus virginiana	Eastern red cedar	600+	2	300	150
Rhamnus frangula columnaris	Glossy tallhedge buckthorn	540	2	240	90
Caragana arborescens	Siberian pea tree	540	2	300	150
Viburnum dentatum	Arrow-wood	540	2	300	150
Crataegus cordata or C. phaenopyrum	Washington hawthorn	600	2	300	150
Acer ginnala	Amur maple	600	2	300	300
Elaeagnus angustifolia	Russian olive, oleaster	600	2	300	300
Viburnum lantana	Wayfarer tree	540	2	300	150
Viburnum prunifolium	Blackhaw	540	2	300	150

Note: 1 cm = 0.4 in.

site. For Iowa, Tables 1 and 2 identify suitable plants and their characteristics (honeysuckle is the most practical for normal Iowa conditions).

5. The applicability of guardrail and the type in use should be examined. Moving the guardrail away from the pavement edge improves the potential for snow-free maintenance. Also, the box-beam type may have reduced propensity for creating snowdrifts.

6. A snowdrift-control plan should be implemented at each overhead location at which actual drifting has been observed so that modification of plantings may be made to minimize snowdrifting on the pavement.

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Abridgment

Alternatives to Sodium Chloride for Highway Deicing

STANLEY A. DUNN AND ROY U. SCHENK

A search has been made for road deicing chemicals to replace sodium chloride (NaCl). The impetus for this search stems from the numerous drawbacks associated with the current extensive use of NaCl as a road deicer. All classes of chemical compounds were reviewed. Deletions were made on the basis of such pertinent criteria as water solubility and freezing-point lowering, corrosion, toxicity, flammability, relative cost or cost potential, and effect on soils, plants, and water supplies. Low molecular weight and high solubility were primary qualifications. Waste products were considered as possible raw-material sources. Two candidate deicers have been selected that, if used, would result in total costs of about one-half those associated with the use of NaCl. Both materials can be made from waste cellulose. Neither is corrosive. One of them, methanol, reacts almost immediately on contact with snow and ice but is less persistent than the other candidate or than NaCl. The other candidate, calcium magnesium acetate (CMA), acts at about the same rate as NaCl in the temperature range of common activity and shows about the same persistence. In strong contrast to NaCl, CMA is a corrosion inhibitor, is beneficial to most soils, and has no potential to harm drinking supplies.

The well-known corrosive effect of sodium chloride (NaCl) on metals has long begged for replacement of this chemical as a road deicer. It has been demonstrated that this obvious defect is but one of many undesirable results attendant on the use of NaCl for deicing purposes (1-7). Accordingly, the present search for workable alternatives was initiated.

Chemical deicing depends on the general effect of dissolved substances or solutes on the melting point of the material in which they are dissolved, the solvent. The effect is always to lower the melting point. The amount of lowering is almost solely dependent on the number of solute molecules or ions present in solution, roughly proportional to this number, and almost entirely independent of the nature, size, or weight of these solute particles. Thus, low-molecular-weight materials produce the greatest lowering of the freezing point for a given weight dissolved in the solvent. Also, the solubility of the solute determines the degree of lowering it can exert on the melting point of the solvent in which it is dissolved.

If the costs of purchasing and applying alone are considered, there is perhaps no other chemical deicer as cost effective as NaCl. In the long run, the net cost of using NaCl or any other deicer, however, must include the associated damages to the natural and manmade surroundings. It is primarily the cost of these types of damages caused by the use of NaCl that provides the economic justification to search for alternative deicers among possibilities that may be more costly to purchase.

METHOD

It was the rationale of this investigation that the purchase cost of the replacement might exceed that of NaCl, but that the excesses in this cost must be made up by a lessened negative impact on the surroundings. Murray and Ernest (1) estimated that the damages caused by the use of NaCl as a deicer were more than 10 times that of the cost of NaCl. Thus, for an alternative deicer that is free of harmful side effects to the surroundings, there is considerable latitude insofar as the purchase price is concerned.

In this study, all combinations of chemical elements were evaluated as potential chemical deicers. Most elements and compounds were quickly eliminated on the basis of general chemical considerations because they are prohibitively expensive, are extremely toxic and/or are gases or otherwise unsuitable, are not available in reasonable quantities, have low water solubility, are corrosive, or contribute to ecological damage. Nine elements appeared to offer hope to produce effective deicer combinations. These elements are hydrogen, carbon, nitrogen, oxygen, sodium, potassium, magnesium, calcium, and phosphorus. All chemical combinations of these nine elements were evaluated further.

Further rounds of elimination from among the resulting combinations required examination of the pertinent physical and chemical properties in greater depth (8). Values were sought from the open literature and supplemented by laboratory determinations when not available from that source. The process is described more fully in Dunn and Schenk (9).

RESULTS

By this process the field was narrowed to two candidates, methanol and a mixture of calcium and magnesium salts of organic acids, primarily acetic. These two candidate deicers, both of which can be produced from waste cellulose (10-13) were scrutinized from a number of performance and environmental points of view. Both methanol and calcium magnesium acetate (CMA) have compared favorably with NaCl in most of these respects and comparably in most of the remaining ones. The performance of the two candidates is summarized below by using NaCl as the standard of comparison. Whenever documentation is not given in what follows, supporting data are to be found in Dunn and Schenk (9).

Methanol

Methanol exhibits a eutectic with water, -120°C, far below that of NaCl or any other inorganic deicer candidate (14,15). In deicing field tests, methanol works much more rapidly and at far lower temperatures than either CMA or NaCl. Under some conditions, its deicing effect improves with lower temperature. At temperatures above -15°C and over the short term, it performs comparably with CMA and NaCl on an equal osmolar basis. Beyond a few hours, however, more than equal osmolar amounts must be added in order to match the persistence of CMA or NaCl. The methods of handling and dispensing liquids such as methanol, although different, are simpler than those for solids and subject to much finer control.

In only one test series out of six did methanol cause a greater degree of corrosion of a metal than did plain water. In one instance out of the same six, it caused less corrosion than water. By contrast, NaCl caused serious corrosion in five out of the six same test series.

Methanol exhibited no adverse effect on portland cement concrete in a triplicated test series of nine months' duration. It gave one instance of minor attack on asphalt concrete--namely, the partial uncovering of a number of aggregate particles at sample surfaces in the freeze-thaw test series. Investigation of this result is perhaps merited.

Methanol has been used as an antifreeze for gasoline engines but was replaced by the glycols because of its relatively high evaporation rate. At snow and ice temperatures, volatility is much reduced. The remaining volatility, however, serves to minimize the concentration of methanol in the runoff and, correspondingly, its contribution to biochemical oxygen demand (BOD). Spills, of course, are self-removing. Methanol vapor is about 10 percent more dense than air, whereas gasoline by comparison is several hundred percent more dense. Accordingly, methanol vapor is much less prone to collect in low spots and is much more easily dispersed than gasoline vapor is.

The flash point of methanol, 15.6°C, is nearly 16.7°C above the freezing point of water. The flash point of an aqueous methanol solution is, of course, even higher than that of the pure material. Fires can be extinguished with water (as gasoline fires cannot) because methanol and water are miscible in all proportions. Methanol's flammability appears to be limited to the period of storage and application. Once applied to a frozen or a snow-covered road, it appears to be difficult, if not impossible, to ignite.

As with all substances, it has toxic limits. But these limits are relatively high; methanol has been cleared as a food additive (16). No ill effects have been found on prolonged exposure to low concentrations or to short intermittent exposures at high concentrations of its vapors (17). Its label as a toxic substance results from its occasional misuse as a substitute for ethanol and is unwarranted in

the context of its use as a road deicer.

Methanol has very few undesirable environmental properties. It is neutral. It contains no nitrogen or phosphorus and thus contributes nothing to eutrophication problems. Although methanol carried into streams and groundwater does create an increase in BOD, its volatility appears substantially to reduce this problem, as already noted. Furthermore, its accumulation from use as a deicer would occur during periods of minimal microbial activity in water that had maximum oxygen capacity. Therefore, harmful BOD effects of methanol would be minimal (18). The vapor gradually oxidizes to water and carbon dioxide.

It would appear that, with reasonable precautions, methanol's use as a deicer should pose no significant operational or ecological problems. In addition, although purchase costs are higher, estimates of total costs, including purchase, application, and environmental, highway, and vehicular damage associated with the use of methanol, are less than half those costs associated with the use of NaCl.

CMA

Late 19th and early 20th century research showed that cellulosic solid waste could be converted to alkaline earth salts of lower carboxylic acids, predominantly acetic, by relatively simple technology and in yields sufficiently large to be interesting (11-13). Most of these salts show sufficient water solubility to function as deicing agents.

The water eutectics of the two primary components, calcium and magnesium acetates, are -15°C and -30°C, respectively, thus bracketing that of NaCl (-21°C). In road and sidewalk deicing tests, CMA performs comparably to NaCl on an equal osmolar basis. On this basis, both salts take effect in about the same time and persist in their effects for similar periods. CMA can be spread with the same equipment used for NaCl.

Braking traction and skidding friction are decreased by both NaCl and CMA when these deicers are applied at dosages insufficient to melt through the ice. By contrast, a sample of unpurified CMA improved both braking traction and skidding friction under the same conditions. To leave the insoluble impurities in the reaction product also reduces production costs.

In repeated tests CMA has shown no significant corrosion of steel, zinc, or aluminum. On the contrary, it has exhibited significant corrosion inhibition effects with respect to A-36 steel and A-3560 cast aluminum. By contrast, both here and in the literature, NaCl has been observed to promote significant corrosion of steel and other metals. Although reinforcing bars embedded in concrete were consistently corroded in the presence of NaCl during nine-month wet-dry tests on reinforced concrete, those bars in the presence of CMA were untouched.

Neither calcium nor magnesium ion presents any more toxicity hazard than sodium ion (19). They are less of a hazard with respect to cardiac patients (20-22). Acetate ion is a food substance, vinegar, and no more hazardous to health than chloride ion. CMA is mildly basic, however, and minimal skin and respiratory protection against dust would be desirable in prolonged exposures during handling.

Environmentally, the more-harmful thing that the calcium and magnesium ions contribute is water hardness. Their acetate salts do not contribute significantly to eutrophication. The acetate is indeed organic, but it is broken down slowly during the cold winter months, which reduces any potential BOD stress. The calcium and magnesium are gradually precipitated as the carbonates and thereby removed from solution where their presence might otherwise influence water density and interfere with the turnover of lakes (23,24).

Soils in the eastern half of the United States, where most deicing is done, are deficient in calcium and magnesium (25,26). Addition of these nutrient elements to the soil in these areas by means of a road deicer could be beneficial. These divalent cations tend to improve the structure of the soil where, by comparison, sodium and to a lesser degree other monovalent cations (e.g., potassium and ammonium) tend to cause the breakdown of soil structure (27-29). Such breakdown results in a decreased permeability for both water and air, often a serious agricultural problem (30).

CMA is essentially nonflammable and generally nontoxic; it retards corrosion of most metals in comparison with NaCl or even water. The one observation of harmful behavior, the superficial scaling of some of the portland cement concrete samples, is probably attributable to the acidification pretreatment given the CMA in these instances rather than to the CMA itself. Rerunning of these tests has been recommended.

Assuming that unacidified CMA will not produce scaling of portland cement concrete, then the total estimated cost of using CMA as a highway deicer, including the cost of all side effects, will be less than half that of using NaCl.

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Deferred Maintenance

MARION F. CREECH

This study investigated deferred maintenance as it concerned roadside vegetation control and drainage. It was also designed to develop the basis for a deferred maintenance program. Field work revealed that vegetation growth control, especially mowing, was being sharply reduced and that most states visited were rewriting their standards to reflect this. Maintenance deferral for drainage facilities, which are less visible, was even more dramatic; maintenance was performed on an as-needed basis, in many cases only when some catastrophic event such as flooding occurred. Major consequences of deferred maintenance were considered in relation to safety, condition of facilities, liability, social and environmental effects, and level of service. A methodology for developing a deferred maintenance program was formulated. This method, which consists of five discrete steps, has the potential to allow selection of maintenance activities to be deferred and determination of the deferment period that has a minimum of risk.

Deferred maintenance is a subject of much interest and concern to many transportation officials. In this time of shrinking revenues, almost runaway inflation, the unknown future energy situation, and environmental restraints, it becomes clear that there will not be enough maintenance dollars to go around. This simply means that some types of maintenance activities performed in the past on a regular basis will have to be deferred or put off completely. Decisions about which activities to defer and the length of deferment are of prime importance. The questions that must always be asked are, If a certain activity is deferred, what are the consequences it will have on the particular element of the highway with which it is associated and what consequences will it have on the overall integrity of the road?

OBJECTIVES OF THE STUDY

This research project was initiated to investigate the feasibility of deferring the maintenance activities of roadside vegetation control and the cleaning and repair of drainage facilities. A second objective was the formulation of a method for developing a deferred maintenance program by using the information uncovered in the investigation.

After such information as was available had been collected and studied, the expectation was that the consequences of deferring maintenance could be determined or predicted in regard to safety effects, integrity of the facility, legality, effects on users, and environment.

PROBLEMS DISCOVERED IN PERFORMING THE STUDY

Several things discovered at the outset of the study