SOME EFFECTS OF DE-ICING CHEMICALS ON ROADSIDE TREES

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•USE OF SALT as a highway de-icing compound has gained wide acceptance during the past 25 years. For example, the amount of salt used on highways in the United States has increased from ½ to 6 million tons during the past 20 years. Its use appears to be increasing at the rate of about 1 million tons per year, and predictions are that it may level off at 10 to 12 million tons (12). It is estimated that 95 percent of the salt used is sodium chloride (NaCl) and 5 percent is calcium chloride ($CaCl_2$).

New Hampshire has been a leader in the use of salt in its winter highway maintenance program. In 1957 the state highway department used 75,000 tons of salt, mostly NaCl, on 3,700 miles of state highways or approximately 20 tons per mile. Ten years later (1966-67) 113,000 tons of salt were applied on 7,700 lane-miles of highway, with a total of 115 applications. This is almost 30 tons per two-lane mile or 5 to 6 pounds per foot per lane. A survey of the other five New England states showed that their use of salt was comparable to that of New Hampshire.

In 1957, the New Hampshire highway department reported 13,997 dead trees along 3,700 miles of highway. The cause of death of these trees was not specified. The estimated cost of removal was $1,000,000.

At that time, highway department officials sought our help in determining the effect of salt on roadside trees. Research reports prior to 1957 were either irrelevant or inconclusive. Most of the research on salt injury had been done with crop plants and had been done in connection with the saline or alkaline soils in the western United States. Considerable work had been done in Holland also where the land had been flooded from time to time with seawater. Most studies conducted in the eastern United States dealt either with $CaCl_2$ applied in summer to reduce dust on unpaved roads (11) or with salt spray from the Atlantic Ocean as a result of storms.

The first report of injury to roadside trees from winter use of salt appears to be from Minnesota (2).

Experiments were started in Massachusetts during the winter of 1952-53. Initial reports indicated no injury to trees from salt applications (5, 9). However, a later and more detailed report stated that injury to roadside maples was correlated with high chloride levels, presumably from uptake of chlorides applied to roads in winter (4). This confirmed an earlier report from Connecticut (1).

We started our research on the decline of roadside trees about 15 years ago. The writer moved out of the state in 1943 and returned in 1951. During that time something had obviously taken place that was affecting the health and vigor of roadside trees, especially sugar maples. Preliminary studies indicated that a few trees were infected with Phytophthora cactorum, the causal agent of bleeding canker. A few others had Armillaria root rot, caused by Armillaria mellea; an occasional tree was suffering from Verticillium wilt (Verticillium alboatrum); but most trees were apparently free from pathogenic fungi.

Norman Lacasse, a former graduate student at the University of New Hampshire, and the writer made a careful study of 550 sugar maple (Acer saccharum Marsh.) trees along US-4 in Northwood, a heavily traveled and salted highway. Trees within 30 ft of the highway were usually moderately to severely affected, whereas trees more than 30 ft away were almost always healthy. Symptoms of affected trees included marginal leaf scorch, late summer coloration and early autumn defoliation, reduced shoot growth, dying of twigs and branches in the crown, and ultimate death of severely affected trees.

Injury was not correlated with size or age of trees, soil type, soil fertility, or parasites including nematodes. Analyses of foliage and twigs from injured trees showed abnormally high sodium levels (748 and 681 ppm respectively), and sap from injured trees tested high in soluble salts (8). We observed that the 30-ft strip along each side of the highway was the area where the snow, slush, and salt were deposited by the snowplows. Soil samples taken in the spring from areas near the highway contained more soluble salts than samples 50 ft or more from the highway. However, the salts were leached rapidly by melting snow and spring rains.

Another study by Kotheimer, Niblett, and Rich (7) showed that sugar maple trees along salted state roads in three townships (Barrington, Kensington, and East Kingston) were injured considerably more than maple trees along unsalted town roads in those townships (Table 1).

These results suggest that salt is an important contributing factor to the decline of roadside maple trees. Other factors such as drought, pavement, mechanical root damage, and possible air pollution should have remained relatively constant for the salted and unsalted roads.

Further work at the New Hampshire Agricultural Experiment Station (6) showed that Cl^- level was a better indicator of salt injury than was Na^+ level. In one study, the Na^+ levels in foliage for healthy, moderate, and severe injury classes were 0.02, 0.03, and 0.17 percent respectively. The corresponding Cl^- levels for the same classes were 0.06, 0.28, and 0.42 percent respectively. These results agree in general with those of Holmes and Baker (4), but they observed little injury at chloride levels below 0.5 percent while injury was common at the 1 percent level.

The shoot growth of injured sugar maple trees is greatly reduced. The mean annual shoot growths for normal, slight, moderate, and severe injury classes were 9.4, 7.0, 4.4, and 3.0 cm respectively. The corresponding mean foliar Cl^- levels were 0.08, 0.13, 0.26, and 0.35 percent. Many terminal buds were dead, and the injured shoots had a "stag horn" appearance as a result of abnormal growth form.

Tolerance to salt varies considerably with both coniferous and deciduous species (10). Coniferous species that are intolerant to salt include Canadian hemlock (Tsuga canadensis), balsam fir (Abies balsamea), white pine (Pinus strobus), and red pine (Pinus resinosa). Deciduous species that are sensitive to salt include sugar maple (Acer saccharum), red maple (Acer rubrum), bass wood (Tilia americana), and American elm (Ulmus americana).

Tolerant species include red oak (Quercus rubra), white oak (Quercus alba), white ash (Fraxinus americana), black locust (Robinia pseudo-acacia), quaking aspen (Populus tremuloides), black cherry (Prunus serotina), black birch (Betula lenta), gray birch (Betula populifolia), paper birch (Betula papyrifera), yellow birch (Betula alleghaniensis), Norway maple (Acer platanoides), and red cedar (Juniperus virginiana).

A greenhouse experiment indicated that white pine was injured by applications of salt to either the foliage or the roots. Observations of injury to nondeciduous roadside trees support these findings. Sensitive trees subjected to wind-blown salt spray from passing cars and trucks are often injured severely (3).

Calcium chloride is less toxic than sodium chloride to roadside vegetation, but very little is used on New Hampshire highways in winter. Calcium chloride is effective in

Table 1. Vigor of sugar maple trees along salted and unsalted town roads in three townships in southeastern New Hampshire.

	Unsalted			Salted		
Township	Total	Healthy	Rating[a]	Total	Healthy	Rating[a]
Barrington	27	26	0.04	51	8	2.33
Kensington	51	48	0.16	45	5	1.86
East Kingston	30	48	0.15	38	3	1.43
Total	108	101	0.11	134	16	1.87

[a]Average rating: 0 = healthy; 5 = dead.

ice removal, but it is more expensive and more difficult to store and handle than sodium chloride.

Applications of gypsum ($CaSO_4$) to the soil have a tendency to improve soil structure, reduce the uptake of sodium, and reduce the visible injury to foliage. However, it is difficult to incorporate the gypsum into the soil around growing trees.

Sodium chloride, applied to the highways in winter to prevent ice formation and to aid in snow and ice removal, is an important contributing factor to the decline of roadside trees. Trees within 30 ft of the edge of the highway are affected most frequently and most severely. Probably other contributing factors include drought, low soil fertility, soil compaction, mechanical injury to roots, and possibly air pollution.

Although research data indicate that salt is harmful to roadside vegetation, it is unrealistic to advocate discontinuation of its use. We are dependent today on safe highway travel for business, pleasure, work, and transportation. No inexpensive, readily available, convenient, and effective substitute for salt has been found. Human life and safety must be given priority over roadside trees, many of which should not be so close to the highway anyway.

So what can we do? Use salt with more discretion. Be sure that salt spreaders on highway trucks are properly calibrated. Mix sand with salt where feasible. Construct new highways so that salt will drain into a ditch between the edge of the road and the nearest row of trees. Select tolerant tree species such as oaks for new plantings. Avoid intolerant species such as hemlock, balsam fir, white and red pine, and sugar and red maple. Mix gypsum with the soil at planting time. It will improve soil structure and reduce salt injury.

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