

Effects of De-Icing Salts on Roadside Soils and Vegetation

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ABRIDGMENT

•A PUBLIC DEMAND to maintain open travel routes for fast speeds during the winter, an increased emphasis on traffic safety, and a change in economic factors have shifted winter maintenance operations in the north to application of salts directly to highways. This policy requires the use of liberal quantities of sodium chloride and calcium chloride. The effect of these de-icing salts on soils and vegetation in the highway environment is of importance.

De-icing salts applied to roads may be carried by surface runoff into streams and waterways or they may infiltrate into the soil bordering the highway. When infiltration occurs, ions of de-icing salts may be carried to groundwaters, remain in soil solution, or become adsorbed by soils. Therefore, salts are potential pollutants of water supplies and soils in the highway environment and may cause the loss of potable water or the ability of a soil to support desirable plant growth or both.

Salt injury to vegetation usually develops as a general growth reduction followed by leaf scorch and curling, leaf drop, stem dieback, and gradual decline in vigor resulting ultimately in death of the plants. Such damaged vegetation creates an unsightly condition that can decrease property value and run counter to the highway beautification programs. It also increases the cost of highway maintenance because of the replanting requirements for new highways and the removal of dead woody vegetation that is a hazard to motorists on old roadways. However, whether de-icing salt is directly responsible for the plant injury is still a controversial subject.

The purpose of this investigation was to determine the distribution and movement of de-icing salt ions in soil bordering the highway at a site in Vermont and to determine the possible role of these salts in causing an extensive silver maple decline in this highway environment.

The site examined is located 5 miles south of Shelburne, Vermont, on US-7. At one time, it contained about 250 trees that were primarily mature silver maples of a similar age and planted opposite each other about 15 ft from the edge of the highway. Because of the slope, highway runoff occurs primarily to the east side of the road. On this side of the highway, the trees are noticeably damaged and many are dead, while trees on the west side of the road are growing vigorously. The soil bordering the highway is primarily a Vergennes clay, a moderately well-drained soil developed from micaceous glacial lacustrine clays.

Leaf and twig samples of the silver maple trees were collected from both sides of the highway on 6 sampling dates over a 4-year period. Samples were dried and ground. Chloride was extracted with a 1:100 ratio of plant material and a mixture containing 0.1 N nitric acid and 10 percent glacial acetic acid. Sodium was extracted from a second portion of tissue that was dry-ashed and brought to a 100:1 ratio of solution to plant material with 0.3 N nitric acid. The chemical data were statistically analyzed by using the paired t-test. Trees growing on the west side of the highway were compared with

trees growing opposite them on the east side of the road for each element at the same date.

Soil samples were also taken from both the east and west sides of the highway mid-way along the slope for 8 sampling dates during this same period. The samples were collected at 3-ft intervals from the road and at 3-in. increments in depth. The samples were dried, ground, and extracted for 1 hour with a 2:1 distilled water to soil ratio.

On the east side of the highway, where visual deterioration of silver maples was evident, the average sodium and chloride contents of the soil were much higher and the specific conductivity of the soil extracts were larger than those of the soil on the west side of the highway, at least in the area where tree roots were more prominent. The specific conductivity on the east side of the road averaged twice as high as that on the west side while the sodium and chloride contents were 6 and 10 times higher on the east than on the west side of the road, respectively. The average content of calcium extracted was not appreciably different on the two sides of the road. Average soil analysis for samples collected from the 9- through 21-ft intervals from the highway and 0-through 12-in. depth in the horizon on all 8 sampling dates is as follows:

| <u>Roadside</u> | <u>Specific Conductivity (μmho/cm)</u> | <u>Chloride (ppm)</u> | <u>Sodium (ppm)</u> | <u>Calcium (ppm)</u> |
|-----------------|---|---------------------------|-------------------------|--------------------------|
| East | 1,045.9 | 268.4 | 243.4 | 59.4 |
| West | 482.1 | 26.8 | 40.2 | 73.4 |

The largest salt concentration in the soil occurred 3 ft from the pavement on the east side of the highway for the April 5, 1969, sampling date. Specific conductivity was 3,960 μ mhos/cm ($EC \times 10^{-6}$) and the contents of sodium and chloride were 1,080 and 2,577 ppm in the soil respectively. A specific conductance this large in a 2:1 water to soil extract would be classified as moderately saline and would restrict the growth of many plant species. The osmotic pressure caused by the salt in the soil system would be about 1.5 atmospheres. However, by the June 24, 1969, sampling date, the amount of salt in the soil diminished sharply, and the osmotic effect at this date was less than 0.5 atmospheres.

It is interesting to note that high concentrations of sodium and chloride occurred to a depth of 18 in. or more in the soil profile on the east side of the road even during the winter. It was evident that salts moved down into the profile during winter. This is contrary to the opinion that de-icing salts carried in drainage water would flow over frozen soil. Apparently, salts are capable of percolation into the soil horizon when the ground is frozen.

High concentrations of chloride and sodium were noted (Table 1) in the leaf and twig tissue of the damaged silver maples as compared to healthy trees. The concentration of chloride in the leaves and stems increased with higher tissue deterioration of silver

TABLE 1
AVERAGE CHEMICAL ANALYSIS IN PERCENTAGE DRY WEIGHT
FOR TISSUES OF SILVER MAPLES

| Sampling Date | Leaves | | | | Stems | | | |
|------------------|-------------------|------|-------------------|------|-------------------|------|-------------------|------|
| | Chloride | | Sodium | | Chloride | | Sodium | |
| | East | West | East | West | East | West | East | West |
| 9-14-66 | 0.83 ^a | 0.30 | 0.04 ^a | 0.01 | 0.36 ^b | 0.18 | 0.05 ^b | 0.01 |
| 9-15-67 | 0.70 ^a | 0.26 | 0.03 ^a | 0.01 | 0.94 ^a | 0.22 | 0.05 ^b | 0.01 |
| 6-20-68 | 0.67 ^a | 0.15 | 0.03 ^a | 0.01 | 0.13 ^a | 0.07 | 0.04 ^b | 0.02 |
| 9-13-68 | 1.18 ^a | 0.32 | 0.05 ^b | 0.00 | 0.19 ^a | 0.09 | 0.02 ^b | 0.01 |
| 4-5-69 | — | — | — | — | 0.20 ^a | 0.14 | 0.16 | 0.14 |
| 6-24-69 | 0.83 ^a | 0.16 | 0.08 ^a | 0.01 | 0.27 ^a | 0.11 | 0.06 ^a | 0.01 |

Note: Statistical comparisons can only be made between trees on the west and east side of the highway for each element and plant part taken at the same sampling date.

^aSignificance at the 1 percent level.

^bSignificance at the 5 percent level.

maples. The increase was greater in the leaves than in the stems. After death, a decrease in the concentration of chloride occurred in stem tissues, which was at times even lower than that in healthy trees. Sodium also gave similar results, but the relationship was less pronounced. The greatest increase in tissue sodium as related to increased tissue deterioration occurred in the stem rather than in the leaf tissue. The percentage range was also greater for the sodium tissue content, although the actual range was an order of magnitude greater for the chloride tissue content.

Examination of this site reveals that de-icing salt sprays are of no consequence to the decline of these silver maples. No visual damage occurred on trees on the west side of the highway or on either side of the highway at the top or far bottom of the slope. Therefore, distance from the highway or prevailing winds could not be responsible for the observed phenomenon. Deterioration of the silver maples increased with higher exposure of the trees to roadside drainage. Dead trees were found at the bottom of the slope where drainage accumulation was maximum, while no visual decline occurred at the top or far bottom of the slope where drainage accumulation was minimum. However, some tree deterioration was noticed midway of the slope on the east side of the road where highway drainage occurred. Damage to the trees, therefore, appears to have resulted from the root uptake of sodium and chloride rather than from the salt spray.

The study indicated that highway salting practices have increased the concentrations of sodium and chloride and the specific conductance in the soil on the east side of the highway for the site examined. This was manifested in an extensive silver maple decline on the east side of the road, while healthy trees were growing on the west side of the road where, due to the slope, highway drainage was limited.

The maximum concentrations of sodium and chloride were generally found at the soil surface and nearest the highway pavement. The concentrations of salt in the soil increased during the winter and then decreased during summer and early fall. Sodium and chloride ions entered the soil profile during the winter and penetrated into deeper horizons as time progressed. Higher than normal concentrations of sodium and chloride were found to depths of 18 in. and distances of 75 ft from the pavement. As the years progressed, the quantity of sodium and chloride increased throughout the entire soil profile. It is suspected that the passage of large quantities of salt through soil profiles cause a deterioration of the physical properties of the soil, thereby causing a decrease in soil permeability.

The increase in sodium and chloride content of the soil solution was manifested through increased uptake of these ions into the leaves and stems of the damaged trees. Deterioration of the silver maples resulted from chloride toxicity rather than from osmotic effect of the salts in soil solution. No damage was observed when the concentration of chloride was less than 0.18 percent. A chloride concentration of 0.20 percent produced leaf scorch and above 0.50 percent produced moderate leaf scorch, defoliation, and ultimately death of the tree. The concentration of sodium was much higher in the damaged than in the healthy trees and may possibly be one of the reasons for the overall deterioration of the silver maples. However, it does not appear to be totally responsible, because high concentrations of sodium were sometimes recovered in trees exhibiting no salt damage. It was noted that, with the onset of death, chloride and in some cases sodium were lost from the woody tissue. Therefore, tissue analysis of a dead or dying tree may fail to reveal large quantities of these ions. The effect of salt spray was apparently negligible.

During the winter season, the de-icing salts move both horizontally and vertically from the highway border. The amount of salt ions present at any given distance and depth depends on (a) highway de-icing practices, which include kind and amount of salt used, time of application, and snow-removal procedures; (b) climate, which includes amount of precipitation, amount of snow cover, and temperature; and (c) soil properties, which include slope, permeability, and salt-retention capabilities.

The detrimental effects of de-icing salts to roadside vegetation are evident; however, public safety demands their use. Therefore, woody vegetation should be located as far from the highway as practicable with pavement drainage directed away from the tree roots. Where possible, the species planted should be chosen on the basis of salt tolerance and placed in a favorable medium.

ACKNOWLEDGMENTS

This work was sponsored by the American Association of State Highway Officials, in cooperation with the Federal Highway Administration, and was conducted under the National Cooperative Highway Research Program. The opinions and conclusions expressed or implied in the report are those of the authors.