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STUDIES OF SALT-INDUCED DAMAGE TO ROADSIDE PLANTS IN ONTARIO[1]

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Abstract. Salt applied to highways runs off into streams increasing their salt content during the winter and penetrates the soil resulting in elevated levels of Na and Cl within 30 m of the highway. The salt that is most damaging to vegetation is that which is carried onto trees and shrubs as wind-borne spray. Evergreens are very sensitive, as can be seen when needles turn brown in early spring. Buds and twigs are killed on deciduous trees, flower buds being the more sensitive. Injury can be reduced by planting tolerant species in salt spray areas.

In the northeastern United States and southern Canada large quantities of salt are used each winter to maintain major roads free of ice and snow. The salt, which is mostly NaCl, is used directly or mixed with sand before it is applied to the road. Applications are made whenever conditions warrant so that the total amount applied in any one winter or any particular location varies. On the average, the total amount applied is somewhere between 8,000 kg and 20,000 kg per linear 2 lane kilometer. Greater quantities may be used in high traffic areas.

All the salt that is applied is dissipated into the environment. Some is picked up by vehicles, some is whipped up as spray and is carried by the wind, but most is removed as run-off onto soil adjacent to the road or into ponds, streams and rivers. The fate of the salt and its effects are a major concern to many people because of its damaging effects on vegetation. This paper will review the effects of salt in the roadside environment, with major emphasis on vegetation.

Roadside salt

Water and soil: High levels of salt occur in run-off during the winter when the ground is frozen. Salt depresses the freezing point and roadside snow containing salt will melt before salt-free snow. Run-off water along the edge of the road can contain 20,000 ppm chloride or more during the winter. Much of this water runs into streams which have a low flow rate at this time. For this reason the salt levels in streams adjacent to roads are highest during January and February. With milder weather the run-off increases and the salt is diluted. During 1971 the salt content of two streams near Guelph was measured during late winter and spring. In the Galt Creek, downstream from the highway, Na and Cl levels were highest during certain days in February and March (Fig. 1). In a metropolitan stream Scott (1976) observed a fiftyfold increase of Na which remained high for several days until diluted by additional snow melt. Generally the smaller the stream the greater the fluctuation in salt content. In larger rivers the changes are mostly not measurable. In most cases contamination of irrigation water should not be a problem, unless roadside ditches run directly into irrigation ponds.

With a lot of the salt running off before the ground thaws, the build up of salt in the soil may not be as great as one might expect. Part of the salt will be ploughed some distance from the road with the snow while more will be splashed or carried as spray causing salt to accumulate especially in areas where surface drainage is poor. In Fig. 2 characteristic values are presented for Na and Cl in the soil along Hwy. 401 for the spring of 1971. Salt levels were highest in the median and declined quickly with distance from the sides of the roadway. Levels on the south side were

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somewhat higher than on the north, indicating that wind played a role in the direction in which salt was splashed or sprayed. During the winter in most of S. Ontario the prevailing winds are from the northwest. No significant increases in salt levels were found in the soil beyond 30 metres from the edge of the pavement. The salt does leach down into the soil to some extent but much of it was found to be retained in the surface layers over the summer and fall.

Vegetation: Since Na and Cl levels in the soil 30 m or more from the roadway were not elevated one would not expect high levels to accumulate in the vegetation. However, the contrary is the case. Chloride and Na analysis of the needles has revealed elevated levels of these ions. Furthermore, we observed a direct relationship between injury and Na or Cl levels. The threshold levels of Cl above which injury occurs to the tip of the needles is about 0.10% of the dry weight. Levels of Cl 20 or 30 times the threshold value have been observed. The values for sodium are somewhat lower (Hofstra and Hall 1971).

Injury to a number of plant species, e.g. white pine and white cedar, can be very severe 100 m or more from the road. On fully exposed trees, needles of white pine were completely killed up to 60 m from the highway and still injured up to 150 m (Hofstra and Hall 1971). The degree of injury was dependent on distance from the road and the degree of exposure to wind. White cedar showed a similar injury pattern. More injury and higher levels of salt are encountered on the south or east sides of roadways (Table 1) (Hofstra and Hall 1971). Evidence indicates that most of the injury to trees especially at distances greater than 30 m is due to wind-borne salt that accumulates during the winter months.

Table 1. Levels of injury and salt content of leaves from white cedar on north and south sides of Highway 401.

	North side	South side
% injury	7	66
Na g/100 g	0.19	0.35
Cl g/100 g	0.39	0.74

Adapted from Hofstra and Hall (1971).

High salt levels in the soil can be a contributing factor to tree injury closer to the road than 30 m or to those trees that are in drainage areas where salt may accumulate. Hall et al. (1973) found higher levels of sodium and chloride in leaves of sugar maple trees on the side facing the road and this was associated with higher levels of salt in the soil and greater amounts of 'scorch' on those leaves during the summer (Table 2).

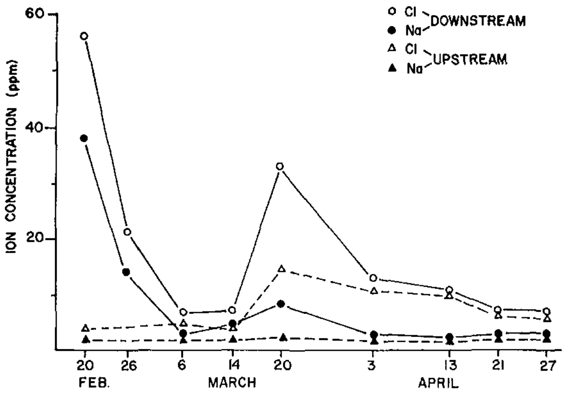

Fig. 1. Sodium and chloride levels in Galt Creek above and below a highway near Guelph, Ontario during late winter and spring.

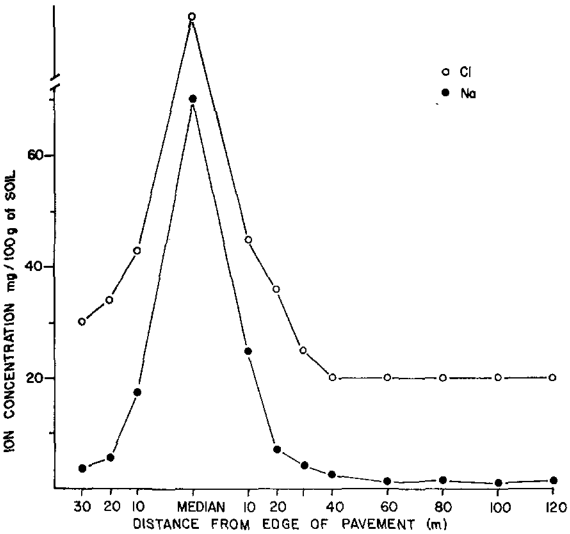

Fig. 2. Sodium and chloride levels in soil at various distances along a transect across a four-lane highway.

Table 2. Analysis of leaves and soil from roadside sugar maple.

	Front of tree	Back of tree
Injury rating	1.6	0.6
Foliar Na g/100 g	0.263	0.046
Foliar Cl g/100 g	0.76	0.54
Soil Na mg/100 g	17.7	7.7
Soil Cl mg/100 g	55.8	44.6

Adapted from Hall et al. (1977).

Injury and salt content

Species: The degree of injury to different species varies greatly and depends on a number of factors which influence salt uptake. White pine shows more injury than Scots pine which shows more injury than Austrian pine. Yet a given amount of injury is associated with the same salt content in each species (Hofstra and Hall 1971). Differences in injury therefore appear to be due to differences in the amount of salt taken up. The latter, in turn, appears to vary inversely with surface to volume ratio of leaves and cuticle thickness. Species of pine with thick needles and species of spruce with thick cuticles take up less salt and are injured less. In deciduous trees other factors such as bud size, the nature of bud scales, twig thickness and bark covering are more important. A list of relative sensitivity of different species has been prepared for Ontario (Lumis et al. 1973) and is available as an OMAF Factsheet, Agdex 275/690 (1977). Fruit trees such as apples are relatively sensitive (Hofstra and Lumis 1975) and losses to orchards close to roadways can be substantial.

Year: There is considerable year to year variation in the amount of injury that is apparent in the spring. This is no doubt largely related to differences in the amount of salt applied to the roads and in weather conditions, such as wind and temperature, that will influence the amount taken up by the plants. Table 3 gives an indication of variability in salt content that can occur in different years. Various climatic factors also influence the severity of injury that is produced by a given salt concentration and will be mentioned again later.

Time of year: Salt accumulates in the needles, buds or twigs throughout the winter months, with the greatest concentrations occurring during February and March (Lumis et al. 1976) (Fig. 3). From the beginning of April, levels decline rapidly reaching background levels by late summer (Fig. 4) (Hall et al. 1972).

Table 3. Relative levels of sodium and chloride in white pine needles 30 m from the pavement at the end of the winter in different years.

	Cl		Na	
Year	Site 1	Site 2	Site 1	Site 2
1970	1.30		1.25	
1971	0.80		0.82	
1972		1.25		0.97
1973		1.00		0.58

Adapted from Hall et al. (1972) and Lumis et al. (1976).

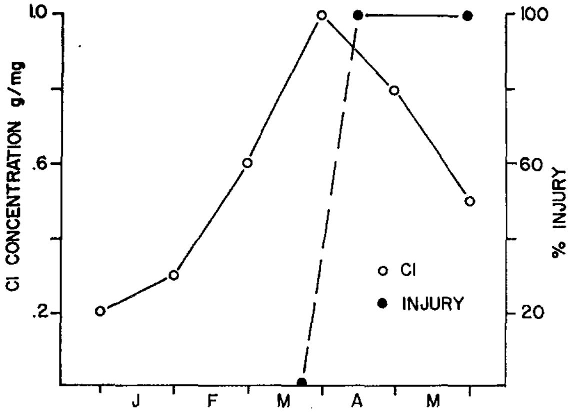

Fig. 3. Chloride levels in Eastern white pine needles and the development of injury. (Adapted from Lumis et al. 1976).

Injury, particularly on evergreens, is most conspicuous in early spring. The appearance of injury can be fairly sudden with the onset of temperatures above freezing. The onset of injury is related both to the salt content and temperature. Laboratory studies with white pine have shown that uptake does not occur when needles are frozen but occurs as rapidly at 2°C as at 15°C (Table 4). The uptake of salt continues as long as the needles remain wet. Furthermore, injury symptoms did not develop in leaves kept at 2°C even after one month of daily salt sprays but within 2 days at 15°C injury was evident and progressed with time (Table 5).

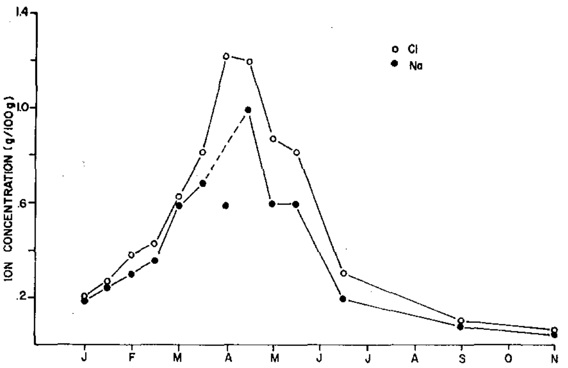

Fig. 4. The accumulation and loss of sodium and chloride in Eastern white pine needles over a one-year period. (Adapted from Hall et al. 1972 and Lumis et al. 1976).

Table 4. Chloride concentrations (%) in needles of white pine at 0, 4 and 8 days after a single salt spray when plants were kept at different temperature with the needles kept moist.

Temp °C	0 day	4 days	8 days
−7	0.06	0.05	0.06
+2	0.07	0.30	0.50
+15	0.06	0.31	0.48

Table 5. Injury of white pine needles at 15°C after 30 daily salt sprays at 2°C.

Days at 15°C	Percent injury
1	0
5	6
10	15
15	25
20	70
25	90

Studies with white pine seedlings sprayed with salt solution revealed that salt is leached from the needles by rain. Seedlings kept outdoors lost salt more quickly from their leaves than those kept under a plastic cover to keep off rain (Fig. 5a). Redistribution of the salt throughout the plant also reduces its concentration in leaves. As shown in Fig. 5a the concentration of Cl in the new growth is dropping at about the same rate as in 1 year old needles but the total amount in the new growth is increasing (Fib. 5b) because of the increase in the amount of new tissue.

Field studies indicate that there is no appreciable build up of salts from year to year in the trees (Hall et al. 1972) unless the salt levels in the soil are elevated.

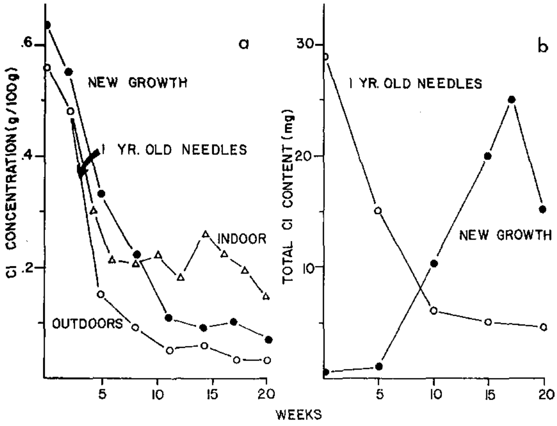

Fig. 5. a. The decrease in chloride concentration with time in salt-sprayed Eastern white pine needles, either exposed to or protected from rain. b. The total chloride concentration in salt-sprayed one-year old Eastern white pine needles and new growth indicating the movement of chloride in the plant.

Symptoms and patterns of injury

Injury symptoms on evergreens appear as a browning of the needles beginning at the tip and progressing toward the base. The higher the salt content the greater the length of needles injured (Hofstra and Hall 1971). Needles drop prematurely and new growth on affected branches is markedly reduced.

Damage on deciduous trees and shrubs is not evident until the buds begin to open in the spring. Injured buds do not open and whole branches may be devoid of leaves (Fig. 6). Affected branches often leaf-out later from dormant or adventitious buds near the base of the twigs giving the tree a tufted appearance (Fig. 7) (Lumis et al. 1973).

Flower buds are more sensitive than leaf buds.

Flowering trees and shrubs frequently have leaves but no flowers on the side of the tree facing the road or have flowers only below the snow line (Fig. 8).

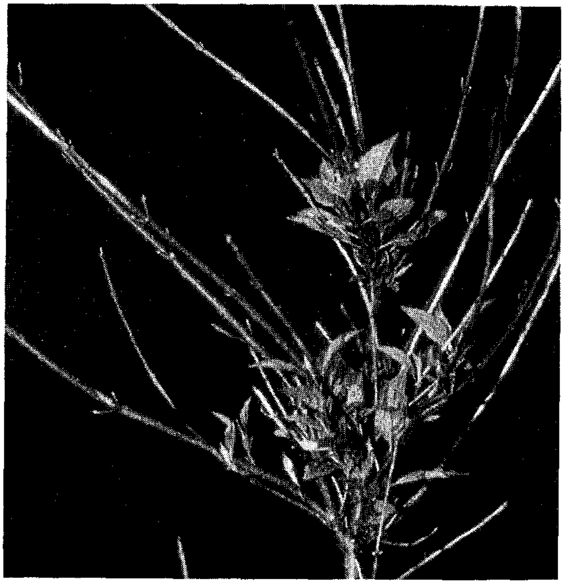

Fig. 6. Branches of red-osier dogwood killed by salt and leafing out from the bases of the branches.

Fig. 7. A lone beech tree close to a four-lane highway. Note the tufted appearance of the tree and the greater injury on the side of the tree facing the highway.

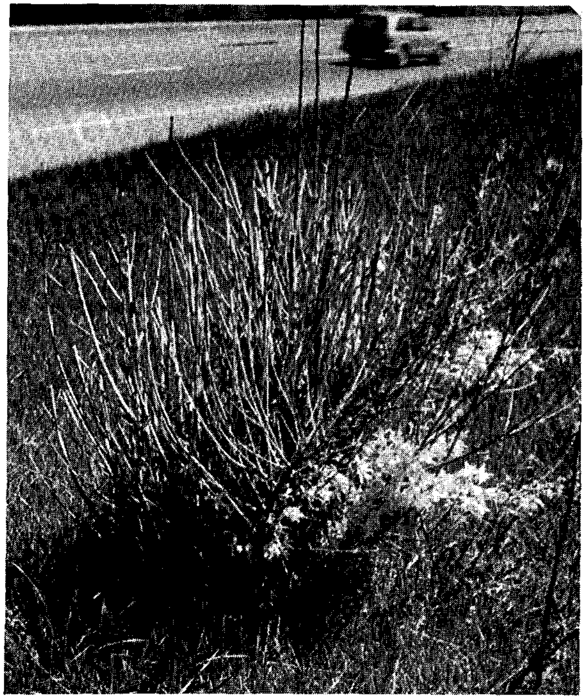

Fig. 8. A forsythia bush blooming only on low branches on the side of the shrub away from the highway.

The pattern of injury is usually distinct and is a useful guide to identifying the cause of injury. Plants are much more severely damaged on the sides facing roadways, very apparent in cedar hedges (Fig. 9). There is usually a distinct injury gradient with distance from the road and the greatest injury occurs on the windwind side of the road. Where branches were covered by snow usually no injury occurs, the snow line often being very apparent on evergreens. The tops of tall trees are unaffected or affected less, the greatest injury occurring within a couple of metres from the ground depending on elevation in relation to the road.

Effects on tree growth

The greatest effects on growth are on evergreens because the leaves are weakened or killed. Trees like Scots pine can become severely stunted and misshapen (Fig. 10). Others become one-sided as needles and branches are continually killed on the road side of the tree.

One of the main effects on pines is that the needles die prematurely and drop off reducing the photosynthetic capacity of the tree. The amount of new growth becomes less and less, causing the tree to weaken and eventually die (Fig. 11a and b). Growth rings of affected trees become thinner with time (Fig. 12). The irregularity in the thickness from year to year reflects both the growing conditions and the differences in the amount of injury from year to year. Only trees close to roadways are greatly affected (Hall et al. 1972).

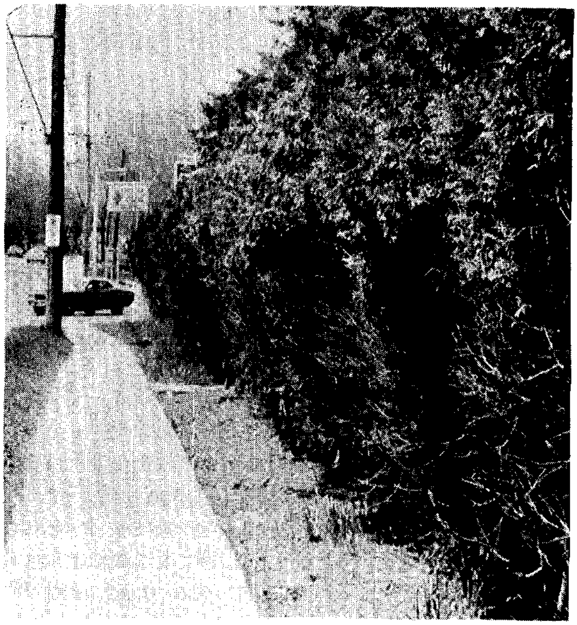

Fig. 9. A cedar hedge close to a busy street. All leaves in the splash zone have died and dropped off.

Reducing injury

Assuming that the amounts of salt used will not change greatly, there are some things that can be done to minimize losses particularly of shrubs. Plant material that is relatively tolerant to salt spray can be planted in locations where exposure to salt is greatest. Various barriers can be erected as well, such as tolerant species or mechanical barriers, temporary or permanent, tr protect sensitive species.

Fig. 10. Scots pine on the south side of a four-lane highway. Trees are approximately 15 years old. Note their stunted, tufted and misshapen appearance.

Other causes of injury

As has been indicated wind is important in carrying spray drift onto the trees. Wind itself can be a cause of injury especially on evergreens. Desiccation caused by wind is particularly prevalent in exposed locations, being more severe on the side of the tree facing the prevailing wind and at the top of the tree. The injury produced is indistinguishable from that caused by salt. Location of the tree and the part of the tree injured are probably the best guides as to the cause of injury. Warm, windy days during late winter when the ground is still frozen can cause a great deal of needle browning especially on white pine. This injury was prevalent in the spring of 1977. Where both salt and wind injury occur together it is difficult to estimate the degree of injury caused by each agent or whether the one agent makes the tree more susceptible to the second.

Conclusions

Deicing salt is detrimental to vegetation especially to trees and shrubs. Most of the injury appears to result from the salt spray that is deposited on the trees during the winter.

Evergreens are particularly vulnerable but deciduous trees and shrubs are also affected. Species do vary greatly in their sensitivity to salt injury and this fact can be used to minimize the damage in roadside plantings.

Fig. 11. Eastern white pine trees approximately 30 m from the highway. (above) Trees next to the fence show severe damage on the side facing the road. (below) The same trees are dead 8 years later. Trees further back are becoming more exposed and are showing more injury.

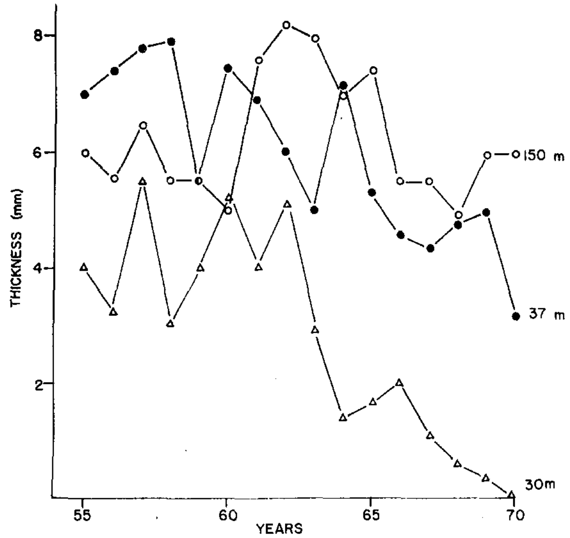

Fig. 12. The effect of road salt on the thickness of annual growth rings of Eastern white pine trees at various distances from the highway. (Adapted from Hall et al. 1972).

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