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Roadside Deicing Chemical Accumulation After 10 Years

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ABSTRACT

Soil and plant samples were collected along the northbound lane of I-95 between Alton and Howland, Maine, from sites identical to those used in a similar study in 1972-1973. The sodium and chloride content of the samples was determined; the values were averaged and treated statistically. The mean values were then compared with values obtained in 1972- 1973. The following conclusions could be drawn. Sodium ion concentration exhibited a general cumulative trend due to application of road salt, sodium chloride (NaCl). However, accumulation was far below exchangeable sodium levels that are considered damaging. The chloride ions leached out of the soil fairly rapidly and had no pronounced accumulative effect. The effect of deicing salt on the sodium and chloride content of hemlock needle tissues was insignificant. The NaCl content of accumulated snow, which is caused by snow plow and blow action during the application of the road salt in the winter season, diminished as the distance from the highway increased. The alkalinity (or acidity) of soil appeared to have a direct relationship with the sodium content of the soil. The present study is generally applicable to areas adjacent to four-lane divided Interstate highways in the northeastern United States.

The use of deicing salt, sodium chloride (NaCl), to remove snow and ice from highways during the winter months has been an environmental concern for more than two decades. Highway maintenance agencies struggle constantly to balance the benefit of highway safety versus the possible harm of the salt to nearby soil and plants. Numerous studies have been carried out to determine the extent of the contamination including the effect of deicing chemicals on soil and plants (1,2) and the effect of deicing chemicals on groundwater (3). The economic aspects of highway snow and ice control are also a subject of much concern (4,5); the cost of damage to the environment and automobiles is compared with the financial benefit derived from road safety and travel convenience. Studies of alternative deicing methods for winter maintenance have also been carried out by many researchers (6,7).

It is generally agreed that most salt vacates the roadside environment via surface runoff and leaching after the winter season. In particular, chloride ions leach out quite rapidly. However, the interaction between the salt and the soil is of great complexity, depending on weather conditions, amount of snowfall, depth of the water table, soil texture, and soil chemistry (8). Therefore, it requires a considerable amount of data to reach a conclusion.

A recent publication by Hudler (9) summarized the effect of salt injury to roadside plants by listing various plants according to their tolerance of deicing salt. Among the highly tolerant plants were Norway maple, yellow birch, mulberry, and mountain ash. Some plants of low tolerance, among others, were balsam fir, red maple, black walnut, Norway spruce, and eastern hemlock.

As early as 1965 concern over pollution caused by deicing chemicals along Maine highways prompted the investigation of soil and water in areas contiguous to the highway under the direction of F.E. Hutchinson of the University of Maine at Orono (10,11). It was found that there was no significant increase in sodium or chloride content of river water during the spring when snowmelt was at its maximum. However,

some of the wells along the highway showed an increase in sodium and chloride content. These contents increased as distance from the highway decreased. Additional information was collected that showed an increase in sodium content along the Maine Turnpike and I-95 as the number of years of salt application increased.

In the summer of 1972 construction on a portion of I-95 near Alton, Maine, was planned for that fall. A study was then initiated by the Maine Department of Transportation (DOT) with the cooperation of the Maine Agricultural Experimental Station under the supervision of A.R. Langille of the University of Maine at Orono (12,13). The study compared methods of salt application in relation to severity of toxicity symptoms in conifers of differential salt tolerance. Soil and plant samples were collected along the newly constructed highway before and after one season of deicing operation and analyzed for sodium and chloride content. The results showed a significant increase of both ions in the soil and in the plant tissues after one deicing season.

With this study as a source for the initial data, it was thought that a comparison of the sodium and chloride levels in 1972-1973 with those in 1981-1982 would give an indication of the accumulative effect of those ions attributable to deicing through the years. The U.S. Department of Transportation, FHWA, approved such an undertaking in 1981 as part of the Maine Department of Transportation Work Program TQX HPR-PR-1(18).

METHODOLOGY

Collection of Samples

Soil samples were collected on five dates, August 13, 1981; September 29, 1981; November 20, 1981; April 15, 1982; and May 26, 1982. It should be noted that the last snowstorm during the 1981-1982 winter season occurred on April 7, 1982, after which most of the snow melted rather quickly. The samples were taken from six sites along northbound I-95 between Alton and Howland, Maine (Maine mileage numbers 195 to 205). These sites were the same as those used in the 1972-1973 study (12). At each site single soil samples were collected at the distances of 20, 40, 80, 160, and 200 ft from the edge of the highway. Soil sampling was done with a steel sampling tube 1 ft long and 3/4 in. in diameter, but only the top 6 in. of soil were collected.

Hemlock branches were cut with a pruning pole. Samples were collected on the last three dates mentioned. The sites were the same as those for soil sampling, but samples at distances of 80, 160, and 200 ft only were collected. At each site there was a cleared area with tall trees (mostly evergreen) growing on both sides. There was a drainage ditch at the vicinity of 40 ft and the ground sloped down on both sides.

The winter of 1981-1982 was relatively severe. Total snowfall in the Bangor area was around 100 in. As a consequence the application of road salt was extensive. The average amount of salt applied during the winter of 1981-1982 was 6.5 tons per lane-mile. To gain some information on the effect of the snow plow and salt and sand drift, samples of the accumulated snow were collected on March 11, 1982. Sampling was done with a metal tube 30 in. long and 2 in. in diameter. The samples were brought to the laboratory immediately, melted, and allowed to reach room temperature.

Analysis of Samples

All the soil samples were air dried and sieved through a No. 10 sieve before testing. The sodium concentration was determined by extracting the soil sample with 1N ammonium acetate (pH = 7) (laboratory procedures used by Department of Plant and Soil Sciences Analytical Laboratory, University of Maine at Orono). Subsequently the extracted solution was analyzed for sodium by atomic emission spectrophotometry (Perkin Elmer Model 403). The chloride was extracted from the soil by mixing 25 g of the soil sample with 50 mL of water for 1 hr. The solution was adjusted for ionic strength and was measured for Cl^- concentration by a specific chloride ion electrode, using Orion Specific Ion Meter, Model 407A. A series of standard chloride solutions with the same ionic strength was used to establish a calibration curve for the determination.

The hemlock branches were air dried and only the needles were collected for analysis. The needles were ashed before testing for sodium and chloride (laboratory procedures used by Department of Plant and Soil Sciences Analytical Laboratory, University of Maine at Orono). The sodium ions were extracted from the ashed samples by a 20 percent hydrochloric acid (HCl) solution (Analytical Methods for Atomic Absorption Spectrophotometer, Perkin-Elmer Corp.) and subsequently analyzed using atomic emission spectrophotometry. The chloride was extracted by a calcium oxide (CaO) paste (laboratory procedures used by Department of Plant and Soil Sciences Analytical Laboratory, University of Maine at Orono) and dissolved in a nitric acid (HNO_3) solution. It was then titrated with 0.0100N silver nitrate ($AgNO_3$) solution by the Gran Plot Method (14,15).

The sample from the snowmelt was filtered and analyzed for sodium and chloride content by atomic emission spectrophotometry and the Gran Plot Method, respectively.

The pH of the soil samples collected at these locations on November 20, 1981, was determined with a combination pH electrode in connection with the Orion Specific Ion Meter, Model 407A.

These data were analyzed statistically by the Waller-Duncan K-ratio t-test method, which is a standard program within the Maine DOT Computer System, SAS ANOVA program.

RESULTS AND DISCUSSION

Sodium Content of Soil

The sodium contents of the soil samples collected on various dates and averaged at each distance for the six locations are given in Table 1. It is apparent that the sodium content at the 20- and 40-ft distances was much higher than that at the 80-, 160-, and 200-ft distances. This was due to the closeness to the salt spray operation at these distances. Al-

TABLE 1 Sodium Content (ppm) of Soil Samples from Various Locations

Distance from Highway (ft)	Date Sampled				
	8/31/81	9/29/81	11/20/81	4/15/82	5/26/82
20	59.7 A[a]	50.0 A,B	50.3 A	70.6 A	68.3 A
40	63.4 A	61.0 A	53.5 A	59.8 A,B	70.8 A
80	16.4 B	16.9 C	18.2 A	18.0 C	27.7 B
160	21.8 B	22.4 B,C	32.2 A	36.9 B,C	19.4 B
200	24.4 B	28.5 B,C	30.9 A	20.1 C	17.3 B

[a] A,B,C: Within the same column, the same letter denotes that there were no significant differences among the means according to the Waller-Duncan K-ratio t-test.

though statistically there were no significant differences between the values at 20 ft and those at 40 ft, the general tendency was for the latter to be slightly higher than the former, which showed that the sodium ion did leach out toward the lower ground near the 40-ft distance, where the drainage ditch was located.

Deicing salt spray during the snow season definitely affects the sodium content of the soil as is demonstrated when the data from November 20, 1981, are compared with those from April 15, 1982, and May 26, 1982. The increase was more obvious for the 20- and 40-ft distances than for the other three distances.

To evaluate the accumulative effect of the deicing salt, the data from the 1972-1973 season (12) are given in Tables 2 and 3. When the data given in Table 1 for November 20, 1981, and those given in Table 2 for November 13, 1971 (before construction) are compared, values from 1981 show a marked increase in sodium content at the 20- and 40-ft distances, but only a slight increases was observed at the 80-, 160-, and 200-ft distances.

This confirms the effectiveness of the drainage ditch. At the same time the accumulative nature of the sodium ion at locations near the highway was evident and should not be overlooked. Samples obtained after the first winter season and after the ninth (i.e., July 10, 1973, and August 13, 1981) indicate in general that the sodium content has not changed over that period of time, with the exception of a reduction of nearly 50 percent in the sodium content at the 20-ft distance.

It must be emphasized here, however, that even for the highest value in Table 1 the exchangeable sodium level is far below those that may be considered damaging. This was also evident from the healthy appearance of the hemlock and other vegetation at the test sites.

TABLE 2 Sodium and Chloride Content of Soil Samples Collected Along a Newly Opened Section of I-95 Before and After the First Winter of Road Salt Application[a,b]

Distance from Highway (ft)	Sodium (ppm)		Chloride (ppm)	
	11/13/72	7/10/73	11/13/72	7/10/73
20	13.82 A	112.67 A[c]	22.17 A	75.75 AB[c]
40	17.87 A	67.83 AB[c]	22.50 A	101.33 A[c]
80	15.82 A	21.33 B	8.83 B	47.17 B[c]
160	14.38 A	23.00 B	11.67 B	51.00 B[c]
200	20.87 A	24.83 B	10.33 B	58.33 B[c]

[a]Based on Langille (12).

[b]Within columns, means followed by the same letter were not significantly different by Bayes L.S.D.

[c]For a particular distance and element, means were significantly different by F-test (p = .01).

TABLE 3 Sodium and Chloride Content of Hemlock Needle Tissue Collected Along a Newly Opened Section of I-95 Before and After the First Winter of Road Salt Application[a,b]

Distance from Highway (ft)	Sodium (ppm)		Chloride (ppm)	
	11/13/72	7/10/73	11/13/72	7/10/73
80	106.85 B	290.00 A	154.00 C	861.50 A
160	112.72 B	282.67 A	126.83 C	613.67 B
200	109.34 B	173.60 A	143.00 C	551.40 B

[a]Based on Langille (12).

[b]For each element, means followed by the same letter were not significantly different by Bayes L.S.D.

TABLE 4 Chloride Content (ppm) of Soil Samples from Various Locations

Distance from Highway (ft)	Date Sampled				
	8/13/81	9/29/81	11/20/81	4/15/82	5/26/82
20	7.3 A[a]	6.0 A	12.2 A	13.3 A	13.3 A
40	10.0 A	6.8 A	10.7 A	23.3 A	57.0 A
80	7.0 A	7.0 A	6.5 A	9.5 A	9.3 A
160	8.4 A	10.5 A	14.6 A	33.1 A	14.1 A
200	11.4 A	16.6 A	13.6 A	19.0 A	19.0 A

[a]Within the same column, the same letter denotes that there were no significant differences among the means according to Waller-Duncan K-ratio t-test.

Chloride Content of Soil

The chloride content of the soil samples collected at various dates is given in Table 4. Statistically there were no significant differences among the means as the distances from the edge of the highway varied. However, on close examination, there appeared to be a significant increase in chloride content after the snow season at the 40-ft distance, the site closest to the drainage ditch. The data from other locations showed that chloride ions were leached out quite rapidly.

Comparison of the chloride ion content of the soil samples collected in November 1981 with that of those obtained in November 1972 indicated no significant change due to accumulation.

Sodium and Chloride Content of Hemlock Needle Tissue

The sodium and chloride content of hemlock needle tissue was determined from samples collected on November 11, 1981, April 15, 1982, and May 26, 1982. The data are given in Table 5. The influence of road salt application was evident from the increase in the values shown by samples collected in November 1981 and those collected in April 1982. Between April and May 1982 the sodium content in the tissue samples decreased, and chloride levels differed insignificantly.

Comparison of the data obtained in November 1981 with those obtained in November 1972 (Tables 3 and 5) shows the sodium content was at nearly the same level, but the chloride level of the present study was considerably lower. In any case, the increase of the sodium in soil due to the accumulative effect appeared to have no influence on the sodium and chloride content of plant tissue.

Sodium and Chloride Content of the Snowmelt

On March 11, 1982, before the snow began to melt in the spring, snow samples were collected and brought to the laboratory for sodium and chloride analysis. The results are shown in Figure 1 in which black circles represent chloride and open circles represent sodium. It is apparent that the deicing salt application by the plow and blow action had the most effect on the areas close to the highway--up to 80 ft away. Trees planted beyond this distance should be fairly safe from damage caused by road salt application.

Soil pH

It has been found that the higher the pH of the soil, the more detrimental the presence of excessive

TABLE 5 Sodium and Chloride Content (ppm) of Hemlock Needle Tissue at Various Locations

Distance from Highway (ft)	Sodium			Chloride		
	11/20/81	4/15/82	5/26/82	11/20/81	4/15/82	5/26/82
80	102.2 A[a]	218.5 A	97.3 A	38.0 A	126.8 A	144.0 A
160	93.5 A	87.7 B	85.3 A	38.6 A	123.8 A	111.8 A,B
200	98.6 A	102.4 B	86.7 A	22.0 A	64.8 A	80.8 B

[a]Within the same column, the same letter denotes that there were no significant differences among the means according to the Waller-Duncan K-ratio t-test.

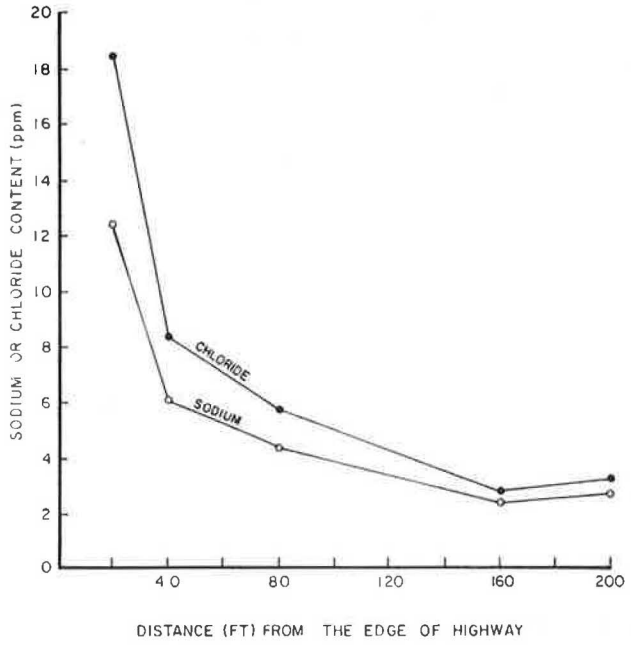

FIGURE 1 Sodium and chloride content of showmelt samples from various locations (collected March 11, 1982).

sodium in soil will be for plant growth (16, pp. 221-222). An increase in a sodium salt, such as sodium carbonate, may cause the pH of the soil to rise, that is, become more alkaline. Therefore, the pH of the soil samples in the test area was determined for samples collected on November 20, 1981, according to the distances from the edge of the highway.

The results are given in Table 6. It is interesting to note that the pH of the soil samples closest to the highway (20- and 40-ft distances) was about one unit higher than that of samples from the other distances. This is about 10-fold higher in terms of the concentration of the OH^- ion.

CONCLUSIONS

Sodium ion concentration exhibited a general cumulative trend due to application of road salt, sodium chloride. However, accumulation was far below exchangeable sodium levels that are considered damaging. The chloride ions leached out of the soil fairly rapidly and thus had no accumulative effect.

The effect of deicing salt on the sodium and chloride content of hemlock needle tissue was insignificant.

The NaCl content of accumulated snow caused by the snow plow and blow action during the application of road salt in the winter season diminished as the distance from the highway increased. The effect became insignificant at locations further than 80 ft from the highway.

The alkalinity (or acidity) of soil appeared to have a direct relationship with the sodium content of the soil. A further study should be made on this point to see if pH measurements could be used as a tool to check the extent of sodium accumulation. It would be beneficial to check the sodium and chloride content of soil and plants 5 or 10 years from now to evaluate the rate of accumulation of sodium in soil.

TABLE 6 pH of Soil Samples Collected November 20, 1981

	Distance from Highway Edge (ft)				
	20	40	80	160	200
pH	5.6 A[a]	5.6 A	4.5 B	4.8 B	4.4 B

[a]The same letter denotes that there were no significant differences among the means according to the Waller-Duncan K-ratio t-test.

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Current Practices of Harvesting Hay on Highway Rights-of-Way

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ABSTRACT

The harvesting of hay on highway rights-of-way has recently received attention by state highway departments. Several states have already implemented a harvesting program. However, concern has been expressed about traffic safety, lead poisoning, and other problems. The pros and cons of a harvesting program are examined, and current practices of the state highway departments are reviewed. The various aspects considered include legal problems, geographic condition, traffic safety, economic benefit, contamination of hay, and aesthetic and environmental concerns. Although the economics of a hay-harvesting program may not make such a program implementable in most states at the present time, changes in the local demand for hay and in labor and administrative costs for roadside mowing programs may make such programs feasible in the future.

Mowing is one of the major tasks of roadside maintenance. Mowing is done to maintain adequate sight distance and drainage and to provide a safe and neat highway environment for the public. However, because of limited maintenance budgets, mowing is not receiving the funding priority it once had. Many state highway departments are looking for ways to reduce their mowing programs by restricting the frequency of mowing as well as the total area mowed. In addition, growth retardants are being suggested to reduce mowing needs.

Recently a program designed to eliminate highway mowing with highway department resources and to allow private individuals and companies to harvest hay on highway rights-of-way has received attention by many states. The hay from the highway right-of-way is, in fact, a usable resource and should not be wasted. If the hay can be cut and used by private interests, it would benefit both the state and the harvester. Several states have already implemented such a program. South Dakota, for example, has been harvesting hay along its highways since 1940 (1). However, a lot of concern has been expressed about safety, lead poisoning, and other problems.

The purpose of this paper is to present the findings of a nationwide survey of current practices of state highway departments regarding highway hay harvesting. Various aspects considered include geographic condition, legal problems, economic benefits, traffic safety, contamination of the hay, and aesthetic and environmental concerns.

TYPE AND SOURCES OF DATA

The Indiana Department of Highways obtained information from 11 states on the practice of harvesting roadside hay in 1976. An inquiry was made of the