Effect of Deicing Salts Applied to Highways on the Contiguous Environment

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ABSTRACT

A research project was conducted to determine the effect of salt applications to deice highways on the sodium and chloride levels in (1) streams and rivers, (2) private water supplies contiguous to highways and (3) soils bordering highways.

Analyses of seven rivers in Maine from six samplings over a two year period indicated that sodium and chloride concentrations were not effected by highway salting, since the level of both ions remained consistent throughout the period. Although the concentrations of both ions tended to increase from the headwaters to the mouth of the rivers the average concentrations for 27 sites were 3.4 and 1.5 ppm for sodium and chloride, respectively.

Semi-annual analyses of 115 randomly selected wells along Maine highways indicated that levels of sodium and chloride were much higher than normal, averaging 69 and 170 ppm, respectively. Nineteen percent of the wells were unfit for potable supplies because they contained in excess of 250 ppm of chloride.

Sodium and chloride levels in soils contiguous to highways exhibited a direct relationship to the length of time over which highways had been salted. In areas where salt had been applied for 20 years, the sodium levels rose over a distance of 60 feet from the edge of the highway, and to a depth of 18 inches. Sodium saturation of the soil approached 15% at some sites, thereby producing the equivalent of a "sodic" condition.

Limestone applied to the surface of three sites along highways at rates of zero, 1, 2, 4 and 8 tons/acre did not reduce sodium levels in the soil over a two year period. Gypsum applied at calcium rates equivalent to those in the limestone significantly reduced sodium levels in the three soils during the same period at the 8 ton/acre rate. Sodium concentration in the soil which originally contained the highest amount (734 ppm) was reduced 31% by the 8 ton/acre rate 18 months following treatment.

INTRODUCTION

Applying deicing chemicals to highways during the winter months has become common practice over the past 20 years in the northern tier of states—from Maine to Virginia and west to Washington. The chemicals used are either sodium chloride (rock salt) or calcium chloride, with the former predominating in most areas because of its effectiveness and low cost.

The amount of salt applied to highways varies somewhat with terrain and frequency of snowfall, but recent surveys indicate that most states in New England apply between 20 and 25 tons of salt per mile each winter. In Minnesota and Wisconsin the average application rate is approximately 15 tons per mile (Schraufnagel, 1967). It should be noted, these rates are averages for a whole state and, therefore, can be misleading for any given section of highway. In some instances it is known that rates exceed 50 tons per mile due to local conditions.

Because sodium and chloride ions can have deleterious effects on water, soil, and vegetation, (McKee, et al, 1963; Peterson, 1965; Qayyum, 1962; Lacasse, et al, 1964) there has developed a concern on the part of many conservationists about the fate of these ions as they move away from roadsides into contiguous areas.

This concern led to the initiation of a research project in 1965 to evaluate sodium and chloride ion levels in soils and private water supplies along highways and in seven rivers in Maine.

Maine purchases in excess of 100,000 tons of deicing salts each year and the average annual application rate for the past several years has been 25 tons per two-lane mile, or an equivalent of 50 tons per mile in the center strip of four-lane highways.

EXPERIMENTAL METHODS

Rivers

Water samples were collected in April, July and October over a two-year period from 7 rivers in Maine. By choosing rivers in Washington County along with those in western Maine, it was possible to compare the effects of highway salting in an area of relatively low road concentration with one where the concentration is much higher.

Samples were collected in quadruplicate across the river at points ranging from the headwaters to the mouth of each river, with a total of 27 sampling points along the 7 rivers. All samples were analyzed by standard techniques for content of sodium and chloride (Black, 1965).

Wells

Samples were collected in April and August from 115 wells chosen at random along highways in the state over a two-year period. Most of these wells were relatively close to the edge of the highway, and the exact distance was recorded in every case. Data were also collected as to the depth of the well, and its origin, i.e. dug or drilled.

Soil

Five sites were selected along Maine highways where soil samples were collected at 5-foot intervals, starting at the point where the roadfill and soil join and continuing to a distance of 45 feet. By locating the sites along appropriate sections of the Maine Turnpike and Interstate 95, it was possible to compare sites subjected to salts for periods ranging from 1 to 18 winters. In fact, one section of Interstate 95 was sampled before it had been opened to traffic, and the sodium concentration at that site (50 ppm) was used as a basis for comparison. All sites along the turnpike system were on marine sediment deposits, mostly Buxton silt loam.

Samples were collected at the 0–6 inch and 15–18 inch depths in order that movement of sodium and chloride ions through the soil profile could be evaluated. The sites were sampled 3 times each year (April, July, October) over a 4-year period and analyses for sodium and chloride were made by standardized techniques (Black, 1965).

In a parallel study soil samples were collected from 22 sites along secondary roads in Maine at distances of 0, 30 and 60 feet from the edge of the road embankment. These sites were sampled and analyzed in the manner described above.

Amelioration of sodium in salt-affected sites

Varying rates of limestone and gypsum were applied to three sites along Maine highways to evaluate their effectiveness in replacing the sodium (Na^+) ions which had accumulated as a result of de-icing compounds. Four rates of each material were applied on an equivalent calcium (Ca^{2+}) basis to each site in a randomized complete block design with 4 replications. The rates were as follow:

1. Limestone ($CaCO_3$) = 2me. Ca/100 grams soil = 2,000 lbs./A
2. Limestone ($CaCO_3$) = 4me. Ca/100 grams soil = 4,000 lbs./A
3. Limestone ($CaCO_3$) = 8me. Ca/100 grams soil = 8,000 lbs./A
4. Limestone ($CaCO_3$) = 16me. Ca/100 grams soil = 16,000 lbs./A
5. Gypsum ($CaSO_4 \cdot 3H_2O$) = 2me. Ca/100 grams soil = 3,460 lbs./A
6. Gypsum ($CaSO_4 \cdot 3H_2O$) = 4me. Ca/100 grams soil = 6,920 lbs./A
7. Gypsum ($CaSO_4 \cdot 3H_2O$) = 8me. Ca/100 grams soil = 13,840 lbs./A
8. Gypsum ($CaSO_4 \cdot 3H_2O$) = 16me. Ca/100 grams soil = 27,680 lbs./A
9. Check - no treatment.

These materials were spread on the surface of the grass sod at each site. One of the sites selected was a marine sediment Buxton silt loam soil near the Hogan Road interchange on Interstate 95 at Bangor. The plots were established with 2 replications adjacent to the edge of the road embankment at each site, and the remaining 2 replications immediately beyond the first on the side away from the road. The sodium level in the soil at this site averaged 734 ppm at the 6-inch and 540 ppm at the 15-inch depths before the treatments were applied, indicating a strong influence by past salting practices since the same type of soil in areas remote from highways averages only 30–50 ppm of sodium. This experiment was established on October 16, 1969.

The second site selected was an alluvial soil called Belgrade sandy loam located along Route 201 north of Brunswick. This site was established on October 11, 1969, in a manner similar to the previous site. Before treatment the sodium level in this soil was 397 at the 6-inch and 334 ppm at the 15-inch depths.

Site number three was on a glacial till Dixmont loam soil along Route 15 east of East Corinth. The design and treatments were similar to those previously described and the treatments were applied on November 19, 1969. The sodium values of 139 and 91 ppm at the 6- and 15-inch depths were somewhat higher than in non-salted soils, but the influence of past treatment was much less evident than at the other sites. Later investigation found that this section of Route 15 had recently been widened during reconstruction, thereby extending the edge of the highway into an area of soil previously uneffected. Presumably the sodium level of this section would increase rapidly in a few years until equilibrium is reached.

In addition to the soil samples collected from each plot prior to treatment, samples were collected in June and October of 1970, and again in May 1971 at both the 6- and 15-inch depths. These soil samples were leached by standard methods (1N NH_4OAc-pH 7.0) and analyzed for content of sodium.

RESULTS

Sodium and chloride content in rivers

The sodium and chloride data for the rivers are reported in Table I. It can be seen that when averaged over all the sites, sodium content of the water was lowest in October and highest in April following the winter period, as would be expected if highway salting had an effect on the concentration. However, the average chloride value was highest in July and lowest in April. Since there is no obvious reason why the trends for the two ions should be different it appears one must conclude that highway salting has little influence on the concentration of these ions in the rivers sampled. The fact that more ions are entering the rivers during and immediately following the winter months is undoubtedly negated by the increased volume of water in the system at that time.

TABLE I

Concentration of sodium and chloride ions in seven Maine rivers at three sampling periods.[1]

Location	Sodium (ppm)			Chloride (ppm)		
	July	October	April	July	October	April
Kennebec River						
Rockwood	0.5	0.5	1.1	T[2]	T	T
The Forks	0.6	1.2	0.6	T	T	T
Bingham	0.6	1.2	1.6	T	T	T
Skowhegan	1.0	0.8	2.2	0.5	T	0.9
Fairfield	1.2	1.6	3.1	1.4	0.7	0.6
Androscoggin River						
Bethel	5.1	5.4	6.2	3.0	4.5	0.8
Rumford	4.5	5.7	6.8	2.1	3.2	1.5
Livermore Falls	8.6	8.8	10.7	6.8	7.8	3.8
Lewiston	10.7	5.8	7.7	7.1	6.8	3.1
Brunswick	10.6	5.8	6.8	5.6	5.2	2.0
Saco River						
E. Hiram	3.8	2.5	4.6	2.9	T	0.9
Hollis	3.7	3.0	3.8	2.7	T	1.0
Biddeford	3.1	3.0	4.0	2.8	T	1.0
Penobscot River						
Jackman	1.6	0.9	0.5	T	T	T
Pittston	0.6	1.2	2.0	T	T	T
Seboomak	T	1.1	0.6	T	T	T
Ripogenus	1.1	1.8	1.9	T	T	T
E. Millinocket	5.5	6.1	6.7	T	1.0	T
Grindstone	1.4	2.6	3.9	T	T	T
Howland	5.7	3.9	5.2	0.8	1.6	1.1
Veazie	5.8	3.5	3.0	1.9	2.0	1.3
Narraguagus River						
Deblois	2.3	2.6	2.4	0.7	0.8	0.8
Cherryfield	4.0	3.7	2.5	1.6	0.9	0.8
Machias River						
Route 9	1.8	3.1	2.3	0.8	1.0	0.9
Machias	2.8	3.4	2.9	1.3	1.0	1.3
Dennys River						
Meddybemps	1.7	3.0	2.7	1.3	1.8	1.1
Dennysville	2.3	3.5	2.1	1.4	2.1	T
Average all sites	3.4	3.2	3.6	1.7	1.5	1.0

[1] Data for all sites are an average of 8 samples collected in 1965, 1966 and 1967.

[2] T = Trace (<0.5 ppm)

Considering the salt content of the individual rivers, it is important to note the relatively high concentrations in the Androscoggin, even at Bethel shortly after it enters Maine from New Hampshire. This particular river is heavily polluted with industrial and municipal wastes which apparently raise its salt content.

It is interesting to compare the salt levels in the Saco River with those in the Dennys, Machias and Narraguagus rivers. The Saco flows through an area heavily covered by highways, while the latter three rivers occur in Washington County where there are very few highways. In the Saco the sodium values were highest for April, decreased for July and were lowest for October while those for chloride were highest in July, intermediate in April and lowest in October.

By comparison, the sodium and chloride concentrations in the Dennys, Machias and Narraguagus rivers were at least as high in October as they were in the other two sampling periods. These results tend to indicate that road salt applications in the area of the Saco River may have increased the levels of both sodium and chloride ions in the water, since the relatively low levels measured in this river show that it had not been strongly influenced by waste pollution. However, it is obvious that the influence was a very minor one, and the level of both ions in all rivers was well below any problem level.

Sodium and chloride content of wells

The data in Table II indicate that levels of both sodium and chloride ions in the wells sampled were much higher than "normal" in many instances, with sodium averaging approximately 70 to 76 parts per million (ppm) and chloride averaging between 150–171 ppm. Considering the fact that most wells sampled away from highways contain only 3–4 ppm of sodium and chloride, it is evident that highway salting has polluted many of these wells.

On the average the sodium content of the wells did not change greatly from October to April, but the chloride levels increased from 150 ppm in October to 171 ppm the following April. The difference between the two ions in this respect was undoubtedly related to the fact that sodium ions are retained by the soil particles while the chloride ions are free to enter the ground water system.

TABLE II

Sodium and chloride concentrations in wells randomly selected along Maine highways to evaluate the effect of salt applications.[1]

Site No.	Distance from Highway (ft.)	Sodium (ppm)		Chloride (ppm)	
		August	April	August	April
1	10	290	301	479	467
1A	35	26	29	210	210
2	60	20	10	65	100
3	40	22	18	79	73
4	125	10	15	10	61
5	80	38	6	173	21
6	25	247	96	327	267
7	15	113	288	162	615
8	40	5	18	17	47
9	75	22	9	40	24
10	—	29	—	30	—
11	16	29	—	69	—
12	15	122	144	184	232
13	51	96	66	325	105
14	10	62	89	178	165
15	27	138	111	209	200
15A	60	7	5	14	30
16	30	75	24	168	92
17	85	8	5	58	86
18	150	3	2	3	5
19	30	22	13	88	55
20	18	72	100	163	182
21	75	9	12	15	27
21A	45	54	45	105	101
22	25	7	4	7	12
23	15	259	125	551	330
23A	16	203	51	390	103
23B	39	8	8	4	20
24	84	5	7	3	28
25	37	38	18	75	68
25A	1250	15	3	13	13
25B	35	69	29	135	48
26	40	14	—	25	—
27	30	49	71	75	200
28	18	37	29	69	97
29	55	23	35	51	135
30	23	118	24	240	57
31	30	200	—	448	—
31A	182	7	5	32	73
32	60	6	7	17	23
32A	40	—	220	—	600
33	27	4	7	3	5
33A	90	—	29	—	74
34	42	15	22	41	50
35	45	4	3	3	32
36	25	88	247	199	210
37	48	46	13	103	39
38	45	7	2	3	9
39	33	97	291	221	620
40	30	66	77	102	173
41	17	80	152	175	345
42	25	83	96	127	273
42A	45	70	524	170	205
43	30	282	272	551	605
44	60	9	—	33	—
45	81	1	—	2	—
46	90	23	5	83	41
47	40	7	4	4	28

[1] Each value is a mean for two annual samplings.

Site No.	Distance from Highway (ft.)	Sodium (ppm)		Chloride (ppm)	
		August	April	August	April
48	65	343	46	1163	90
49	45	194	135	331	280
50	35	15	—	7	—
51	15	163	257	249	365
52	60	16	7	36	90
53	24	94	94	256	255
54	100	9	4	12	24
55	68	13	9	6	62
56	27	69	47	239	240
56A	20	290	314	560	625
57	15	92	121	259	355
58	15	12	55	21	202
59	20	219	191	322	455
60	21	6	10	21	65
61	52	35	34	66	128
62	27	73	74	168	290
63	20	7	5	5	16
63A	30	20	13	41	43
64	20	9	8	9	19
65	30	16	6	29	15
66	30	79	60	175	130
67	250	41	37	65	120
68	6	280	68	487	138
69	15	7	2	3	6
70	24	19	11	31	44
71	30	29	32	118	128
72	15	41	22	67	61
73	36	3	2	13	8
74	20	4	5	4	22
75	36	103	58	212	143
76	36	73	—	211	—
77	45	80	37	155	113
78	25	846	518	1889	3150
79	75	82	20	201	76
80	9	6	5	4	10
81	32	27	20	3	26
81A	40	7	3	4	10
82	60	26	28	194	235
83	63	48	56	257	208
84	8	2	36	3	84
85	80	1	1	2	3
86	45	14	26	18	57
87	42	12	12	23	56
88	7	37	54	107	93
89	38	46	35	133	75
90	27	5	12	6	50
91	30	54	223	90	528
92	30	3	4	2	6
93	30	14	21	43	83
94	48	38	24	52	52
94A	10	4	199	4	114
95	17	83	43	191	121
96	48	20	—	13	—
97	36	53	87	93	135
98	22	388	173	791	395
99	19	199	35	363	67
100	9	25	97	29	185
101	30	—	96	—	220
$\bar{X}$	39.9	76.3	69.7	150.3	170.6

It should be noted if one considers 250 ppm of chloride as the upper limit of acceptability in water for human consumption (U.S. Public Health Service, 1962) that 19% of the wells sampled in October and 19% of those sampled in April were unacceptable for human consumption. In addition, there were many other wells which were approaching this upper limit. Distance from the edge of the highway was closely related to the level of salt pollution, as evidenced by the fact that the average distance for all wells was approximately 40 feet, while the average for those wells which contained in excess of 250 ppm of chloride in April was 24 feet.

In an attempt to trace the movement of salt from a roadside snowbank into the adjacent soil and groundwater system, a fluorescent dye, Sulpho-Rhodamine B, was sprayed on the snowbanks at several sites on February 9, 1968. Samples were collected at these sites in May of the same year and were analyzed by a Turner fluorimeter, Model III. Detectable levels were found in the wells at sites 5 and 48, indicating that "melt" water from the snowbank had moved from the roadside to the well water system. Thus, it is logical to assume that sodium and chloride ions present in the snowbank would also have moved from one point to the other in the melt water.

Sodium and chloride content of soil

The results from this study pertaining to the levels of sodium and chloride ions present in the soils bordering major highways demonstrate clearly that these ions move laterally to distances of 60 feet and downward at least 18 inches (Tables III and IV). At site 10 in Stillwater where salt had been applied for only 4 winters, the sodium levels had been increased fourfold at the edge of the highway, but the influence was significant only to a distance of 15 feet, whereas at site 13 in Kittery where salt had been applied for 22 years the sodium levels had been increased sevenfold near the edge of the highway and fourfold at a distance of 45 feet.

Since the soils at each of the sites along the turnpike system were similar (derived from marine silts and clays) it is valid to assume they all contained 50–60 ppm of sodium prior to the initiation of road salting in the late 1940's. These data clearly indicate that the sodium ions have been built up to high levels in the soil with time. It does not appear that annual precipitation in the area (35–40 inches/year) is adequate to leach the sodium ions through the soil profile.

Data presented in Table IV indicate the wide range in sodium and chloride values found in the 22 soil sites sampled along secondary highways. When averaged over all sites the effect of distance from the highway is consistent, obviating the conclusion that deicing practices have strongly influenced the content of both ions in the soils along highways.

It is interesting to note the sodium content of the Bangor site along Interstate 95 (Table IV) was 1056 ppm in the surface soil. If one assumes a cation exchange capacity of 20 meq./100 grams of this Buxton soil it can be calculated that 23 percent of the cation exchange sites were occupied by sodium ions. This site could properly be

TABLE III

Exchangeable sodium levels in the soil at five sites along the Maine Turnpike and Interstate 95, expressed as an average of ten samplings over a five year period (ug/g).

Site No.	Depth Inches	Distance from Highway (feet)										
		0	5	10	15	20	25	30	35	40	45	Ave.
10[1]	6	273	188	117	97	72	78	57	64	73	60	108.2
Stillwater	18	190	136	93	77	60	55	46	45	43	48	79.2
5[2]	6	107	178	205	194	126	99	84	78	66	62	121.1
Burnham	18	86	144	166	141	113	96	87	65	60	54	100.8
1[3]	6	239	163	123	90	62	64	47	43	44	39	91.3
Bangor	18	164	97	70	50	60	49	40	36	44	32	63.2
7[4]	6	409	392	297	277	270	247	192	155	112	122	246.8
Sydney	18	445	292	260	198	190	139	96	115	85	94	191.2
13[5]	6	258	413	404	359	342	314	292	316	279	278	326.0
Kittery	18	265	318	275	259	249	241	209	213	197	213	243.6

[1] Site had been salted for 4 winters at the conclusion of this study.
[2] Site had been salted for 6 winters at the conclusion of this study.
[3] Site had been salted for 7 winters at the conclusion of this study.
[4] Site had been salted for 9 winters at the conclusion of this study.
[5] Site had been salted for 22 winters at the conclusion of this study.

TABLE IV

Levels of exchangeable sodium and chloride ions in soils at 22 sites contiguous to major highways in Maine.

Site Location	Depth Inches	Sodium (ppm) 0'	Sodium (ppm) 30'	Sodium (ppm) 60'	Chloride (ppm) 0'	Chloride (ppm) 30'	Chloride (ppm) 60'
Carmel (2)[1]	6	356[2]	80	95	135	75	85
	18	133	31	43	83	29	33
Bangor (95)	6	1056	651	442	651	490	351
	18	900	379	350	768	314	172
Pittsfield (95)	6	141	72	35	89	108	16
	18	168	63	30	64	27	21
Fairfield (95)	6	56	53	64	63	49	24
	18	65	52	49	61	30	20
Sydney (95)	6	501	176	54	184	101	19
	18	324	119	39	119	65	63
Greenbush (95)	6	30	42	45	37	50	84
	18	34	34	53	53	37	26
Sydney (95)	6	449	118	81	120	35	33
	18	319	107	68	211	50	34
Scarboro (95)	6	143	156	59	45	30	25
	18	256	225	75	69	68	18
Biddeford (95)	6	456	179	179	156	68	54
	18	372	206	210	176	83	34
Gorham (202)	6	94	39	33	19	21	13
	18	192	32	23	20	18	32
Guilford (15)	6	290	72	22	30	26	26
	18	160	23	14	46	13	18
Dover (6)	6	256	61	34	40	43	16
	18	275	64	40	28	22	26
Caribou (1)	6	333	66	165	41	34	41
	18	263	54	40	58	66	28
Monticello (1)	6	296	156	153	202	91	88
	18	183	129	149	131	73	71
Perry (1)	6	293	180	93	124	74	59
	18	276	127	86	108	45	29
Jonesboro (1)	6	34	64	40	37	40	31
	18	29	49	36	51	40	33
Bangor (2)	6	89	101	42	44	59	25
	18	155	98	52	61	82	47
Bangor (15)	6	311	141	101	149	40	36
	18	242	89	51	210	33	16
Northport (1)	6	48	45	34	82	67	28
	18	64	39	35	38	43	27
Lisbon (196)	6	270	21	16	69	26	16
	18	190	32	14	49	63	8
Topsham (201)	6	234	421	254	144	181	98
	18	412	309	237	289	106	62
Yarmouth (1)	6	445	170	68	80	21	29
	18	511	130	121	101	36	21
$\bar{\bar{X}}$	6	281.4	139.2	95.9	115.5	76.5	54.4
	18	250.6	108.7	77.9	127.0	61.0	38.2

[1] Maine highway number where samples were collected.
[2] Each value is an average of 5 samplings at each site over a 3-year period.

termed a "sodic" soil. Although the physical properties of this soil were not measured, it can be estimated that drainage may have been adversely affected at some of the sites included in this study. Furthermore, these sodium concentrations might be high enough to create toxicity in some plants grown at the sites studied.

Amelioration of sodium in salt-affected soils

The data presented in Tables V, VI and VII indicate the extent to which sodium values in 3 soils were lowered over time following the application of varying rates of limestone and gypsum.

Results obtained agree with soil chemistry theory (Black, et al, 1969) in that gypsum applied at the highest rate significantly lowered the sodium content of the two sites where sodium content was high initially, whereas limestone did not reduce sodium levels. It has long been recognized that calcium ions can effectively replace sodium ions in the soil system, but the associated anion is a critical factor. In the presence of carbonate ions an insoluble sodium carbonate is formed and this does not result in the leaching of sodium through the soil profile. When sulfate is the associated anion, such as that supplied by gypsum, the sodium sulfate formed when calcium replaces the sodium results in a high degree of leaching.

TABLE V

Reduction of sodium levels in three soils eight months following treatment with limestone and gypsum.

Treatment	Reduction in sodium level 10/14/69 to 6/4/70 Hogan Road	Topsham	Duran
	6" Samples		
Lime— 2,000 lbs/A	+67ab[1 2]	+8a	+22ab
Lime— 4,000 lbs/A	+76ab	+58a	+29ab
Lime— 8,000 lbs/A	+123ab	+69a	+13 b
Lime—16,000 lbs/A	+89ab	+52a	+32ab
Gypsum— 3,460 lbs/A	+104ab	+15a	+30ab
Gypsum— 6,920 lbs/A	+76ab	+38a	+46a
Gypsum—13,840 lbs/A	+17 b	9ab	+27ab
Gypsum—27,680 lbs/A	27 b	54 b	+8 b
No Treatment	+189a	+44a	+35ab
	15" Samples		
Lime— 2,000 lbs/A	+43a	+27 c	+8ab
Lime— 4,000 lbs/A	+79a	+62abc	+31ab
Lime— 8,000 lbs/A	+24a	+48abc	+14ab
Lime—16,000 lbs/A	+19a	+98a	+46a
Gypsum— 3,460 lbs/A	+77a	+36 bc	+22ab
Gypsum— 6,920 lbs/A	+12a	+90ab	+16ab
Gypsum—13,840 lbs/A	+17a	+32 bc	7 b
Gypsum—27,680 lbs/A	49a	+22 c	+19ab
No Treatment	+26a	+66abc	5ab

[1] Pounds per acre.
[2] Positive values mean an increase in sodium level rather than a reduction.

TABLE VI

Reduction of sodium levels in three soils twelve months following treatment with limestone and gypsum.

Treatment	Reduction in sodium level 10/14/69 to 10/21/70		
	Hogan Road	Topsham	Duran
		6" Samples	
Lime— 2,000 lbs/A	137a[1]	98 bc	+11a[2]
Lime— 4,000 lbs/A	194ab	43ab	+22a
Lime— 8,000 lbs/A	140a	22a	+22a
Lime—16,000 lbs/A	206ab	37ab	+13a
Gypsum— 3,460 lbs/A	187ab	30ab	+25a
Gypsum— 6,920 lbs/A	147a	18a	+15a
Gypsum—13,840 lbs/A	125a	128 c	+14a
Gypsum—27,680 lbs/A	280 b	150 c	+1a
No Treatment	92a	48ab	+8a
		15" Samples	
Lime— 2,000 lbs/A	72a	28abc	17ab
Lime— 4,000 lbs/A	49a	0ab	4ab
Lime— 8,000 lbs/A	104a	36 bc	+13a
Lime—16,000 lbs/A	49a	0ab	+7ab
Gypsum— 3,460 lbs/A	78a	52 c	27 b
Gypsum— 6,920 lbs/A	8a	32 bc	23ab
Gypsum—13,840 lbs/A	23a	61 c	+3ab
Gypsum—27,680 lbs/A	125a	60 c	13ab
No Treatment	34a	0ab	16ab

[1] Pounds per acre.
[2] Positive values indicate an increase in sodium level rather than a reduction.

TABLE VII

Reduction of sodium levels in three soils eighteen months following treatment with limestone and gypsum.

Treatment	Reduction in sodium level 10/14/69 to 4/29/71		
	Hogan Road	Topsham	Duran
		6" Samples	
Lime— 2,000 lbs/A	+47ab[1,2]	+7 b	55ab
Lime— 4,000 lbs/A	77ab	+129ab	36ab
Lime— 8,000 lbs/A	+102a	+100ab	55ab
Lime—16,000 lbs/A	+20ab	+153a	42ab
Gypsum— 3,460 lbs/A	16ab	+34ab	76a
Gypsum— 6,920 lbs/A	+8ab	+153a	48ab
Gypsum—13,840 lbs/A	+38ab	+5 b	45ab
Gypsum—27,680 lbs/A	180 b	+25ab	11 b
No Treatment	+51ab	+79ab	55ab
		15" Samples	
Lime— 2,000 lbs/A	+5a	+92a	52a
Lime— 4,000 lbs/A	98a	+119a	70a
Lime— 8,000 lbs/A	78a	+100a	57a
Lime—16,000 lbs/A	25a	+97a	76a
Gypsum— 3,460 lbs/A	37a	+87a	44a
Gypsum— 6,920 lbs/A	79a	+108a	57a
Gypsum—13,840 lbs/A	1a	+45a	56a
Gypsum—27,680 lbs/A	130a	+63a	48a
No Treatment	74a	+141a	40a

[1] Pounds per acre.
[2] Positive values indicate an increase in sodium level rather than a reduction.

It should be noted that following the winter period each year of the study the sodium values for all treatments tended to increase, undoubtedly as a result of the continued application of deicing salts to the highways contiguous to the three experimental sites. The continued effectiveness of the gypsum over this entire period is evidence that when applied at high rates to the surface of these soils this material dissolves slowly and that it would not need to be applied to salt-affected soils along roads every year. In fact, it would appear infrequent applications would be adequate. Further research is needed to determine the optimum frequency of application under the conditions which prevail in this region of the country.

SUMMARY

During the period 1965–69 a series of samplings were made of soil and water areas contiguous to Maine highways which had been salted previously for de-icing purposes.

Repeated analyses of sites along seven rivers revealed there was no significant increase in sodium or chloride content of the water during the spring when snowmelt was at a maximum. Neither was the content of these ions in the water ever at unusual levels, since no values exceeded 11 ppm. Undoubtedly, some road salt was present in the rivers but the dilution effect was adequate to avoid a concentration problem. The average concentrations for 27 sites were 3.4 and 1.5 ppm of sodium and chloride, respectively.

Semi-annual analyses of 115 wells selected along Maine highways for a two-year period indicated that deicing practices have elevated the sodium and chloride content of ground water in many areas of the state. The average content of these ions was 69 and 170, respectively, when averaged over the entire study period. Nineteen percent of the wells were unfit for potable water supplies because they contained in excess of 250 ppm of chloride. Nearly all wells which were more than 40 feet from the highway were not significantly affected by salting practices.

Sodium and chloride levels in soils contiguous to highways exhibited a direct relationship to the length of time over which salt applications had been made. In areas where salt had been applied for 20 years, the sodium levels rose over a distance of 60 feet from the road embankment, and to a depth of 18 inches. Sodium saturation of the soil cation exchange capacity approached 15 percent at several sites, thereby producing the equivalent of a "sodic" condi-

tion. The highest sodium content encountered was 1056 ppm, which represented 23 percent saturation of that soil site.

Limestone applied to the surface of three salt-affected sites along Maine highways at rates of zero, 1, 2, 4 and 8 tons/acre did not reduce sodium levels over a two-year period. Gypsum applied to the same sites at calcium rates equivalent to those in the limestone significantly reduced sodium levels during the same period at the highest rate of application. Sodium content of the site which contained the highest initial level (734 ppm) was reduced 31 percent by the highest gypsum treatment over an 18-month period.

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