Anti-Icing Activities in Finland: Field Tests with Liquid and Prewetted Chemicals

TAPIO RAUKOLA, RAUNO KUUSELA, HEIKKI LAPPALAINEN, AND ANTTI PIIRAINEN

Preventive ice control methods were discussed and even promoted in the 1970s in Finland. Because of bad results, such practice did not become generally used. At the end of the 1980s, the liquid and prewetted salting methods were introduced in Finland; these methods made preventive ice control feasible. In field studies preventive methods were tested in practice using liquid NaCl (23 to 25 percent). Salt residues were measured after the applications with Sobo 20 to find out how long the residues are effective on the roadways. The tests included a comparison between liquid NaCl and liquid $CaCl_2$ (at 32 percent). The spreading patterns were studied with prewetted salt at different rates of application and at different spreading speeds. A few anti-icing tests conformed to each other: preventive treatment was successful. In the residues, there was no difference between how well the NaCl and $CaCl_2$ stayed on the roadways. Quite often the salt residues diminished more during the first 200 vehicles than afterward. It is recommended to treat the most heavily trafficked highways with liquid salt preventively, when the road is expected to freeze. Spreading patterns were found to be at their best when the spreading width for a road 7 m (23 ft) wide is less than 5 m (about 16 ft)—3 to 4 m is good—and the speed is not more than 30 to 40 km/hr (19 to 25 mph). If these limits are exceeded, more salt is wasted to the slopes. Six road master districts were involved in these tests, all of which were executed on trafficked highways.

Black ice increases the risk of traffic accidents tremendously—20 to 25 times over the risk on a dry surface. It is therefore worthwhile to reduce such conditions as much as possible. In the 1970s it was recommended that preventive actions with dry, granular salt be used. Some areas tried it but were disappointed with poor results, and motorists thought that the maintenance personnel were out of their minds.

Large-scale use of liquid and prewetted salting methods began a few years ago in Finland. Since then, the investments in the equipment have been substantial; they include mixing units, spreaders, and tanks for spreading and storing brines. The increase in the number of spreaders illustrates this (Table 1).

FIELD TESTS

Spreading the liquid and prewetted salts has been the first effective method for highway maintenance personnel to carry out anti-icing activities, because the wet agents stick to dry surfaces and it is possible to control the rate of application. (In this paper, "anti-icing" means a preventive treatment, and "deicing" means a curative treatment.) One advantage of liquid salt is the minimization of total salt used. The first experiences showed about a 20 percent savings in tonnage used on the heavily trafficked Finnish areas. The cost savings were not realized because of the expense of the equipment.

Most of the maintenance people still remember failures of earlier experiments, and they are reluctant to fail again. Therefore, it was decided to implement field tests to show the effectiveness of brines in preventing ice from forming on highways (*1*).

Objective

The objective of testing was to develop recommendations for anti-icing activities. The recommendations were to include advice on how early treatments can be done, the rates that should be used, the condition under which the method can be used, the risks, the type of equipment that is best, and the differences between sodium and calcium chlorides.

Implementation

Normally black ice forms during weather conditions occurring mostly in October and November. Unfortunately, there were only a few good occasions for testing in 1991 because the fall was much milder than normal. It will be necessary to continue field tests to collect more data to make final conclusions.

The anti-icing tests were carried out in two maintenance areas: a NaCl spinner spreader was used in the Orivesi area (Figure 1), and a $CaCl_2$ spray bar spreader was used in the Karstula area (Figure 2). The two areas are about 140 km (90 mi) apart as the crow flies. Spreading equipment was calibrated before tests, and traffic counts were made in 15-min increments during residue tests.

Working Pattern

Anti-Icing

Results were evaluated in the traffic lanes after the applications. Salt residue tests were taken in many places on tes

Finnish National Road Administration, Research and Development Unit, Kanslerinkatu 6, Tampere SF-33720 Finland.

TABLE 1 Spreaders Available for Liquid and Wet Salt Application

Period	Liquid Spreaders	Pre-wetting Spreaders
89-90	2	50
90-91	32	80
91-92	85	100
92-93*	125	125

** includes 40 spreaders on order*

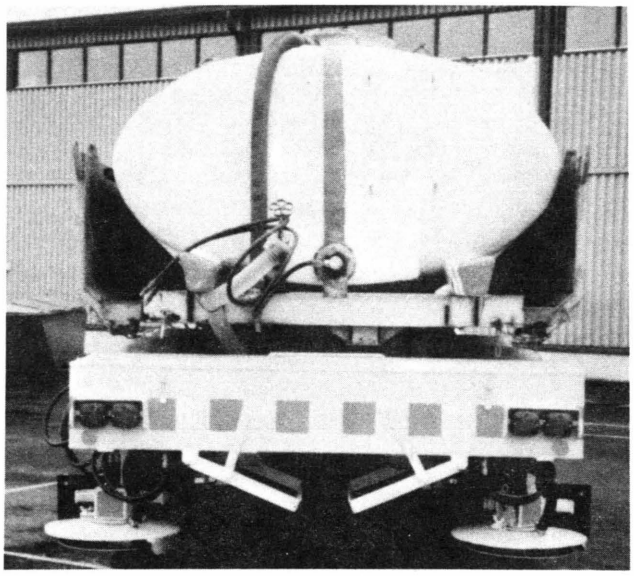

FIGURE 1 Liquid spinner spreader in Orivesi.

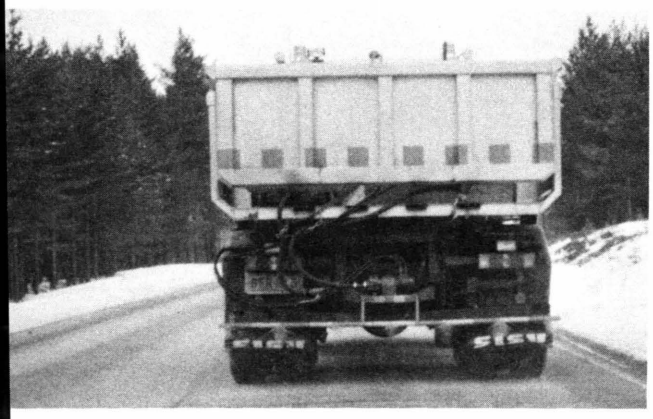

FIGURE 2 Liquid spray bar spreader in Karstula; accessory consists of thin spray bar and nozzles, pump, and hydraulics.

ections and control roads. The personnel in the Orivesi area ound that the anti-icing method worked great and started to se it on a large scale immediately.

Treatments were applied when the forecasts predicted reezing or when the first signs of freezing could be seen. For orecasted snowfalls, an anti-icing treatment was made once efore the occurrence. Chloride quantities were measured soon after spreading and usually some time after. The results of salt residue tests can be used to estimate how much salt was left when freezing occurred at that location. The night patrolman and the supervisor reported the time of freezing on the control sections and whether the test sections remained unfrozen. The measurements were taken as described in Figures 3 and 4.

Residue Tests

About the same measurement pattern was used as described in Figure 3. Wide-shoulder roads were used as test roads to see how much of the salt flew over the edge markings.

Instruments

The Sobo device was used to define how much chloride existed on the test pavements (Figure 4). It works well to measure

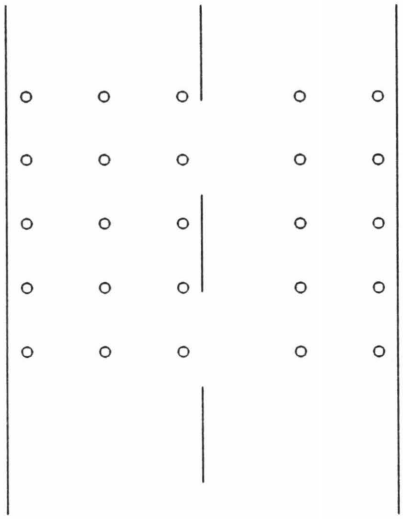

FIGURE 3 Location of salt measurements on lanes and beside road markings.

FIGURE 4 Sobo 20 measurements in progress.

both sodium and calcium chloride quantities on the basis of electric conductivity definitions. The specific resistances of both agents are about the same.

Sobo uses liquid acetone and distilled water mixture for measurements. The readings are from 0 to 45 g/m². The accuracy of Sobo varies depending on salt gradations: Sobo records only about 50 percent of very coarse salt, about 75 percent of fine-graded salt, and about 100 percent of brines. On dry surfaces the Sobo gives somewhat lower readings than on wet ones. If the electrodes of the Sobo get dirty, readings become far too low, so the electrodes must be cleaned frequently.

Spreading Equipment and Liquid Concentrations

Both spinner and spray bar spreaders were used for testing: spinners were used with liquid sodium (Figure 3), and spray bars were used mainly with liquid calcium chloride (Figure 4). The concentration of liquid sodium chloride was targeted at 23 to 25 percent. Liquid calcium chloride was applied at a 32 percent concentration. From these data, an application rate of liquid calcium chloride would be roughly 20 percent less than the liquid sodium chloride to have the same results for salt per square meter.

RESULTS

Anti-Icing

Orivesi

The Orivesi test section was a three-lane section on Highway 9. When the maintenance staff enlarged the anti-icing treatments to cover the entire section of the highway, additional measurements were taken. The control roads were in the same vicinity as the test sites. The average daily traffic of the test road is about 6,100.

Case 1: November 16, 1991 The anti-icing treatment was applied to all salt-classified highways (those with a bare-pavement policy) at 4:20 p.m. at a rate of 20 g/m² liquid NaCl, or 5 g/m² salt. Two of the nearby low-volume roads were frozen 2 to 3 hr later. At that time, 4 to 5 g/m² salt remained on the test section and its condition remained unfrozen. Hoar frost started to build up 12 hr after the treatment (at 4:00 a.m.), but the test road did not freeze until between 8:00 and 9:00 a.m. Another treatment was made 17 hr after the first treatment. The residue was 1 g/m² salt on the liquid salt test road (Figure 5). The road temperature was 0°C (32°F) at 4:00 p.m. and −7°C (25°F) at 8:00 the next morning. The dew-points were −0.2 and −4.6°C (31.6 and 24°F), respectively.

Case 2: November 22, 1991 The anti-icing treatment was applied at 2:10 p.m. to the wet highway surface at a rate of about 11 g/m² liquid NaCl, or 3 g/m² salt. After 3 hr, all control roads with no salt were frozen and the others remained wet. At the freezing time, the salt residue on the test section was 1 g/m² (Figure 6). The road temperature was −1.4°C (29.5°F) at 5:00 p.m. and −3.6°C (25.5°F) at 8:30 p.m.

Case 3: November 23, 1991 The forecast at 8:45 p.m. was for ice buildup in 9 hr. The anti-icing treatment was started at 10:30 p.m. at a rate of 11 g/m² liquid NaCl, or 3 g/m² salt, onto the wet surface. Other roads were treated with prewetted NaCl at a rate of 5 g/m². The control roads were frozen at about 3:00 a.m. Salted roads remained wet (Figure 7). The road temperature at 10:00 p.m. was 2.5°C (36.5°F), and skies were partly clear.

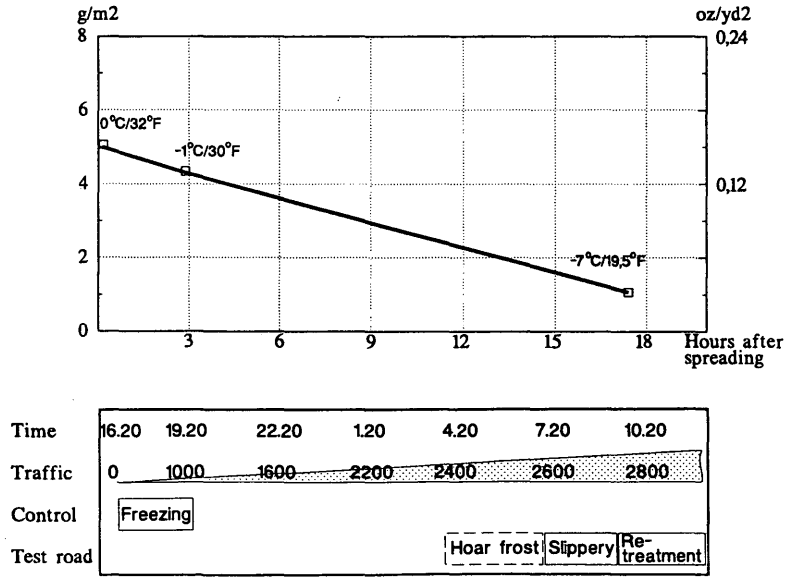

FIGURE 5 Average salt residues on November 16, 1991.

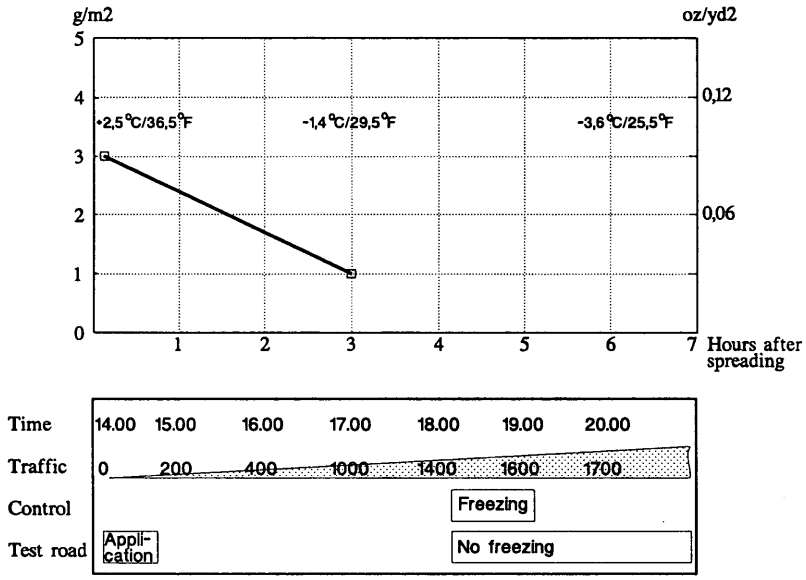

FIGURE 6 Average salt residues on November 22, 1991.

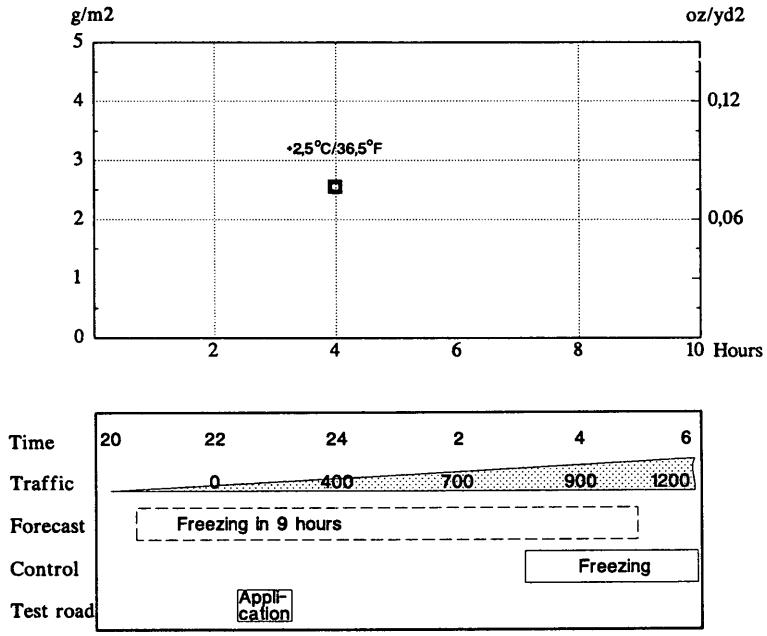

FIGURE 7 Average salt residues on November 23, 1991.

Case 4: November 11, 1991, Karstula

At 7:30 p.m. the forecast was for snowfall in 3 hr. Liquid $CaCl_2$ application took place between 8:15 and 8:30 p.m. on the test section. It was applied to a dry surface. The section length was 9 km (5.6 mi), and the application rate was 34 g/m² brine, or 11 g/m² salt, to a width of 3.1 m (10 ft) for both of the lanes. The salt measurements were done on the test road only. The bare- and wet-pavement condition on the test section was achieved earlier than on the control section, because no salting was needed because of slipperiness. The details are shown in Figure 8.

Other Anti-Icing Experiences

Prewetted NaCl was used in the Orivesi area for anti-icing purposes on some of the highway sections because the liquid spreader did not have time to cover all of the highways. The application rate used was 5 g/m², which normally worked well. In an interview about the 1990–1991 winter, the supervisors said that they used a liquid for preventive salting in 10 percent of the liquid applications. The temperature range was from 0°C (32°F) to a little below freezing. Treatments were done under dry, moist, and rainy conditions. Rates varied between 15 and 20 g/m² liquid. No failures were reported.

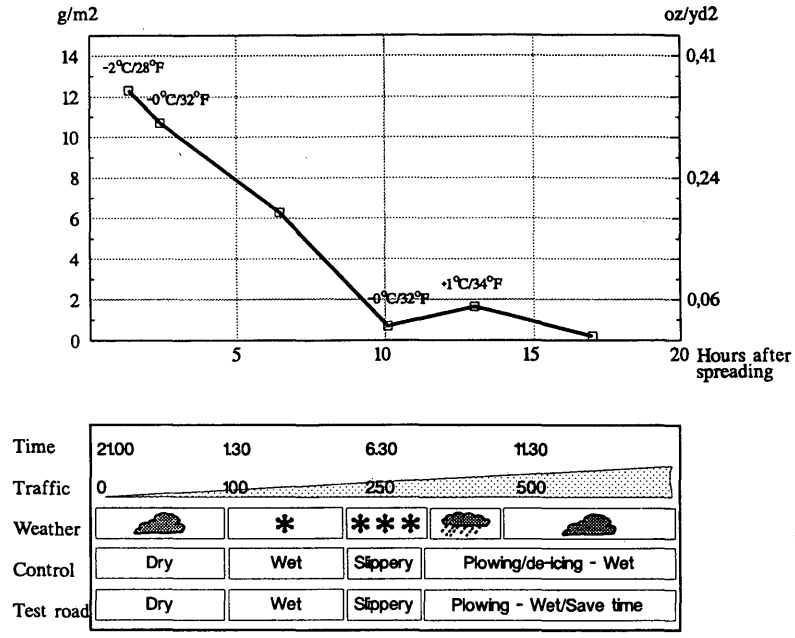

FIGURE 8 Preventive treatment with liquid $CaCl_2$ in Karstula. Reapplication was not required on test section to maintain residue; on other section prewetted salt was required to restore bare pavement.

The Raahe maintenance area used prewetted NaCl mainly as a preventive treatment for black ice. The night patrolman started the treatment at about 11:00 p.m. at 50 km/hr (30 mph). The salt had to be dripping wet. Spreading rates were 3 to 7 g/m². During the morning hours the operator checked the result to avoid refreezing. Salt was reapplied where needed. They were very confident and satisfied with this method.

Salt Residue Tests in Various Areas

Case 5: NaCl/$CaCl_2$ Tests in Karstula, November 11, 1991, at 3:00 p.m.

Four test sections were used to compare saline residues of small and large quantities of NaCl and $CaCl_2$. Each section was placed 200 m (220 yd) long, and two were on the right-hand lane and two on the left-hand lane:

- Section 1: 22 g/m² liquid NaCl or 5 g/m² salt
- Section 2: 15 g/m² liquid $CaCl_2$ or 5 g/m² salt
- Section 3: 51 g/m² liquid NaCl or 12 g/m² salt
- Section 4: 34 g/m² liquid CaCl or 11 g/m² salt

Case 6: Different Amounts in Hämeenlinna, November 6, 1991, at 9:30 a.m.

The application rates of 10 and 30 g/m² of prewetted NaCl were used to find out the spreading pattern at a width of 5 m (16.4 ft) and at a speed of 35 km/hr (22 mph). A spray bar spreader was used. Tests were carried out on Highway 57. The surface was moist all the time.

The aforementioned results are shown in Figures 9 and 10. Figure 11 describes saline residues within 3 hr. The difference in residues remained between the two applications. The measurements for the small application rate were done 10 to 15 min after the application, and those for the large rate, 30 to 35 min after application.

Case 7: Effect of Speed in Kankaanpää, April 1992

Prewetted NaCl was spread to the width of 5 m (16.4 ft) at the speeds of 30, 50, and 60 km/hr (19, 30, and 38 mph). The application rate was 20 g/m². The scatter patterns are shown in Figure 12. The higher the speed, the more salt was found on the shoulders. The highway was moist all the time. The residue measurements took place 5 min after the application for 30 km/hr, 15 min for 50 km/hr, and 20 min for 60 km/hr.

After about 250 vehicles—of which 25 percent were trucks—the salt residue on the road was about 30 percent of the original concentration within 3 hr. The spreading patterns show that the salt concentration was low in the middle of the truck spreading lane for the two higher speeds. The probable reason for this is a turbulence effect behind a truck and a straight current of air between the wheelpaths under the truck. The phenomenon should be examined further so as to make a sure judgment.

Other Results

The drivers and supervisors from the Finnish National Road Administration found testing useful for several reasons. They could get immediate feedback on their working methods, such as the effectiveness of adjustments to the devices, the proper spreading width, and the best possible driving line for optimum results.

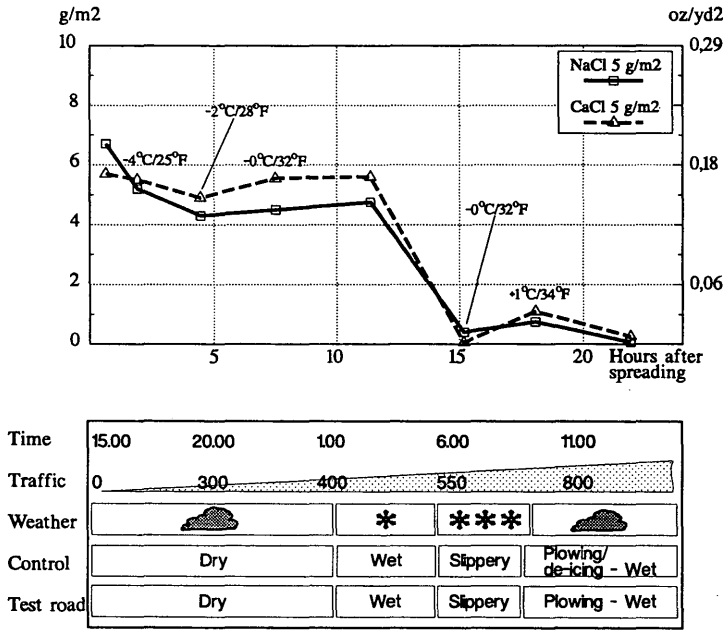

FIGURE 9 No difference between residue of liquid NaCl and $CaCl_2$, regardless of application rate.

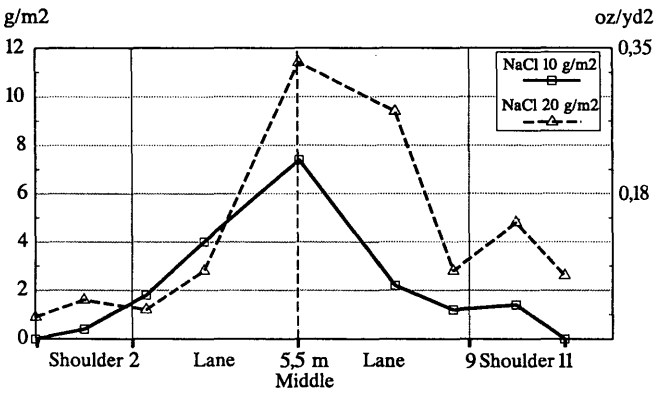

FIGURE 10 Spreading patterns at different application rates.

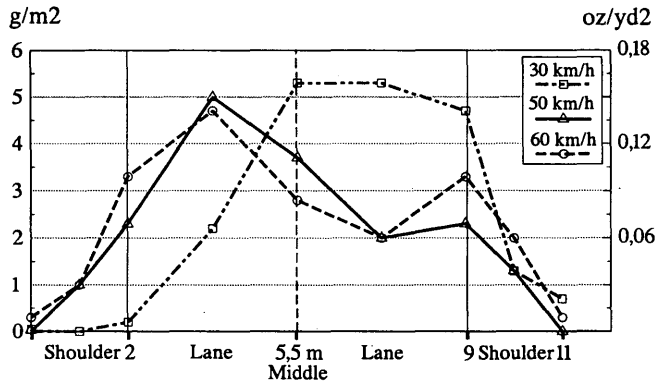

FIGURE 12 Effect of speed with prewetted salt.

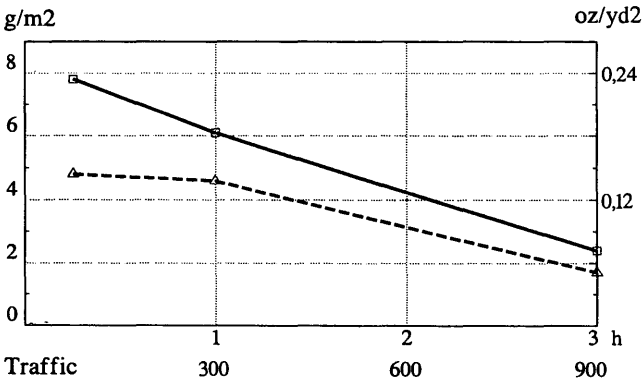

FIGURE 11 Residues of prewetted salt at high and low application rates on roadway 7 m (23 ft) wide.

CONCLUSIONS

Preventive chemical treatments improve safety for the motorists. If such activities are done with only minimum amounts of salt, road surfaces become moist and there is no splash phenomenon, resulting in a better image for the maintenance personnel.

Use of brines and prewetted materials decreases total salt application. Much of the dry salt flies or rolls away during spreading operations. The operations can be done in advance so that fewer emergency applications are needed.

If the temperature starts to decrease or surplus moisture occurs in a rain, snow, or hoar frost, brines dilute so much that the highways may refreeze; high amounts of preexisting moisture do the same (Tables 2 through 5). Malfunction of spreaders is possible. Frequent inspections of treated roads are necessary as well as checks of salt concentrations of brine

TABLE 2 Highway Moisture Description

Definition	Water g/m²	Description
Little Moist	5 - 20	Detectably dark pavement
Moist	20 - 50	Clearly dark pavement
Wet	50 - 200	Spray phenomenon starts
Very Wet	200 - 400	Small drops of water in the air
Flowing	400 -	Flow according to gradient, splash

TABLE 3 Water Films and Corresponding Ice Thicknesses

Water (g/m²)	Ice Thickness(mm)
10	0,01
30	0,03
100	0,10
300	0,30
500	0,50

A typical ice thickness of salted roads is 0,02-0,2 mm.

just before loading. A failure in these obligations can lead to unpleasant surprises.

Trying to minimize the use of salt through liquids increases costs, because of investments in equipment and a more frequent need for reapplications.

Prewetted salt flies away almost as easily as dry salt if there is much heavy traffic on the highway. However, if salt is dripping wet, it is less obvious.

High application rates disappear faster from the highways than small ones, over a period of time and traffic. Quite often a rapid decrease in salt residues can be seen very soon after the application; then the residues are decreased much more slowly (Figures 13 through 19).

Conclusions for preventive treatments drawn here are based on an insufficient number of tests because of the weather conditions during the test period. Yet all the tests were successful in preventing ice from forming or causing snow to melt right after plowing. The tests consisted of two important elements: salt residue measurements and visual checks (no friction measurements) of whether the road was icy, dry, or moist. Experiences in many Finnish road maintenance areas support the test results.

TABLE 5 Freezing Points for Liquid NaCl (23%) Spread on Road

		Freezing points by liquid (g/m²)				
Description	Water (g/m²)	5	10	20	40	
Little Moist	10	-5	-6	-10	-16	°C
		23	21	14	3,2	°F
Moist	30	-1	-4	-5	-9	°C
		30	25	23	16	°F
Wet	100	0	-1	-2	-4	°C
		32	30	28,4	25	°F
Very Wet	300	0	0	0	-2	°C
		32	32	32	28,4	°F
Flowing	500	0	0	0	0	°C
		32	32	32	32	°F

When there is a lot of water on the road surface, liquid salts should not be applied because of dilution.

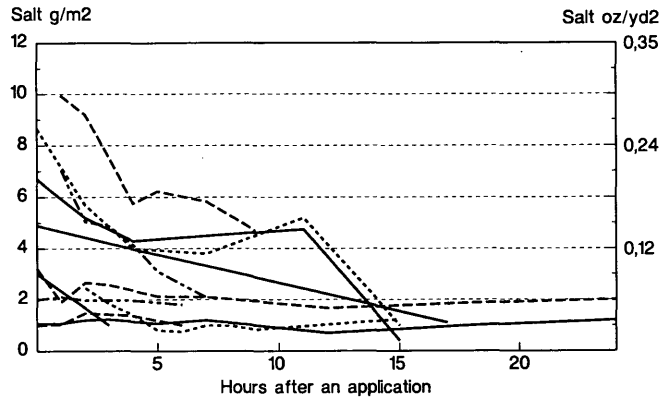

FIGURE 13 NaCl residues in relation to hours, all liquid NaCl tests.

RECOMMENDATIONS

Some preliminary recommendations can already be given. Anti-icing treatments are recommended, if weather forecasts predict black ice. The main method is liquid application. It is also obvious that good working speeds are as follows:

- Maximum of 30 km/hr (20 mph) for dry, granular salt;
- 30 to 40 km/hr (20 to 25 mph) for prewetted salt;
- 40 to 55 km/hr (25 to 35 mph) for liquids with spinner spreaders; and
- 50 to 70 km/hr (30 to 45 mph) for liquids with spray bar spreaders.

TABLE 4 Freezing Points According to Moisture and Salt Content

		Freezing points by salt (g/m²)					
Description	Water (g/m²)	2	5	10	20	30	
Little Moist	10	-16	-21	-21	-21	-21	°C
		3	-6	-6	-6	-6	°F
Moist	30	-3	-10	-21	-21	-21	°C
		26,6	14	-6	-6	-6	°F
Wet	100	-1,5	-2,5	-7	-11	-21	°C
		29	27,5	19,4	12	-6	°F
Very Wet	300	-0,4	-1	-2	-3,5	-5	°C
		31	30	28,4	26	23	°F
Flowing	500	-0,1	-0,4	-1,5	-2	-3	°C
		31,8	31,3	29	28,4	26,6	°F

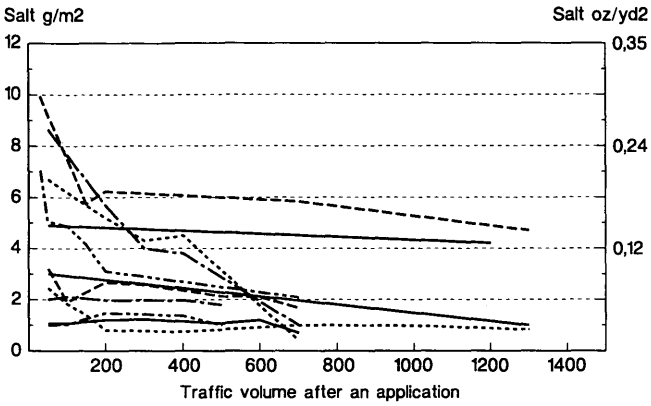

FIGURE 14 NaCl residues in relation to traffic volume, all liquid NaCl tests.

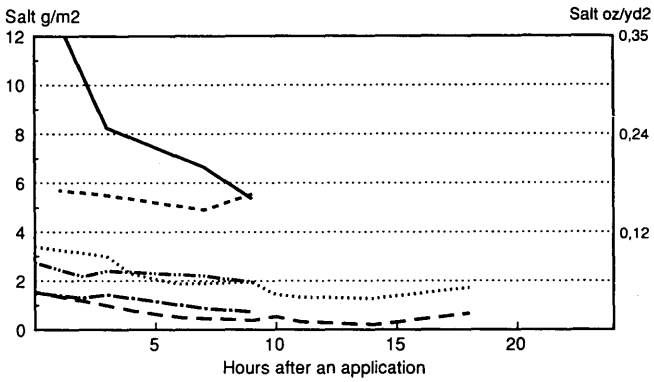

FIGURE 15 CaCl residues in relation to hours, all liquid CaCl tests.

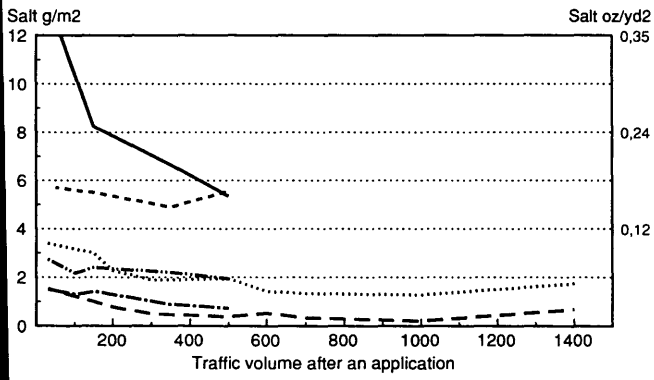

FIGURE 16 CaCl residues in relation to traffic volume, all liquid CaCl tests.

Narrow spreading patterns with dry and prewetted salts are recommended over the use of broad ones. For black ice the need should be directed to the middle of the highways. According to the test results, preventive treatment is efficient for black ice with very small application rates: about 2 to 3 g/m² salt. These amounts can be reached accurately only in liquid form: about 10 g/m² NaCl liquid. Because of the refreezing risks, treatments must be carefully controlled.

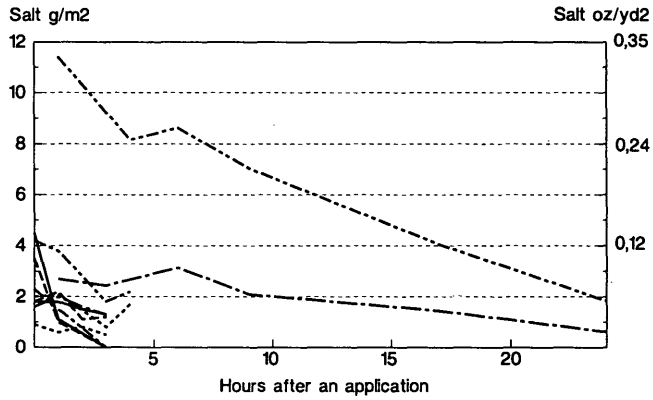

FIGURE 17 NaCl residues in relation to hours, all prewetted NaCl tests.

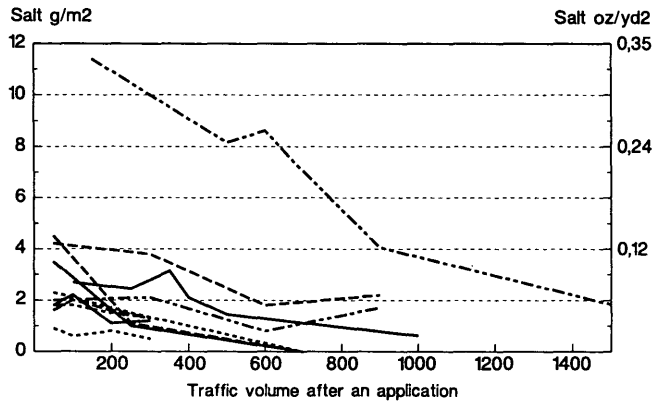

FIGURE 18 NaCl residues in relation to traffic volume, all prewetted NaCl tests.

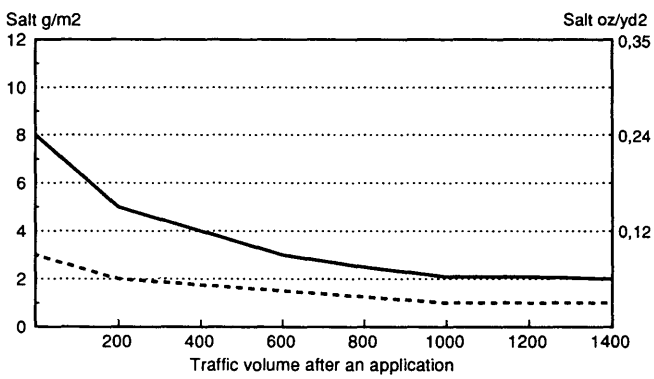

FIGURE 19 Estimated average salt residues in relation to traffic volume for moist but drying road surface.

Anti-icing can be done with brines and prewetted salts. There is practically no difference at all between liquid NaCl and $CaCl_2$ in decrease of residues. Even the small amounts of calcium chloride can keep the surfaces a little dark (moist) for 1 to 2 days.

It is not recommended to apply liquid salt during snowstorms. If done, the operations must be executed by plowing units. Second treatments follow during the next plowing cycles,

when needed. According to experiences, this method creates less slush. It is useful to apply salt at the beginning of a snowfall to prevent the snow from adhering to the surface.

Preventive actions for black ice can be done at least 6 hr before forecasted freezing. Changes in weather must be taken into account, especially precipitation. Anti-icing applications can be done with both spinner and spray bar spreaders. Frequent calibration of spreading equipment is necessary.

Both a good training program and motivated personnel are required to succeed.

REFERENCE

1. T. Raukola and K. Vaani. *Field Tests for Liquid and Prewetted Salt Application* (in Finnish). Report 1/1993. Finnish National Road Administration, Tampere, 1993.