Methods and Reasons for Cutting Use of Salt in Finland

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

Current standards in Finland require that all roads with average daily traffic above 6,000 be treated with salt through the winter. Sodium chloride is used in solid, prewetted, and liquid form, typically 120 000 t/winter. Calcium chloride is used as prewetter or in liquid form; annual quantities are less than 200 t. The application rates of salt vary from 5 to 40 g/m^2. The main argument against road salt has been the proven or suspected effects on groundwater resources, partly because of the glacial origin of Finland's soil. Thus, the pressure to minimize or even stop the use of salt has increased. One example shows that after an area of groundwater was contaminated, it took about 30 years for the soil to return to normal. The new strategy for reducing salt use is to use only prewetted salt and liquid salt whenever sensible. Low-volume roads are no longer treated. Accurate and fast snow clearing is one of the basic issues: dual-blade plows and hydraulically extendable plows have been developed for better snow and slush removal.

Finland is situated in Europe near Sweden, Norway, and the former Soviet Union (Figure 1). In terms of size, only a few European countries are larger than Finland. The distance between Helsinki and North Lapland is 1200 km. Of 5 million inhabitants, 60 percent live in urban areas, primarily in the south. The Finnish National Road Administration (FinnRA) is responsible for a road system of 76 000 km. The country is divided into 13 road districts, each of which is divided into 152 subareas (or road master areas).

CLIMATE

The average annual temperature is about 5.2°C in the southern region (the maritime climate of Helsinki) and about −1.0°C in the north. The thermal winter lasts between 125 and 200 days, and annual precipitation is 400 to 600 mm. The average annual snowfall is about 35 percent of the total precipitation. The greatest snow depth of the winter in forests is 450 mm in Helsinki and 800 mm in Lapland.

The last three winters have been very mild. In Helsinki the long-term average temperature in February is −5.5°C, but this year it was nearly 0°C. This type of weather necessitates much deicing and snowplowing (Figure 2).

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

TERMS

Some terms to be used in the paper are defined:

- Esker: an elongated ridge of rounded stratified fluvioglacial deposits consisting primarily of sands and gravel with some finer and coarser materials. Some are only tens of meters long, but others extend for hundreds of kilometers.
- Aquifer: water-saturated horizon that has sufficient porosity and permeability to yield economic supplies of groundwater; consistent groundwater area.
- Curative: a treatment before ice formation or snow accumulation.
- Preventive: a treatment after ice formation or snow buildup.
- Prewetting spreader: a type of a spreader that facilitates the wetting of granular salt.

DEICING METHODS IN FINLAND

In Finland the roads are classified for winter maintenance operations. Classes I and I Super are chemically treated throughout the winter (*1*) (Table 1). Sodium chloride (NaCl rock salt) is used in solid, prewetted, and liquid form, typically 120 000 t/winter (7 to 10 t/two-lane-km) (Figure 3). Calcium chloride ($CaCl_2$) is used as prewetter or in liquid form (32 percent); annual quantities are less than 200 t. The application rates vary from a preventive 5 g/m^2 to a curative 40 g/m^2.

The roads in Maintenance Class II or lower are treated with a sand-salt mixture of 25 kg for one cubic meter of sand (approximately 1:50). The sand application rate is about 300 g/m^2.

RISK LEVELS OF CHLORIDES

Different organizations have set up limits for chloride content in drinking water (*2*). The waterworks' standard maximum level of chloride content in drinking water in Finland is 100 mg/L if the works provide water for more than 200 consumers. The optimum level is below 25 mg/L. No recommendations for sodium content in water have been set.

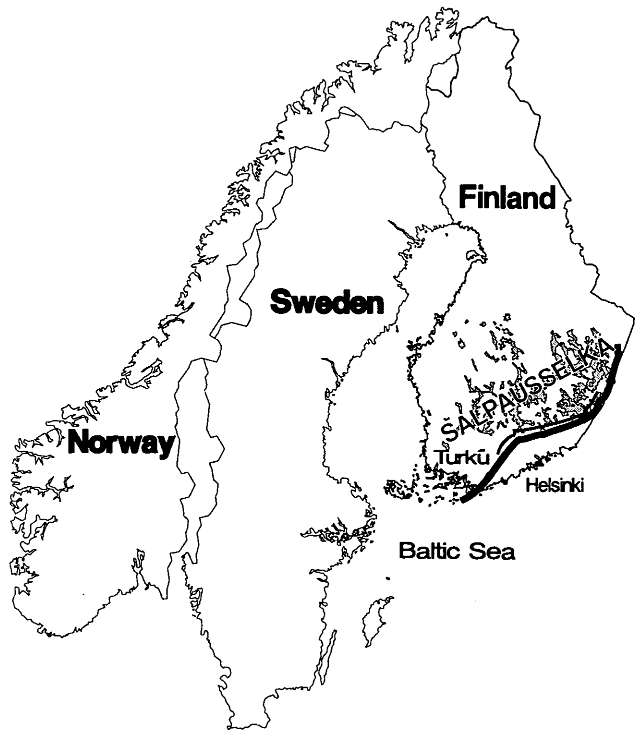

FIGURE 1 Finland and its Scandinavian neighbors.

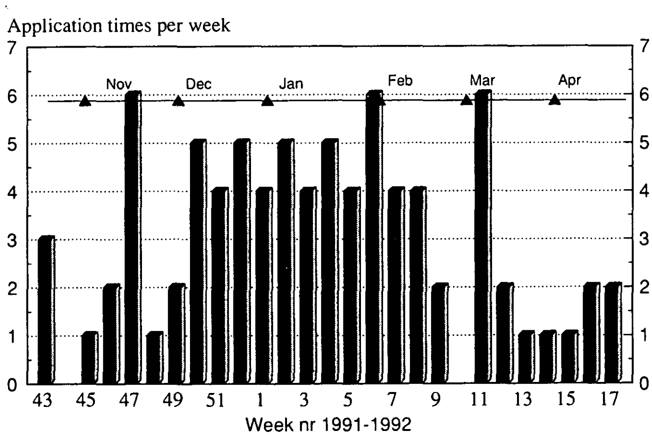

FIGURE 2 Deicing application on Highway 8 (Raisio district near Turku seacoast, 15 km from Gulf of Bothnia.)

TABLE 1 Winter Maintenance Classification

Category	Traffic Volume
I Super Divided	Freeways
I Super	ADT > 6000
I	ADT 1500 - 6000
II	ADT 200 - 1500
III	ADT < 200
IV	Pedestrian and Bicycle Paths

ADT = average daily traffic

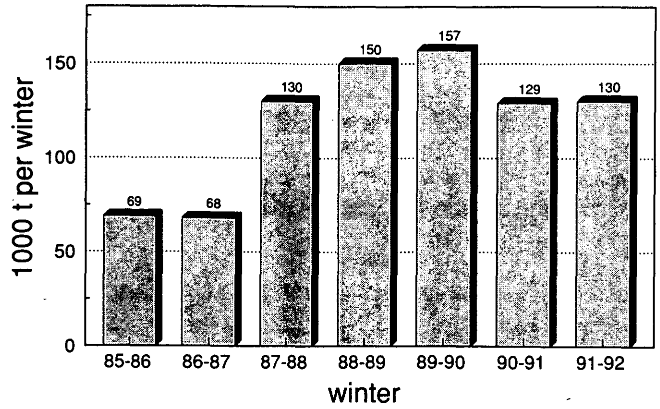

FIGURE 3 Usage of deicing salts in Finland, 1985–1992, for about 10,200 two-lane-km at application rate of 10 to 15 t/two-lane-km.

ENVIRONMENTAL EFFECTS OF SALTING

Effects on Plants

In Finland the results of the analyses show only a limited effect to plants from road salting. The sensitivity of trees is highly dependent on the species. The main problem is the salt spray from melted snow or ice. The most common trees—such as pine, spruce, and birch—are relatively resistant to the effects of road salt. However, local discoloration problems with young pine trees growing very close to the road have been found. The salt spray seems to decrease their tolerance to cold and disease (*3*).

Effects on Groundwater Resources

In the mass media the main argument against road salt has been the proven or suspected effects on the groundwater resources. Part of the problem is the glacial origin of Finland's soil. The Salpausselkä Ridge comprises nearly 400 km of virtually continuous esker (Figure 1). Building roads on the top of a gravel-filled ridge used to be cheap and easy; for this reason old highways have been built over the ridge. The huge banks of gravel and sand are also a very important groundwater formation area. Unfortunately, the contamination sources—in this case, traffic and maintenance—are in the worst possible place.

A recent study for FinnRA examined road salting on the Salpausselkä Ridge because it contains Finland's most important groundwater reserves (*4*). There are more than 80 municipal waterworks (each waterworks serves more than 200 inhabitants) as well as many private wells and small waterworks along the ridge. Nearly 1 million Finns (a fifth of all inhabitants) receive their drinking and domestic water from the Salpausselkä aquifers.

The study examined the salt concentration variations at 27 waterworks. In most cases it could be shown that the salt concentration in the groundwater had clearly increased because of the use of road salt. The Salpausselkä Ridge comprises many small aquifers, the geohydrological conditions of which differ. Thus, the salt content in the groundwater can vary regionally as well as locally.

The chloride concentrations vary significantly in the aquifers along the Salpausselkä, although the road salt loading had been consistent on the highway. As the risk of the future groundwater contamination caused by salting is estimated, the subjects should be examined separately. No single recommendation for road salt use can be supplied on the basis of this paper.

Most waterworks are located in large aquifers. In such cases, salt dilutes effectively. Because of this dilution, the changes in the quality of the aquifer water caused by salting are delayed, or they cannot be observed at all in areas where long-term sampling or a sufficient yearly sampling schedule for chloride analysis has not been arranged.

If the aquifer becomes salinated slowly, the purification is even slower. Measurements have been carried out since 1933 for the Kaaringo waterworks near the town of Turku (Figure 4). It became salinated from 1960 to 1966; the amount of chloride rose from 20 to 65 mg/L. Here, road salt may not be the only cause, because extensive deicing did not start until 1966.

There are two other possible sources of contamination: industrial waste waters and "natural" salt soil layers of sea origin, which make the determination of a normal chloride level difficult. In the northern part of Finland are groundwaters with chloride levels of only 2 to 5 mg/L. Some esker origin waters have values of 15 to 20 mg/L, and near the west coast of Finland, groundwaters contain a natural chloride level of up to 200 mg/L.

A protective silt-clay layer was built in 1969 mainly to prevent oil damage. It also stopped saltwater penetration. However, it will take about 30 years for the soil to return to normal. In the large aquifers of the Salpausselkä, it would take notably longer for salinated groundwater to become pure again.

There are 4100 km of public roads in the Kymi district, near the Salpausselkä. The total winter maintenance costs are $6.3 million. Ice control costs in the main network (720 two-lane-km, salt deicing) are $1.6 million. Substantial payments were first made in 1991 for the contamination of wells. Most of the wells supply water to only one or two houses. The costs for new wells or for providing an alternative water supply were $500,000, and these costs were probably at about the same level in 1992. Compared with ice control costs, this bill is high. Figure 5 shows the salt content in relation to the distance from the road; the numbers come from 72 waterworks in the Häme district. Correlation between the distance of the road and chloride concentration is not very strong.

STRATEGY FOR REDUCING SALT USE

Today it is impossible to do without the application of salt on the high-capacity roads. No other deicer can be used on a larger scale for road maintenance. However, there are several possibilities for reducing the problems caused by salt. FinnRA's present strategy is as follows:

1. Because traffic flow improves the effect of salt, less salt will be applied to high-volume roads and none to roads under ADT 2,000 (except in fall and spring).
2. Large quantities of salt are needed for melting snow and ice, so rapid and efficient snowplowing is needed and routine

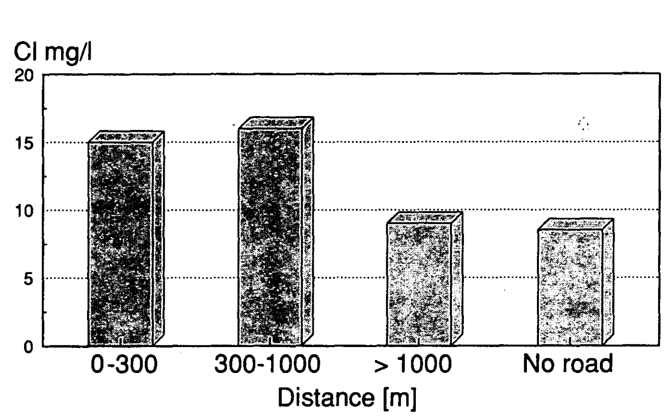

FIGURE 5 Average chloride concentration by distance of Class I highway; "no road" means nearest road is more than 10 km from waterworks.

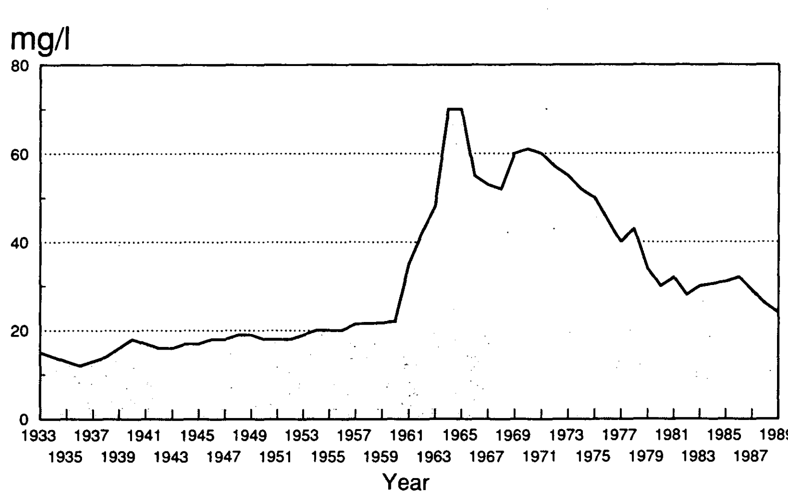

FIGURE 4 Chloride concentration in groundwater at Kaaringo waterworks.

salting is not necessary during snowfalls if the snow does not pack onto the road surface (temperatures under −3°C).

3. To minimize the loss of salt, prewetting salt will be the standard method, and for temperatures down to −3°C and for anti-icing, the liquid salt method will be used.

4. As for equipment, road speed–related control and frequent calibration are needed; the same equipment should not be used for salt and sand because calibration is almost impossible.

5. A standardized method of reporting is needed, and differences between districts must be followed and analyzed.

6. Motivation and training: human activities are important.

The winter maintenance policy for the coming years permits chemical deicing but only in certain cases: to prevent the formation of black ice, to keep snow from becoming compacted, and to maintain a slushy consistency to make snowplowing easier. Roads are cleared and dried by salting away a thin layer of snow and slush.

In Finland effective techniques have been introduced that make it possible to improve greatly the speed and quality of work. A greater removal speed will reduce the possibility of snow's becoming compacted. A typical investment period is 1 to 2 years.

The road-weather information systems give more time and opportunities to optimize the procedures. In temperatures below −6°C, no salting is carried out because the quantities of chemicals needed are not in line with the safety code. Drivers should also take care and pay attention to their own safety.

A relatively good safety benefit is gained by new slush plows. The amount of salt needed to convert snow to dry slush is about half of that required to make snow totally wet.

The use of wet or brine salt as a standard method supported by plants that produce a heavy volume of brine (30 to 40 m^3/H) reduces by up to 30 to 50 percent the amount of salt per treatment compared with dry salt. Yet rapid snow and slush removal helps to cut down the amount of deicers even more as there will not be so much snow to be melted away. During the last 3 years the number of prewetting spreaders has grown from 50 to 125 and liquid spreaders, from 2 to 125.

Liquid salt is one of the keywords when reducing salt use in Finland. From FinnRA's experiences, the advantages of liquid salt are

- Very rapid reaction time (only minutes),
- Greater spreading speed (up to 70 km/hr),
- First good method for preventive treatment during fall and spring,
- Possibility of operating over longer distances because of even distribution when using very small quantities, and
- Application rates are 75 to 50 percent less than with granular salt, because of accuracy.

But there are drawbacks:

- Because of refreezing, the temperature of the road surface may not be below −3°C;
- The critical snow depth is 10 to 20 mm at −1°C;
- If the total amount of water is low, temperatures under −3°C are possible, but the correlation between these must be thoroughly understood;
- Two types of equipment, brine mixing plant and storage facilities, may double deicing costs; and
- Total saving in tons is less than 20 percent if most snowfalls occur in temperatures below −1 to −5°C, in which granular salt is needed.

In southern Finland during the 1990–1991 and 1991–1992 winters, nearly 75 percent of all application times were in the possible liquid salt operational temperature from the Raisio district (Figure 2).

REFERENCES

1. M. Teppo. Highway Winter Maintenance and Cost Efficiency. Presented at the Third International Symposium on Snow and Ice Removal Technology, TRB, National Research Council, 1992.
2. *Curtailing Usage of Deicing Agents in Winter Maintenance.* Road Transport Research, Organization for Economic Cooperation and Development, Paris, France, 1989.
3. *Effect of Salt Application on Road Side Plants* (in Finnish). Report 4/1991 TIEL 3200004. Finnish National Road Administration, 1991.
4. J. Soveri, A. de Coster, and J. Vesterinen. *Effect of Salt Application on Ground Waters in Salpausselkä Esker Area* (in Finnish). Report 21/1991 TIEL 3200020. Finnish National Road Administration, 1991.