MINIMISING SALT CONSUMPTION ON GROUND WATER AREAS IN THE UUSIMAA REGION OF FINLAND

Seppo Mäkinen ja Tapani Angervuori

Finnish Road Administration (Finnra), Uusimaa Region
Opastinsilta 12 A, P.O.Box 70, FIN-00521 Helsinki, Finland
TEL. +358 204222959/FAX. +358 204222709

1. Abstract

Located on the southern coast of Finland, the Uusimaa road district started to reduce the amount of salt applied to roads to prevent slippery conditions on roads located in areas with ridges. The latter are sand and gravel formations that are highly permeable to water. The combined length of the roads selected for the salt reduction experiment during the first winter was 162 km.

The purpose of the experiment was to determine what the chances are of reducing the application of salt as a means to combating slippery conditions. Simultaneously, the surface friction requirement for the roads was decreased from 0.30 to 0.25. The aim is to prevent a rise in the chlorine concentration of groundwater. Natural chlorine levels in Finland in typical groundwater area formations are less then 10 mg/l. On the roads used for the experiment, the effects of reduced salt application on groundwaters have been studied by measuring the chlorine concentrations over a five-year period. There are a total of 52 water pumping stations which have to be monitored. During the first year of the experiment, the chlorine concentration in the groundwater has decreased by an average of 1.26 mgt/l.

On the roads used for the experiment the amount of salt applied is reduced by approximately 40 % compared to the average over the previous winters. An average of 5.8 tons of salt per road kilometre is being applied. No changes at all are discernible in the number of accidents compared to the years used as the control years for the experiment. Changes in speeds are extremely slight. In conjunction with the experiment, feedback was gathered from the road users using the roads featured in the experiment. There is nothing that could directly be linked to the experiment in this feedback. The opinions of road users were also surveyed using a questionnaire in March 2001. The majority felt that the amount of salt ought to be reduced. Some corresponding motorway roads were included in the experiment during the 2000-2001 winter.

2. Introduction

Finland is situated on either side of the Arctic Circle, its surface area being 93% of that of Japan, but its population equivalent to only 4% of Japan's. There are a total of 78,000 km of public roads. Finland's southern areas are located at a latitude of 60º North. The Uusimaa road district, which was involved in the present salt reduction experiment, is located on Finland's south coast. Within the Uusimaa road district there are 4,640 km of road under State care. Some 620 km of these roads are situated in groundwater areas that are important from the water supply standpoint. The combined length of the roads subjected to reduced salting in this experiment during the first winter was 162 km.

On Finland's south coast, winter begins in November and ends in April. The total amount of snow falling during the winter is equivalent to around 155 mm of water. Converted to snow, this is equivalent to a depth of 1.55 metres. On average there are 12 days on which a lot of snow falls. On such days, over the 24-hour period an average of 10-20 cm is received. Smaller snow showers occur

much more frequently. The winter temperature varies from a few degrees over zero to approximately 20 degrees Celsius below zero. Snow ploughing with the modern snow ploughing equipment does not generally cause any serious problems. Controlling slippery conditions, on the other hand, calls for continuous maintenance procedures. Every winter, it is necessary to send out the road maintenance equipment an average of 100 times in order to combat slipperiness. This is mainly controlled using salt and grit.

The Uusimaa road district, which is located on the south coast, started reducing the amount of salt applied on roads situated in important groundwater areas. The roads selected for the experiment lie in areas with ridges where there are sand and gravel formations highly permeable to water. The area features the Salpausselkä ridge, which was formed at the end of the latest Ice Age at the edge of the receding continental glacier some 11,000 years ago. This formation is extremely important geologically. The use of salt for controlling slippery conditions threatens to increase the concentration of chlorine in the groundwater and to cause a serious environmental problem.

Figure 1. One Of The Roads Featured In The Experiment Runs Across A Forested Gravel Ridge.

The Uusimaa road district began the experiment on reducing salting for controlling slipperiness in the 1999 autumn. A reduced amount of salt is applied in particular when freezing weather is growing warmer, causing a thin layer of ice (frosting) to form on the road surface and a slight increase in slipperiness. The use of salt for preventing slipperiness following a snow storm is also being reduced in the experiment.

Slippery conditions resulting from a damp, warm road freezing are, however, being controlled on the roads in the experiment by normal salting. Similarly, slipperiness due to supercooled rain is being managed by applying salt in the normal way.

On the roads chosen for the experiment the new maintenance practices were assessed as reducing the use of salt by 20-30 % compared to previous salting. According to the normal salting practice, 7.5 - 10 tons more salt per road kilometre is used on roads equivalent to those included in the experiment.

The purpose of this experiment was to determine what the chances are of reducing salting for preventing slippery conditions, as well as how the reduced use of salt affects the chlorine concentration of groundwater, road safety, the speed adopted by traffic, and feedback from road users. In addition, the changes required in other control of slippery conditions when making reductions in the amount of salt were studied.

3. General Guidelines For Winter Road Management In Finland

According to the general requirements set for winter maintenance, the freezing of wet road surfaces is also prevented by pre-salting before and after the actual winter period (11.12-15.3) in surface frosting and road conditions where there is no precipitation. For this purpose, soluble salt is used, as on other roads.

The tables below give the general requirements for preventing slippery conditions

Table 1. Quality Requirements For Controlling Slippery Conditions In Finland.

QUALITY REQUIREMENTS FOR CONTROLLING SLIPPERY CONDITIONS							
Winter care category	**Is**	**I**	**Ib**	**II**	**III**	**K1**	**K2**
Normal	**0.30**	**0.28**	**0.25**	**According to traffic require-ment**	**According to traffic require-ment**	**According to traffic require-ment**	
Friction requirement	road surface under -6ºC **0.25**	road surface under -4ºC **0.25**	point gritting **0.25** route applica-**tion 0.20-0.22**				
At night	22.00 hrs 05.00 hrs **0.28**	22.00 hrs 05.00 hrs **0.25**	22.00 hrs 05.00 hrs as required	22.00 hrs 06 as required	22.00 hrs 06 as required	after 2200 hrs K1 05.00 hrs K2 by 06.00 hrs	
From start of procedure	**2 h**	**2 h**	salt **3 h** grit **4 h**	**6 h** route gritting	**10 h** route gritting	**2 h**	

Table 2. Reciprocity Of Friction Value And Road Condition

Friction value	**0.00 - 0.14**	**0.15 - 0.19**	**0.20 - 0.24**	**0.25 - 0.29**	**0.30 - 0.44**	**0.45 - 1.00**
Description of road surface	dangerous conditions, i.e. wet ice, extremely slippery	icy, slippery	compacted snow and ice **satisfact-ory winter conditions**	coarse compacted ice and snow **good winter conditions**	bare and wet **good friction**	bare and dry **good conditions**

4. Existing Guidelines For Controlling Slippery Conditions On The Roads In The Experiment

Salting should be reduced on roads in groundwater areas.

For the salt reduction experiment a lower friction requirement (0.25) than normal (0.30) is accepted. Skidding is effectively eliminated below a friction level of 0.25. Friction values of less than 0.20 are not acceptable.

In addition to the daily weather and road condition forecasts serving the needs of road maintenance, 2-3 day forecasts are prepared. It is particularly important to take temperature changes into account when the weather is growing warmer after a bout of frost. Also, as the temperature continues to fall, it is important to contact road maintenance teams to give them time to eliminate any packed snow before the road surface becomes colder.

The correct timing of salting is extremely important. An attempt should be made to carry out salting before traffic uses the road, so that a good result is obtained even with a small amount of salt.

In autumn and spring, problems arising due to black ice should be resolved using soluble salt by precisely predicting the weather conditions. Road condition forecasts in this kind of situation are in a key position. The amount of salt used for dealing with black ice per application should be only 2-5 gr/ sq.m.

When frost forms on the road surface, the friction values must be carefully followed. No salting is carried out unless the situation looks as though the friction value is going to drop below 0.25. In this kind of situation, there is a real risk of road junctions becoming slick. Road junctions should be maintained on an individual basis, by either salting or grit application. Slippery conditions should only be dealt with where a definite need exists.

When a snowstorm is expected, the roadway should be salted, if necessary, in advance by spreading approximately 10 gr/sq.m of salt along it. Snow should be removed as it falls and afterwards mechanically as completely as possible. If snow becomes attached to the roadway, it should be removed by a lorry chassis snow plough equipped with a toothed blade. This ensures that the packed snow is kept as thin as possible, i.e. 2 cm thick at maximum. To prevent road junctions from becoming slick, salt may be used even while it is snowing. Otherwise there should be no salting in conjunction with snow ploughing.

After a snow storm, the roadway should be carefully cleaned of snow mechanically. The road can be salted, if required, using a small amount of salt to produce the required quality. Small accumulations of packed snow and ice come free partly as a result of traffic and the rest should be removed mechanically either with a lorry chassis snow plough or with a road grader. Slush removal should be carried out in the normal way within the required time.

During a frosty spell, road junctions should be managed by gritting. In awkward situations, small amounts of CaCl2 solution can be used. The aim is for a maximum of 5 t of salt to be applied per road kilometre.

5. Monitoring The Salt Concentration Of Groundwaters

As the aim of the experiment is to prevent a rise in the concentration of chlorine in groundwater, groundwater quality monitoring is one of the main tasks of the experiment.

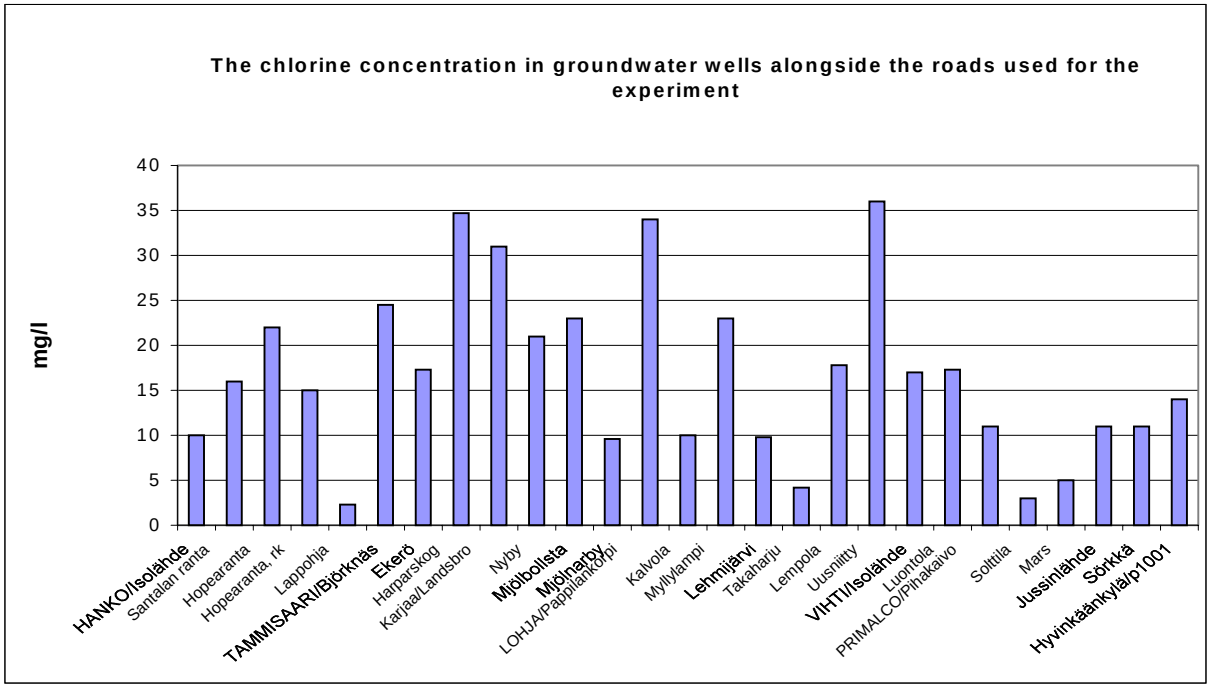

Figure 2. Fluctuations In The Chlorine Concentration In Groundwater Wells Alongside The Roads Used For The Experiment

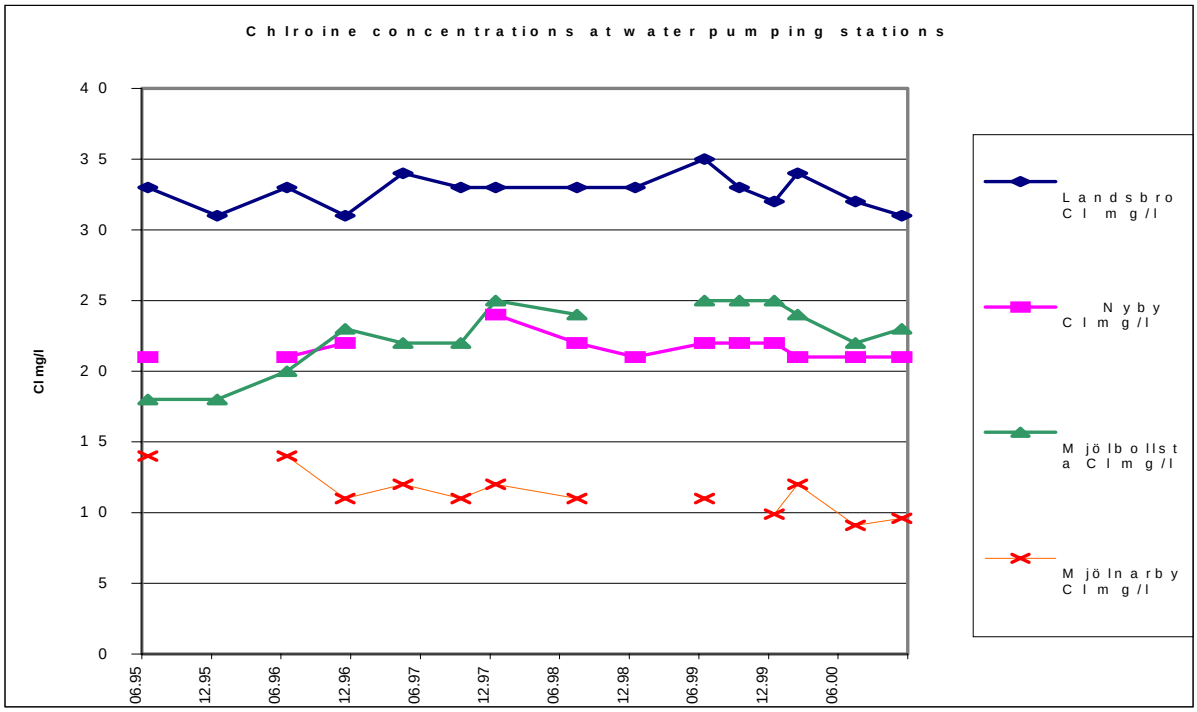

Figure 3. Trends In Chlorine Concentration In Four Groundwater Pumping Plants Over A Five-Year Period

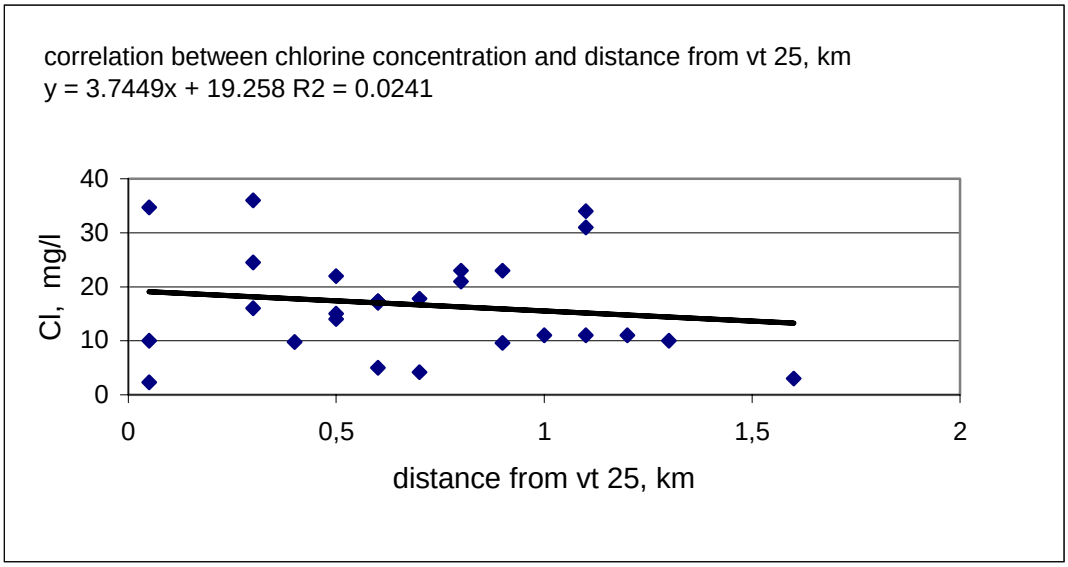

Figure 4. The Chlorine Concentration Decreases Somewhat In Proportion To The Distance From The Road

Sodium chloride (NaCl) is readily soluble and 338 g of this salt will dissolve in one litre of water. In an aqueous solution, sodium is in the form Na^+ and chlorine in the form cl^-. Chlorine percolates along with the groundwater flow below the groundwater table. The water pumping plants are located in extremely permeable sand and gravel formations. The flow rate of groundwater in ridge formations has been shown to be in the region of 0.5-100 m/day.

Limit Of Chlorine Concentration In Household Water

A limit has been placed on the chlorine concentration of household water for technical-aesthetic reasons. In Finland, the limit set by the Road Administration for chlorine is 100 mg/l. Should this level be exceeded, compensation has to be paid to the consumers of the water. If the chlorine concentration exceeds 25 mg/l, a study is undertaken to determine whether road salting is affecting the chlorine concentration of the groundwater. The limit set by the World Health Organisation (WHO) is 250 mg/l, this value having been set on the basis of taste. The high level set by WHO is most likely a consequence of the groundwater in many hot countries being appreciably salty. Concentrations of over 250 mg/l make household water rather unpalatable. Natural chlorine concentrations in Finland in the formations typical to groundwater areas generally fall below 10 mg/l.

Corrosion

One hazard of increased chlorine concentration is the corrosion caused by this. Corrosion can be reduced by treating the water at the groundwater pumping plant before it is fed into the water supply. A high temperature increases the rate of corrosion, for which reason the copper piping generally used for hot water is more sensitive to corrosion than cold water pipes. There are always salts present in groundwater, so that this conducts electricity. Chemical and electrochemical corrosion takes place in metal objects immersed in groundwater. In addition to chlorides, many other substances, including sulphates, iron, manganese, calcium, nitrates, carbonic acids, and so on, are dissolved in groundwater.

6. Monitoring The Effect Of Reduced Salting

A start was made on monitoring the effect of reduced salting on the roads in the experiment by gathering data on the location of water pumping plants in connection with these roads, and by studying the chlorine concentration of the groundwater for a period of around five years before the commencement of the salting reduction experiment. There are 52 water pumping plants to be monitored, 27 of them located alongside the roads used for the experiment. Chlorine concentration data has been obtained up to the end of 2000, so that it is possible to draw some initial conslusions on the efefcts of reduced salt application on groundwaters.

During the first year of the experiment the changes in chlorine concentration were only slight. As a control, the end of 1999 and end of 2000 have been used. On average, the groundwater chlorine concentration has fallen by 1.26 mg/l. The chlorine concentration decreased at 20 water pumping plants, remained unchanged at 12, and rose at 20. Where the chlorine concentration decreased, the change ranged between 1-36 mg/l, with an average of 5.9 mg/l. Those places in which the change varied between 0-0.7 mg/l have been regarded as unchanged. In places where the chlorine concentration rose the range was between 1-9 mg/l, with an average increase of 2.6 mg/l.

7. Changes In Road Care

During the period of the experiment in the 1999-2000 and 2000-2001 winters all the road maintenance procedures carried out on the roads in the experiment were recorded and the use of salt monitored.

On the roads in the experiment it was possible to reduce the use of salt by 40% compared to the average use in previous winters. On these roads an average of 5.5. tons per road kilometre were used. Previously 10 tons/ road km have been used on these roads.

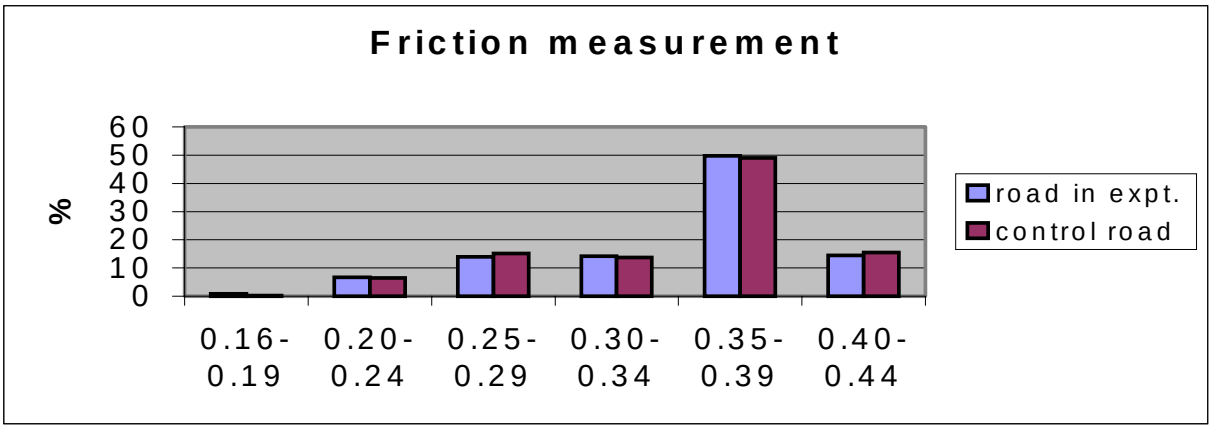

Figure 5. Friction Values Measured At The Road Surface In Winter On The Roads In The Experiment And On The Control Roads

The costs of winter maintenance in total have not decreased on the roads in the experiment because it has been necessary to control slipperiness in other ways in proportion to the decrease in salting. The real benefit is obtained from the groundwater salt concentration over the long term remaining at a lower level compared to a continuation of previous maintenance practices.

Table 3. Maintenance Work And The Use Of Salt On A Road Used For The Experiment In The 1999-2000 Winter

WINTER ROAD MAINTENANCE 1999-2000
Length of road in expt. 138.3 km

month	salt t/km/month	applic. date	no. of applications	mainten. days other roads
October	0.1	3	3	3
November	0.5	21	23	21
December	2.3	27	33	26
January	1.0	23	30	24
February	1.2	24	28	26
March	0.6	15	15	15
April	0.6	2	2	1
	t/km/winter	total number of times		
	5.3	114	133	116

use of salt on other roads t/km	
IS-tiet	8.2
I-tiet	7.9
IB-tiet	5.0

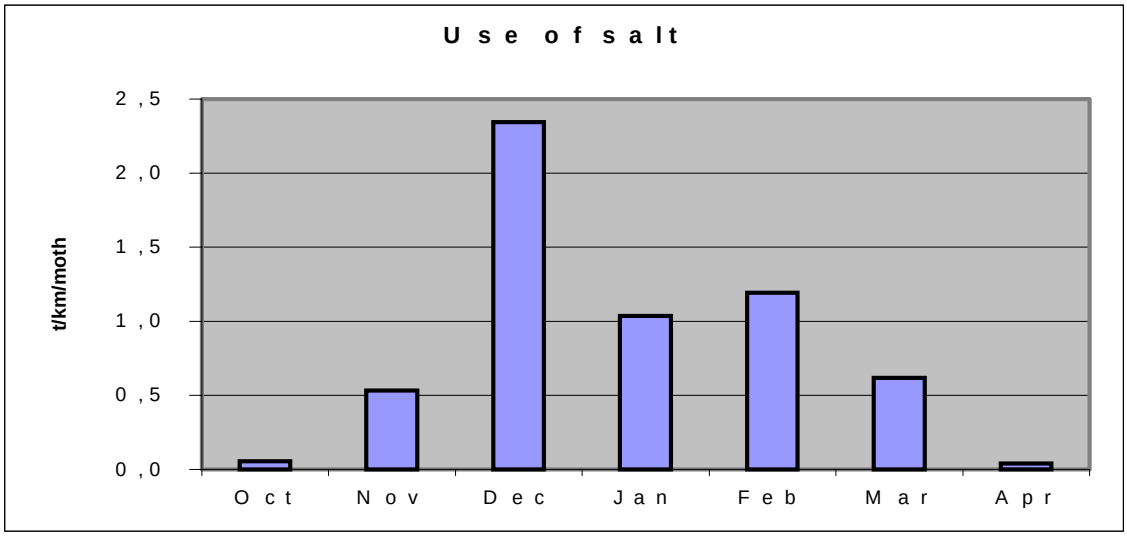

Figure 6. Monthly Use Of Salt On The Roads Used For The Experiment

8. Accidents

When maintenance procedures for roads are changed it is important to monitor the trends in road safety. In conjunction with the present experiment, accidents occurring in winter road conditions were studied over five winters from 1996-1997 to 1999-2000. In this connection, “accidents under winter conditions” means accidents in association with which the road surface has been icy, snow covered or slushy. The total number of accidents under winter road conditions were counted from the beginning of October to the end of April. When the accidents occurring in the 1999-2000 winter period are examined, it can be observed that there were 14 such accidents, which is exactly the same level as in the 1996-97 and 1997-98 winters. By contrast, 25 accidents occurred during the 1998-99 winter, which is a markedly higher number than in other winters, even though the traditional maintenance

practice was used at that time. This large number of winter accidents was due to exceptional weather conditions.

On the roads used for the experiment, beginning with 1995 there have been 2.5 accidents a year resulting in deaths. During the 1999-2000 winter there were two accidents resulting in death. The first of these occurred on 3.11.1999 in conditions in which the grooves in the road surface worn by winter tyres were full of water. It was a pedestrian accident. The other accident took place on 10.12.1999. This was a turning accident under conditions in which the road was bare and dry. Neither of these two accidents occurred in conditions in which winter road maintenance could possibly have affected the quality of the road surface, because when they occurred there was neither snow nor ice on the road surface.

Road users were warned about the change in the practice of controlling slippery conditions by means of a sign at general public road junctions along the roads used for the experiment, as shown in Figure 7. This is assumed to have been influential in keeping the number of accidents down to the previous level.

Figure 7. Road Users Were Warned Of Slippery Conditions By Means Of Road Signs.

9. Changes In The Average Speed Of Traffic

On the roads used for the experiment there are three points at which the speed of traffic is continuously recorded. Over the 1999-2000 winter period the monthly average speeds of the traffic have been compared with those of previous years. Changes in speed are extremely small. The lowest average speed for any one month was 82.9 km/h, the highest average speed being 95.5 km/h. On average, the average speeds during the 1999-2000 winter have decreased by only 0.1 km/h. The change is insignificant when one takes into account that changes of less than 0.5 km/h fall below the measuring accuracy of the equipment used for recording speeds. One can thus state that the speeds adopted by traffic have not changed during the experiment.

Table 4. Road Accidents Occurring In Winter Road Conditions Over The Past Four Years

Road accidents in winter conditions on the road in the experimet

month	96-97	97-98	98-99	99-00
Oct	0	0	0	0
Nov	1	2	5	1
Dec	6	8	5	6
Jan	2	3	11	3
Feb	2	1	3	2
Mar	1	0	0	2
Apr	1	0	1	0
Total	13	14	25	14

10. Feedback From Road Users And Imparting Of Information

During the reduced salting experiment road users have been informed by supplying the media with information about the experiment.

In conjunction with the experiment, feedback from motorists was gathered. The information received contained nothing at all directly connected with the experiment. It can thus be concluded that the salt reduction experiment carried out in the 1999-2000 winter period caused neither a negative nor a positive reaction among the road users, at least to the extent that somebody or other would have bothered to provide feedback.

There was a second questionnaire in March 2000. This was directed at those road users who use those roads that are parallel to motorways and on which salting had been reduced in the 2000-2001 winter. The purpose of this questionnaire was to discern whether people were aware that salting had been reduced on these roads, and what their opinions were on the matter.

Almost all the respondents had been driving either passenger cars or vans. The use of salt was widely criticised. Approximately one driver out of three expressed the hope that salting would cease completely. Around 30% of the respondents did not want little used roads to be salted at all. Most of them felt that salting should be reduced.

11. Final Conclusions

The reduction in salting experiment produced some encouraging results in the 1999-2000 winter period.

During the first year of the experiment the chlorine concentration of groundwater has decreased on average by 1.36 mg/l.

It proved possible to reduce the amount of salt by about 40% compared to the average for the previous winters. An average of 5.8 tons of salt was used per road kilometre. Other control of slippery conditions has had to be resorted to in order to compensate.

No change is detectable in the number of accidents compared to the control years. Changes in the speed of traffic have been extremely slight.

In connection with the experiment feedback was requested from road users using the roads in the experiment. In the feedback there was nothing that could be directly linked to the experiment. Road

users' opinions were also sought through a questionnaire. Most of the road users were of the opinion that salting ought to be reduced.

A decision has been taken to continue and expand the experiment. During the 2000-2001 winter period certain roads parallel to motorways were incorporated in the experiment. This experiment is aimed at offering motorists an opportunity to use roads on which less salt than normal has been used. Groundwater quality monitoring, the monitoring of road safety, traffic speed monitoring, and the gathering of feedback from motorists will also continue; opinions will also be sought and changes in road maintenance will be determined.

This experiment also constitutes a learning process for those personnel using salt; salt does not need to be used in the quantities which they have grown accustomed to.