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ICE CONTROL WITH BRINE SPREAD WITH NOZZLES ON HIGHWAYS IMPLEMENTATION OF BRINE SPREADING TECHNOLOGIES IN DENMARK

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ABSTRACT

During the years 1996-2006, the former county of Funen, Denmark, gradually replaced pre-wetted salt with brine spread with nozzles as anti-icing agent in all her ice control activities. The replacement related to 1000 kilometres of highways. Jeopardizing neither road safety nor traffic flow the spreading rate of pure sodium chloride (and thus the environmental impact) compared to neighbouring counties was less than fifty percent per square meter.

Successful pre-salting is, of course, dependent on reliable weather forecasts and on staff well trained in the art of interpreting this information. The improvements gained by the county of Funen were mainly due to the use of technologies (brine spreading with nozzles) giving a more precise spread pattern than the traditional gritting of pre-wetted salt.

The spread pattern for every spreader, tested in The County of Funen, has been measured 3 hours after spreading on a highway with traffic. A total of 800 spots were measured for residual salt for every spreader. The measurements and the spread pattern for brine spreading with nozzles were so precise, that we learned: “When there is moisture, water or ice on the road, we need to take into account that the salt will run from the high level of the road to the lower level”. In the test the salt moved 1 meter in 3 hours.

The knowledge gained from the measurements in the county of Funen - brine spread with nozzles, spreading salt to high levels of the road and using GPS controlled spreading – was implemented on the major roads (150 km) in the municipality of North Funen from the winter 2007/8. The result has been a dramatic reduction in the number of traffic accidents on slippery roads during the winter season: From 7 and 5 accidents in the previous 2 winters to 1 accident in the winter 2007/8. Neighbouring municipalities had an increasing number of traffic accidents on slippery roads in the same period.

KEYWORDS

BRINE / ICE CONTROL / SPREADERS / SPREADING / HIGHWAYS / DENMARK

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1. INTRODUCTION

1.1 The challenge – a waste of salt

Winters in Denmark are chill. Temperatures oscillate near the freezing point causing risk of slippery roads. Slipperiness disturbs the traffic. Road safety is strained, and the flow of the traffic is delayed. This is why highway authorities put ice control as an important objective of their winter maintenance. Dominating the ice control technology is the spreading of salt on the road surface. Salt can prevent ice to bond to the road surface.

However, salt spread for ice control also contributes to the impact on environment. The salt does not remain on the road surface. Traffic, amongst others, will spread the salt to the roads surroundings. Here it influences upon biotopes. If it penetrates into the soil, the salt becomes a threat to ground water resources.

The total amount of salt used for ice control varies of course from one winter to another. Consumption depends on how wintry the winter turns out and on the number of salting-turnouts called upon by the weather. Consume also depends on how many roads are treated with salt – the quota have increased over time.

Like in all other countries, Danish highway authorities have been most aware of the environmental impact from the use of salt. The spreading rates used in each spreading-operation have been diminished by taking advantage of the possibilities arising from better technologies and methods. The most successful step was the introduction of pre-salting (i.e. salt spreading carried out before slipperiness occurs in order to prevent snow and ice formation on the road surface). This step took place on the major road network in Denmark – the state and the county highways – in the middle of the 1980’s. Improved road weather information systems (RWIS) and better weather forecast combined with a more widely use of pre-wetted salt for ice control lead to this reformation. The methods are still being improved – especially has the incorporation of information technology in the RWIS given better basis for deciding whether to initiate salt spreading-operation on the highways.

Due to the pre-salting the environmental impacts have roughly spoken been a cutback on 2/3 of the dose of salt. Traditional post-spreading (i.e. salt spreading carried out after the road surface has become slippery) would typically call for a spreading rate of 40-50 grams pure, dry sodium chloride per square meter. Using pre-salting one can obtain the same result by spreading 10-15 grams pre-wetted sodium chloride per square meter.

In the late 1990’s Fyns Amts Vejvæsen (FAV) – i.e. the Highway and Transportation Division in the former County of Funen, Denmark – became aware that the use of pre-wetted salt had some disadvantages one might be able to avoid by spreading pure brine in stead. The major problem by using pre-wetted salt seemed to be that a great amount of the salt never came to effect on the road surface either because it was not distributed precisely or because traffic would ‘blow’ it away from the road before it came to work.

The challenge was how to reduce this waste of salt jeopardizing neither road safety nor traffic flow. The challenge could be met, if salt could be spread more accurately on the target surface of the road, or if one could make the salt stay longer on the road surface. To get these effects A) technologies had to be developed to meet the needs and B) these technologies had to be implemented.

1.2 Winter in Denmark

Denmark has a maritime climate. Winters are mild; summers are cool. In the period 1961-1990 annual the average temperature for the country was 7.5 ºC. During the winters, temperature is around the freezing point. The coldest months were January and February with an average temperature at -0.0 ºC. February was the month with less precipitation: 38 millimetres.

In average, the climate is the same all over the country. The annual average temperature at the west coast of Jutland differs as an example only by approximately 1 ºC from the temperature in the central parts of the peninsula.

One should notice that there are considerable differences from one winter to the next. This means that the number of turnouts for snow removal and ice control operations differs as well over the years. For instance, the winter 2005/06 had almost trice as many turnouts as the following winter, 2006/07.

Furthermore, weather conditions here and now can be quite different from one location to another, depending on the local topology and on the ruling meteorological factors. This means that the present climatic conditions determine when winter maintenance, e.g. pre-salting operations, are to be considered and that differences in the number of turnouts are established between various parts of the country depending on the direction from which the winter-weather hits Denmark.

2. SPREADING TECHNOLOGIES

2.1 Studies 1998-99 – Brine versus pre-wetted salt on highways

Studies carried out in the winter season 1998-99 by FAV and the Danish Road Directorate, proved brine to be an interesting ice-control agent compared to pre-wetted salt. During the winter, FAV treated two road stretches with a 20 % solution of sodium chloride (*NaCl*). Width of the road sections were 5.6-6.0 metre. Nozzles spread the brine, and the spread rate was 20 millilitres brine (4.6 grams pure *NaCl*) per square meter. FAV used a portable salinity tester, SOBO 20, to measure residual salt 2, 5 and 10 hours after spreading. The measurements took place in six points placed 0.5, 1.5 and 2.5 metres on each side of the road's centre line. FAV made similar measurements on two road stretches treated with pre-wetted salt but otherwise comparable. The pre-wetted salt was mixed of 70 % (weight) pure, dry *NaCl* and 30 % brine (20 % solution). Spread rates were 10 or 15 grams pre-wetted salt per square metre (analogous to 7.6 respectively 11.4 grams pure *NaCl*). Measurements were carried out in 1,800 spots. The conclusions of the study were [1]:

- SOBO 20 resistance measurements gives adequate information of the residual salt,
- When using brine, a significantly higher percentage of the salt spread is still present on the road surface 2-10 hours after spreading compared to the use of pre-wetted salt,
- 85-90 % of the brine and 60-65 % of the pre-wetted salt is remaining on the road surface 2 hours after spreading,
- On highways with AADT at 2,500-3,000 vehicles per lane, the residual salt decreases with the number of passing vehicles. A similar correlation was not found on highways with AADT at 500-1,000 vehicles per lane.

FAVs conclusion from the study was that it would be possible to reduce the consumption of salt considerably by using brine-spreading technologies – however the technologies available were still to be improved.

The solution of sodium chloride (*NaCl*) was later changed to 24 %.

By spreading 10 grams pre-wetted salt (7.7 grams pure *NaCl*) per square metre, one can expect to have 4.9 grams *NaCl* per square metre (64 %) on the road surface after 2 hours, while the remaining 2.8 grams are dispersed. By spreading 20 ml brine (23 grams) in a 24 % solution (5.5 grams pure *NaCl*) per square metre, one can expect to obtain 4.9 grams *NaCl* per square metre (88 %), while only 0.6 grams are dispersed. In other words, compared to the use of pre-wetted salt the environmental impact is reduced by 78 % (2.2 grams pr. square metre) of the *NaCl* dispersed within 2 hours (without affecting the ice control), or by 29 % of the total amount of *NaCl* spread. Of course, the result is only valid if one has chosen the spread rate correctly, and if the remaining 4.9 grams *NaCl* per square metre are uniformly spread on the road surface.

The study failed to prove whether brine would be feasible in all situations with snowfall. FAV continued the study in the winter seasons 1999-2001, but did not obtain any measurements in such snowfall-situations that were considered especially critical.

2.2 Studies 2000-02 – Brine versus pre-wetted salt on motorways

Consecutively FAV and the Danish Road Directorate carried out studies to compare the use of brine versus pre-wetted salt on the motorway crossing Funen (E20) (80 km). The northern lanes, leading from East to West, were treated with pre-wetted salt, while the southern lanes, leading from West to East, were treated with brine.

The study [2] showed that in hoar frost situations, the use of brine instead of pre-wetted salt enables salt savings of at least 30 %. In snow situations it was found that the motorways slow lane (with the heavy vehicles) needed lesser salt than the fast lane (with the light traffic). This finding was almost a result of serendipity: the spreader used to spread pre-wetted salt had by fault an imbalanced distribution pattern: More material to the left-hand side (i.e. to the fast lane closest to the centre strip) than to the right-hand side (i.e. the slow lane closest to the emergency lane). Combined with the impact of the traffic (heavy vehicles mainly in the right-hand lane) the imbalance could explain the observations.

Because of this result, it was decided to imbalance the dosage so the right-hand lane of the motorway got 40 % less *NaCl* (brine or pre-wetted salt) than the left-hand lane. However, while this seemed to be a solution on the motorways, FAV could not implement it on her ordinary highways with traffic in both directions. Instead, it became even more important to find spreaders that could ensure the desired uniform distribution of the salt.

2.3 Measurements 2004 – Spreading patterns

In 2004, FAV carried out measurements of the spreading pattern of all her models of spreaders. Individual test-schedules were planned for each model, each schedule consisting of 10 typical situations with variations in spreading width, velocity and dosage. In each situation, the residual salt was measured (SOBO 20) in five cross-sections with a distance of 2 metre, and in each cross-section measurements were taken every 0.5 meter. In total, approximately 7,500 measurements were made. Average and standard deviations were calculated, and the results were compared to the required distributions in the test-schedule, cf. Figure 1 showing results from three spreaders in comparable situations.

FAV reported the measurements in eight reports [3]-[10]. The overall conclusion was that the road authorities should explicitly express demands on the quality of the salt-distribution when asking for tenders for spreaders. The measuring-programme had provided FAV with experience and procedures to carry out control that such demands were fulfilled.

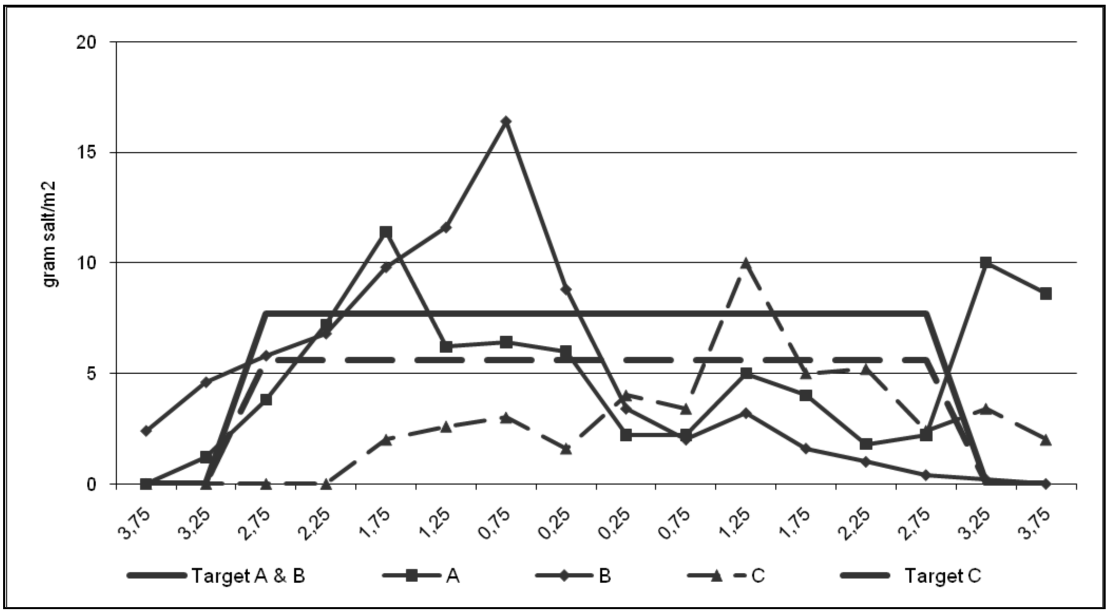

Figure 1. *Spreading pattern from three different spreaders: A, B and C, all spreading by using a rotating plate. Spreading width is 3 metres on each side of the road centre line, total 6 metres. Spreaders A and B are spreading 10 g pre-wetted salt (7.7 g* NaCl*) pr. m*^{2}*. Spreader C is spreading 10 ml brine and 3 g salt (5.6 g* NaCl*) pr. m*^{2}*. Note that spreaders A and B are rotating counter clockwise and overdose to the left, while spreader C rotates clockwise and is imbalanced to the right. Neither of the spreaders provide satisfactory spreading pattern. Based on reference [3], [4] and [5].*

Furthermore, the measured spreading patterns from, especially the most modern, nozzle-spreaders showed a better fit to the required uniform distribution than the pattern from spreading pre-wetted salt. FAV found that the measurements implied brine spreading with nozzles to be a promising technology with potential of further improvements towards providing the correct spreading pattern even at high velocities. Contrary to this, spreading of brine and of pre-wetted salt using rotating plates provides dubious spreading patterns and is not likely to offer improvements in the technology.

FAV had not planned the measurements in order to provide data for direct comparisons of the spreaders. This makes it somehow hard to establish objective parameters to express the spreading quality. Looking into the measurements of each of the 10 situations in the test-schedules for the spreaders, one can however calculate A) the percentage of salt measured outside the target-area of the surface, and B) the percentage of salt overdosed in the best-supplied lane, providing that the less supplied lane has received exactly the amount required. Both of these numbers represents waste of salt. For the 10 situations of each spreader, average and standard deviation can be calculated. Staff from the companies that had provided the equipment adjusted the spreaders before the measurements took place. Nevertheless, the average thus calculated may be explained by inaccurate adjustments. The standard deviation, on the other hand, must be interpreted as an expression of the individual spreader's ability to adjust to various settings of spreading width, velocity and dosage. Figure 2 shows that when using spreaders with two technologies (so-called combi-spreaders) one should expect far the largest deviations in the spreading pattern, i.e. less precision in the spreading. This observation confirms that one is, if possible, best off when settling with single-technology spreaders. Spreaders using nozzles seem to give slightly smaller deviations than those using rotating plates.

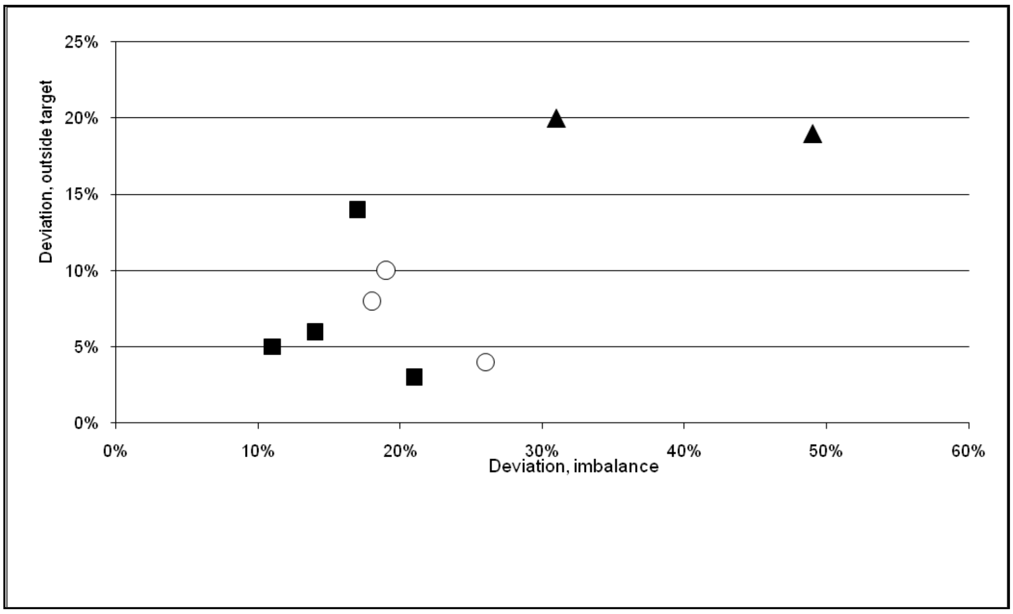

Figure 2. *Standard deviations of the percentage of wasted salt from nine series, each of ten sets of measurements of residual salt after spreading with spreaders using rotating plates ○ (pre-wetted salt or brine), with nozzles ■ (brine) or both ▲ (pre-wetted salt or brine). The X-axis shows the standard deviation of the waste of salt due to imbalance between left and right lane of the road, assuming the lane provided with less salt has received just the required amount. The Y-axis shows the standard deviation of wasted salt measured outside the target area of the road surface. Combi-spreaders (▲) using nozzles for brine spreading and a rotating plate for spreading pre-wetted salt tend to have the larger deviation in the percentage of waste. Based on measurements in reference [3]-[10].*

3. IMPLEMENTATION

3.1 Spreaders

FAV purchased her new brine-spreaders in 2002 and in 2005 – then later completed the investments of equipment to accomplish the implementation of brine for ice control. Both purchases were coordinated with new contracts with contractors to operate the winter maintenance activities, i.e. with redesigning the ice control- and snow-ploughing-routes.

The spreaders purchased used a type of nozzles with an adjustable hole allowing the spreading to take place at a determined constant pressure whatever volume spread. The calibration of these nozzles could be verified simply by collecting brine from each jet in a bucket and weighing it. The type of nozzles also proved the most promising at the measurements conducted by FAV in 2004.

However, when asking for tenders in 2005 FAV put down additional requirements and evaluated the biddings by combining the price with effective volume of brine in the spreader's tank, precision of the spreading, how simple the spreader was to operate and the spreader's capability to retrieve data giving documentation of location, spreading width and dosage. These requirements led to significant improvements of the effective volume: With the 2002-models, one could benefit approximately 9-m^3 brine in an 11-m^3 tank, while only 20-litres of the new 14-m^3 tank remained after spreading. Furthermore, the collecting of data has proved it possible to determine the dosage of a spreading route with an accuracy of 3 percent, i.e. when planning the activities, one can establish longer routes and still be certain that the spreaders will contain a sufficient amount of ice agent to complete the route.

Additionally, in 2005, FAV installed *GPS*-technology to control the spreading, i.e. the spreaders would determine the present position by means of the global positioning system and adjust the spreading pattern to variations in lane-width, presence of bus stops, transverse gradient etc. The driver could concentrate on driving the spreading vehicle.

3.2 Brine

FAV used to have storages of salt in barns at eight surveillance centres on Funen and at one site on the island of Aeroe. When introducing brine for ice control, FAV had to decide on installing mixing plants at each centre or only a number of the centres. Brine is produced simply by mixing fresh water with pure salt and make sure that all the salt is dissolved. The challenges are A) to get the required quantum, which calls for adequate supply of water and storage capacity and B) to avoid stratification, which calls for equipment to monitor the brine and to ensure continuous circulation.

FAV decided on two plants on Funen. The main argument was the economies of scale: The demand of staff to supervise the plants could be cut back. This was attractive from not only a fiscal point of view but also considering a high average age of the employees and the recognized difficulties of recruiting and due to the legislations of rest hours raised from the health and safety at work acts. Furthermore, the larger plants would ensure supply of brine with the quality prescribed. The plants were established in 1999 and in 2002, and both were enlarged in 2005. The plants were located at two of FAV's surveillance centres in order to make use of the staff facilities established at the surveillance centres, and to allow the staff to take part in other site-activities when not supervising the mixing plants.

The island of Aeroe is short of subsoil water, and in order not to strain the groundwater resource FAV gained a special permission from the environmental authorities to use seawater for mixing the brine for the island and thus established a small mixing plant at the harbour.

3.3 Organisation

The implementation of brine spreading lead to redesigning the ice-control-routes: All the routes on Funen and Langeland had to be readdressed to the two mixing plants, and of course had to be optimized under this condition.

The introduction of *GPS*-technology meant, of course, that all routes had to be programmed with information of width etc. However, it turned out to be vital as well to instruct thoroughly all the drivers that they had to start on the route where planned and to drive through the route in the planned direction – otherwise the *GPS*-controlled spreading would be of no use.

Reallocating the staff to the two mixing plants meant that the duty rosters had to involve fewer persons. In a situation where several employees were planning on retiring, this was accepted, as it even allowed to adjust the rosters so the impact on the staff no longer exceeded the limits laid down by the health and safety at work act, even during severe winter conditions.

The new technologies placed a broader spectrum of challenges upon the mechanics at FAV's garage. During the period where brine as well as pre-wetted salt was used for ice-control, the number of various types of spreaders was high, and each type was unique and required unique skills. Especially combi-spreaders, being able to spread brine as well as pre-wetted salt, were skill demanding due to the two different spreading technologies of the spreaders. Each mechanic had to specialise, and thus the garage became vulnerable to illness or retirements, and the new advanced technology requires more training to ensure that the garage in all circumstances is fit to fix damages or break-downs.

3.4 Political and financial aspects

As all other activities on the road network, the winter maintenance is very visible to the public, and hence changing of technologies are to be considered with respect to the public opinion and the political employers of the highway authority. FAV aimed to inform thoroughly the political committee as well as the press when and why alterations took place, and when new equipment was introduced. The observation is that both parties grew seriously interested in the activity, they were concerned about the environmental impact, but they never questioned the technical decisions made by FAV.

On the island of Aeroe, FAV converted to brine in the winter season 1998/99 – reductions in the consumption of salt and the use of brine based on seawater matched perfectly the island's own branding of giving preference to sustainability, and the change of technology was accepted without any discontent on the island.

On Funen, it was considered also to locate the mixing plants near to the coastline in order to take advantage of the accessibility to seawater. However, the amount of water required to serve the entire county highway network with brine equalised the annual consumption of approximately 1,000 families, and the political committee found this acceptable when considering the logistic benefits of inland locations of the mixing plants.

Purchasing the new brine-spreaders in 2002 and in 2005 became a part of FAV's annual reinvestments of equipment. The price of 40,000 € each was 20 percent cheaper than buying the alternative considered, combi-spreaders being able to spread brine with nozzles as well as pre-wetted salt. FAV had, off course, to adjust other reinvestments, making those replacements a year or two earlier or later than intended, but the overall value of the fleet of equipment was unchanged.

The mixing plants, each at a price of 0.35 million €, were financed by selling two surveillance centres that had become superfluous – the sale even financed improvements of the staff facilities on the remaining surveillance centres.

Table 1. *Consumption of salt (*NaCl*) per square metre in Funen and in the neighbouring counties, Vejle to the West, Storstrøm to the Southeast and Vestsjælland to the East. The winter 2005/06 was more snowy than normally, while the winter 2006/07 was less snowy. Only the county of Funen used brine spread with nozzles. Reference [11].*

Season	Funen	Vejle	Storstrøm	Vestsjælland
2005/06	1,10 kg/m^2	2,11 kg/m^2	2,13 kg/m^2	2,59 kg/m^2
2006/07	0,34 kg/m^2	0,89 kg/m^2	0,94 kg/m^2	0,83 kg/m^2

4. RESULTS

4.1 Amount of salt

Compared to the neighbouring counties, Funen used less than half the amount of salt per square metre during the winters 2005/06 and 2006/07, cf. Table 1.

Table 2 gives the dosages used by FAV on the national highways, where pre-wetted salt as well as brine were still used. The table shows that the dosage of *NaCl* is 39-65 percent less when using brine compared to the dosage when using pre-wetted salt. FAV used similar dosages of brine on her own highways.

Table 2. *Recommended dosages of pre-wetted salt and brine respectively under various circumstances. Used by FAV on the national highways (not motorways) on Funen during winter season 2005/06. The brine used is a 24 % solution. Reference [12].*

		Pre-wetted salt		Brine	
Road- and weather-conditions	Temp.	Dosage g/m^2	Dosage g *NaCl* per m^2	Dosage ml/m^2	Dosage g *NaCl* per m^2
Dry or moisture	> -3 Cº	10	7.7	10	2.7
Risk of hoar frost	< -3 Cº	10	7.7	15	4.3
Moisture or wet	> -3 Cº	10	7.7	15	4.3
Risk of freezing surface	< -3 Cº	15	11.6	25	7.1
Before snow and rime ice		15	11.6	35	10.0
For curative treatments		15	11.6	35	10.0

4.2 Lower accident rates

During the three winter seasons, 2002/03 – 2004/05, where both brine and pre-wetted salt was used on the county highway network of Funen the police reported 48 accidents with slippery roads on the network treated with brine (58 % of the total network) and 40 accidents with slippery roads on the network treated with pre-wetted salt (42 %). The corresponding rates of accidents with slippery roads are 0.08 accidents pr. km pr. 3 years (brine) and 0.09 accidents pr. km pr. 3 years (pre-wetted salt) respectively. The figures should be interpreted with caution. The parameter ‘road condition’ in the police reports is seldom used for analysis and the quality of the registrations should be examined.

It is remarkable that an ‘Anti Icing Fact Sheet’ from North Dakota states [13]: “Lower accident rates – Colorado experienced an average decrease of 14 % in snow- and ice-related crashes during a 12-year study utilizing the anti-icing process of the interstate system in the Denver metro area”. It is precisely the same as in the 3 years period in the county of Funen.

5. FAV'S MAIN CONCLUSIONS

In a superior context, the topic approached by FAV may be worded: "In which way can highway authorities use brine for ice control and in the same time meet the standards in the winter maintenance and reduce the consumption of salt?" Honestly, it has to be admitted that the attitude at the beginning was far more humble: "How much of the pre-wetted salt are distributed where it will be of no use on the road surface and would the result be better using brine?" and "Is the pre-wetted salt that proves useful on the road surface evenly distributed across the road surface and would the spreading pattern be better (more even) using brine?"

The initial questions were answered in favour of the use of brine, and inspired to further investigations over a number of years. The findings can be summarized:

- Brine can substitute pre-wetted salt for ice control purposes in all situations. Brine is not so likely to blow off the road surface as pre-wetted salt, and the dosage of pure salt (*NaCl*) can be reduced by one fourth due to this.
- It is possible to distribute brine successfully at the same velocity as the spreading of pre-wetted salt – and by using nozzle-spreading technologies even at a higher velocity.
- Brine spread with nozzles is distributed more accurately with a uniform pattern at the target area of the road surface. Actually, the distribution is so precise that one can benefit from taking into account the fact, that water (and thus brine) runs downwards, so the spreading should be biased distributing the more on the high levels of the road surface, cf. section 6.2.
- The dosage of salt can be reduced similarly due to these factors. This also means less impact from salt on the environment.
- The necessary quantum of brine in adequate quality can be ensured by using mixing plants – provided approval is given from the environmental authorities even seawater can be used to mix the brine.
- Brine-spreaders' tank volume can, when designed properly, be utilized at almost 100 % meaning that the planned ice control-routes can be longer. Use of *GPS*-controlled brine spreading will make it possible to optimize the planning to benefit from almost 'the last drop'. These factors mean improved day-to-day economy.
- Using brine is not more expensive than using pre-wetted salt. Implementation of brine-spreading technologies calls for initial investments in mixing plants and adequate (nozzle-spreading) spreaders. The price for various kinds of spreaders has only little influence on the overall economy, however by implementing the technology over some few yeas most of the equipment can be incorporated in the highway authority's reinvestment scheme, meaning that the improved day-to-day economy will be able to pay off the investments in mixing plants.
- Introducing new technologies calls for careful training and instruction of all staff involved. So do introducing new ice control-routes. The basic brine spreading technologies did not cause any serious and unforeseen troubles. But the implementation of *GPS*-controlled spreading revealed an unexpected challenge: to convince the private contractors chauffeurs to drive the routes exactly as planned.
- The rate of accidents with slippery roads does not seem to be higher on roads treated with the lesser amount of *NaCl* from brine compared to roads treated with 'normal' amount pre-wetted salt, cf. section 6.2.

What remains is the question whether brine and pre-wetted salt are of equal effect if one fails the pre-salting and has to melt ice bond to the road surface. Simple thermodynamic calculations will show, that the water in the brine is negligible compared to the amount of water caused by the melted ice. Never-the-less some parties have argued that the use of brine causes a higher risk of having ice bonding to the road surface.

6. USE OF BRINE IN NORTHERN FUNEN

6.1 Renewal of the Danish road administration

Until the turn of the year 2006-07 Denmark had three levels of highway authorities. The Danish Road Directorate administered the national highways. The county councils managed the county highways, and the municipalities were in charge of the local road network. Moreover, the municipalities were the authority regarding the private roads.

On Funen, the national highways consisted of 135 km. The length of the county highways was 1.011 km, while the local roads of the 32 municipalities summed up to 5.684 km.

January 1st 2007 the local Danish administration was renewed. A number of municipalities joined into 98 new and larger municipalities. On Funen the old municipalities formed 10 new, including one municipality covering Langeland and another covering the island of Aeroe. Only the “county-capital”, Odense, was unchanged. The reorganisation closed down the Danish counties, and their obligations were distributed among the new local and regional actors. The county highways of major interregional importance became part of the state road network; the remaining highways were included in the municipalities’ local road network. Staff and equipment were divided and transferred with the roads.

FAV’s studies of the use of brine were not prolonged, and FAV never had the opportunity to conclude on the findings.

6.2 Taking advantage of precision in spreading with nozzles

However, the little municipality of North Funen (Nordfyns Kommune) implemented the findings of FAV on 150 km major roads from the winter 2007/2008. On these roads brine was spread with nozzles and *GPS*-controlled spreading combined with route navigation – 2 brine spreaders (14 m^3) was sufficient for the 150 km in both ice- and snow-related situations.

When implementing the *GPS*-controlled spreading the municipality took advantage of one of the findings, FAV had not got to make use of: Nozzle-spread brine is so precisely distributed across the road, that one can benefit from taking into account that when there is moisture (water or ice) on the road, the salt will run from the higher level to the lower. Or in other words: It is not necessary to place the salt near the lower level of the road, but it is essential to place salt at the high level in curves!

The results on snow- and ice-related accidents were dramatic.

In the Winter 2007/2008 there was only 1 police reported accident with slippery road on the highways of the Municipality of North Funen. The winter 2006/2007 had 5 and the winter 2005/2006 7 such accidents on these roads. The expected number of accidents, when using pre-wetted salt or brine would be 4-5 (based on the data from FAV, 2002-2005, cf. section 4.2). This expected number corresponds with the fact, that 5-10 % of all traffic accidents in Denmark takes place on slippery roads [14], and that the municipality of North Funen in 2007 had 76 traffic accidents reported by the police.

Table 3. Numbers of accidents on slippery roads in the winters 2006/2007 and 2007/2008 in the local road networks in Funen. Only the municipality of North Funen has a dramatic decrease from 2006/2007 to 2007/2008. It is remarkable that in the municipality of North Funen nearly all accidents with slippery roads occur on major roads.

Highway authority	#1	#2	#3	#4	#5	#6	#7	Northern Funen
Winter: 2006/2007	15	7	7	6	6	3	1	6
Winter: 2007/2008	31	17	6	7	7	7	2	1

The remaining 7 local highway authorities on Funen had an increasing number of traffic accidents on slippery roads from the winter 2006/2007 to the winter 2007/2008, cf. Table 3. All eight highway authorities all used the services from The Danish Road Directorate to call out for pre-salting. It means, that only the precise spreading, caused by *GPS*-controlled spreading of nozzle-spread brine and the use of route navigation, can explain why North Funen had such dramatic decrease in accidents with slippery roads compared to the neighbouring local highway authorities.

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