MEASUREMENTS OF RESIDUAL SALT ON A TEST TRACK UNDER CONTROLLED CONDITIONS

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ABSTRACT

In order to develop a new model for predicting residual salt on roads and thereby enabling a more precise and economic salt spreading without compromising traffic safety and road network accessibility, a Nordic research project was formed under the NordFoU umbrella and financed by the road administrations of Denmark, Sweden, Norway and Iceland. A field site for studying the processes behind salt loss from roads under semi-controlled conditions was established in Denmark.

The field campaigns at the test site showed that the quality of sensor instalment is crucial for the quality of data, mainly due to that a faulty installed sensor reads the road surface wetness wrongly and, hence both road surface wetness and amount of residual salt data will be of low quality. This implies that the quality of sensors used in RWIS systems needs to be checked on a regular basis in order to secure the quality of data output.

The results also show that run-off is a very important process of salt loss and influences on both road surface wetness and residual salt.

The field site will be further developed and used for field campaigns during the upcoming winters of 2013/-14 and 2014/-15.

1. INTRODUCTION

Nordic road authorities have for a long time had the ambition to reduce the use of salt in winter maintenance activities, while continuing to fulfil the goals of availability, accessibility and traffic safety of the road network. The use of salt as a chemical anti- and de-icing agent plays an important role, not only for traffic safety, but also for heavy vehicles accessibility of the road network during winters, why it thus influences on both public and commercial transports, with economic consequences as a result when failing. But, on the other hand have also negative issues of salt exposure been known for decades. Corrosion of vehicles and road equipment, environmental issues as pollution of ground and surface waters and effects on roadside vegetation and soil structure are examples of the latter. The use of salt on the roads is therefore a delicate and complex balance between different goals, where the aim must be to use neither too little salt nor too much.

One way to enhance the possibility to reach an optimal use of salt would be to have an operational tool that could predict the durability of each single salting measure under various external conditions.

In order to develop such a tool for the winter maintenance personnel to use in their daily decision making, a Nordic cooperation was started under the project acronym MORS – Modelling Residual Salt [1].

The MORS project was initiated under the NordFoU umbrella, the common platform of the Nordic road administrations for research collaboration. The funding partners for MORS are the road administrations of Denmark, Sweden, Norway and Iceland.

Pre-MORS, parts of the project team presented 2011 an empirical residual salt model where the salt amount was related to traffic amount and road surface wetness measured by in-situ sensors from Vaisala [2]. Even if that model had a fair to very good fit of the 18 test cases it was based on, it was decided that the development of a new generic tool needed a more physically based model description including all relevant processes involved in the fate of a salting action. Furthermore, the quality of the read-outs from the sensors used, which are part of the permanent Danish road weather information system was not known, why it was decided to also evaluate similar sensors under controlled conditions within the MORS-project.

The processes that are involved in the fate of residual salt on the road surface are: run-off, blow-off (solid salt), spray-off (liquid splash and spray), evaporation, condensation, precipitation, and salt spreading, and these processes are influenced by several factors, including salt spreading method, traffic and road characteristics, road surface wetness and present weather conditions. How the processes are approached in the model concept is further described in [Eram et al, these proceedings].

In order to study the processes involved in the fate of residual salt and to compare the sensors used to manual measuring methods, a designated test track for semi-controlled road salt experiments was prepared in Bygholm, Horsens in Denmark.

2. METHODS

To gain better knowledge regarding the processes behind salt leaving the road surface, field measurement campaigns were made three times (January, May and December) during 2012 at the test track in Bygholm under various meteorological conditions.

2.1. Test-site

Under the Nordic research and development project MORS, a designated test track for winter maintenance road salting equipment was prepared in Horsens Denmark (N55° 51.84', E9° 48.85', WGS 84). The experimental set-up is arranged on a former air-strip and operated by the Research Centre Bygholm, Faculty of Agricultural Sciences, University of Aarhus in Denmark. The test site consists of an approximately 650 m long two-lane road with a turnaround at each end, enabling circular traffic to simulate traffic passing through the measurement section halfway down the track (Figure 1).

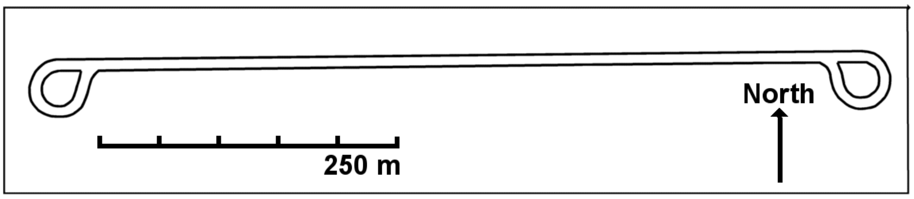

Figure 1 – The test track at the field site in Bygholm where the tests were performed.

The test facilities enables detailed measurements of residual salt on the pavement surface under controlled conditions, both with manual measurements and by automatic road sensors (Table 1 and Figure 2). In 2012, several intensive measurement campaigns were conducted in order to monitor the properties and performance of anti- and de-icing chemicals (liquid and pre-wetted NaCl).

During the first test period the pavement was old, uneven, somewhat cracked and almost without cross-fall, while for the second and third test period the pavement was resurfaced to Danish highway standard, although only ten meters wide, and with a slope towards the roadsides. The cross-fall of the road surface was measured to be 6 ‰ for the old road and 21 ‰ for the new road. Also the road surface macro texture varied between the two pavements with a mean profile depth of 1.1 mm in the old pavement, and only 0.3 mm in the new pavement.

2.2. Automatic measurement techniques

For monitoring the road conditions and meteorological variables the road weather information system ROSA produced by Vaisala was used (Table 1). The sampling interval of weather parameters was 5 minutes.

Table 1 – Continuously measured variables at the road weather station

Variable	Sensor
Precipitation	Vaisala PWD12
Air Temperature	Vaisala HMP155
Air Humidity	Vaisala HMP155
Surface temperature	Vaisala DRS511 and DST111
Wetness and salt amount	Vaisala DRS511
Road Surface State (wetness)	Vaisala DSC111

Figure 2 – Road surface condition sensor (Vaisala DRS511) installed in the pavement

2.3. Manual measurement techniques

For comparison to the automatic sensors, and also to have the possibility to measure at other positions of the road than wheel track and in-between wheel tracks, where the automatic sensors were installed, manual methods were used in order to measure salt concentration, salt amount and road surface wetness.

1.1.1 *Salt measurements*

The salt was measured and calculated in several different ways: the salt concentration (%) of the salt solution on the road surface was established by a refractometer, the salt content (g/m^2) was measured or calculated by using SOBO20, WDS or by combining the concentration measured by the refractometer to the wetness measured by other devices.

The refractometer (Index instruments, Hand held visual refractometer REF-212) measure the salt concentration between zero and 28% NaCl with 0.2% resolution by light refraction principles (Figure 3).

Figure 3 - Salt concentration determined using the hand held refractometer.

By combining the read-out from the refractometer, which gives the salt concentration in per cent, to the amount of liquid on the road surface measured by other methods, the total amount of salt can be calculated per road surface area (g/m^2).

SOBO20 – the salt amount was measured using the commercially available instrument SOBO20 from Boschung (Figure 4), which uses a measuring fluid of 15% acetone to water that is spread on the road surface within a confined chamber to a known amount. The calculation of the salt amount is then based on the electric conductivity of the dissolved salt in the measuring fluid within the chamber, the volume of liquid and the measured area, and given digitally on a display on the instrument. A disadvantage is that it requires that the salt is dissolved in the fluid in order to be measured. Measured interval is 0–45 g/m^2.

Figure 4 – Measuring residual salt with SOBO20 (old pavement).

In order to measure the salt content also when un-dissolved salt was present on the road surface, and when the salt content exceeded 45 g/m^2, the Wet Dust Sampler [3] was used (Figure 5).

Figure 5 – Salt sampling with the Wet Dust Sampler (old pavement).

The Wet Dust Sampler (WDS) is designed to collect all loose material available on a road surface, regardless of particle size. The principle is that a surface is cleaned with a high pressure wash appliance and collected in a sampling bottle. The nozzle (filled cone) is mounted in a cylinder that has a rubber beading facing the road surface. As the user is standing on the platform encircling the cylinder, enough loads is put on the rubber beading to make it air and water tight against the road surface. A circular area is then washed clean by a certain amount of deionized water and the loose material is suspended in the applied water. In the latter phase of the cleaning an air compressor is started that presses the sample volume to a sampling bottle. The water sample can then be studied according to desired application; in this case the electric conductivity is measured once all un-dissolved salt crystals have had time to dissolve in the bottle. Figure 6 shows the different parts of the WDS.

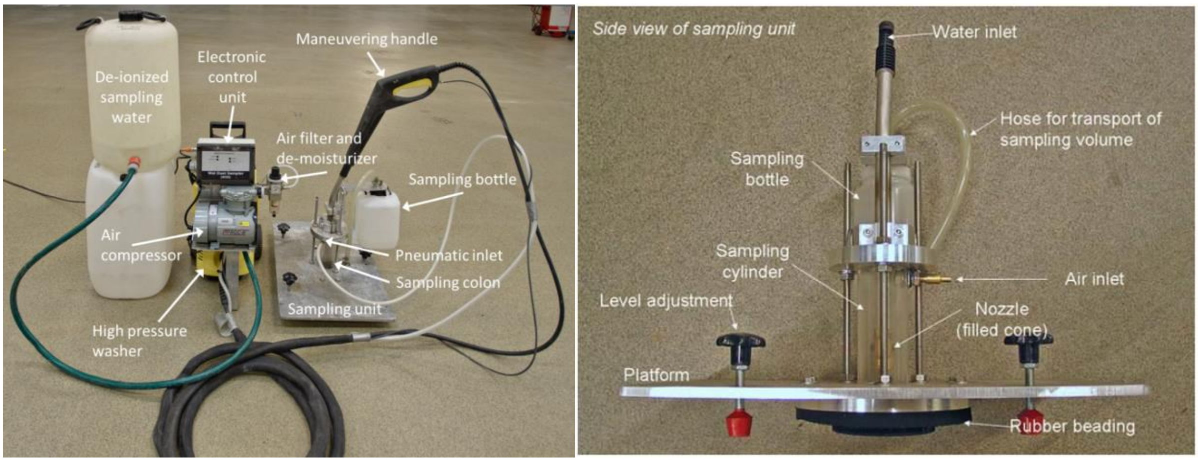

Figure 6 – Wet Dust Sampler

The electronic control unit regulates the start and stop times of the high pressure washer and the air compressor. Both can be adjusted in order to change the amount of sampling water and timing of the compressed air that transfer the sample from the sampling colon to the sampling bottle. Two rubber beading leakage barriers are visible; the inner collapses when put under the operator's weight and the outer further helps to air and water tighten the device.

The electric conductivity of the collected liquid is related to a function for determination of chloride concentration that is calibrated for the actual case. The calibrated function for the Bygholm-tests is presented in Figure 12.

1.1.2 *Wetness*

The road surface wetness was manually monitored using the "Wettex"-method, which is a method using a commercially available absorbing textile / cleaning cloth [4]. By placing the wettex-cloth (265 x 410 mm) on the road surface it will absorb the present liquid (Figure 7). By weighing the cloth before and after absorption, the amount of water on the road surface can be estimated. Some earlier laboratory tests under controlled conditions showed a good linear fit between pavement wetness and the amount of water absorbed by the cloth. There is however a slight underestimation of wetness that seems to be positively related to the road surface macro texture, the larger macro texture, the more water seems to be unavailable to the cloth [5].

Figure 7 - Wetness as measured with the “Wettex”-method (new pavement).

1.1.3 *Salt loss*

The salt loss as described in the conceptual model [see Eram et al, these proceedings] is either naturally caused by gravity, i.e. run-off or caused by the passing vehicles as spray-off (splash and spray of wet salt solution) or blow-off (loss of un-dissolved salt) [6].

Loss from spray-off and blow-off were measured by collecting the deposition in petri dishes (diameter 138 mm) in profiles across the test track extending out to maximum five meters on each side of the test track (Figure 8).

Figure 8 – Sampling the salt deposition (new pavement).

The salt depositions were collected during each traffic round, where the traffic varied between 15 and 217 passing cars. After exposure, the petri dishes are collected and dried at room temperature. The salt content in each petri dish is then analysed at the VTI-laboratory by rinsing the dried salt with a known amount of distilled water. By using a calibrated function for the relation of electric conductivity and chloride concentration, calculation of the deposited amount of salt is made possible. The total amount of salt that is lifted and redistributed by each car is defined as the splash and spray potential and the amount that is deposited outside the driving lane is the actual salt-loss caused by traffic.

The profile of deposited salt after each salting occasion was also measured using the same technique in order to evaluate the distribution of the spread salt in a section across the road, and thereby find the initial loss of salt i.e. the salt that is spread but ends up outside the system boundaries of the driving lane.

Tests were made to measure the run-off by collecting the run-off in one meter long trays fixed to the road edge and leading the run-off liquids into a bottle. It turned out to be too personnel consuming why the method will be further developed and automated for the upcoming field seasons of 2013/-14 and 14/-15. The run-off is, however modelled, which is further described in Eram et al [these proceedings].

2.4. Salt application

To simulate salting activities and create a certain road surface wetness, the road was wetted by salt solution from a standard highway maintenance vehicle using eleven nozzles flooding the solution on the road surface at approximately 30 km/h (Figure 9, right). The salt solution had a concentration of approximately 10%. Using standard method for the road type did not give enough road surface wetness and resulted in too uneven salt distribution in order to be able to study the salt loss mechanisms in detail (Figure 9, left).

Figure 9 - Salt application (left: old pavement, right: new pavement)

2.5. Traffic

Since there is no regular traffic at the test-site, the traffic may be controlled as to when, how fast and which vehicles should be used. During the three field campaigns ordinary cars were used and during each traffic round (up to ca 200 vehicle passes) the speed were held constant and either 50, 80 or 100 km/h. The majority of rounds were held at 80 km/h.

3. RESULTS

Figure 10 show the data output from one field day (May 14, 10–23h) at the Bygholm test site. The x-axis show the time, and from top to bottom the graph show: traffic (speed), hourly wind speed, wind vectors (5 min), precipitation (5 min, mm/h), salt amount (g/m2) from WDS, SOBO, Wettex·refractometer and Vaisala DRS511-sensors, road surface wetness from the Wettex method and Vaisala DRS511-sensors.

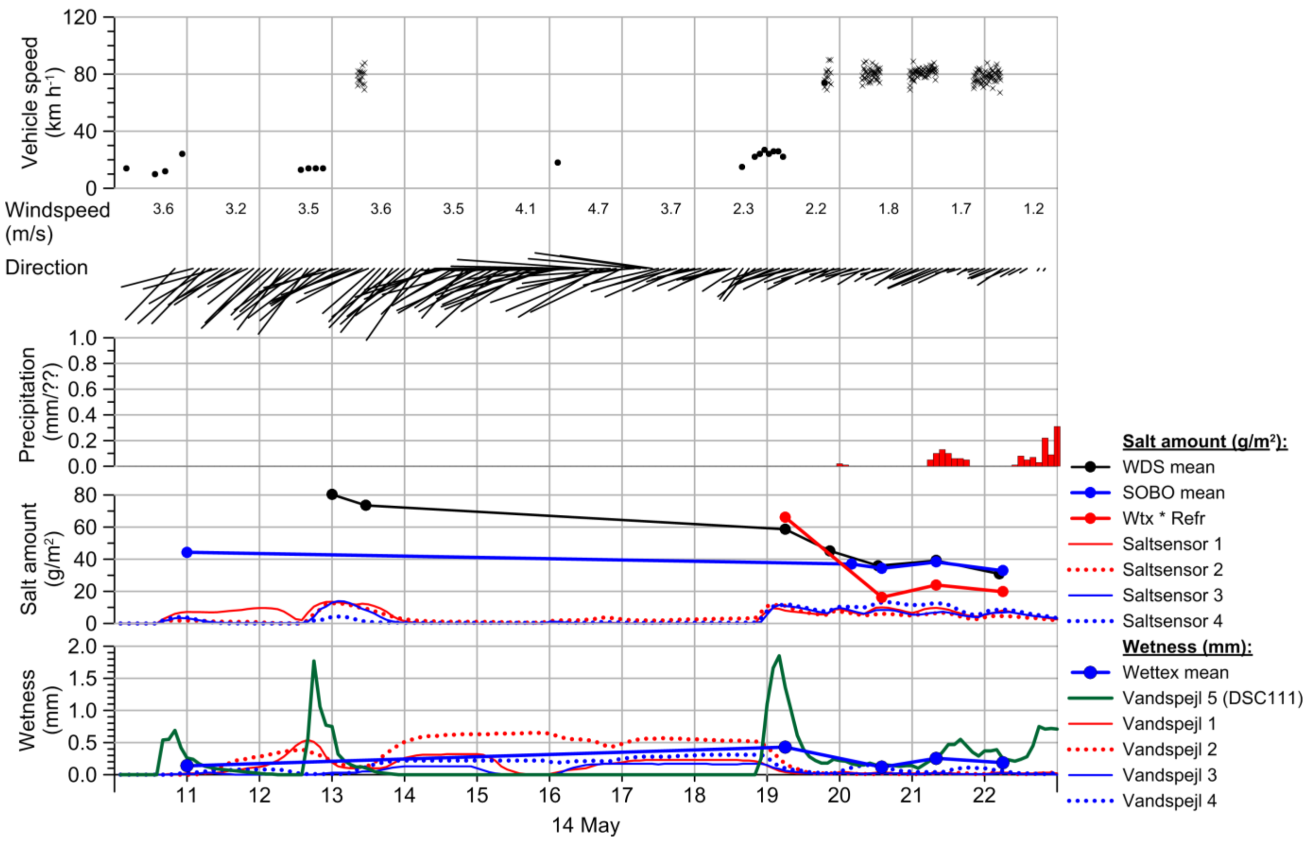

Figure 10 – Example of measurement results from the test site in Bygholm.

What is most striking about the results is the very large discrepancy between the salt amounts measured with the manual methods versus the automated sensors (Figure 10, second graph from the bottom). When examining the difference between SOBO20 and Vaisala DRS511 using data from both January and May it turned out that the Vaisala sensor showed only 18% of the SOBO-measured values (Figure 11).

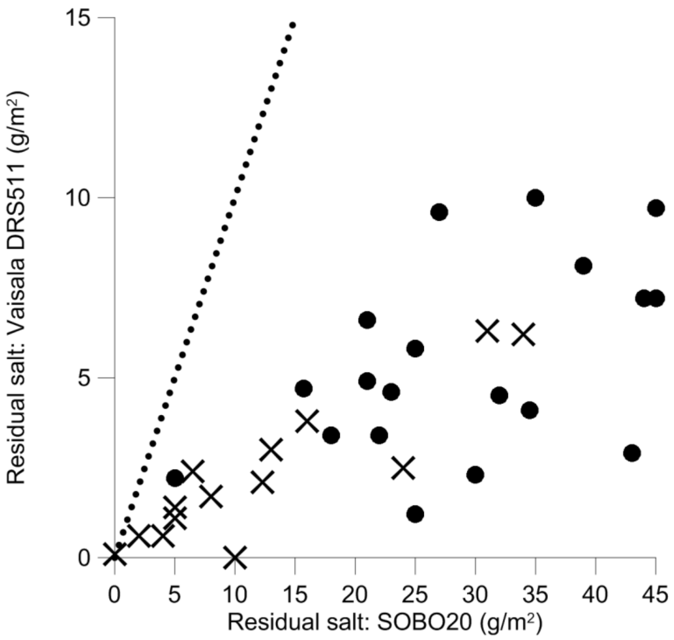

Figure 11 – Comparison between residual salt using manual method (SOBO20) and automatic sensor (Vaisala DRS511) when the automatic sensor is inadequately installed. X:es are measurements made in January and dots in May. The dotted line is the expected 1:1-relation.

Further examination of the possible reasons for why the automated sensors only showed a fraction of the manual methods, showed that the road surface sensors (Vaisala DRS511) were not installed correctly in the pavement. Since the calculation of the salt amount is based on measurements of both salt concentration and wetness, it is crucial that the wetness is measured correctly. This is most likely the explanation for the large differences found in figure 10.

How the wetness, weather parameters and traffic is used to model salt loss and residual salt so far in the conceptual model is further described in Eram et al [these proceedings].

The relation between electric conductivity and chloride concentration, which resulted from the field campaigns in Bygholm, and is needed in order to calculate salt loss from salt deposition measurements or salt content in WDS-samples is presented in Figure 12.

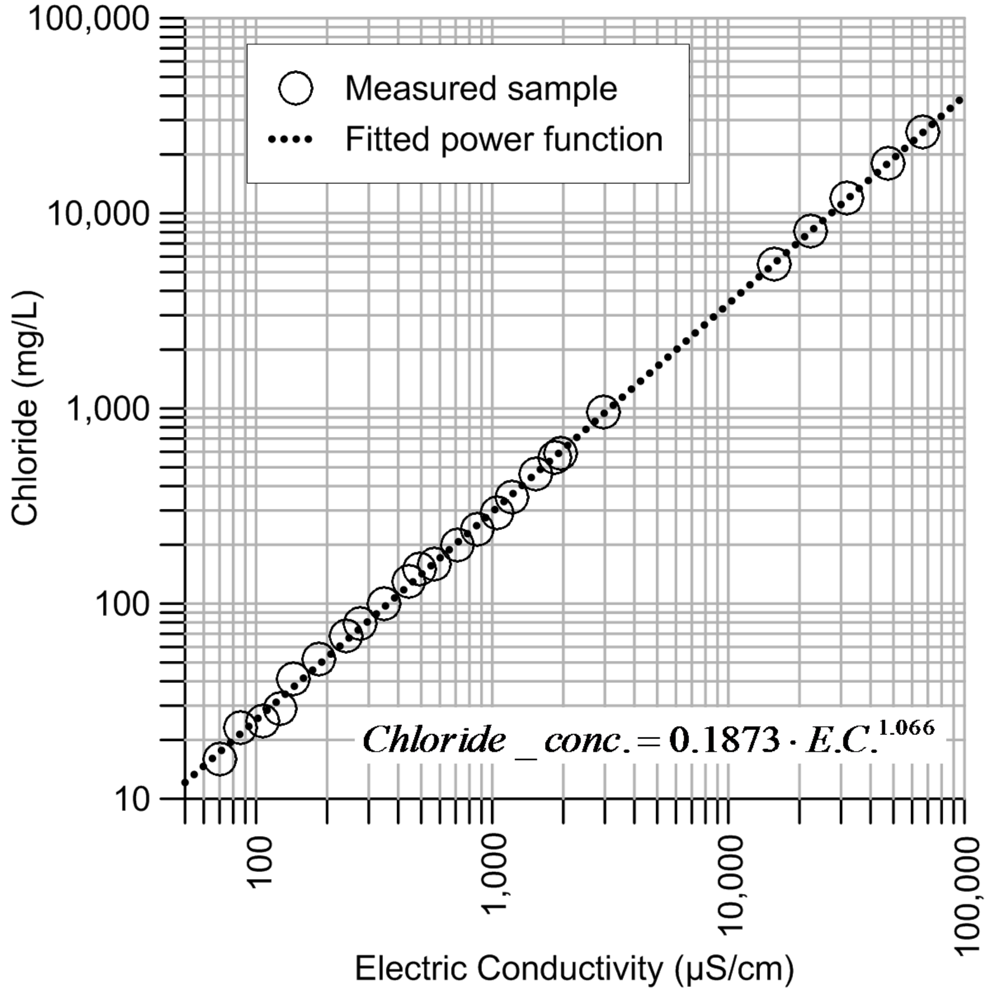

Figure 12 – The calibrated relation between electric conductivity and chloride concentration in Bygholm.

4. CONCLUSIONS

The field campaigns at the Bygholm test-site have shown that the quality of the sensor instalment in the pavement is crucial for the quality of the read-outs from the sensors. If they are to give reliable results, they must be installed correctly as related to the depth of the sensor surface beneath the surrounding pavement surface. Since the sensor calculates the salt amount from the salt concentration and the measured road surface wetness, it will also impair the salt amount read-outs, if wrongly installed. This means that the quality of sensors used in road weather information systems need to be checked on a regular basis in order to secure the quality of the RWIS-data.

The results also show that run-off is a very important process for the development of road surface wetness and the fate of residual salt, as a large amount of salt might be lost by just draining at the road sides. The results indicates that run-off from roads might be much larger than anticipated.

The field site in Bygholm will be further developed in order to also better incorporate measurements and calculations of run-off, evaporation and condensation and further data collection and field campaigns will be executed during the 2013/-14 and 2014/-15 winter seasons.

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