

## Measuring salt on road surfaces -A discussion of salt concentration versus salt amount

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### ABSTRACT

The amount of salt is critical for the state and development of road surface conditions. Knowledge and information about the amount of salt is therefore crucial for decision makers in winter maintenance. In principle, salt can be measured by two different units of measure; (1) salt concentration (g/l), or salt amount (g/m<sup>2</sup>). It has become customary to express salt amount as freezing point i.e. as salt concentration. These two units of measure are different and do not express the same information. The robustness of a road can be seen as the capacity to meet the expectant weather and traffic conditions without getting drastic and unexpected changes in road surface conditions. The robustness of a salted road can be seen as the capacity against freezing. Information from salt measurements used in decision making has to give information of the robustness of the road. Robustness of a road can not be fully described by using salt concentration as a unit of measure. In some conditions the salt amount has to be known to assess the robustness and in some conditions both salt concentration and salt amount is needed.

**Keywords:** roads, winter maintenance, salting, measuring salt

### 1. INTRODUCTION

The application of salt or other chemicals often forms an essential element in the winter maintenance of roads. It is applied to; prevent freezing (anti-icing), melt ice or snow (de-icing) or prevent the build-up of compacted snow on road surfaces (anti-compaction and anti-adhesion). There are several factors that determine the effectiveness of a salt application. The most critical factors are considered to be timing, the mechanical removal of snow and slush prior to the application and spreading rate of the application. The amount of salt on the road surface is critical for the road surface conditions and whether ice formation or snow compaction occurs or not. Recognizing this, information or knowledge about the amount of salt on road surface after salt application is crucial for decision makers in winter maintenance.

The background for this paper was a study on the development of salt amount on roads after salt application. The objective of the study was to investigate how the salt amount developed after application, to understand the mechanisms that remove the salt from the road and to identify the important parameters behind these mechanisms. Part of this study is presented in Lysbakken and Norem [1]. To perform such a study it was necessary to do measurements of salt on road surfaces. This need for performing salt measurements lead to a basic question: *What is the appropriate unit of measure for salt on road surfaces?*

This paper is a discussion of what is the appropriate unit of measure for salt on road surfaces. The discussion is made in perspective of the decision making process and in the perspective of research and development activities. It is principles that are discussed and questions like the technical possibilities or challenges of measuring salt on road surfaces are not concerned.

### 2. TWO PRINCIPLE UNITS OF MEASURE

In principle, salt on road surfaces can be expressed by two different units of measures; (1) *in salt concentration*, or (2) *in salt amount*. Salt concentration is either given directly in gram per litre water or expressed in freezing temperature. Salt amount express the salt in grams per unit area. Salt concentration refers only to the dissolved salt, whereas the amount salt per unit area refers to the undissolved and dissolved salt.

Turunen [2] states that for historical reasons and for the sake of descriptiveness it has become customary to express salt amount on the road as freezing point, i.e. as salt concentration, based on the assumption that the freezing point is low when there is much salt on the road, and higher when there is a little. As Turunen [2] points out that approach is problematic.

There are several physical processes that influence on the road surface conditions [3]. Examples of such processes are precipitation, ice deposition, evaporation, spray-off and run-off. Some of these processes have an influence on the salt concentration or the amount of salt on the road. But these processes do not always influence both salt concentration and salt amount and not always in the same way. Consequently, there is not always a linear relationship between these two dimensions. Precipitation or deposition of dew are physical processes that add water on the road surface and thereby reduces salt concentration. However, they will not affect the amount of salt per unit area assuming that the amount of water is insufficient to cause run-off or spray-off. In the same way, evaporation will increase the salt concentration, but not affect the amount of salt per unit area. On the other hand when the road is wet, but the precipitation (supply of water) has ended, spray-off or run-off reduces the amount of salt per unit area while the salt concentration is still constant. These examples shows that the two main principles of measures of salt; salt concentration and salt amount per unit area, are different and does not express the same information

The relationship between the salt concentration and the salt amount per unit area are obvious. The amount of water (brine) per unit area on the road surface decides the relationship between them. If the salt concentration is known and the amount of water per unit area known, then the salt amount per unit area are known.

### 3. MEASURING SALT IN PERSPECTIVE OF THE DECISION MAKING PROCESS

Decision making in winter maintenance implies making decisions and taking actions based on questions like: *“How is the road surface conditions at the time? How will the road surface conditions develop? Is maintenance actions required? What type of maintenance actions is needed? When to apply salt? How much salt to apply?”* A large diversity in weather and road surface conditions both spatial and in time, makes decision making in winter maintenance a challenging task. A key to successful use of salt in winter maintenance is to perform proactive salting actions. That means that the spreading of salt shall take place before the road surface becomes slippery or snow compaction occurs. This requires that the decision maker has information about the present weather situation, weather forecast and the prevailing road surface conditions. Recognizing that the amount of salt is critical for the road surface conditions, information about the amount of salt is should be an important part the information that decision makers require.

In Norway, road contractors and their decision makers are recommended to use salt measurements as important information in decision making. Several instruments are presented as feasible for this purpose, see figure 1. Some of them are measuring salt on road surfaces as salt concentration and some as salt amount. No discussion is made which of the two units of measure that is appropriate, and if the information given by these instruments are the same and can be interpreted in the same way.

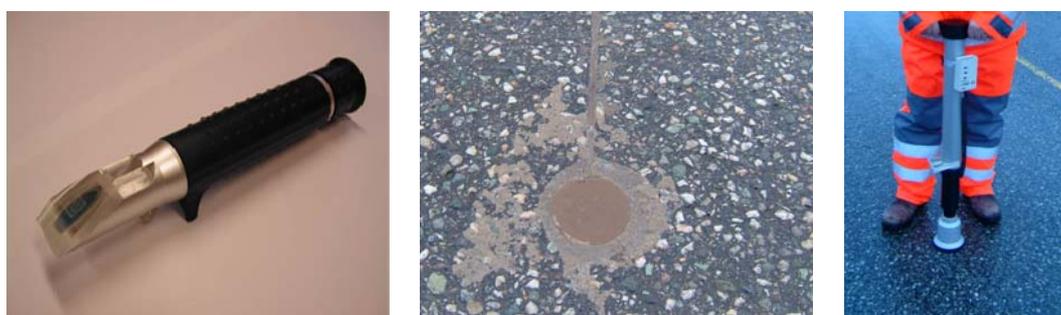


Figure 1. Refractometers, road sensors and Sobo 20 are examples of instruments presented for decision makers for measuring salt on road surfaces.

#### 3.1 Using salt measurements for information in the decision making process

In general, from salt measurements or in any type monitoring of road surface parameters, there are two types of or information that can be derived:

1. the state of road surface conditions at the moment
2. the robustness of road surface conditions

The robustness of the road surface conditions can be seen as the road surface capacity to meet the expectant weather and traffic conditions [4]. That means that the road conditions should ideally be in a state so that the expectant weather and traffic conditions do not give drastic and unexpected changes in road surface conditions. The robustness of a salted road can be seen as the road surface capacity against freezing. By taking into account the proactive nature of salting the robustness of the road surface conditions is the most important information from road surface monitoring. Hence, the readings from salt measurements have to give information about the robustness of the road surface. So, which of the two principle measures for salt on road surface, concentration or salt amount, express the robustness of the road surface? Can just one of them cover all type of road and weather conditions or is both needed?

Strictly there are three weather situations that can make a bare road slippery and thereby cause a need for salting actions:

1. A supply of water due to precipitation or dew on a dry, cold road
2. An increase of water amount due to precipitation on a wet road
3. A drop of road surface temperature on a wet road

On a dry road with surface temperature below 0° C dew will deposit as ice. Rain or super cooled rain will freeze to ice and snow can be compacted to form a snow layer. The robustness of the situation is depended on the salt amount salt that is present and how much water that will be supplied to the surface in form of precipitation or dew. On a dry road there is meaningless to talk about salt concentration and the robustness can only be assed by knowing the salt amount. If the road is wet, salt is present and precipitation is expected, the robustness of the situation can neither be assessed by only knowing the concentration or the salt amount per unit area. For example a high salt concentration but small amount of brine means that the salt amount is small. That means it only takes small amount of precipitation before the brine is so diluted that freezing can occur. Opposite, a high salt amount per unit and high amount of water also means that there can be only relatively small amount of precipitation before freezing can occur. One must know the salt amount and the amount of water to asses how much the amount of water can increase before freezing will occur. One must consequently know the relationship between the concentration and the salt amount to assess the robustness. If the expected weather is a drop in temperature and the road is wet the robustness of the situation can easily be assessed by knowing the salt concentration. A drop in temperature and a dry road with no hazard for deposit of water is of course not a relevant problem. The table below shows which unit of measure that is needed to assess the robustness of road surfaces under different weather and road conditions.

<b>Expectant weather conditions:</b>	<b>Information needed to assess the robustness:</b>
supply water on a dry, cold road	salt amount
increase of water amount on a wet road	salt amount, salt concentration
dropping temperature on a wet road	salt concentration

Table 1. Information about amount of salt on road surfaces needed to assess the robustness of road surfaces under different weather and road conditions.

These theoretical examples may be conventionalized and does not fully correspond with all of the decision makers every day problems. But these examples clearly show that the approach of using salt concentration as the only unit of measure for salt on road surface uncritical is problematic. Salt concentration describes well the current state of the road surface conditions. If the road is wet and there is expected a drop in surface temperature, the robustness of the road is also well described by the salt concentration. On the other hand if precipitation or dew is expected on a dry, cold road the robustness can be assessed by the salt amount. If precipitation is expected on a wet, cold road surface both salt amount and salt concentration has to be know to assess the robustness.

The robustness of a road surface can not be described by the salt concentration alone in all conditions and therefore is insufficient unit of measure for salt on road surface.

### 3.2 Relating salt measurements to the other parts of the decision making system

In Norway the decision of winter maintenance actions are being taken on a low level in the organisation often meaning the operators of the maintenance trucks. This is partly because of historical reasons. Winter maintenance has been a low-tech area. But mainly this is due to the fact the large local and a timely variation in weather gives a diversity of road conditions so that local knowledge and presence is necessary. Decision making is often carried out by personal with low formal skills but high level practical knowledge. This fact requires that information given by systems meant for decision support has to be intuitive and coherent. How to interpret salt measurements expressed in salt concentration directly or by freezing point is not so evidently. This is partly because of the fact pointed out in the discussion made in chapter 3.2, and partly because all other information or

tools does not use salt concentration as a unit of measure. Take the control unit on a salt spreader as an example. The spreading dosage is given in amount per unit area. The guidelines for salting give recommendations for spreading rates under different conditions also is in salt amount per unit area. It is not difficult to imagine that there is problematic to relate readings from e.g. a road sensor, giving a freezing point, to this other information the maintenance crew has.

It is the experience of the author that in Norway, salt measurements from e.g. road sensors are not highly used for decision making process. The problems addressed here seem to the author to be one of the main reasons for this fact.

#### 4. MEASURING SALT IN PERSPECTIVE OF RESEARCH AND DEVELOPMENT

There is not only directly in the decision making process that salt measurements is desirable. In research and development activities this is highly relevant. Development activities that require salt measurements can be e.g. testing of salt spreaders, different spreading methods, spreading materials or additives to salt. Research activities can be documentation of the effect of maintenance actions and so on. These research and development activities can indirectly be related to decision making because the knowledge are often one of the basis for making salting guidelines, training of maintenance personnel and so on, i.e. a basis for better decision making. In this way the required information from salt measurements in research activities does not differ from the information needed in decision making. The discussion made regarding the unit of measure for salt on a road surface for decision making is relevant also for research problems.

The background for the authors interest in the discussion addressed in this paper was as stated earlier a research problem: *How does the salt amount develop after salt application? What are the mechanisms that remove salt from road surfaces and important parameters behind these mechanisms?* Field observation with salt measurements was essential. Without knowing about the discussion addressed here it seemed to be a proper method using data from road sensor installed with RWIS-stations in daily use as decision making support system. Road sensors expressing the salt on the road surface as freezing point. By giving these research problems a more thorough considering it was obvious that using salt concentration as a unit of measure would be incomplete. Using salt concentration would not reflect the movements of salt from and on a road surface at proper way. The amount of salt has to be measured as salt amount per unit area and be independent of the amount of water on the road surface. The same conclusion has to be the same for many other research and development problems related to salting e.g. assessments of spreading methods or spreading equipment.

#### 5. CONCLUSION

The amount of salt is critical for the state and development of the road surface conditions and therefore is knowledge about the amount of salt on the road surface important in the decision making process. The robustness of a road is an important concept considering road surface conditions and the robustness of a salted road can be seen as the capacity against freezing. If a drop in road surface temperature is expected on a wet road, salt concentration expresses well the robustness of the road. Precipitation or dew on a dry road means that the amount of salt has to be known to asses the robustness. On the other hand if the road is wet and precipitation is expected both salt concentration and salt amount has to be known to assess the robustness. The presented discussion has showed that using only salt concentration as a unit of measure for salt amount is not always sufficient.

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