LASTING OF SALT ON RURAL ROADS IN GERMANY

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ABSTRACT

Sodium chloride is the most common de-icing agent used for winter maintenance operations. In Germany, usually prewetted salt (70 % rock salt and 30 % brine) is used. Sometimes, depending on availability of technology, pure salt solution is used, especially for preventive operations.
The lasting of salt on roads is influenced by many different factors like traffic volume and traffic composition, driven speeds, surface conditions (wet, dry,…), surface and air temperature, humidity, location of road stretch (in a sheltered or exposed area), weather conditions (precipitation, fog, dry,…), gradient, crossfall, texture depth, etc..
The aim of this research project are time series of how long salt is lasting on rural roads depending on the factors mentioned above as well as on spreading techniques, salt composition and spread rate. The output should result in advice of how to handle rural road stretches during winter time and concerns organisation issues (e.g. which road to spread first if black ice is expected) as well as spreading techniques. This is another important step towards winter maintenance management systems, getting more and more important especially for inhomogeneous road networks like rural road networks, which most of the time are rarely equipped with means of automatic weather and pavement sensors.

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1. INTRODUCTION

An important factor during winter maintenance measures is the knowledge about how long de-icing agents are lasting on roads, depending on traffic volume, location of road stretch and weather conditions.
Experiences of already completed research projects in Germany resulted in advice to the drivers of winter maintenance vehicles [7], how much salt (spread rate) should be spreaded depending on surface conditions and temperatures, as well as how long the spreaded salt is lasting on the road surface under traffic. These results are based on examinations on motorways only and therefore valid for high traffic volumes and speeds.
Examinations to be named here are the ones of HAUSMANN [1] and NIEBRUEGGE [2]. They both examined the lasting of salt on German motorways, for prewetted salt [1] and for salt solution [2]. But due to differences in traffic volume and velocities, those results can hardly be transferred on German rural roads.

[1] indicates, that after spreading prewetted salt on a dry or slightly moist surface (preventive measure), only 12 % of the spreaded salt, mainly the brine fraction, comes into action. This happens due to high traffic volumes and velocities, transferring salt grains to

the edge of the carriageway. Therefore, preventive spreading actions should be rather “in time”, at most 60 minutes on a dry surface or 120 minutes on a moist surface before snow or ice is about to occur.

The results of [2] show, that generally the driven velocities have a higher impact on the lasting of salt than the actual traffic volume. It is also mentioned, that preventive operations can save up to 60 % of salt when using brine, as even little amounts are enough to avoid ice on roads. Furthermore, the losses in the beginning, right after the spreading procedure, are much less.

Some more international examinations showed the following:
[3] analysed residual salt amounts on different roads, highways and rural roads, in Austria when spreading prewetted salt with a ratio of 3:7 (brine to dry salt). The results show, that after around 10 minutes (or 100 cars) only 60 % of residual salt was left in wheel track. High losses in the beginning right after spreading result from airstream behind passing cars, but also from precipitation and adherence to wheels. On wet surfaces, almost no residual salt was left. On moist or dry roads, residual salt amounts of 1 to 5 g/m² could still be determined, even after 8.000 vehicles.

After analysing more than 1.800 spots on Danish roads after spreading prewetted salt (3:7-ratio) as well as brine (20 %), [4] was able to describe some advantages of brine compared to prewetted salt. It can be described, that prewetted salt is much more affected by traffic than brine. At low traffic volumes < 2.000 vehicles/24hours, the relative loss of prewetted salt is 21 % higher than the one of brine. On roads with traffic volumes > 5.000 vehicles/24hours, the relative loss is up to 30 % higher. This means, that the pure amount of salt spreaded can be 36 % lower with brine compared to prewetted salt for the same amount of residual salt measured after around 2 hours.

The results of [5] and [6] on Norwegian roads show, that the lasting of brine on wet roads is neither longer than the one of prewetted salt, nor shorter. And when spreading preventively, brine is better to prevent slipperiness than prewetted salt. Salt with smaller grain size lasts longer than salt with bigger grain size. And the higher the traffic volume, the lower can be the spreading rate as the salt will be crushed and distributed more quickly by the traffic.

Generally, it was attempted to gain knowledge about the influence of parameters like the texture depth and traffic volume. Therefore tendencies can be given due to the results in chapter 4.

2. DESCRIPTION OF TESTED ROAD STRETCHES

This research project considers the spreading of salt on rural roads, i.e. two-lane roads with less traffic volumes and speeds than on motorways. In total, 13 road stretches in different climatic areas in Germany and with different traffic volumes (from 500 to 7000 cars per day) and speed patterns as well as differences in design were examined.
Table 1 shows the characteristics of the single road stretches.

Table 1 – Overview of tested road stretches

road stretches	ADT [vehicles/24h]	height above mean sea level	surrounding area of road stretch	Mean Texture Depth [mm]
SM Gernsbach				
L76b RT	1650	360	hillside situation	**direction A** 1.81; **direction B** 0.94
L76b KB1	500	850	hillside situation	1.01
L76b KB2	500	900	slope, woodland area	1.02
AfA Karlsruhe				
L604	7500	115	woodland area	0.41
Grabener Strasse	5000	115	exposed area	**direction A** 0.37; **direction B** 0.95
Querspange	5000	115	exposed area	0.63
SM Schwaebisch Gmuend				
L1075	3700	420	exposed area	**direction A** 1.05; **direction B** 0.75
L1159	2200	560	slope, hillside situation	**direction A** 0.63; **direction B** 1.07
L1160	4100	550	exposed area	0.66
SM Wuerzburg				
B19	6000	280	exposed area	0.68
Wu4	3200	350	slope, woodland area	0.63
Wu9a	700	340	exposed area	0.31
Wu9b	700	340	bridge, exposed area	0.70

As can be seen from the last column in Table 1, the Mean Texture Depths of the different road stretches vary a lot. For example for “Wu9a” as well as “Grabener Strasse direction A”, the texture depth is below 0.40 mm. All of the road surfaces examined were asphalt surfaces in very different states (old and new). The surface material is not known of all road stretches due to their age, that’s why the texture depth was measured.

3. MEASURING EQUIPMENT AND EXECUTION OF MEASUREMENTS

For measuring the residual salt amount, the salt measurement device SOBO 20 was used. One disadvantage of this device was the measuring on dry roads or the measuring of freshly spreaded prewetted salt. The results were always quite low due to salt grains on the road. Due to fast dissolving processes, the “real” residual salt amount could better be measured on moist or wet roads. This should be considered regarding the results (e.g. low salt amounts right after a spreading procedure).

The residual salt was measured in four tracks in one lane: Middle of lane (ML), 90 cm apart to the left (LT) and the right (RT), indicating the wheel tracks and at the most outside point of lane (OL) (Figure 1). From five measured points in each track, the arithmetic mean was used to represent the residual salt amount on the road in g/m².

The measured salt on the most outside point of the road, which varies considerably from time to time, was used to get an idea, how exact winter maintenance vehicles distribute salt and later to see, if salt was redistributed on the road due to the influence of traffic. It was not used to represent the average of residual salt on the road (see chapter 4, results).

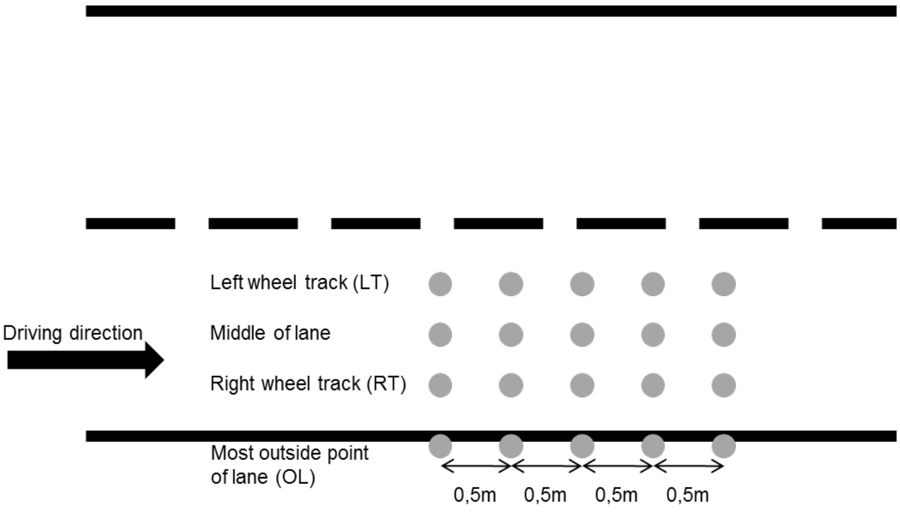

Figure 1 – Testing area for every measurement

For detailed traffic and speed measurements, radar-sensors (hiding in reflector posts) came into action, which were placed at every road stretch during measurements.
For measuring air temperature, road surface temperature and relative humidity, mobile sensors were used. To get an idea of how much water was on the road, the towel test was used (Figure *2*): On an area of 0.1 m², water was wiped up with highly absorbent towels, which were weighted before and after soaking. After that, water film thickness was calculated.

Figure 2 – Towel test on wet road surface

To have an idea about surface properties, the Mean Texture Depth (MTD) of every road stretch in every direction was determined (Figure 3). Therefore, 25 mm³ of glass beads are poured onto the road surface to fill the voids (at least four times in each direction). When the beads are spreaded to their limits, the diameter of the circle is measured. After that, MTD was calculated [8].

Figure 3 – Determination of mean texture depth with the sand patch method

4. RESULTS

4.1. Brine

The following figures show the results of measurements taken, when using brine (23 %) for spreading. The spreading rate was 20 g/m², what results in an actual salt amount of 4.6 g/m². Generally, figures always show the actual salt amount.

In Figure 4, the results on a moist and wet surface are shown (due to changes from precipitation to no precipitaion the surface conditions varied during measurements). The relative humidity was always above 80 %, the sky was overcast.

It is clearly visible, that after 500 vehicles (3 hours) passing the road stretch, the amount of residual salt falls below 2 g/m². This means, 23 % of the initial salt amount is left. After around 600 vehicles more (in total 7 hours after spreading), only 8 % of the initial salt amount is left.

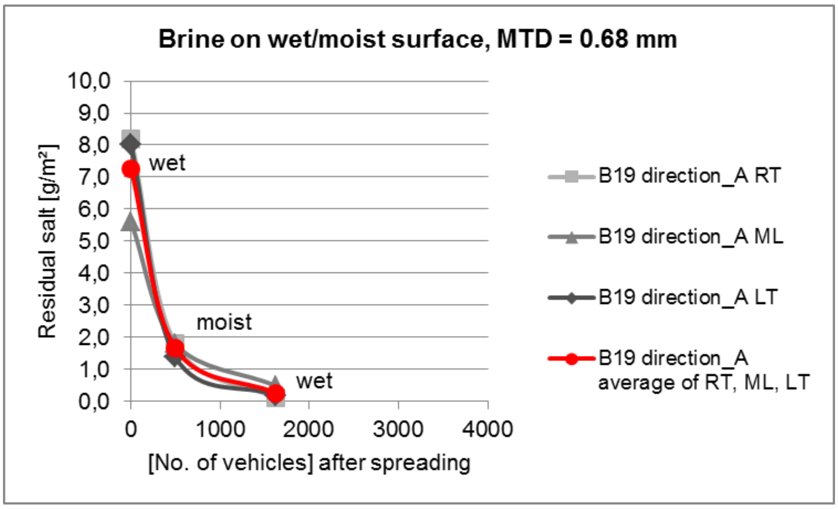

Figure 4 – Spreading of brine on wet/moist surface, B19 direction A, MTD = 0.68 mm

Figure 5 – Road B19 direction_A with wet (left) and dry (middle) surface conditions, close-up view of road surface (right)

On the same road stretch, the test was repeated during dry surface conditions (Figure 6). The relative humidity was always above 60 %, the sky was overcast. After around 600 vehicles (or 3,5 hours respectively), the residual salt amount is almost the same (94 % are left) as in the beginning, just after spreading. After 1.600 vehicles, or 7 hours respectively, the residual salt amount is just at 2 g/m², which is 55 % of the initial amount. After 24 hours no salt was left on the road. These results can be confirmed due to measurements on the same road stretch in opposite direction.

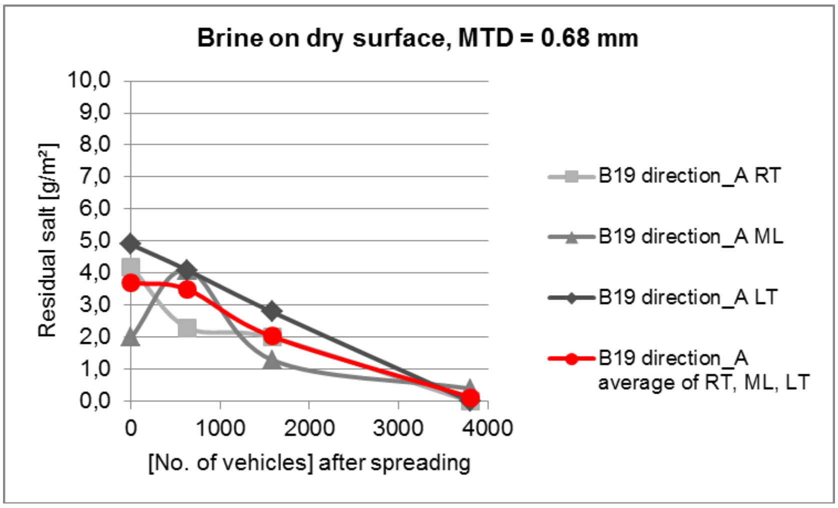

Figure 6 - Spreading of brine on dry surface, B19 direction A, MTD = 0.68 mm

It can be said, that brine on a dry surface lasts almost three times longer as on a moist surface for this kind of road surface and overcast sky.

Tests on a road with very little traffic amount give the following, quite surprising, results:

On a wet surface, almost no salt (only 4 % of initial amount) is left on the road after just 40 vehicles passing the road (in 3 hours). This can only be explained with the texture depth of the road surface. Where the first road has a Mean Texture Depth (MTD) of 0,68 mm, the second one only has a MTD of 0,31 mm, which is quite uniform and smooth when looking at the picture (Figure 8), with hardly any bigger voids.

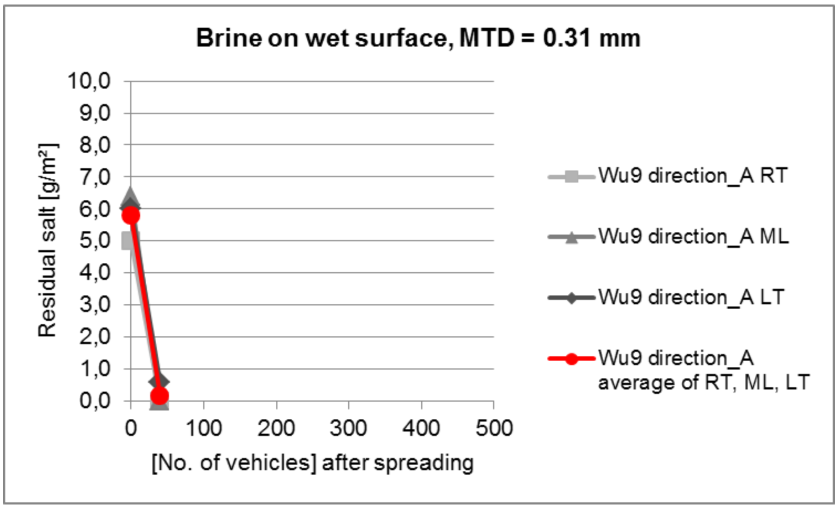

Figure 7 - Spreading of brine on wet surface, Wu9a direction A, MTD = 0.31 mm

Figure 8 - Road Wu9a direction A with wet (left) and dry (middle) surface conditions, close-up view of road surface (right)

The same road stretch under dry conditions gives the following results: After around 40 vehicles (3 hours), there is no decrease in salt amount on the road. The loss after 6,5 hours (around 125 vehicles) results from a change from dry to wet weather conditions.

These results can also be confirmed due to measurements in opposite direction.

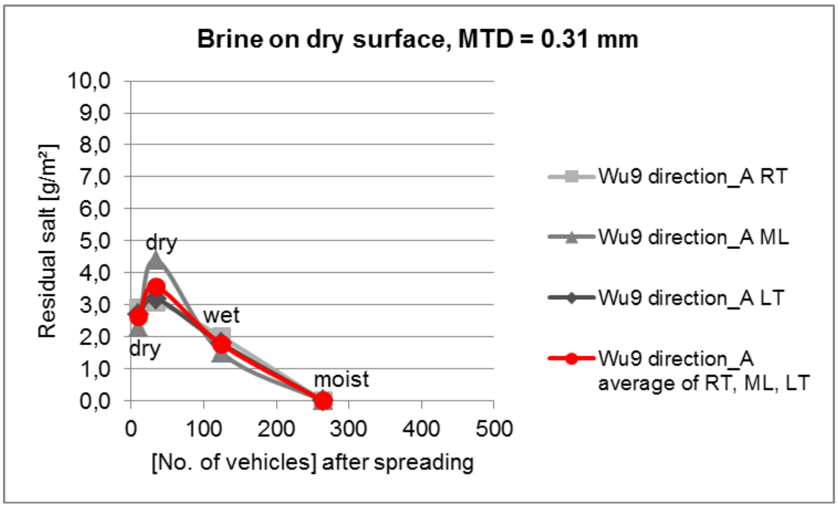

Figure 9 - Spreading of brine on dry surface, Wu9a direction A, MTD = 0.31 mm

Therefore it can be said, that the texture depth has an enormous influence on the residual salt on rural roads when using brine, especially on wet road surfaces.

4.2. Prewetted salt

The following Figure 11 to Figure 13 show the decrease of residual salt on three different road stretches (L1075 direction A, L604 direction A, Querspange direction B) after spreading 20 g/m² prewetted salt (an actual amount of 15,4 g/m²). Figure 11 (L1075 direction A) and Figure 12 (L604 direction A) have at least in the beginning a wet surface, which explains the fast decrease in salt in the beginning of the measurements. Measurements shown in Figure 13 only have a moist surface, which explains the less losses in the beginning of the measurements. For Figure 11 and Figure 12 it can be said, that on rather wet surfaces the residual salt amount decreases to under 2 g/m² (12 % of initial salt amount) after 400 to 450 vehicles passed the road stretches. Although MTD in Figure 11 is much higher (1,05 mm), than in Figure 12 (0,37 mm, quite smooth with some bigger voids) (see Figure 10), the results are quite similar.

Regarding time, this state was reached after 4,5 hours on road L1075 (Figure 11), and after approximately 2,5 hours on road L604 (Figure 12). This aspect should be considered when (re-) organising winter maintenance measures.

Figure 10 – Close up views of road surfaces: L1075 dir. A (left), L604 dir. A (middle), Querspange dir. A (right)

On the moist surface in Figure 13, even after around 600 vehicles passing the road stretch, 65 % of the initial amount of salt is still left. Regarding time, 600 vehicles correspond to 4,5 hours which is similar to the road stretch in Figure 11.

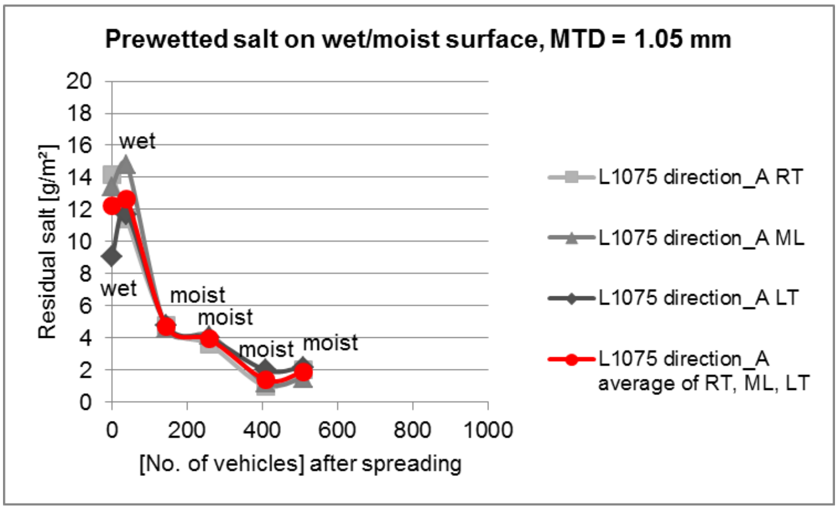

Figure 11 – Spreading of prewetted salt on wet/moist surface, L1075 dir. A, MTD = 1.05 mm

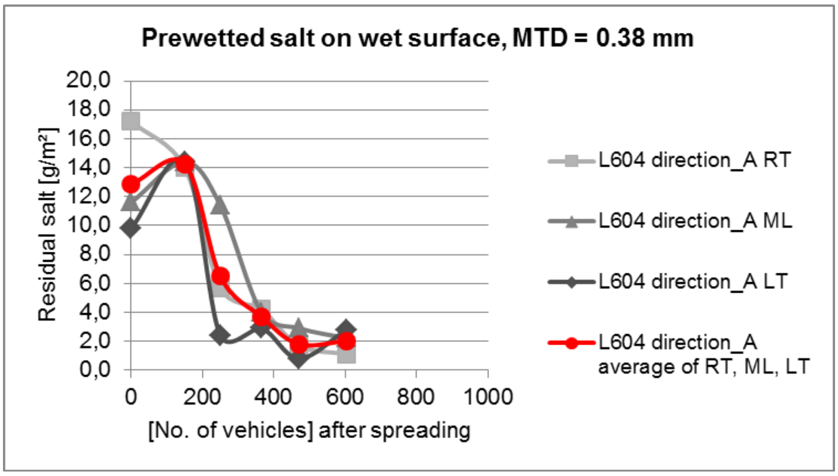

Figure 12 – Spreading of prewetted salt on wet surface, L604 dir. A, MTD = 0.38 mm

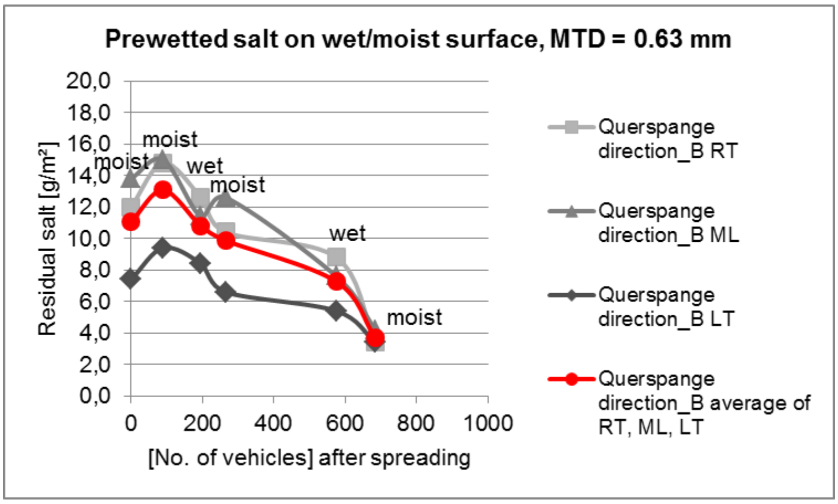

Figure 13 – Spreading of prewetted salt on moist surface,Querspange dir. B, MTD = 0.63

All three measurements show some redistribution of salt in the beginning of the measurements (a slight increase in residual salt). The effect, that the values increase, is probably due to the measuring technique than due to a real increase (as explained in the beginning). Passing cars crush the salt grains and distribute the salt better onto the road surface. This is no real increase, but no loss either.

Figure 14 shows the same road stretch from Figure 11 in opposite direction under dry conditions. The spreading rate was 10 g/m² (an actual amount of 7,7 g/m²). Before spreading, an average amount of 8 g/m² was detected. It can be seen, that after 300 vehicles (almost 5 hours), no loss can be detected in the average. The slight increase indicates some redistribution again. This indicates a long life span of prewetted salt on rural roads, also due to some “impregnation” from spreading actions at the day before.

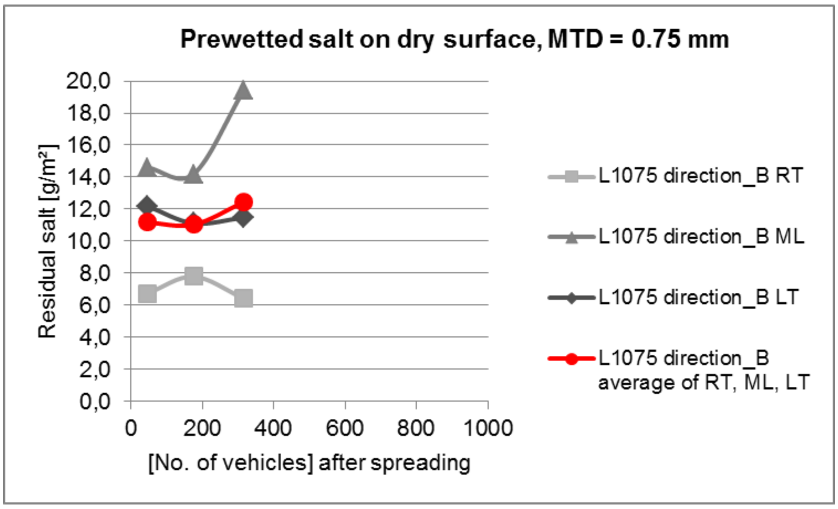

Figure 14 - Spreading of prewetted salt on moist surface, L 1075 dir. B, MTD = 0.75

4.3. Influence of crossfall and slope

4.3.1. Slope

To have an idea about the effect of fog (and therefore moist and wet surfaces) together with a high gradient (> 4%), the following Figure 15 shows a measurement taken on a road stretch which is either in the shadow during the day (western side of a mountain), or in the clouds (foggy) during night hours (around 900 m above sea level). Therefore the surface is most of the time moist to wet.

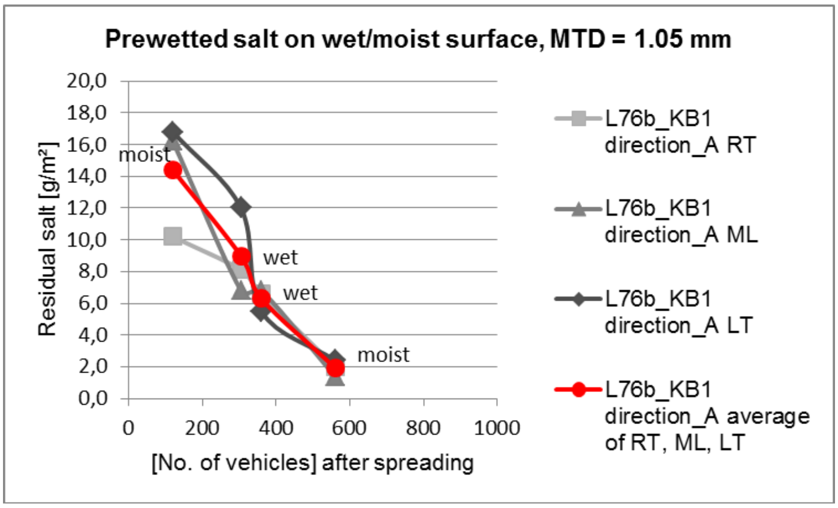

Figure 15 – Spreading of prewetted salt on wet/moist surface due to fog, L76b_KB1 dir. A, MTD = 1.05

It can clearly be seen, that after 600 vehicles or 55 hours respectively, the residual salt amount reaches 2 g/m² (13 % of initial amount), which can be compared with the losses of Figure 11 and Figure 12 due to traffic volume.

As seen at the measurements before (Figure 13), salt is lasting quite long on only moist surfaces. Therefore the high gradient might be another purpose of the decrease of residual salt, especially during wet surface conditions: After 50 vehicles or 3.5 hours respectively (between the measurements with wet surface conditions), a salt loss of 30 % was detected.

The picture below (Figure 16) shows the situation during a measurement (wet surface conditions). After determining the waterfilm thickness with the towel test, the water on the surface was flowing quite fast into the dry area of the towel test. After 1 minute the 0.1 m² were half covered with water again.

Figure 16 – Influence of fog on the road surface, L76b_KB1 dir. A

4.3.2 Crossfall

Another example for the influence of steep slopes, this time crossfall, shows the following Figure 17. The measurements were taken on a bridge (road stretch Wu9b) with a very steep crossfall and very low traffic volume (10 vehicles in total during the measurements). The first measurement (taken at 11 a.m.), shows the initial salt distribution approx. 1 hour after spreading 20 g/m² of brine (actual amount of 4.7 g/m²). The waterfilm thickness is quite high and indicates wet surface conditions. Similar to the waterfilm thickness, the amount of residual salt is much higher at the bottom of the crossfall. This indicates a high influence of crossfall. After 2 hours (10 vehicles passing), 2 g/m² were detected at the bottom of the crossfall only.

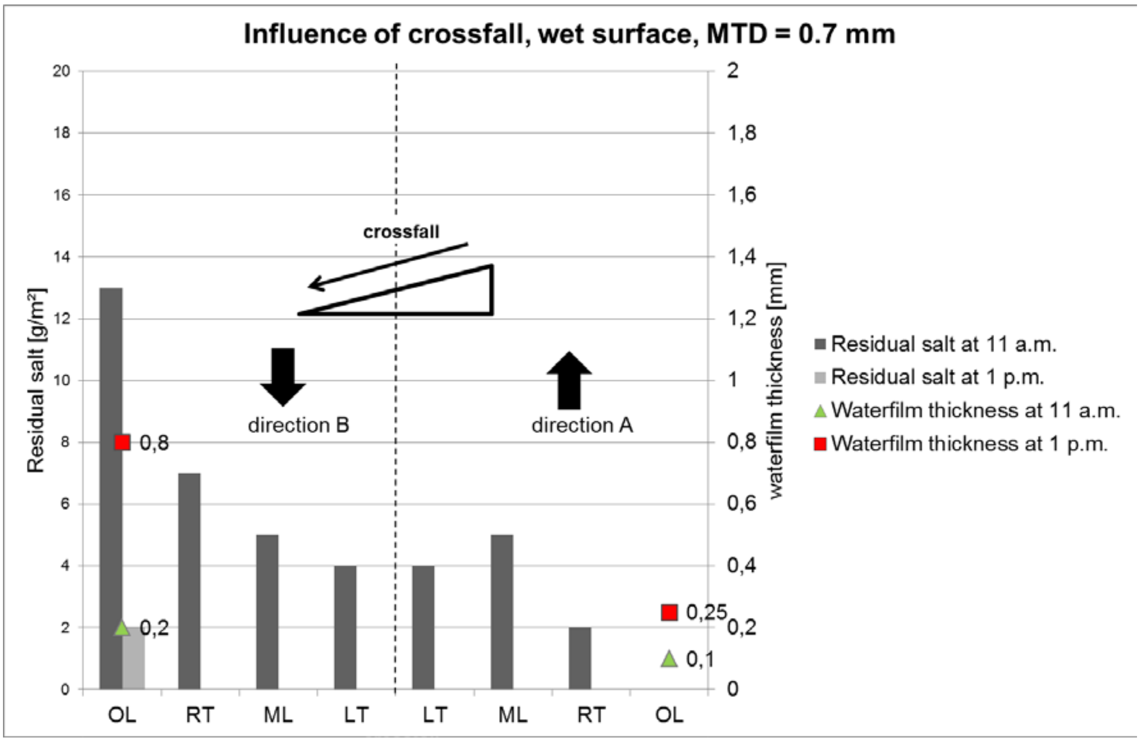

Figure 17 – Influence of steep crossfall on a wet surface, Wu9b

Both examples shown here were especially detected on roads with very low traffic volumes, this means the influence of traffic might, on wet surfaces, be exceeded by the influence of crossfall or a high slope, even at a quite high mean texture depths. Even more for brine than for prewetted salt.

5. CONCLUSION

The results shown in chapter 4 partly support the results from earlier examinations, but also give new information about the behaviour of brine and prewetted salt on rural roads with different traffic volumes and texture of the road surface:

- After around 500 vehicles on wet surfaces, most of the initial salt amount has gone. This is the same for prewetted salt and salt solution. Therefore brine is a good way to save salt (and money) on roads. Attention needs to be taken on roads with low texture depths when using brine on a wet carriageway. Even under very low traffic volumes, the brine will be taken away quickly (after around 50 vehicles) from the carriageway. Therefore
- Texture depth should be considered when planning winter maintenance measures associated with brine. In these cases, measures with prewetted salt or a combination of both might be thought of.
- Special attention needs to be given also on roads with low traffic volumes and steep slopes and/or crossfalls on wet surfaces. The influence of these factors might exceed the influence of traffic (this means, although there is very low traffic on a road, salt might be gone quite quickly, as the salt will be washed away from the

water on the road). This is merely, when brine is used as de-icing agent which means that also in this case measures with prewetted or a combination of both salt might be thought of.

- Due to some “impregnation” effects (e.g. spreading every night on a dry surface), salt (as a solution or prewetted) can stay quite long on roads, especially at sunny days (no clouds) and lower relative air humidity. The usage of salt solution can save (material) costs, but prewetted salt is as effective as salt solution. Due to the lower velocities on rural roads compared to motorways, the initial losses aren’t as high as on motorways and salt grains distributes quite well into the voids/pores of the road surface and can stay there for a long time and get activated again when moisture occurs.

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