Winter Maintenance on the Irish Road Network

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ABSTRACT: This study investigates the developments carried out internationally particularly in the UK and Europe in the use of brine and pre-wet salt in the de-icing of public roads in comparison to traditional dry salt treatments. Brine only treatments were conducted by Offaly County Council for the 2019-2020 winter maintenance season in addition to the normal pre-wet and dry salt operations. Furthermore, Offaly County Council was the first local authority in Ireland to conduct brine only treatments.
Brine only trials were conducted by Offaly County Council using a similar methodology to the brine trials carried out by the Transport Research Laboratory (TRL) on behalf of the National Winter Service Research Group (NWSRG) for the Highways Agency in the UK.
The results of brine trials conducted by Offaly County Council illustrate similar findings to the TRL trials in the UK. For brine spreading at 27g/m², longevity of over 9 hours was observed on moist roads at temperatures below -2°C. Furthermore, brine trials carried out by Offaly County Council provided an effective treatment on roads where moisture was present to temperatures between 0 and -3°C.
The brine trials indicate positive findings from an operational, economic and environmental perspective when compared to dry and pre-wet salt treatments and present a future case for developing a more efficient and sustainable approach to winter maintenance practices by local authorities in Ireland.

KEY WORDS: Winter maintenance; Brine; Offaly County Council; MD30; SOBO; DRS511 Embedded Road Sensor.

1 INTRODUCTION

Transport Infrastructure Ireland (TII) have facilitated significant improvements through the development of a sophisticated national weather prediction system, the funding of capital improvements and the provision of specialised training for designated local authority staff. TII has also procured the services of private companies under the Motorway Maintenance and Renewals Contract (MMaRC) to deliver the winter service on selected elements of the national motorway network [1].
Winter maintenance is an essential component of road maintenance in Ireland and throughout the world. Understanding the efficiency of salt treatment in an economic and a sustainable environment context is an important element of winter maintenance.
The aims and objectives of this study were:

- Review national and international practice and research on the performance of de-icing treatments of brine, pre-wet and dry salt on Ireland's public road network.
- Assess the effectiveness and longevity of precautionary treatments of brine, pre-wet and dry salt on the road surface.

Traditionally, dry salt has been used as a de-icer for the treatment of the road network in Ireland. The overall material costs of dry salt treatments can be higher than other treatment types due to the higher spread rates that are required in certain conditions in order to overcome greater de-icer losses [2].
Pre-wetted treatments involve dry salt or a granular chemical de-icer being 'pre-wetted' with a brine solution at the point of delivery from the spreader. Capital investment and maintenance costs for pre-wetted treatment can be higher than dry treatment as a result of the need for more sophisticated spreading equipment, brine production and/or storage and increased maintenance requirements. However, pre-wet treatment may provide service delivery economies through the use of lower spread rates in certain conditions. As a result of these lower spread rates, pre-wetted treatment may also improve resilience and reduce environmental impact, when compared to dry treatment.
Brine spreading involves a salt brine, or other liquid de-icer, being applied directly onto the road surface without any accompanying solid de-icing material. This system has the potential to offer particular advantages over other forms of treatment when road surface temperatures are close to zero, as well as in situations of very low traffic flows [2].
Hanke & Nutz, 2019 stated that research publications have shown that on motorways the loss of salt is around 70 % in a short period after spreading. This is mainly the dry salt constituent, with only approximately 30 % brine element found after one hour. The conclusion of this is that in cases of preventive spreading the use of brine (without dry salt) should be more effective because the laying performance is much better [3].

2 LITERATURE REVIEW

Salt is used to either break the bond of ice to the road surface or to prevent it from forming by lowering the freezing point of water. Rock salt is the most commonly used salt treatment. The salt utilised for application on the road network is usually at or close to its natural moisture content and has a dry appearance, hence the process is sometimes known as 'Dry salting'. The level of moisture can be a critical issue affecting the value of salt as an anti-icing agent. This is because dry salt, primarily sodium chloride (NaCl), has no direct melting action. Melting occurs only after the salt forms a solution by absorbing moisture from the atmosphere or from the road surface to be treated [4].
Most of the road de-icing salt, used in Ireland and the UK, is derived from mining a natural salt bed stretching from Ireland to North West England. Highway authorities have moved towards using a rock salt composition of 6.3mm grain size [2]. BS3247 requires the rock salt to contain no more than four per

cent moisture by weight and the soluble sodium chloride content to be not less than 90 per cent of the dry mass [4].
Precautionary salting operations are designed to protect road users by preventing frost and ice formation over a period of time following treatment. Significant salt losses are likely to occur during this period as a result of weather conditions and the action of traffic [5].
There is relatively little literature on the opportunities that brine would offer in the treatment of snow and ice by Irish local authorities. In the UK, the results of TRL Phase 1 trials indicated a difference in the behaviour of residual salt levels after spreading on the Hot Rolled Asphalt (HRA) and UK Specification Proprietary Thin Surfacing (UKPTS). In the first 2 hours of spreading there was a higher rate of salt loss for the pre-wetted salt in direct comparison to the brine in the UKPTS trials, then similar loss for each treatment type over the next few hours [10].
In Germany, research has shown that by using brine treatments, there was approximately 54% savings in salt usage and better residual salt concentration after four hours compared to pre-wet salt treatments [3].
Publications from other parts of Europe and indeed in the USA have shown that the use of brine was used successfully in the winter maintenance of their respective roads.

3 TECHNICAL REVIEW

TRL, 2007 stated that there appeared to be no simple and reliable method of measuring residual de-icer levels on the surfaces of highways. Furthermore, winter maintenance operators are therefore required to use their judgement combined with the weather and traffic information available to them to gauge the correct time and application rates for re-treatment [6].
The Boschung SOBO, Vaisala's MD30 and DRS511 Embedded Road Sensor testing devices were the devices selected for salt testing in the Offaly County Council trials during the 2019-2020 winter maintenance season.
The basic principle of the Boschung SOBO is to measure the resistivity of a solution between two immersed electrodes in this solution [7].
The Boschung SOBO meter (Figure 1) measures the mass of salt (Sodium chloride or calcium chloride) per area of the road using conductivity measurements. It injects a fixed quantity of anti-freezing liquid consisting of de-mineralised water and acetone (15% by weight) into a small chamber pressed to the pavement. A thick rubber gasket around the bottom of the chamber is designed to seal the interface to contain the solution [7].

Figure 1 SOBO Meter [7]

The MD30 device (Figure 2) was hired from Vaisala in Finland following their presentation of its capabilities for monitoring weather conditions on road surfaces during a winter maintenance seminar for local authorities in Athlone, Co. Westmeath on the 1st October 2019. The agreed trial between Offaly County Council and Vaisala was for the winter maintenance season from October 2019 to April 2020. The device was installed on the author's personal car for ease of access and use.

Figure 2 MD30 Device [8]

After installation it was calibrated in accordance with MD30 setup guidance documents and paired with the Road AI app on a mobile phone. Initial trials were carried out to ensure the device was functioning correctly. The real time data including 'Grip', surface state, surface layer thickness, surface temperature, air temperature, dew point, frost point and relative humidity could then be viewed on the Vionice section of Vaisala Road DSS Manager for analysis of results [8].
The MD30 device was used in conjunction with the SOBO device for measuring road surface condition parameters on Co. Offaly trial sites 2, 3, 5 & 6. The MD30 was solely used for Trial 6 on the Edenderry Salting Route.
The DRS511 (Figure 3) is located within the wheel tracks of the road or runway so that the tyres of vehicles and aircraft interact with the surface of the sensor [9]. This means the sensor is directly measuring its environment, which ensures accuracy. The DRS511 is known as a passive sensor, which means it does not change or alter the environment that it resides in [9].

Figure 3 DRS511 Road Sensor [9]

The DRS511 road sensor can:

- Detect the amount of de-icing chemical
- Identify road conditions
- Determine Water Film Thickness
- Measure surface temperature
- Measure ground temperature (-6cm)

- Measure freeze point
- Detect hoar frost

DRS511 road sensors are located along the M6 Athlone, R445 Roscrea, R446 Kilbeggan, N80 Killeigh, M6 Miltownpass routes and provide real time data of road surface conditions. Offaly County Council conducted Trial 1 using this device at the N80 Killeigh weather station, Tullamore, Co. Offaly.

4 METHODOLOGY

The methodology design was determined by research in the literature and technical review of this study, in addition to communications between the author and TII, BAM Public Private Partnership (PPP) on M11 and Transport Research Laboratory (TRL), UK. The focus of the methodology design involved the use of brine salt by Irish local authorities in addition to pre-wet and dry salt operations. It was envisaged to undertake experimental analysis methodology including field testing and surveys to achieve a positive type research paradigm.

The author is currently the winter services manager in Offaly County Council. The brine only Boschung 11,550L (Figure 4) capacity spreader was used to conduct brine trials for the winter maintenance season 2019-2020.

Figure 4 Hired Boschung 11,550 Litre Capacity Liquid Hopper Mounted on Offaly County Council Owned 32 Tonne Tipper

Figure 5 indicates the locations of salt trials that were carried out during winter maintenance season 2019-2020.

Offaly County Council conducted all salting operations in Trials 1, 2, 3, 5 & 6 except Trial 4 which was carried out by Westmeath County Council on the R446 at Kilbeggan weather station.

Offaly County Council were presented with spread rates for brine from the TII on 10th October 2019 prior to commencement of 2019-2020 season.

The details of the spread rates and widths along with road surface material used in each trial are summarised in Table 1. The spreading speed (km/h) was determined from tracking devices fitted in spreaders. The spread rate (g/m^2) was processed between 20% to 23% salt concentration and spread width (m) parameters were entered by drivers onto controller pads located within the cab of the lorries operating the gritters.

Table 1 Spreading Characteristics for each Trial

				Brine		Dry		Pre-wet	
Trial	Trial Date	Surface Type	Spreading Speed (km/h)	Spread Rate (g/m^2)	Spread Width (m)	Spread Rate (g/m^2)	Spread Width (m)	Spread Rate (g/m^2)	Spread Width (m)
Trial 1	07/11/2019	HRA	61	13 (2.99g as dry salt)	11.2	N/A	N/A	N/A	N/A
	10/11/2019		62	15 (3.45g as dry salt)	11.2	N/A	N/A	N/A	N/A
	12/11/2019		47	20 (4.6g as dry salt)	11.2	N/A	N/A	N/A	N/A
	13/11/2019		62	N/A	N/A	10	11.2	N/A	N/A
	14/11/2019		65	N/A	N/A	N/A	N/A	10 (7.7g as dry salt)	11.2
	15/11/2019		77	27	11.2	N/A	N/A	N/A	N/A
	16/11/2019		62	N/A	N/A	N/A	N/A	20 (15.4g as dry salt)	11.2
Trial 2	01/12/2019	SMA	41	27 (6.21g as dry salt)	7	20	7	20 (15.4g as dry salt)	7
Trial 3	09/01/2020	SMA	48	15 (3.45g as dry salt)	7	10	7	10 (7.7g as dry salt)	7
Trial 4	27/01/2020	SMA	50	N/A	N/A	10	8.5	N/A	N/A
Trial 5	27/01/2020	Mixed	43	15 (3.45g as dry salt)	6.5	10	6.5	10 (7.7g as dry salt)	6.5
Trial 6	27/01/2020	Mixed	Varies	15 (3.45g as dry salt)	6.5	N/A	N/A	N/A	N/A

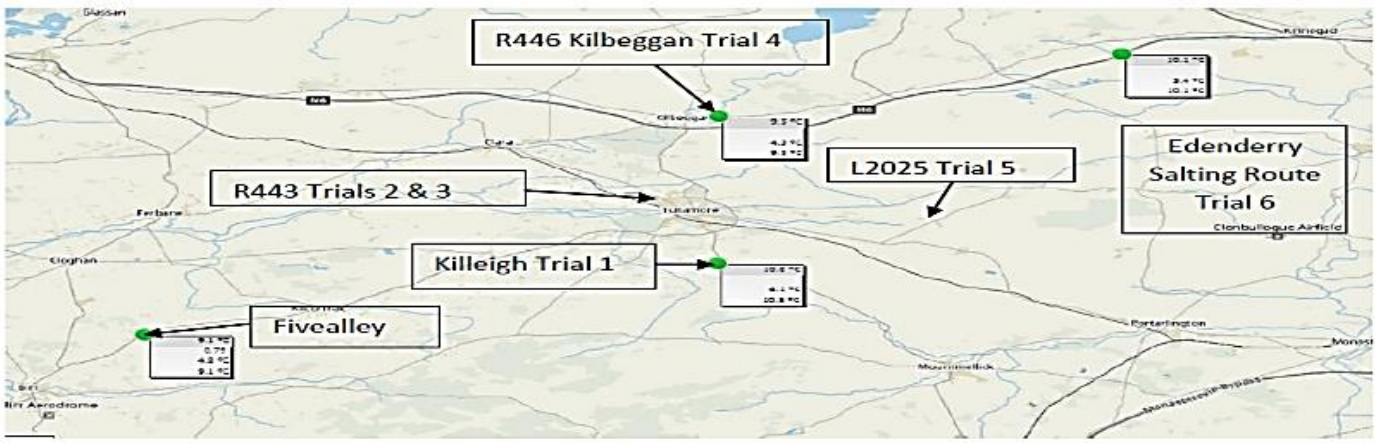

Figure 5 Offaly County Council Trial Location Overview Map

Research analysis to monitor the performance of brine, pre-wet and dry salt were carried out by using the following instruments, selected following consultation with Bunce Ltd and TII:

- MD30
- SOBO device
- DRS511Embedded Road Sensors

5 RESULTS, FINDINGS & ANALYSIS

Table 2 presents a summary of treatments types used on Offaly County Council salting routes during winter maintenance season 2019-2020.

Table 2 Summary of Treatments in Offaly County Council

Days of Treatment	No. of Dry Salt Treatments	No. of Pre-wet Salt Treatments	No. of Brine Treatments
57	2	24	31

The results of the winter maintenance trials conducted by Offaly County Council for dry, pre-wet and brine salt spreading were obtained using the MD30, SOBO and DRS511 Embedded Road Sensor testing equipment.

The MD30 provided road surface parameter information for the specific location in each trial site where SOBO testing was conducted except for Trial 4 as the DRS511 Embedded Road Sensor provided this information. In addition, Trial 6 was conducted using only the MD30 device and no SOBO testing was undertaken.

Figure 6 presents a graphical overview of the performance of brine, pre-wet and dry salt after time of application with regard to residual salt concentration treatment longevity. The readings of salt concentration at 17:00 are the equivalent dry salt content at the time of application by the spreader on the road surface for pre-wet, dry and brine salt at a salt concentration of 23%.

Observations in Figure 6 illustrate that in the first hour after spreading, there is a higher rate of salt loss for the pre-wetted and dry salt in comparison to the brine. It must be noted that the spread rates are the spread rates at the time of application from the spreader and are not the SOBO values. SOBO meter readings of residual salt concentration were measured on the road surface at 18:00, 21:30, 00:15 and 07:30 respectively.

Salt losses after exiting the spreader and application on to the road surface for pre-wet and dry salt are approximately 70% and 80% respectively. This compares to 50% for brine following salt dispersion from the spreader and application on to the road surface. The salt losses in the following hours are considerably less after salt applications were applied on the road surface.

For brine spreading at 27g/m², longevity of over 9 hours was observed on moist roads at temperatures below -2°C in the Offaly County Council trials. There were also long lasting treatments observed for 15g/m² and 20g/m² spread rates in dry and moist conditions.

Furthermore, brine trials carried out by Offaly County Council provided an effective treatment on roads where moisture was present to temperatures between 0 and -3°C. The MD30 device recorded an average 'Grip' value of 0.68 for Trial 6 that was carried out on the Edenderry Salting Route using brine only. This recorded average 'Grip' value is within the optimum range of 0.6-0.82.

The speed of application of brine only treatments that the 11,550 litre Boschung spreader mounted on 32T vehicle can carry out is greater than that for pre-wet and dry salt spreading. In certain instances, where higher spread rates were utilised as a result of prevailing weather conditions, pre-wet salt spreading operations were employed to make up any capacity shortfall that the brine only treatment encountered. This requirement could be eliminated if a 14,000 litre brine only spreader is employed for 2020-2021 winter maintenance season.

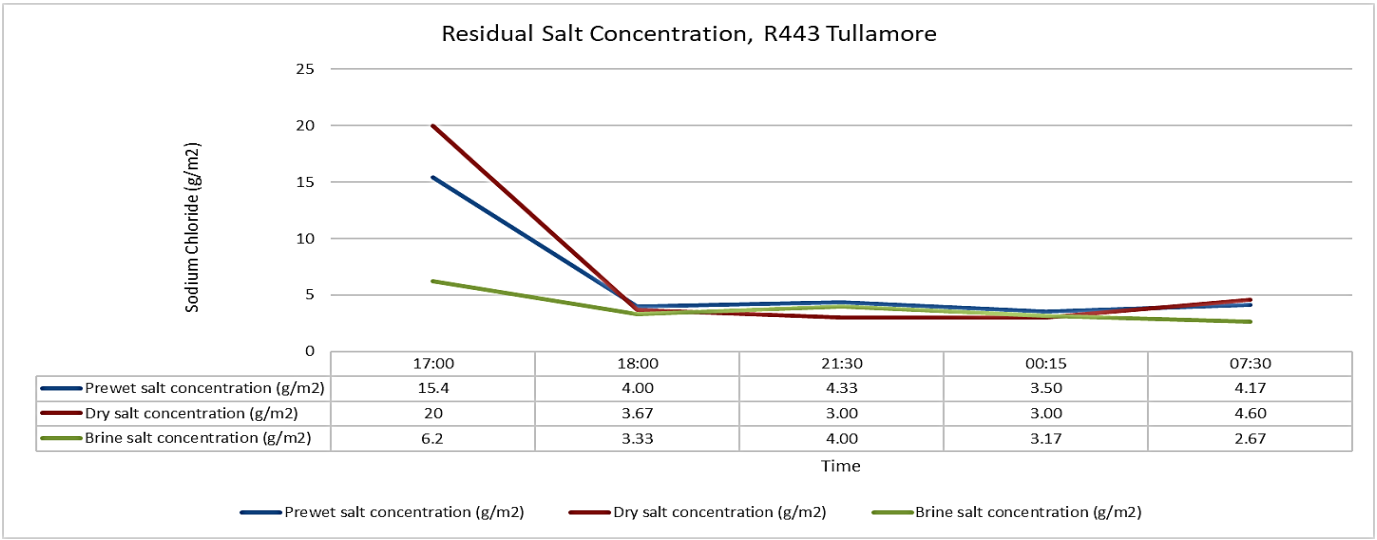

Figure 6 Trial 2 Residual Salt Concentration using SOBO for Pre-wet, Dry and Brine Salt along R443 in Tullamore, Co. Offaly

The results of questionnaire surveys were determined of current winter maintenance practices undertaken by all local authorities and the majority of MMaRC contractors in Ireland. There were 100% responses from the 30 local authorities surveyed. Offaly County Council are the first local authority in Ireland to use brine only treatments in addition to pre-wet and dry salt treatments (Figure 7). Cavan, Cork, Clare, Donegal, Louth and Offaly are currently the only six local authorities undertaking pre-wet salting operations. All responses from the MMaRC contractors indicated that they are using pre-wet salting operations. BAM who operate the M11 PPP in Co. Wicklow and Co. Wexford have been using brine since 2015.

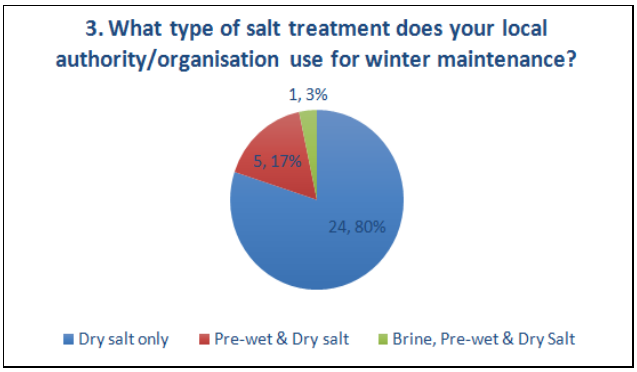

Figure 7 Type of Salt Treatment used by Local Authorities

Finally, a cost benefit analysis of using brine only treatments by Offaly County Council salting routes was determined for the 2019-2020 winter maintenance season.
It was calculated that there were significant savings in dry salt consumption and in the cost of this resource as a result of using brine only treatments in conjunction with pre-wet and dry salt operations.

6 CONCLUSIONS

Offaly County Council carried out its winter maintenance operations for 2019-2020 winter maintenance season using brine only treatment in addition to pre-wet and dry salt operations on its salting routes.
Based on the findings of this study it is concluded that brine only treatment is a suitable treatment financially and environmentally for use on Offaly County Council routes under specified conditions.
International practices and research have showed positive findings in the use of brine treatments on the road network. 60% of countries use brine treatments in addition to pre-wet and dry salt operations. The PIARC (World Road Association) conclude that the use of brine is increasing but is dependent on capital expenditure [3].
In the UK, the efficacy of using brine in terms of effectiveness and cost was carried out by the TRL on behalf of the National Winter Service Research Group (NWSRG) for the Highways Agency in 2009. They concluded that for precautionary salt treatments, especially on dry and moist surfaces, that sodium chloride brine only spreading requires less salt and a greater proportion stays longer on the surface [10].
In the Offaly County Council 2019-2020 winter season trials, savings of 46% in salt usage were achieved on specific salting routes as a result of using brine and pre-wet salt treatments instead of dry salt only treatments. If the 46% savings in dry salt usage analogy from specific salting routes are applied on a national level, there could have been potentially a saving of approximately €44 million in total tonnage of dry salt if pre-wet and brine salt operations had taken place since 2000. However, Ireland would require significant capital investment in new vehicles, spreading equipment, brine saturators and civil infrastructure to modernise winter maintenance operations. The savings generated in salt usage could assist in this investment.
The engineering economy formula calculated total annual costs for the remaining 24 local authorities in Ireland to modernise their infrastructure would cost approximately €8.9 million if a loan was considered over 5 years.
The Offaly County Council trials were conducted using only one SOBO and one MD30 testing device. Additional resources could improve further trials. The extra testing equipment together with additional personnel could enable testing to be carried out simultaneously on trial sections of brine, pre-wet and dry salt and hence could provide more consistent results.

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