NWSRG
NATIONAL WINTER SERVICE RESEARCH GROUP

# Section Three

## De-Icer Types

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In association with INSTITUTE OF HIGHWAY ENGINEERS

# Contents



# 3.1 Introduction

3.1.1 This chapter explains the principal de-icer types used on UK roads and footways. This chapter provides information on de-icer products typically used for treating UK paved assets to help prevent the formation of ice and for the treatment of snow and ice as well as to help provide a debonding layer to facilitate removal of snow and freezing rain.

3.1.2 The term “de-icer” is used generically in this guidance to describe chemicals and additives commonly used for UK winter service de-icing (reactive treatment) and anti-icing (preventative treatment) operations

3.1.3 De-icers may be supplied and/or used in either dry or liquid form. Details of the de-icer properties and some of the advantages and disadvantages for use in different situations as well as their “usability” are described within this chapter and will provides users the information necessary to make better-informed decisions on the most appropriate de-icers for their network and the prevalent conditions.

3.1.4. Sodium chloride (salt) is the most commonly used chemical de-icer in the UK because it is suitable for the majority of UK winter conditions, is relatively low cost and is readily available.

3.1.5 The type of spreading technology/methods available will dictate the range and type of de-icers that may be used whilst storage and handling requirements for different de-icer products also needs to be considered when choosing the most appropriate to use

3.1.6 The condition of a environment impacts dry de-icer, in terms of moisture content and grading, impacts the effectiveness and efficiency when spreading in granular form. This should be a consideration when specifying supply contracts as well as requirements for subsequent storage and handling to maintain good condition

3.1.7 All chemical de-icers will have implications for Health, Safety and Environment when storing, handling and in use. The relevant H&S documentation and COSHH assessments should always be referred to and risk assessed. new note on seeking approval from the Environmental Authority for storage method.

3.1.8 The type of de-icer(s) selected should ideally provide an affordable but economical and efficient method of treating the network considering the paved surfaces, assets and range of conditions likely to be encountered and such resources that are available.

3.1.9 Consideration for changing de-icer types from those currently used should include improving efficiency, effectiveness and resilience not necessarily reducing costs, though a key consideration, asset damage and environmental impacts and when considering procuring new spreading equipment the most affordable but effective, economical and efficient treatment methods should be considered that will deliver the required outcomes over time. Short term economies in de-icer or spreading equipment may be outweighed by longer term savings and improved service level/

** Please note that the NWSRG recommendations for moisture content in this guidance that enable optimum effectiveness in spreading differ to those given in the British Standard.*

## 3.2 The Types of Chemical De-Icer/Anti-Icer Available in the UK and Which is Best to Use

3.2.1 This section outlines the wide range of de-icers used in the UK with ones most commonly used referenced in this guidance. They may be available in either dry or liquid form or both.

3.2.2 The most commonly used are:

- Sodium Chloride
- Calcium Chloride - Best spread as a liquid. It can also be used as a solid to treat small areas but must be stored in sealed containers
- Magnesium Chloride - Best spread as a liquid. It can also be used as a solid to treat small areas but must be stored in sealed containers
- Sodium Chloride brine

The above chlorides may sometimes be also used by:

- Mixing of different de-icers types
- Adding ABP (Agricultural By-products) or similar additives
- Mixing with sand or grit*

3.2.3 Less commonly used de-icers include:

- Potassium Acetate -Spread as a liquid
- Calcium magnesium acetate
- Potassium formate- Spread as a liquid
- Ethylene glycol - Spread as a liquid
- Propylene glycol - Spread as a liquid
- Urea - Spread as a solid

** Sand & grit mixtures may present issues with removal from paved surfaces and drainage assets and spreading with the equipment as well as requiring specialist disposal due to contamination and should only be used in accordance with the recommendations given in the Treatments for Snow and Ice section used referenced in this guidance. They may be available in either dry or liquid form or both.*

3.2.4 There are a number of factors to consider in determining the best de-icer or de-icers to use depending on a variety of factors including:

- Cost of de-icer(s)
- Cost of storage, handling and spreading
- Cost of preparation for spreading (e.g. brines)
- Effectiveness on the range of paved surfaces to be treated
- l Effectiveness for all weather and traffic conditions encountered that require to be treated
- Damage to assets and vehicles
- Environmental highway impact considerations concrete and metal Structures such as Bridges, specialist paving on foot-ways
- Salt is usually suitable for the more common winter conditions in the UK. It is generally readily available and is also the most economical de-icer for most treatments for typical UK conditions.

3.2.5 The choice of the best de-icer to use is dependent on a range of factors many of which will be unique to the network being treated when accounting for

- the physical aspects of the network,
- weather conditions experienced,
- winter service policy,
- available equipment,
- storage and resource availability,
- cost of delivery
- budget availability for improvements or upgrades
- environmental impact
- impact on service life of equipment
- H&S , COSHH requirements
- Time to treat network

3.2.6 The cost of de-icer and the equipment to distribute them generally relates either directly or indirectly to its effectiveness i.e. more expensive de-icers tend to be more effective in use, may be more efficient, have specific properties limiting damage or impacts, or treat a wider range of conditions, in particular lower temperature conditions.

# 3.3 How Chemical De-Icers Work

3.3.1 Chemical de-icers prevent ice formation or melt ice and snow by forming a solution (the process of dissolution) thus lowering the freezing point of the combined de-icer and water. The resulting solution is referred to as brine and can be any chemical salt dissolved in water. Chemical salt de-icers only work once they have formed a solution with the water on the road. The concentration of the solution determines the temperature down to which they are effective in preventing ice forming this however slows as temperatures drop well below zero.

3.3.2 The amount of de-icer that will dissolve is dependent on temperature and water present. At lower temperatures less de-icer can be dissolved before the solution is saturated. If saturated or near saturated solutions are produced at higher temperatures salt crystals may form in the liquid as temperatures reduce. For brine & pre-wet spreading this may cause blocking or reducing flow for pumps, nozzles, valves and supply pipework. Where liquid de-icers are applied, the concentration level is immediately lowered by any water which may be on the road and lowered further by any subsequent dilution through humidity, ice melting or precipitation. Therefore, the temperature at which they are effective is that applicable to the final solution formed after application Different de-icer types have different rates at which they dissolve and this slows as temperature reduces. Thus, the time available (amongst other factors) for the solution to form is critical to effectiveness.

3.3.3 Chemical de-icers are not effective unless they remain in the target area. The amount of salt that is likely to remain within the target area is dependent on the salting technology. (All other things such as wind, traffic and precipitation being equal). Therefore, it is essential to carry out checks and De-Icer being used on the performance of the spreader, as described in the Spreader Calibration section of the NWSRG Practical Guide.

3.3.4 Solid chemical de-icers must dissolve to form a brine solution with the water on the road or in the air before they become effective. The amount of water present at the surface (water film), its temperature and/or humidity of the air and the amount of traffic using the road determines how quickly de-icers dissolve. The temperature of the surface water is dependent on both the road surface temperature and air temperature. The traffic acts to crush the grains of de-icer and mix them with the water. The effects of traffic are highly significant in the rate of dissolution.

3.3.5 Liquid de-icers become effective as soon as they are spread.

3.3.6 Sodium chloride and some alternative de-icers attract moisture (are hygroscopic) which helps to dissolve the solid dry salt component after precautionary treatments where there is sufficient moisture in the air even when no surface water may be present. Some alternative de-icers have a higher level of "attractiveness" (are more hygroscopic) and therefore may dissolve more readily. Humidity in winter conditions in the UK is generally greater than 80% .The hygroscopic properties of de-icers may cause the road to appear wet after spreading even in otherwise "dry" road surface conditions. Testing has shown that alternative de-icers when mixed with sodium chloride also help the sodium chloride salt dissolve more quickly when treatments are made on ice and compacted snow.

## 3.4 The Types of Sodium Chloride De-Icer Salt Normally Used in the UK

3.4.1 Because the vast majority of de-icer spread on highways in the UK is sodium chloride (salt), the following sections of this chapter concentrate on sodium chloride based de-icers. However, much of the information on the salting methods and the equipment required is applicable to all de-icers, and many of the factors referred need to be taken into account when spreading the alternative de-icers listed above.

3.4.2 The two main types of UK de-icer salt used are:

- Rock salt – mined – indigenous (but can be imported)
- Marine salt (or salt produced by evaporative processes) – generally imported

Sodium chloride de-icers are available in various forms that cover purity, types and levels of impurity, grading and additives.

The salt will usually have an anti-caking agent added and may also be treated with an additive to improve performance e.g. ABP

3.4.3 Indigenous rock salt is mined on the UK currently at Winsford Mine in Cheshire, Boulby Mine in Cleveland and Kilroot Mine in Carrickfergus, Northern Ireland.

Rock salt is used in either dry, pre-wetted and treated salt spreading and is usually procured as a 10mm or 6.3mm graded product and is not suitable for brine production except in specially designed saturators that are able to deal with the impurities.

3.4.4 Marine salt is generally used for brine production for brine spreading and pre-wetted salting and can sometimes be used directly for spreading using pre-wet or dry spreading technologies. It is typically more finely graded at 6mm or less and commonly a 3mm grading is used. Marine salt and some imported salts have a higher sodium chloride content than UK rock salt. There is potential to reduce the spread rates given for rock salt given in this guidance. Marine and rock salt can also be sourced from overseas, predominantly to meet the increased demand created by colder than average winters. Imported marine salt has been used for both dry and pre-wetted salting and has been used to create strategic stockpiles around the UK.

# 3.5 The Main Differences in Composition and Purity Between Types of Sodium Chloride De-Icer Salt

3.5.1 Different types of salt vary slightly in the amount of sodium chloride, impurities and insolubles (e.g. marl) in the material. The composition of the salt in this context includes impurities and additives such as anti-caking agents. The purity of the compound influences its effectiveness as a de-icer. Impurities and other trace compounds may be detrimental to vehicles, assets and the environment.

3.5.2 BS 3247:2011 (Specification for salt for spreading on highways for winter maintenance) states that

- The soluble chloride content of procured salt, expressed as sodium chloride, should not be less than 90%. The soluble sulphate compounds expressed as calcium sulphate should not be more than 2.5%.
- The insoluble content should not be more than 7.5%

Consideration should be given to the amount of trace compounds, including anti-caking agents and their effect on assets, vehicles and the environment and Spread rates should be increased and spreaders calibrated appropriately if salts with a purity <90% must be used.

3.5.3 The salt spread rates given in the Spread Rate section of the NWSRG Practical Guide have been calculated assuming a sodium chloride content of salt of 90% (therefore spread rates allow for the moisture content as well as the impurities of the salt in rates expressed as g/m2 of de-icer).

3.5.4 Tests have been undertaken for the NWSRG on six types of salt - three UK rock salts, two imported rock salts and a marine salt; the results are shown in the table below:

| PURITY OF TYPES OF SODIUM CHLORIDE DE-ICER SALTS | | |
|---|---|---|
| **Salt type** | **Sodium Chloride Content (%)** | **Insoluble content (%)** |
| **UK rock salt** | 91.9 – 95.2 | 2.4 – 5.5 |
| **High purity imported rock salt** | 99.1 – 99.5 | <0.1 |
| **Marine salt** | 99.5 | <0.1 |

A review of potential imported salts in 2010 found that the sodium chloride content of imported rock salts was typically 91% to 99% and that of marine salt was greater than 99%.

3.5.5 The NWSRG Practical Guide and Well-maintained Highways spread rates assume a minimum purity of 90%. Therefore, it is important to measure the purity of an imported salt and make allowances by increasing spread rates and dealing with the effect of the impurities after spreading where necessary. It is recommended that salt with a purity of less than 90% is not procured The tests should be undertaken by approved Lab to approved British standard on de-icing salts for the NWSRG found that their de-icing performance was proportionately better the higher the purity because of the greater chloride content per unit of higher purity salts.

## 3.6 The Temperature Range Over Which Sodium Chloride Salt Can Be Effective

3.6.1 All chemical de-icing/anti-icing salts are limited by their individual properties in their effectiveness to melt ice or prevent ice forming. The two most important properties are the minimum temperature at which they are practically effective and the rate at which they enter solution, which is also dependent on temperature. Sodium Chloride is suitable for use in the conditions predominantly encountered in the UK but not the more extreme cold conditions encountered on some occasions and in some areas.

3.6.2 The main factors to consider are:

- A sodium chloride solution of sufficient concentration to be effective needs to have formed before temperatures of -7°C (or -5°C in low humidity conditions) are reached
- As temperatures lower towards less than 80% humidity the above limits dissolution rates will reduce and this should be considered for the timing of treatments
- Sodium chloride, even in near saturated solution, is not practically effective at temperatures below -15°C
- As the brine solution absorbs additional water from precipitation or humidity or melting ice the temperature down to which it is effective changes i.e. it becomes less effective
- Effective temperature and dissolution rate may be affected by spreading technology, additives, traffic and weather conditions

3.6.3 The guidance given in the Spread Rates section of the NWSRG Practical Guide should be followed for treatments when the sodium chloride salt can enter solution before the minimum of the air or road surface temperatures are at or below -7°C when humidity is 80% or greater (or -5°C in low humidity conditions below 80%). This is typically when treatments can be made at least 2 hours before the temperature falls below -7°C (or -5°C in low humidity conditions).

Therefore, alternative de-icers should be considered for precautionary treatments when **spreading** at:

Temperatures at or below -7°C in normal winter humidity conditions (80% or above)

Temperatures at or below -5°C in low humidity conditions

3.6.4 When low temperatures are expected, spreading at temperatures above -5°C (or -7°C as above) should be considered when this would provide sufficient time for the salt to go into solution. Other factors such as traffic levels and precipitation should be taken into account.

3.6.5 While salt can be used to melt ice or compacted snow at temperatures down to -15°C, a lot of salt and a great deal of time is required. Alternative de-icers should be considered as they are more effective, likely to be more economical while they are less damaging environmentally and improve resilience.

*N.B. While these recommendations may generally apply to other specific guidance for the provision of a winter service this should not be taken as an endorsement of the overall recommendations of any such guidance by the NWSRG.*

3.6.6 Salt spread at temperatures at or below -7°C (-5°C in low humidity conditions i.e. <80%), will not or may not dissolve sufficiently quickly (depending on conditions of humidity and surface water) to be effective even when large amounts are spread **and** much water is present (i.e. is added during spreading, is on the road surface or in the air. ). it may however become effective if the road surface temperature has risen above this temperature for sufficient time for it to enter solution where there is also sufficient surface water or moisture in the air.

3.6.7 Sodium Chloride is not considered to be an effective de-icer for preventative or reactionary treatments at temperatures below -15°C even when in a near saturated solution before this temperature is reached.

3.6.8 When the relative humidity is low, i.e. less than 80%, salt will not readily absorb moisture from the air to help it dissolve and therefore this also needs to be taken into account.

3.6.9 When salt is fully dissolved to form a saturated solution, it has the potential to prevent freezing down to -21°C. However, it is not practical for saturated salt solutions to be present on the road network, as this requires very specific temperature, moisture and dissolution conditions, which are unlikely to occur. Furthermore, in practice, any brine solution that forms is soon further diluted by the water present in the air and water or melting ice on the road surface.

3.6.10 Near and below -15°C, sodium chloride salt alone i.e. when used without an alternative de-icer/additive may be of little or no practical benefit for post treatments.

*N.B. While sufficient research and practical experience allows this guidance to be specific on effective temperatures for sodium chloride information provided for alternative de-icers is deliberately conservative on effective minimum temperatures for practically achievable solution.*

3.6.11 Salt treatments in sufficient quantities will still be effective for precautionary treatments to prevent freezing at road surface temperatures down to -15°C when treatments are carried out in plenty of time for full dissolution or sufficient time for the required brine concentration to be reached i.e. before the temperature becomes too low for salt to enter solution. This may require spreading earlier in the day rather than later, or at other times when temperatures are suitable for dissolution, if this can avoid spreading salt at temperatures at or below -7°C (-5°C in low humidity conditions).

3.6.12 Accidents have occurred on roads well salted with sodium chloride because the salt spread has been unable to enter solution in order to prevent some ice forming. This may be caused by very low temperatures or where spreading has been taken place without sufficient time for the de-icer to enter solution.

A similar scenario may occur when alternative de-icers are used in certain conditions, depending on timing and what those conditions of low temperature, humidity and surface water are.

## 3.7 The Ideal Condition Salt Should Be In When Spreading

3.7.1 The condition of the salt, particularly in relation to the moisture content, particle size and amount of fine material, are all very important as they affect the spreading characteristics of the de-icer. Thus, salt condition affects both retention on the road and losses. These factors are highly relevant to dry salting and the dry component of pre-wet salting in most conditions.

- The moisture content of the salt being within the optimal range for each spreading method is critical to efficient salt spreading and delivering effective treatments
- During spreading, the rate at which salt is discharged from a spreader and its distribution on the road surface is critically dependent on the moisture content of the salt and the salt grading.
- This is particularly critical for dry salting but pre-wet salting may also be affected by tunnelling in the spreader where salt has a moisture content over 4.5%
- The maximum particle size affects spread patterns and losses. Spreaders should always be calibrated for the salt used
- The amount of finer particles also affects spread pattern and losses particularly for dry and to some extent the dry element of pre-wet salting

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3.7.2 Salt should be procured with a moisture content within the optimum range for the salting method used whenever possible. The salt moisture content should be kept at a consistent level and should not differ from that used for spreader calibration by more than 0.5% (see following bullet point if outside optimum range).

*N.B. Guidance on remedial actions if salt moisture content is outside the optimum range is provided in the Salt Storage section of the NWSRG Practical Guide*

3.7.3 The optimum moisture content for different salt types and spreading technologies are given below:

| TABLE 3.7.1 – SODIUM CHLORIDESALT OPTIMUM MOISTURE CONTENT | | |
|---|---|---|
| **Salt type** | **Sodium Chloride Content (%)** | **Insoluble content (%)** |
| **UK rock salt** | Dry salting | 2 to 3.5% |
| **UK rock salt** | Pre-wetted | Less than 3.5%* |
| **UK rock salt** | Treated | 2 to 3.5% |
| **Marine salt** | Dry salting | 1.5 to 4% |
| **High purity imported rock salt** | Dry salting | 2 to 3.5% |
| * A lower limit does not apply as the pre-wetting agent helps to prevent the loss of the finer particles during and after spreading | | |

3.7.4 The target range for the salt moisture content is dependent on the type of salt (e.g. UK rock salt, imported rock salt, marine salt) and the salting technology (dry, pre-wetted or treated salting). The moisture content of salt is given as a percentage value. This is the weight of water in the salt expressed as a percentage of the dry weight of salt. The higher the percentage value the wetter the salt.

3.7.5 BS 3247:2011 is the British Standard (BS) for salt used for highway winter maintenance. While this gives information on a "British Standard" for acceptable condition of the salt and also how to test it, specifies a range of particle sizes and a maximum moisture content on delivery of 4%. The BS does not cover the optimum moisture content for dry salt spreading and the dry component of and pre-wet salt spreading. Optimum moisture contents recommended by NWSRG for spreading are generally lower than the maximum given in the BS. Salt can be used with moisture contents slightly higher (0.5% higher) than the 4% advised in BS, but for salt with higher than 4.5% moisture content there is a risk of tunnelling occurring in the hopper. This tunnelling could result in large areas of road being left untreated (see warning below).

3.7.6 Although there is a specification for marine salt in BS 3247, test sieves should include 6.3mm, 2.36mm and 300μm or European sieve size equivalents to facilitate the assessment of their suitability.

3.7.7 The best spreading performance (and possible reduction in spread rates as a result) will be obtained if salt moisture content is kept within the recommended optimum ranges.

*N.B. The BS standards are not fully in line with the NWSRG's opinion on optimum condition for spreading.*

# 3.8 Salt Grading and How It Affects Spreading Performance

3.8.1 Salt grading is important for dry spreading and the dry element of pre-wet spreading mainly to ensure that there is not a predominance of finer particles that are likely to be removed from or not reach the roads surface due to wind and vehicle draughts. The grading will also effect the spread pattern which is why it is important (along with moisture content consistency) for the spreader to be calibrated for the salt used.

3.8.2 Salt containing a lower proportion of fine particles is less effected by wind and vehicle draughts when spreading resulting in lower losses and therefore spread rates. Larger salt particles have been shown to penetrate ice and snow more effectively but are more prone to bouncing over the road surface and off of the target area for precautionary treatments. The grading affects the dissolution rate for the salt where traffic is not available to crush the larger salt grains.

3.8.3 Spreaders should be calibrated for the salt grading used to ensure effective and economical spreading and should always be calibrated for the salt grade being used and the moisture content.

3.8.4 The grading of salt should be regularly checked to determine if recalibration of spreaders is required.

6.3mm rock salt and 6 to 3mm graded marine salt have been shown to provide good spread patterns and low losses from a properly calibrated spreader for precautionary treatments. 10mm rock salt has been shown to be effective in penetrating ice and snow for reactionary treatments .

# 3.9 When Alternative De-Icers Other Than Sodium Chloride Should Be Considered for Effective Treatments

3.9.1 There are various scenarios where alternative de-icers may present benefits in terms of effectiveness, efficiency and economy however, based on research and experience, the NWSRG consider that -15°C is the lowest practically effective temperature for salt as a de-icer on the road surface due to limits on the practical formation of brine solutions on paved surfaces.

3.9.2 For salt to be effective as a de-icer it must be in solution. At low temperatures the rate at which a solution may form may be too slow for salt to be used effectively. Therefore, solutions must be formed at higher temperatures for use down to -15°C.

3.9.3 Where conditions are expected that can be defined as:

- Extreme Cold
- Corrosion damage to infrastructure by sodium chloride is unacceptable
- Environmental impacts are unacceptable
- They offer a more cost effective solution

Consider the use of alternative de-icers and/or additives that are appropriate for the local network and conditions.

3.9.4 Where the decision is to not make such provision consider how local winter service policy will deal effectively with situations where sodium chloride treatments may not be appropriate.

## 3.10 The Anti-Icing and De-Icing Performance and Effectiveness of Different Chemical De-Icers

3.10.1 The performance or effectiveness of a chemical de-icer for use on UK paved surfaces can be measured in several ways. While the chemical performance characteristics are very important, the practical performance in use needs to be taken into account. Consideration should be given to the full range of factors described in this section when choosing the most effective and economical de-icer or de-icers to use for a particular network and its associated range of condition.

The overall performance of any de-icer is dependent on a number of aspects including the method of application, its purity and the particle size distribution (grading) as well as the fundamental properties of the chemical and the form in which it is delivered to the paved surface (e.g. dry or in solution). See Annex 3.2.

# 3.11 The Factors to be Considered When Comparing De-Icers

3.11.1 The main considerations to take into account when comparing de-icers.

- De-icers are wasted unless they remain in the target area during and after spreading and is also dependent on the salting technology
- Some de-icers or the method by which they are spread may be less liable to losses when spreading due to traffic, wind, vehicle draughts or over spreading outside of the target area
- Different types of de-icers or composition (e.g. grading and moisture content) effect the accuracy of spreading and likely losses
- The de-icers should be suitable to cover the full range of treatments and conditions that are likely to be encountered on a given network in line with the requirements of the winter service policy and plan

3.11.2 For existing technologies and facilities to be fully suitable for spreading the chosen de-icers including the efficiency and accuracy of any existing spreading technology also consider:

- The purchase and maintenance cost of any additional facilities and plant required to store and spread the de-icers
- The effectiveness of the de-icer for the likely range of conditions and whether they will allow the winter service policy and plans to be met
- How much needs to be spread to effectively prevent ice formation and melt ice and snow – how does this affect equipment requirements, route lengths, times and costs to treat
- The impact on infrastructure and the environment Before using alternative de-icers thorough investigations of the impact on infrastructure and the environment should be made and the appropriate environmental authority should be consulted

3.11.3 The potential impact of de-icers on skid resistance (for some this is a concern, for others the effect is negligible and for others it may only be an issue where a build-up of the de-icer on the road surface occurs over time) Some de-icers can leave residues on roads although these should not reduce friction levels significantly.

3.11.4 Weight for weight, the alternative de-icers to sodium chloride generally available in the UK are more expensive. However, the relative cost of different de-icers, one to another, is dependent on many factors including their effectiveness and cost of storage, preparation and delivery to the road surface, which generally will not be comparable on a weight for weight basis.

3.11.5 The following table highlights some of the factors that can be considered when using alternatives to sodium chloride. Further consideration should be given to the effect on the skid resistance:

| TABLE 3.11.1 – DE-ICER INFRASTRUCTURE AND ENVIRONMENTAL IMPACTS | | |
|---|---|---|
| **De-icer** | **Infrastructure** | **Insoluble content (%)** |
| **Sodium chloride** | Corrosive to steel, aluminium, reinforced concrete | Harms vegetation, relatively low impact on water quality. |
| **De-icers containing ABP** | Similar to sodium chloride, potentially less corrosion of spreaders | Similar to sodium chloride. Service providers should contact the relevant national environmental agency to agree their use |
| **Calcium chloride** | Corrosive to steel, aluminium and reinforced concrete | Damages vegetation, relatively low impact on water quality |
| **Magnesium chloride** | Corrosive to steel and aluminium, damages weak concretes | Damages vegetation, relatively low impact on water quality |
| **Calcium magnesium acetate** | Non-corrosive to most metals, moderately corrosive to galvanised steel | Benign – least harmful de-icer |
| **Potassium formate** | Non-corrosive to most metals, moderately corrosive to galvanised steel | Slightly lower BOD than potassium acetate so less impact on water quality |
| **Ethylene glycol** | Non corrosive | High BOD and COD so damages water systems, toxic to mammals |
| **Propylene glycol** | Non corrosive | High BOD (higher than ethylene glycol) and COD, damages water systems |
| **Urea** | Non-corrosive | High BOD and COD, damages water courses by releasing ammonia and nitrates to water courses, toxic to aquatic life |
| **NOTES:**<br>Factors highlighted in red are high impact<br>Factors highlighted in green are low impact | | |

# 3.12 Further Issues to be Considered

3.12.1 Solid de-icers must dissolve to form a solution before they become effective. Smaller particles dissolve more rapidly than larger particles, and therefore (in all but low humidity and low temperature conditions) become effective as de-icers more rapidly. 6.3mm salt will dissolve more rapidly than 10mm salt, but the difference in the percentage of finer particles is relatively small - about 50% to 60% of 6.3mm rock salt may pass through a 2.36mm sieve, while for a 10mm salt it may be about 45% to 55%.

3.12.2 De-icers are not effective unless they remain in the target area, Although smaller particles may dissolve more rapidly, they are more likely to be affected by the wind or spreader and traffic induced turbulence during spreading. Wind effects are likely to be greater the larger the spread width.

3.12.3 Marine salt tends to have fewer fine particles and therefore are less affected by wind or vehicle induced turbulence. Marine salt can tend to be softer and break up more easily than UK rock salt to help the salt dissolve more rapidly and compensate for the lack of fine particles in the grading.

3.12.4 For dry salting, particularly for salts with low moisture content finer particles are more likely to be affected by wind and traffic induced turbulence, and be displaced by vehicle tyres in the period before they dissolve after spreading.

3.12.5 Wind/turbulence can affect particles of all sizes. Particles less than 0.6mm in size are particularly prone to displacement, although the effects are less for pre-wetted and treated salt than for dry salt. The size of a particle also affects the distance it travels after leaving the distribution system of a spreader. Larger particles travel further than smaller particles and it is more difficult to control their movement. This may affect the uniformity of the salt distribution profile and the wastage.

3.12.6 If the target area is wide (e.g. more than two lanes wide), the finer particles of salt will not be spread to the edges of the distribution. Only the larger particles will reach these areas.

3.12.7 Tests for NWSRG found that the distribution profile was more uniform and salt losses after 2 hours of trafficking were lower for pre-wetted 3mm salt than for 6.3mm salt.

3.12.8 For post-treatment on layers of snow and ice, larger salt particles are more effective because of their greater potential to penetrate and undercut layers of the snow/ice before the solution they form becomes too dilute to be effective. 10mm salt is therefore considered marginally more effective on snow than 6.3mm salt. However, only about 10% to 15% of 10mm rock salt does not pass through a 6.3mm sieve.

3.12.9 Damage to passing vehicles is more likely when spreading 10mm than 6.3mm salt.

*Figure 3.11.4 - Displacement of de-icer by turbulence from vehicle draughts immediately after spreading*

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# Annex 1

**Grading of Salt**

The grading is the proportion by weight of the different particle sizes in the salt. It is obtained by the sieve analysis of a representative sample of the salt.

BS 3247:2011 specifies a range of acceptable particle sizes for salt used in the UK. These are shown for coarse (10mm grade) and fine (6.3mm grade) rock salt in the figure below.

The grading of some types of de-icer can vary significantly from one delivery to another and therefore it is important to have a process in place to check the grading of deliveries. Checking two or more batches from each delivery is recommended.

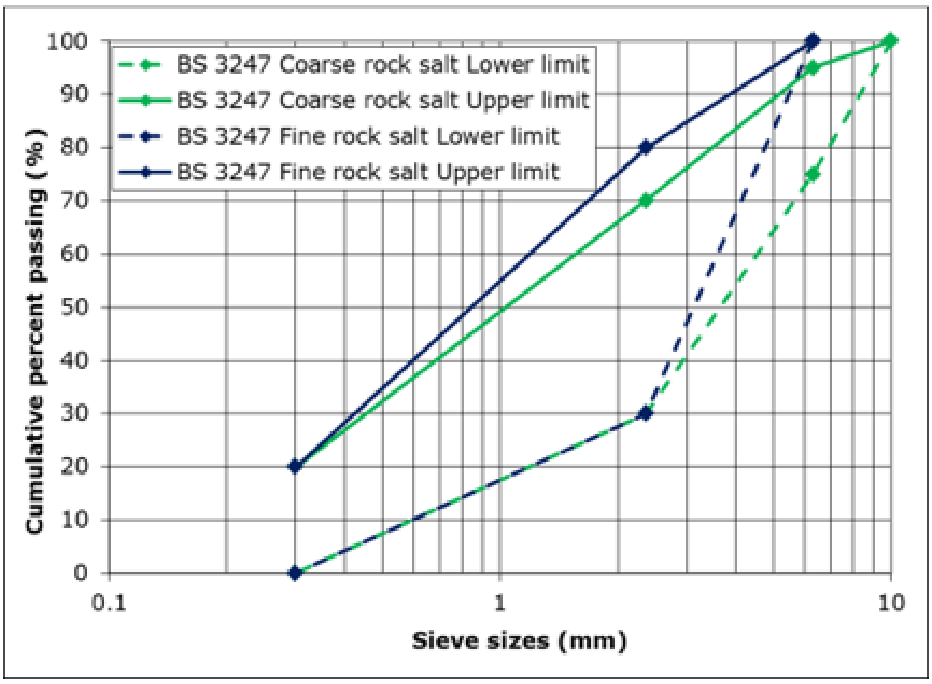


*Figure 3.8.1 – BS3247 Upper and lower limit for grading of fine & course UK rock salt*

UK rock salt is processed so that the particle size distribution (grading) is fairly well centred within the limits in BS 3247:2011.

Marine salt is normally de-dusted, therefore the number of finer particles is (generally) much less in marine salt than in UK rock salt.

Typical gradings for salt available in the UK are shown in the figures given below.

When referring to common types of salt used in the UK, e.g. 6.3mm salt, the '6.3mm' relates to (what should be) the largest particles found within the salt.

For a particular salt, generally the higher the moisture content of the salt, the lower the percentage of fine particles.

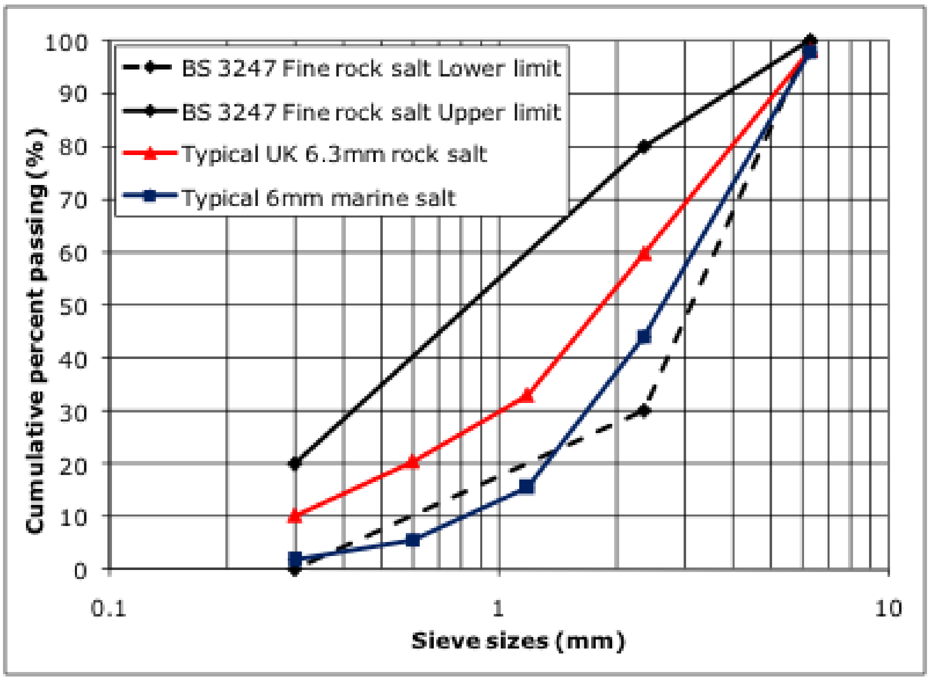


*Figure 3.8.2 –Typical & BS3247 limits to gradings for fine & 6.3mm UK rock salt & 6mm marine salt*

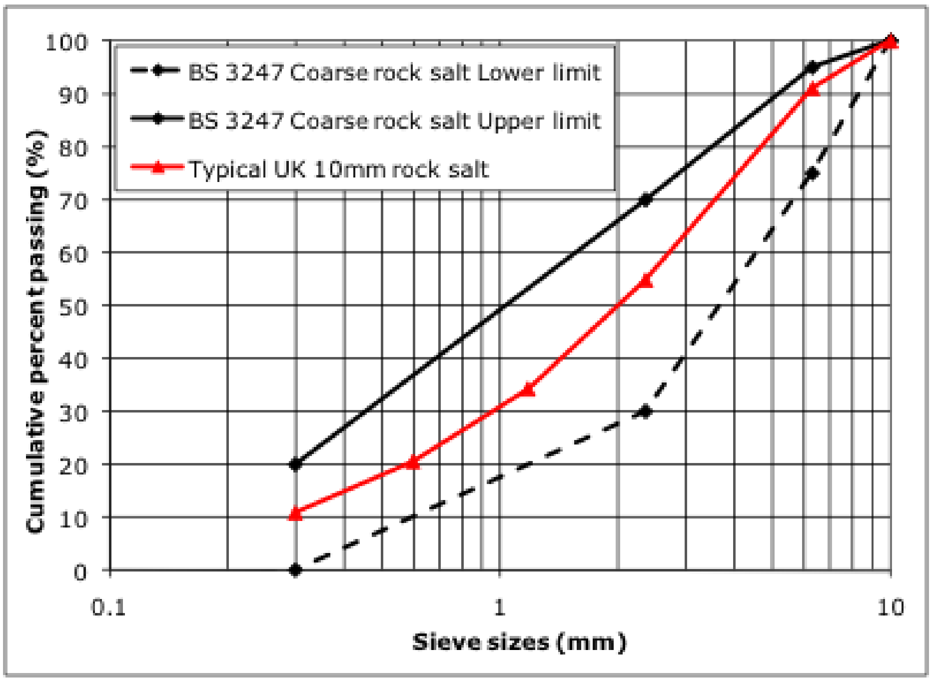


*Figure 3.8.3 - Typical & BS3247 limits to grading for 10mm UK rock salt*

The grading affects how quickly salt dissolves, the loss of salt due to wind and vehicle draughts during and after spreading, the salt distribution across the road and the ability to melt snow and ice. These factors are also affected by the salting method (See Spreading Methods/Technologies section of the NWSRG Practical Guide).

# Annex 2

The SHRP handbook (the Strategic Highways Research program of the USA National Research Council produced SHRP-H-322 - “Handbook of Test Methods for Evaluating Chemical De-icers”), UK practice, UK research and the wider body of expert knowledge help to inform the following key factors which should be considered.

**1) Effective minimum temperature**

For the purposes of this guidance, the effective temperature is the lowest temperature at which a particular concentration of a salt (de-icer) solution will not start to freeze. i.e. ice crystals have not started to form in the solution. The effective minimum temperature for a particular de-icer is the lowest temperature for a practically achievable maximum solution of that de-icer.

Effective temperature is indicated in absolute terms by the phase diagram of a de-icer that shows:

i) the temperature at which solutions of different concentration freeze

ii) the eutectic temperature. i.e. the minimum temperature at which freezing can be prevented where the maximum amount of salt (de-icer) capable of being dissolved is available in the solution (**BUT** such a solution is not practically achievable in winter service conditions for the reasons stated elsewhere in this chapter)

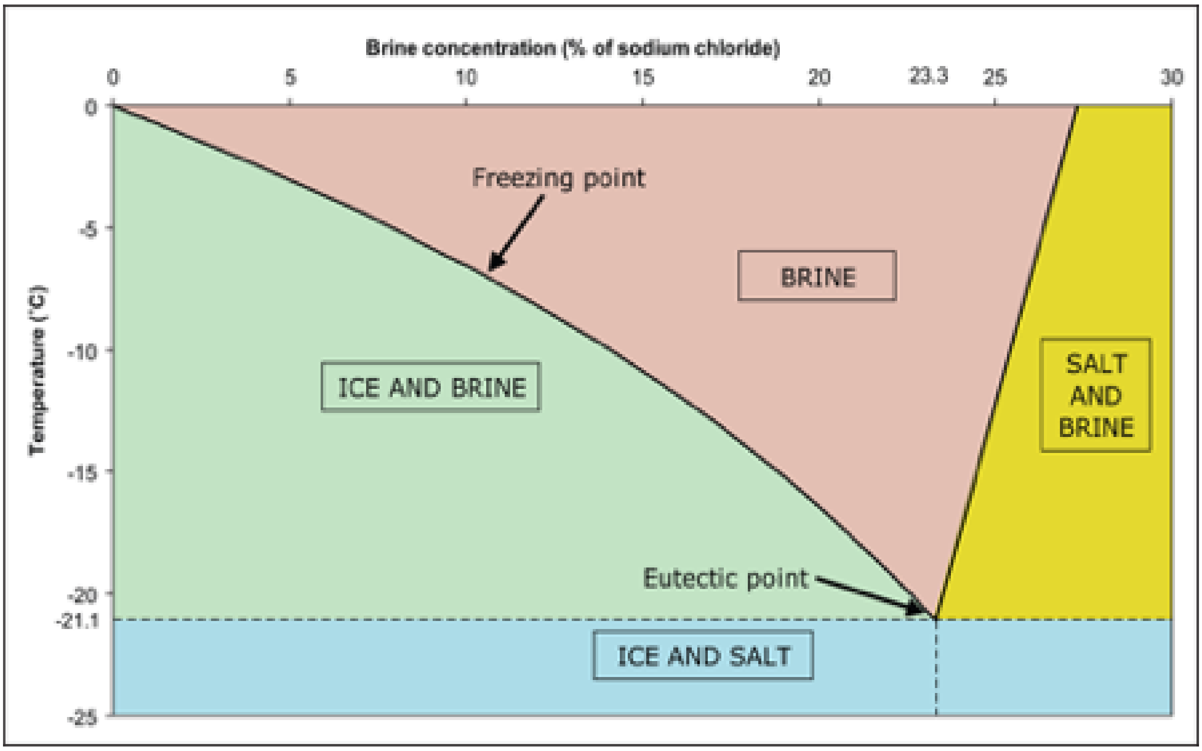


*Figure 3.6.1 - Phase diagram for sodium chloride and water*

The effective temperature is a term that is frequently used to indicate the minimum temperature down to which a de-icer solution is considered to prevent or melt ice. However, this figure is often misunderstood (or confused with eutectic point) because of the significance of the concentration of the brine solution. The amount of water present and rate of dissolution at low temperatures both affect the practically achievable maximum concentration of the solution. In addition, as the solution absorbs more water from the air, surface water or melting ice the temperature to which it is effective diminishes. These facts are not always accounted for when considering the effectiveness of de-icers and may lead to incorrect assumptions for treatments

An important factor is the amount of de-icer that needs to be in solution to create an effective solution. This impacts cost and effectiveness considerations, particularly where the de-icer is able to dissolve and form effective solutions at lower temperatures

As previously noted, based on research and practical experience the NWSRG consider -7°C (or -5°C in low humidity conditions) as the lowest effective treatment temperature at the time of spreading dry or pre-wetted sodium chloride salt. The reasons for this are dealt with in more detail at 3. below

For the purposes of defining extreme cold conditions for winter service in the UK the NWSRG have determined that temperatures below -7°C (or -5°C in low humidity conditions) should be termed as “Extreme Cold” in this guidance

While sodium chloride salt could be spread as brine at temperatures in the extreme cold range this is considered to be impractical due to the large amounts of brine that would need to be spread and the fact that the brine solution may freeze to form sheet ice if insufficient is spread or the absorption of water into the solution from humidity, surface water/melting ice renders the treatment ineffective.

**2) Time for forming an effective solution (rate of dissolution)**

There are situations when the time the de-icer takes to dissolve to form a fully effective solution may be critical.

A de-icer that dissolves rapidly may be applied later than a slower alternative, this may be beneficial in time restricted circumstances, allowing for later treatments where this may be critical e.g. after precipitation, periods of very heavy traffic or sudden unexpected, or lower than forecast, temperature drops.

As salt and other chemical salt de-icers must be in solution for them to be effective i.e. prevent ice forming, sufficient time must be available to form an effective solution.

How quickly any solid chemical de-icer dissolves is dependent on the amount of de-icer, particle size, temperature and the amount of moisture present on the road surface, in the air or added during spreading.

For granular de-icers the size of the particles and grading affect the rate of dissolution, smaller particles dissolving more rapidly.

Traffic has a significant effect both crushing the de-icer grains to form smaller particles and “agitating” the mix of salt and water/brine to aid more rapid dissolution.

Some de-icers are very hygroscopic, i.e. they absorb water, including moisture from the air and therefore dissolve more readily.

Hygroscopic de-icers usually must be stored in sealed containers or a controlled environment when in solid form and are may be unsuitable for bulk storage. For this reason, they are most usually prepared for use in liquid form, e.g. calcium chloride and magnesium chloride brines.

Further information on the storage of alternative and liquid de-icers, many of which are hygroscopic, is given in the “Treatments for Extreme Cold” chapter of the NWSRG Practical Guide. (N.B. it is recommended that the local office of the relevant national environmental agency is contacted for advice on safe storage of such de-icers).

Some dry chemical de-icers are exothermic and give off heat when they dissolve. Others are endothermic and absorb heat. These effects are short term and generally considered to be insignificant to dissolution or road surface temperature in relation to the thermal mass of the road surface for the quantities spread.

However, these exothermic and endothermic properties may be very significant to the safe and effective production of solutions from dry stored materials. Appropriate Health and safety measures should be taken and proper processes for production implemented.

**3) Minimum temperature down to which an effective solution can be formed**

- As has been shown above, de-icers vary in their ability to prevent ice-forming in solutions and the minimum temperature at which they can be effective and this is indicated in the “Phase Diagram” for a particular salt
- When sodium chloride treatments are made in extreme cold conditions, it is considered that the salt will not enter solution sufficiently rapidly for them to provide a practical treatment. Where sufficient salt can be spread at temperatures higher than -7°C and also has sufficient time and available water on the surface or in the air (as moisture/humidity) to enter solution, it is considered, that -15°C is the lowest temperature to which salt can prevent ice on the road surface
- Brine treatments are not recommended at extreme cold temperatures for the reasons outlined above

**4) Minimum temperature down to which an effective solution can be formed**

**5) Cost per unit weight (delivered to the paved surface)**

Where less weight of de-icer is required to produce the same effectiveness of treatment, this creates important considerations for its use for the following reasons:

- The amount required for a treatment relates directly to the cost of purchase
- As noted earlier de-icers that require less material by weight to form an effective solution and/or are able to be dissolve and/or be effective at lower temperatures may be a more economical solution than would appear from a direct comparison of price per unit weight

- For de-icers that are spread in dry form (dry and pre-wet spreading), either less de-icer has to be transported in the spreader or longer routes can be covered. This presents cost savings
- For de-icers that are spread as brine there will be a small difference but this is more dependent on the effectiveness of a solution at a particular concentration.
- Where less weight of material is required to be purchased for treatments savings may be made in transport and storage costs

6) **Weight per unit volume (density)**

- The most important factors relating to the density of de-icer are applicable to lower density materials. However, the quantities required to be effective, as outlined above, will impact on some of these considerations
- A lower density de-icer will require a greater volume of storage space that may have land take and cost implications
- Lower density de-icers, when spread as dry materials, are likely to be more susceptible to wind and vehicle draughts. This may require more material to be spread or it being unsuitable in some conditions
- Lower density de-icers may affect the length of route that can be covered if the volume that can be held in the spreader becomes the limiting factor

7) **Effectiveness to melt ice or snow and**

8) **Effectiveness to penetrate ice or snow and**

9) **Effectiveness to undercut ice or snow**

- Although these may appear to be similar properties, they are individually important when the de-icer is used for reactionary treatments
- The effectiveness in melting ice or snow of a particular de-icer may be quite different to its effectiveness in preventing the formation of ice compared to the melting, penetration and undercutting of ice or snow
- Penetration of the ice or snow is important, particularly for thicker layers, as this helps a more rapid melting of the ice or snow.
- It also aids undercutting as it helps the de-icer to penetrate to the paved surface
- Undercutting is important as it aids the clearing of ice and snow by ploughing and traffic, particularly where a de-bonding treatment has not been applied or has become ineffective. Undercutting also presents a second surface for the de-icer to help with the melting process

- It is not only the type of de-icer but also the form in which it is delivered that is important:
    - It has been shown that the grading of rock salt affects its ability to penetrate ice or snow. The larger grains of a 10mm graded product being more effective than 6mm or smaller gradings
    - The application of brine to all but the thinnest layers of ice or snow is problematical due to the rapid dilution effects as the ice or snow is melted

Standard tests produced in the USA,( the "SHRP tests"), provide a method to measure all of the above properties and it is recommended that the results of these methods is considered where de-icers are acquired for treating ice and snow.

**10) Required spreading technology and "spreadability"**

- The technology or method of spreading is an important consideration.
- Some technologies are more economical in use of de-icer than others mainly due to the accuracy of spreading and thus reduction in wastage of de-icer spread outside of the target area
- Further detailed information is given in the chapters "Treatment Methods and Technologies", "Spreader Calibration",
- "Treatments for Extreme Cold" and "Salting Spread Rates" (The future "Business Case" chapter will also provide information to help with decisions on purchase of spreaders and de-icers)
- The "Spreadability" of the de-icer, for the purposes of this guidance, relates to two important factors:
- The ease with which it can be spread using traditional spreading technology
- The accuracy with which it can be spread over a range of conditions
- Factors likely to affect the spreadability of dry and granular de-icers include:
    - Grading
    - Density
    - Largest & smallest particle sizes
    - Moisture content
    - Susceptibility to tunnelling or restriction in delivery mechanisms

## 11) Retention on paved surface after spreading

**The retention of the surface is important for various reasons, including:**

- Economical use of the de-icer
- Effectiveness of the treatment
- Asset damage
- Environmental impacts
- The conditions in which the de-icer is spread will affect retention including road surface wetness, wind and vehicle drafts, amount of traffic, precipitation after spreading and treatments on ice or snow
- Some de-icers are more susceptible to removal from the road surface by wind, vehicle draughts and traffic. These effects may be due to a combination of factors relating to the de-icer properties and/or the conditions in which they are spread
- The effects of the above conditions are discussed in more detail in other chapters including, "Spreader Calibration", "Treatments for Extreme Cold" and "Salting Spread Rates". However, due to the variation in spreading conditions, there is not one de-icer or technology that performs better than others across all conditions

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