CLEAR ROADS
research for winter highway maintenance

RESEARCH BRIEF

AUGUST 2022

UNDERSTANDING SALT CHEMISTRY HELPS FIGHT SNOW AND ICE

RESULTS SUMMARY

Training materials developed using the salt phase diagram will help winter road maintenance managers and operators determine optimal concentrations of salt in deicing materials to keep roads clear.

PROJECT DETAILS

Project Title: Understanding the NaCl Phase Diagram

Project Number: CR20-02

Project Cost: $100,000

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Need for Research

Clear Roads agencies have years of experience using sodium chloride for deicing. The effects of salt on water, however, vary depending on salt concentrations and ambient temperatures. As temperatures drop, salt's effectiveness diminishes; adding more is not always the best choice. A brine solution will no longer be able to prevent freezing at the *eutectic* point (the coldest temperature where liquid solution will be present), when the salt concentration is 23.3 percent and the temperature is -6°F. Adding more salt will not be effective and can be wasteful.

The salt phase diagram—a graph that shows the effects of temperatures and concentrations on salt brine solutions—can be a useful tool for understanding the chemistry of when salt brine solutions freeze. Commonly used by scientists and engineers, the phase diagrams typically don't include an explanation as to how they apply to practical purposes like road maintenance. Clear Roads members wanted a tool for maintenance managers to better understand and help demonstrate the basics of salt phase chemistry to optimize the use of road salt and keep roads clear.

Objectives and Methodology

The goal of this project was to more clearly demonstrate how salt brine solutions with different concentrations react at various temperatures and the implications for road application.

After reviewing existing examples of salt phase diagrams and test methods to assess deicer performance, researchers conducted a series of lab demonstrations. Eight brine solutions of varying salt concentrations were tested at temperatures ranging from -6° to 32°F. Researchers observed ice crystal formation and salt precipitation from the solutions and documented the changes using high-definition photography and a stereomicroscope, which provides a three-dimensional view.

Drawing from these observations and existing data, researchers produced educational materials applying the salt phase diagram to road salt applications.

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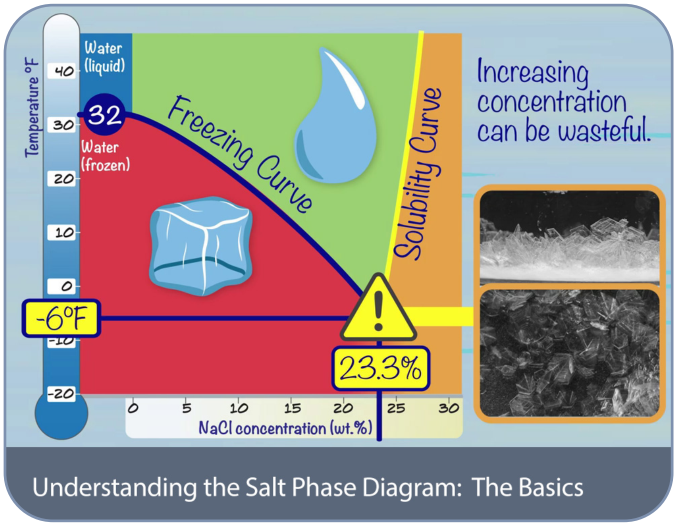

The adapted and annotated salt phase diagram shown in the project video will help winter maintenance managers and operators better understand how salt behaves when treating roads.

Results

The researchers' efforts resulted in informational materials that clearly explain the salt phase diagram and how it applies to keeping winter roads clear. A one-page fact sheet illustrates the impact of brine concentration on anti-icing operations, showing how temperature and salt concentration influence ice formation. This resource includes the solubility curve below which salt crystallizes and precipitates from the liquid. According to the fact sheet, and from a practical salt application standpoint, peak performance is obtained above 15°F. However, at temperatures below 20°F, most agencies will consider blending other products or brine additives to expand the effectiveness of the brine solution and provide an additional margin of error for actual weather variations.

A short video also explains salt phase diagram concepts and how they apply to winter road operations. The video includes frequently asked questions, including:

- **How do temperature and concentration affect salt brine performance?** While the eutectic point of brine solution is 23.3 percent salt concentration at -6°F, in practice, brine gets diluted by snow and ice, so it is most effective at or above 15°F.
- **How will this information assist in improved winter operations?** If salt concentrations are too low, pavement is more likely to refreeze.
- **Is more salt better?** Increasing the concentration beyond 23.3 percent will not help melt more snow and ice, and the salt will be wasted.
- **What happens as the salt brine layer on the road gets diluted?** Even at optimal concentrations, dilution will occur over time and reapplication may be needed.

The lab experiments resulted in a series of images illustrating the concepts of the salt phase diagram. The video and images also showed that as the solutions froze, liquid brine was trapped inside the ice, which implies that a frozen brine solution may not be as strong as ice from water alone and may be active when temperatures rise.

Benefits and Further Research

The educational materials produced in this project, available at the Clear Roads website, clearly explain the basic chemistry of salt brines to help inform decisions on the appropriate salt concentrations at various temperatures. State departments of transportation and local public works agencies can use these tools in winter maintenance training programs. The compendium of images from the lab work promotes a deeper understanding of the concepts of the salt phase diagram depicted in the educational materials.

The chemistry of other deicing chemicals—such as calcium chloride and magnesium chloride—will be different from sodium chloride brine. This may prompt further study and analysis of phase diagrams for other salt brine blends.

"This project provided easy-to-understand materials to interpret the salt phase diagram and assist winter maintenance managers in optimizing their use of salt and salt brine. Images taken during the research clearly show how and when ice forms at different concentrations of salt."

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