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Final Report

EVALUATION OF SELECTED DEICERS BASED ON A REVIEW OF THE LITERATURE

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The SeaCrest Group

October 30, 2001

COLORADO DEPARTMENT OF TRANSPORTATION

RESEARCH BRANCH

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16. Abstract
A literature review was conducted on the following deicers used for snow and ice control: magnesium chloride (e.g., FreezGard Zero®, Ice-Stop™ CI, Caliber™ M1000, Ice Ban™ M50), calcium chloride (Liquidow*Armor*), sodium chloride (road salt and Ice Slicer®), Calcium Magnesium Acetate (CMA®), Potassium Acetate (CF7®), CMAK™ (mixture of CMA and Potassium Acetate), Sodium Acetate (NAAC®), and sanding materials. These deicers were evaluated for chemical contaminants, environmental effects, human health effects, corrosion, application rates, performance, cost, and advantages and disadvantages. For most of the deicers reviewed there were gaps in available information. Thus, additional studies would be necessary to further elucidate the potential impacts of the deicers. A summary of the water quality data collected by the U.S. Geological Survey (USGS) and the Roaring Fork Conservancy in the Roaring Fork watershed in Colorado is also provided.

A qualitative worker survey was also conducted. Questionnaires were sent to 126 employees of the Colorado Department of Transportation and Roaring Fork Transit Authority having daily contact with deicers. Of the 69 employees that responded to the survey, 26% reported minor symptoms including eye, skin, respiratory, and intestinal irritation. It was not possible, based on the qualitative nature of the survey, to determine whether the symptoms were related to deicer use.

Implementation
Based on a review of the literature, it is concluded that each of the deicers evaluated has both advantages and disadvantages, in terms of environmental effects, human health effects, cost, performance, and corrosion. Thus, the maintenance supervisor should evaluate the trade-offs in determining which deicer(s) to use in order to best meet the needs of the State, city, town, and the public.

17. Key Words	18. Distribution Statement
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EXECUTIVE SUMMARY

Sand and sodium chloride (the first deicer used) have been used for snow and ice control in the United States since the 1930s. These materials were cheap and abundant and enabled many roads to remain open during winter storms. By the 1950s some of the harmful effects of deicing salts had become widely known. However, the benefits of using deicers and sand for increasing safety of winter driving remained a major factor in the continuing use of these snow and ice control materials. Since the 1960s numerous studies have been conducted on the environmental and human health effects and corrosion from the use of deicers. A report prepared by Environment Canada (2000) proposed that road salts be considered "toxic" under the Canadian Environmental Protection Act of 1999. However, the report also stated that the use of deicing agents was an important component of the strategies to keep roads open and safe during the winter and minimize traffic accidents. It further concluded that human safety must never be compromised (Environment Canada 2000).

The deicers reviewed in this study are divided into the following three groups: chloride-based deicers, acetate-based deicers, and sanding materials. The chloride-based deicers include magnesium chloride (FreezGard Zero® with Shield LS®, Ice-Stop™ CI, Caliber™ M1000, Ice Ban™ M50), calcium chloride (Liquidow* Armor*), and sodium chloride (road salt and Ice Slicer®). The acetate-based deicers include Calcium Magnesium Acetate (CMA®), Potassium Acetate (CF7®), Sodium Acetate (NAAC®), and CMAK™ (a mixture of CMA and Potassium Acetate). For each of the deicers and sand, information is provided on chemical contaminants, environmental effects, human health effects, corrosion, application rate, performance at low temperatures, costs, advantages and disadvantages. Summary tables are also provided.

Chemical Contaminants

Chemical and corrosion specifications have been developed for deicers by Colorado, other states, and a consortium of northwestern states and British Columbia [Pacific Northwest Snowfighters (PNS) Association]. These specifications limit the amount of trace metals and other chemicals allowed in deicers and require that deicers containing corrosion inhibitors be at least 70% less corrosive to mild steel than salt (sodium chloride).

The concentrations of trace metals and other chemicals are provided for each of the deicers reviewed in this report. The trace metals that were analyzed include arsenic, barium, cadmium, chromium, copper, lead, mercury, selenium, and zinc. Other chemicals and parameters that are provided include cyanide, total phosphorus, pH, sulfate, ammonia, nitrate, and Biochemical Oxygen Demand (BOD).

Environmental Effects

The environmental effects of the deicers are grouped into chloride-based deicers, acetate-based deicers and sand. The deicers are evaluated in terms of their effects on soil, surface water, groundwater (i.e., drinking water supplies), air, aquatic organisms, terrestrial vegetation, and terrestrial animals.

Chloride-based Deicers

The chloride ions in deicers increase the salinity of the soil near the roadways where they are applied. The magnesium and calcium ions increase the stability and permeability of the soil, whereas sodium ions decrease soil stability and permeability. Sodium chloride, magnesium chloride, and calcium chloride may contribute to the mobilization of trace metals from the soil to surface and groundwater, but field evidence of this effect is limited.

The chloride-based deicers have the potential to increase the salinity of the rivers, streams and lakes. Since the dilution of deicers from the roadways to nearby streams is estimated to range from 100 to 500-fold, salinity increases are only likely to occur in slow-flowing streams and small ponds. Increased salinity has been reported in groundwater at a distance of more than 300 feet from roadways.

The organic corrosion inhibitors present in some chloride deicers have the potential to cause oxygen depletion of streams near the roadways where the deicers are applied and can result in mortality of fish and other aquatic organisms. However, the 100 to 500-fold dilution estimated to occur from the roadways to the streams reduces the likelihood of these effects.

The chloride deicers have relatively low toxicity to fish and aquatic invertebrates. They reduce air pollution through a reduction in sand use. The solid chloride deicers, such as salt, may contribute to air pollution through particulates released into the air.

The chloride-based deicers have been shown to have adverse effects on terrestrial vegetation. Damage to vegetation from deicing salts has been reported to a distance of 100-650 feet. However, there is a wide range of tolerance of different species of plants to the effects of chlorides.

Sodium chloride crystals attract birds and mammals, which can contribute to road kills. Magnesium chloride and calcium chloride deicers, on the other hand, do not attract wildlife since the main chemical attractant is sodium. Acute toxicity tests show that there is slight oral toxicity of the chloride deicers to small animals.

Acetate-based Deicers

The acetate-based deicers are organic and have different kinds of effects on the environment than the chloride-based deicers. The acetate ions are broken down by soil microorganisms and may result in oxygen depletion of the soil, which can impact vegetation. The acetate deicers also have the potential to cause oxygen depletion in rivers, streams and lakes. Since the dilution of deicers from roadways to nearby streams is estimated to range from 100 to 500-fold, oxygen depletion is likely to occur only in slow flowing streams and small ponds. The aquatic toxicity of CMA to fish and invertebrates is low. The acetate deicers Potassium Acetate, Sodium Acetate (NAAC), and CMAK have higher toxicity to aquatic organisms.

The use of the acetate deicers results in the decrease of air pollution from the reduction in sand use. However, the solid acetate deicers CMA and NAAC may contribute fine particulates to the air and increase air pollution.

The acetate deicers CMA and Potassium Acetate are not harmful to terrestrial vegetation at the concentrations typically used on the roadways. However, NAAC may potentially have an adverse effect on vegetation because of the presence of the sodium ion, which decreases the stability and permeability of the soil. The depletion of oxygen in the soil from the breakdown of

the acetate ion can have a negative effect on plant growth. However, field evidence of this effect is limited.

Slight acute oral toxicity to mammals has been reported for the acetate deicers. No studies have been conducted on whether the acetate deicers attract wildlife to roadways.

Sand

Sand is not a deicer, but has been used for snow and ice control since the early 20th Century. Sand has a negative effect on water quality as a result of the increased turbidity caused by the presence of sand particles in water. The increased water turbidity can result in mortality of fish and bottom-dwelling invertebrates that may be covered by the sand. The increased turbidity will also reduce or inhibit photosynthesis in aquatic plants. Sand used for snow and ice control increases air pollution and contributes approximately 45% of the small particulates present in air.

Water Quality Data Collected in the Roaring Fork Watershed

Water quality data has been collected by the U.S. Geological Survey (USGS) and the Roaring Fork Conservancy in the Roaring Fork watershed between Difficult Creek near Aspen, Colorado and the Roaring Fork River at Glenwood Springs, Colorado. The study was conducted to characterize the episodic occurrence of dissolved chloride resulting from the deicing of roadways. Mean daily stream flow, specific conductance, and dissolved chloride were measured and compared with historic data. The dissolved chloride concentrations were lowest at the upstream stations and highest at the downstream station at Glenwood Springs. The high levels of dissolved chloride found in the Roaring Fork River near Glenwood Springs may be the result of the interaction of the water with the sedimentary geology in the watershed.

The Roaring Fork Conservancy collected water samples from various locations in the Roaring Fork watershed and measured total chlorides and conductivity between September 2000 and September 2001. Samples were collected from the Roaring Fork River between Difficult Creek and Glenwood Springs, and the Crystal River, Frying Pan River, and several creeks that flow into the Roaring Fork River. The chloride levels were generally highest at the downstream stations near Glenwood Springs. A large geological feature and hot springs near Glenwood Springs was postulated to be the cause of higher chloride levels at that location. However,

the chloride levels were still below the Colorado regulatory limit of 250 ppm for domestic water supplies.

Studies conducted by the Aspen Department of Environmental Health showed that chloride levels increased in the Roaring Fork River from above Aspen to downstream of Aspen when chloride-based deicers were used (L. Cassin, Aspen Environmental Health Department, personal communication).

Human Health Impacts

Potential human health effects of deicers may include irritation of the eyes, skin, respiratory tract and digestive tract, and possibly small increases in cancer rate from trace metals. Toxicity tests conducted on rats indicate that the deicers could have slight oral toxicity to humans. Elevated levels of sodium in drinking water have been linked to hypertension in humans. The deicers Ice Ban M50, inhibited calcium chloride, and CMAK have levels of nitrates above the Colorado drinking water standards. High blood levels of nitrates in infants and young children can interfere with oxygen uptake from the blood. Inhalation of sand over long periods of time could lead to diseases of the lungs, such as silicosis. Sand is also listed as a carcinogen.

Trace metals are naturally occurring elements that are present in some deicers in minute amounts. Vehicles and industrial activities also are sources of trace metals. Long-term exposure to trace metals may cause diseases of the lung, liver, kidneys, blood, nervous system, respiratory tract, kidneys, and skin. The trace metals arsenic, cadmium, and chromium (VI) have been identified as carcinogens. Lead and selenium (as selenium sulfide) may be carcinogens, but there is insufficient evidence that they can cause cancer in humans. Since the dilution of the deicers from the roadway to drinking water supplies is estimated to range from 100 to 500-fold, the small amounts of trace metals in deicers would probably not cause serious human health effects.

A study conducted by the Colorado Department of Public Health and the Environment (CDPHE) on the health effects of the deicers sodium chloride and magnesium chloride from exposure to air is summarized in this report. The results of the risk assessment indicated that arsenic, cadmium and chromium exceeded a cancer risk of 1 in 1,000,000 ($1x10^{-6}$) when exposure was 24