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Environmental Protection Technology Series

Water Pollution and Associated Effects from Street Salting

National Environmental Research Center
Office of Research and Monitoring
U.S. Environmental Protection Agency
Cincinnati, Ohio 45268

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WATER POLLUTION AND ASSOCIATED EFFECTS FROM STREET SALTING

By

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ABSTRACT

This report comprises a state-of-the-art review of highway deicing practices and associated environmental effects.

The bare pavement policy has resulted in a great increase in the use of deicing salts, in many cases replacing the abrasives previously used. However, no conclusive evidence has been found to substantiate that salt usage makes winter travel safer.

Besides chemical melting, various methods for anti-icing/deicing are available or have been conceived (external and in-slab thermal melting systems; mobile thermal "snow melters"; compressed air or high speed fluid streams in conjunction with snowplow blades or sweepers; snow/ice adhesion reducing [hydrophobic/icephobic] substances; improved vehicular and/or tire design) which may become more prominent in the future especially when communities realize that a price must be paid to alleviate the environmental effects of wintertime salting.

Salt storage facilities often become a major contributing source of local groundwater and surface water contamination and vegetation damage. Coverage and proper drainage of salt piles is becoming more prevalent, but there has not been an adequate acceptance of approved practices and a proper recognition of pollutional problems associated with this material storage. Types of enclosed structures are illustrated, and cost considerations given.

High chloride concentration levels have been found in roadway runoff. The special additives in deicing salts may create more severe pollutional problems than the chloride salts. Many roadside wells, due to contamination by salt laden runoff, have had to be replaced in such snow belt states as New Hampshire, Maine, and Massachusetts. Widespread damage of roadside soils and vegetation has been observed in areas of liberal salt usage.

Areas of future research are also indicated in this report.

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ACKNOWLEDGEMENTS

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SECTION I

CONCLUSIONS[1/]

Some of the more pertinent conclusions drawn from the study are as follows: (Table I presents a synoptic version)

1. Highway salts can cause injury and damage across a wide environmental spectrum, and these effects although not yet evident in certain areas of the country, may appear in the future.

2. Practically all highway authorities in the U.S. believe that ice and snow must be removed quickly from roads and highways, and that "bare pavement" conditions are necessary, often resulting in excessive salt application. Conclusive evidence is needed to substantiate using salt to make winter travel safer.

3. Salt storage sites are persistent and frequent sources of ground and surface water contamination, and vegetation damage.

4. The special additives found in road deicers provoke great concern because of their severe latent toxic properties and other potential side effects. Significantly, little is known as to their fate and disposition. Field investigations must provide considerably more data to determine safe levels when using these additives.

5. A sufficient number of incidents and detailed studies have been described to show the adverse impact of deicing salts to water supplies and receiving waters.

6. In less severe cases of salt intrusion into public water supplies, salt-free patients have been cautioned to change their potable water source.

7. Deicing salts are found in high concentrations in highway runoff.

8. Surveillance data are needed to clearly define the many influences of deicing salts upon the environment.

9. The majority of in-depth studies support the finding that deicing salts are a major factor in vehicular corrosion and roadway damage. The literature also indicates that rust inhibiting additives do not produce results to justify their continued use. It is further noted that deicers may attack and cause damage to telephone cables, water distribu-

tion lines, and other utilities adjacent to streets and highways.

10. There is little doubt that road deicers can disturb a healthy balance in soils, trees, and other vegetation comprising the roadside environment.

TABLE I

CONCLUSIONS
(ABBREVIATED LISTING)

1. SALTS CAN CREATE VARIOUS ENVIRONMENTAL PROBLEMS

2. "BARE-PAVEMENT" IS GENERAL PHILOSOPHY — EXCESSIVE APPLICATION USUALLY RESULTS

3. STORAGE SITES CAN CAUSE POLLUTION

4. DEICING ADDITIVES INCREASE PROBLEMS

5. HIGH SALT CONCENTRATIONS FOUND IN HIGHWAY SNOWMELT

6. SALTS CAN CONTAMINATE WATER SUPPLIES AND RECEIVING WATERS

7. SALTS CAN BE DETRIMENTAL TO HEALTH

8. SALT MONITORING IS NEEDED

9. SALTS INCREASE CORROSION

10. SALTS CAN DAMAGE VEGETATION

1/ Selected from a more comprehensive listing of conclusions contained in the Edison Water Quality Research Laboratory report(3).

SECTION II

RECOMMENDATIONS[1]

Resulting EPA Projects

Two major projects have been instituted and sponsored by the U.S. Environmental Protection Agency's Office of Research and Monitoring which were based on recommendations from the state-of-the-art survey on the environmental impacts of highway deicing.

One of these projects, recently completed, involved a search for new technology in snow and ice control by Abt Associates, Inc.(1). This work has covered the alternate concepts as highlighted by Table II. It revealed that many studies have been made on ice adhesion in general and that a few experiments have been performed on ice releasing agents for aircraft and vessel exteriors, and outdoor mechanical equipment. However, little has been done to directly investigate the use of such agents on pavement. The search indicated the high potential of using a hydrophobic or icephobic (water or ice repellant) substance for ice control and further recommended that development be sought.

Recognizing the importance of this recommendation, EPA prepared a request for proposal (RFP). The product of this RFP will be a study to develop a hydrophobic or icephobic substance which can be used to reduce the adhesion of ice or hard packed snow on pavements. This study will evaluate the relative merits of using these substances, once determined, as an alternate to salt. The study will be undertaken from the point of view of finding an economical hydrophobic anti-icing/deicing agent which can be placed on or within pavement surfaces and that would not have irreversible harmful effects on the environment. While this approach is novel, it is potentially the most valuable alternative.

Another study which is also being considered, as a result of recommendations from the Abt Project, aims to carefully evaluate the environmental and economic impacts of the continued use of deicing compounds in a more proper perspective.

TABLE II

CHLORIDE SALT REDUCTION POSSIBILITIES
(ABBREVIATED LISTING)

1. EXTERNAL/IN-SLAB THERMAL MELTING
2. STATIONARY/MOBILE MELTERS
3. SUBSTITUTE DEICING COMPOUNDS
4. COMPRESSED AIR TYPE SNOWPLOW
5. ADHESION REDUCING PAVEMENT MATERIALS
6. SOLAR ENERGY STORING PAVEMENT SUBSTANCES
7. ELECTROMAGNETIC ICE SHATTERERS
8. IMPROVED DRAINAGE, ENHANCING RUNOFF, ACCIDENT REDUCTION, AND SNOWMELT CONTROL/TREATMENT
9. SALT RETRIEVAL/TREATMENT
10. IMPROVED TIRE/VEHICULAR DESIGN

The second, and larger project(2) will provide the following:

1. A Deicer Users Manual, to describe snow and ice removal practices and the best systems of applying deicing chemicals to streets and highways. (Several highway agencies and the salt industry are known to have various instructional material that are principally directed to operational performance. The best data in this area will be incorporated into the Manual. Pollution of the surrounding environment and potential in cost savings do not warrant excessive saltings, and the Deicer Users Manual will give utmost priority to environmental protection.) More specifically, the manual will include:

a. Absolute minimum amounts of deicing chemicals necessary to maintain safe traffic flows;

b. Critical points or placement of application;

c. Higher degree of instrumentation, improved calibration, and increased reliability of existing and new deicing equipment;

d. Incorporation of applicable weather detection, prediction, and warning systems as a basis for projecting manpower, equipment, and material requirements for combatting winter storms more efficiently and effectively;

e. Proper maintenance and repair schedules;

f. Methods of salt spreading to optimize operational and manpower efficiencies;

g. A rating test(s) for materials and methods;

h. Suggested prime systems and alternatives;

i. Canadian, European, and British practices as they may apply; and

j. Model codes or ordinances for using deicing compounds.

2. A Manual of Design and Recommended Practices for Storage Facilities and Methods of Handling Deicing Materials Throughout Storage. (Although certain instructional materials are available from highway agencies and the salt industry on proper salt storage, there has not been an adequate acceptance of approved practices, and a proper recognition of pollution problems associated with materials storage. Many storage sites are located on marginal lands adjacent to streams and rivers with the deicing materials often stockpiled unprotected in open areas, and too frequently these sites have become chronic sources of ground and surface water pollution.) This Manual will describe:

a. Proper siting of materials storage to eliminate pollution;

b. Adequate covering of storage sites to protect materials and preclude surface drainage;

c. Suggested design of storage facilities, particularly shielded structures;

d. Adequate foundation and footing;

e. Sequence and timing of materials delivery;

f. Alternative methods for preventing caking of salt materials including physical, mechanical, and chemical techniques; and

g. Drainage requirements for all storage sites including those of salt manufacturers.

The aforementioned Deicer Users and Storage Manuals will include important information necessary for policy making and management.

3. An evaluation of the pollutional magnitude from continued practices of removing and dumping the enormous quantities of snow from streets and highways into nearby water bodies or onto water supply watersheds. Particular studies will be undertaken to:

a. Determine the characteristics and quantities of the snow now being disposed of in several selected locations within the snowbelt states;

b. Identify the areas and specific locations where the snow is being disposed of (such as, water bodies and water supply watersheds);

c. Monitor the depository, before and after dumping, for time effects, unit pollutant loads, and any other detrimental effects upon it from the melted snow;

d. Summarize the toxic materials found in the snow from the various snow dump test sites;

e. Develop model codes or regulations for the practice of snow dumping;

f. Forecast what effect technological advances are expected to have upon the future snow accumulations in the previously selected locations of investigation. (New snow disposal practices will be compared from an economic and technical standpoint); and

g. Develop recommendations for specific changes in existing snow removal practices that are considered environmentally unacceptable.

Present program work plans anticipate relating feasible project recommendations for deicer alternatives into full-scale, municipal demonstration(s).

Additional Needs

In addition to the present work being carried out, the following are recommended: (Table III presents a synoptic version of these recommendations)

1. Foster increased recognition of the problem at various governmental levels which would include accelerated training, environmental impact awareness, and demonstration of optimum procedures and techniques

in wintertime deicing.

2. Carry forth detailed studies both in the laboratory and field on the various toxic and nutrient additives mixed with deicing materials so as to determine their potential hazards and safe levels of use.

3. Initiate a program for obtaining base-line data on long-term environmental changes that may be taking place due to the increasing use of deicing chemicals. Data are especially needed on deicing chemicals in surface and groundwaters; in selected soils and vegetation; and the deterioration levels prevailing among salt-affected vehicular traffic, highway pavements and structures, and underground utilities.

4. Consideration be given by the various governmental authorities in roadway design to reduce deicing requirements, and enhance the control, collection, and treatment of ensuing salt runoff.

5. Various suppliers and highway authorities make available full information on marine salts - their current and future expected use in highway deicing, chemical composition, physical properties including melting efficiencies, and comparison with the common chloride salts. Evaluation of the pollutional impact of marine salts should be made as soon as possible.

6. Information be compiled and disseminated, and in other cases developed, on best selection of roadside plantings, and the various remedial measures for restoring roadside soils and vegetation damaged by deicing chemicals.

7. Findings of past studies dealing with vehicular corrosion, deterioration of highway pavements, structures, and utilities, potentially caused by road deicers, be made readily available for further study and use.

8. Various suppliers and users of highway deicers investigate and present information on the merits and demerits of various substitute materials that may be used in place of the common chloride salts. A major objective is to identify those deicers having high efficiency and demonstrating minimum side effects.

9. Conduct studies to determine the use of deicing salts with regard to the purpose for which they are intended, i.e., making winter driving safer.

TABLE III

RECOMMENDATIONS
(ABBREVIATED LISTING)

1. FOSTER PROBLEM RECOGNITION AND ALLEVIATION METHODS

2. INVESTIGATE TOXIC ADDITIVE EFFECTS

3. ESTABLISH ENVIRONMENTAL BASE-LINE DATA

4. REDUCE SALT POLLUTION BY IMPROVED HIGHWAY DESIGN

5. FURTHER INVESTIGATE MARINE SALT IMPACTS

6. IMPROVE ROADSIDE CONDITIONS

   — Better Plant Selection

   — Soil and Vegetation Restoration

7. FURTHER EVALUATE VEHICULAR AND ROADSIDE CORROSION

8. FURTHER INVESTIGATE SALT SUBSTITUTES

9. SUBSTANTIATE THAT SALT USAGE MAKES WINTER TRAVEL SAFER

1/ Selected from a more comprehensive listing of recommendations contained in the Edison Water Quality Research Laboratory report(3).

SECTION III

INTRODUCTION

Salt contamination in runoff is generated by storm events. Accordingly, countermeasures for this form of pollution are being investigated by the U.S. Environmental Protection Agency's Storm and Combined Sewer Pollution Control Research, Development, and Demonstration Program.

This report comprises a state-of-the-art review of highway deicing practices and associated environmental effects, and offers a critical summary of the available information on:

1. Methods, equipment, and materials used for snow and ice removal;
2. Chlorides found in rainfall and municipal sewage during the winter;
3. Salt runoff from streets and highways;
4. Deicing compounds found in surface streams, public water supplies, groundwater, farm ponds, and lakes;
5. Special nutritious or toxic additives incorporated into deicing agents;
6. Vehicular corrosion and deterioration of highway structures and pavements attributable to salting; and
7. Effects of deicing compounds on roadside soils, vegetation and trees.

SECTION IV

USE OF DEICING COMPOUNDS

It has been found from a study(3) that the current annual use of highway deicers is approximately 9 to 10 million tons of sodium chloride, 0.3 million tons of calcium chloride, and about 11 million tons of abrasives(3-5). Reported amounts of these materials deployed for highway deicing by individual States and Regions during the winter of 1966-1967 are presented in Table IV. Twenty-one states in the eastern and north-central sectors of the country use more than 90 percent of all chloride compound deicers. Leading States in deicer use are Pennsylvania, Ohio, New York, Michigan and Minnesota. It is noted that the State of New Hampshire, although relatively small in area, has used highway salts since the mid-40's, and over this period the cumulative use of highway salts in this State alone has probably exceeded 2.3 million tons.

The demand that roads be safe and usable at all times, and that June driving conditions be provided in January, has in recent years led to adoption of a "bare-pavement" policy by practically all highway departments in the snow belt region. As a result, the use of deicing salts has greatly increased and in many cases has replaced the abrasives previously used. Unfortunately, the more damaging chlorides are more efficient in melting snow and ice, won't be blown off the road as easily by wind and traffic, require less application time, and are less costly both in application and cleanup. At the end of the winter, large amounts of abrasives must be retrieved from shoulder areas, catch basins, and conduits in order to establish proper road drainage(6); whereas chemical deicers directly attack and melt the ice and packed snow surfaces. The salt dissolves the ice and most importantly, causes a break in the tight bonding of ice to pavement. Chemicals also prevent the formation of new ice. The resulting salt residue is then readily washed off the pavement.

Marine salts have shown to be comparable in cost/effectiveness to rock salt and are receiving use for highway deicing(6). These salts are probably being sold separately or mixed together with commercial rock

TABLE IV

REPORTED USE (TONS) OF SODIUM CHLORIDE, CALCIUM CHLORIDE, AND ABRASIVES BY STATES AND REGIONS IN THE UNITED STATES, WINTER OF 1966-1967[a,b]

STATE	SODIUM CHLORIDE	CALCIUM CHLORIDE	ABRASIVES
EASTERN STATES			
Maine	99,000	1,000	324,000
New Hamsphire	118,000	-	26,000
Vermont	89,000	1,000	89,000
Massachusetts	190,000	6,000	423,000
Connecticut	101,000	3,000	335,000
Rhode Island	47,000	1,000	86,000
New York	472,000	5,000	1,694,000
Pennsylvania	592,000	45,000	1,162,000
New Jersey	51,000	6,000	70,000
Delaware	7,000	1,000	2,000
Maryland	132,000	1,000	40,000
Virginia	77,000	22,000	204,000
	1,975,000	92,000	4,455,000
NORTH-CENTRAL STATES			
Ohio	511,000	12,000	43,000
West Virginia	55,000	9,000	230,000
Kentucky	60,000	1,000	-
Indiana	237,000	6,000	77,000
Illinois	249,000	10,000	60,000
Michigan	409,000	7,000	6,000
Wisconsin	225,000	3,000	102,000
Minnesota	398,000	14,000	84,000
North Dakota	2,000	1,000	13,000
	2,146,000	63,000	615,000
SOUTHERN STATES			
Arkansas	1,000	-	-
Tennessee	-	-	-
North Carolina	17,000	2,000	75,000
Mississippi	-	-	-
Alabama	-	-	-
Georgia	-	-	-
South Carolina	-	-	-
Louisiana	-	-	-
Florida	-	-	-
	18,000	2,000	75,000

WEST-CENTRAL STATES			
Iowa	54,000	2,000	291,000
Missouri	34,000	3,000	-
Kansas	25,000	2,000	31,000
South Dakota	2,000	1,000	36,000
Nebraska	10,000	-	6,000
Colorado	7,000	-	150,000
	132,000	8,000	291,000
SOUTHWEST STATES			
Oklahoma	7,000	-	2,000
New Mexico	7,000	-	-
Texas	3,000	-	1,000
	17,000	-	3,000
WESTERN STATES			
Washington	2,000	-	155,000
Idaho	1,000	-	47,000
Montana	4,000	-	80,000
Oregon	1,000	-	200,000
Wyoming	1,000	-	43,000
California	11,000	-	94,000
Nevada	4,000	-	50,000
Utah	28,000	-	56,000
Arizona	-	-	-
	52,000	-	725,000
District of Columbia	36,000	-	-
1966-1967 REPORTED TOTALS c/	4,376,000	165,000	6,164,000

a/ Data taken from Salt Institute 1966-1967 Survey for U.S. and Canada(4).

b/ Represents data by all governmental authorities reporting within each State.

c/ Overall values given in Table IV represent about 75 percent of true values (reported and unreported) of salts and abrasives used in 1966-1967. With confidential data and appropriate adjustments, the Salt Institute estimates that U.S. total consumption for the winter 1966-1967 was 6,320,000 tons sodium chloride, 247,000 tons calcium chloride, and 8,400 tons abrasives.

salt amounting to hundreds of thousands of tons annually. It is known that the major constituents in sea water approximate 30.5% sodium, 55.1% chlorides, 3.7% magnesium, 7.7% sulfates, 1.2% calcium, 1.1% potassium, 0.2% bromides, and 0.4% bicarbonates and carbonates(7-9). Although commerical marine salts exclude impurities to a large extent, information on product composition is not readily available. Further marine salt data are definitely required on composition; comparative deicing efficiency; and significantly, the potential consequences of sulfates, magnesium, potassium and other available constituents possibly contributing to environmental pollution.

Highway salting rates are generally in the range of 400 to 1,200 pounds of salt per mile of highway, per application(10-12). Over the winter season, many roads and highways in the U.S. may receive more than 20 tons of salt per lane mile, or more than 100 tons per road mile.

Considerable wasting of highway deicers undoubtedly occurs because of excessive application, misdirected spreading, and general wintertime difficulties. In some cases, salts are applied as soon as or even before snow occurs, based upon weather forecast probability. It is believed that there have been frequent instances where highway salts were used but no snow followed.

Environmental problems are minimized by deploying chemicals as sparingly as possible to maintain "bare-pavement" conditions. The proper application and spreading efficiency of highway salts have generated some studies but nonetheless this area has not received deserved attention. The Highway Research Board in a 1967 report(15) indicates several challenges presented by previous research findings, one being to improve present maintenance practices including the over-application of highway salts where conditions do not warrant; poor regulation of spreading equipment which distributes salt material beyond the pavement break; and too many improperly located and inadequately-protected stockpiles of chloride salts. Greene(16) cites the viewpoint of the Bureau of Public Roads that improper calibration of salt spreaders is extremely common. This along with improper operation of equipment leads to excessive salt application rates, which not only increases over-all costs but also contributes to the damage of vegetation and water supplies, and the deterioration of concrete pavement and structures. In Ontario, it is claimed $1 million per year is saved by better application of highway salts(16). Over recent years salt use in the State of Maine is reported to have been reduced some 30,000 tons annually due to improved practices(11). Greene estimates operational savings of several million dollars per year are possible Nation-wide without reducing the quality of wintertime road maintenance(16). Significant improvements in wintertime road maintenance practices would be derived from better field testing and control, good equipment with good maintenance schedules, greater use of mechanized equipment, frequent calibration, increased reliance and improvement of salt metering instrumentation, education and awareness through the ranks particularly at the working level, concerted effort and increased training carried forth at the state highway department level, and due consideration to environmental protection.

Various types of snow-control equipment are used, two of which are shown in Figures 1 and 2. These figures show the use of screen grids in salt spreaders for precluding problems with salt lumps. Other new salt spreader designs include "electronically-controlled" 10-wheel vehicles, capable of distributing 14 cubic yards of salt before reloading(13,14). We should not neglect the possible use of sweepers as a substitute for snow plows to alleviate pavement damage. This snow removal mechanism could also allow direct snow pick-up as opposed to just pushing it aside.

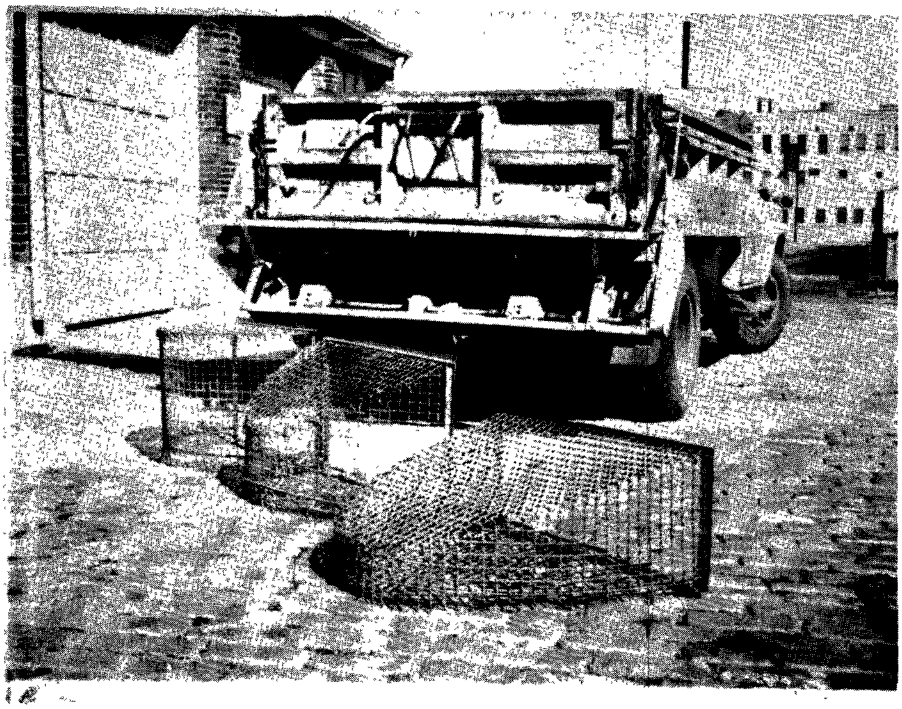


FIGURE 1
Twin-disc salt spreader with tail-gate screens (placed inside truck body) to prevent salt lumps from reaching feeder ports

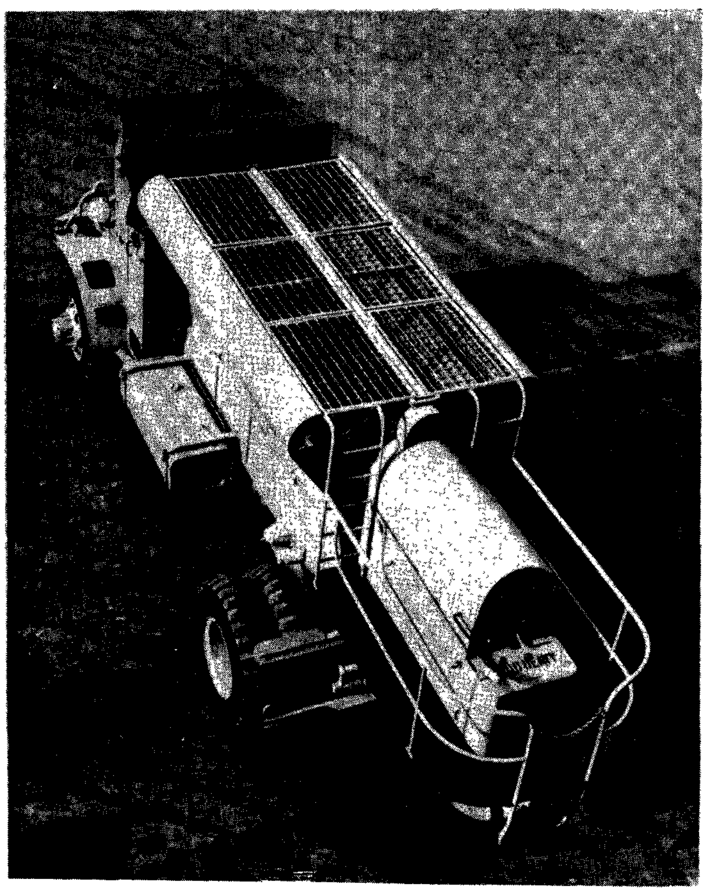


FIGURE 2
New design salt spreader with screen grid over top to preclude salt lumps

SECTION V

CHLORIDE SALT REDUCTION POSSIBILITIES

Besides chemical melting, various methods for deicing are available or have been conceived which may become more prominent in the future especially when communities realize that a price must be paid to alleviate the pollutional effects of wintertime salting. Some of these methods are:

1. External and in-slab thermal melting systems;
2. Stationary (or pit) and mobile thermal "snow melters";
3. Substitute deicing compounds;
4. Compressed air or high speed fluid streams in conjunction with snowplow blade or sweepers to loosen pavement bond and lift snow;
5. Snow adhesion reducing substances in pavement;
6. Pavement substances that store and release solar energy for melting;
7. Electromagnetic energy to shatter ice;
8. Road and drainage design modifications to enhance runoff, reduce wintertime accidents, and capture snowmelt for treatment or control;
9. Salt retrieval or treatment possibly enhanced by the addition of chelating agents; and
10. Improved tire or vehicular design to reduce deicer requirements.

Although it is recongized that power, maintenance, and chemical costs for the above systems are high when compared to rock salt, municipalities, such as Burlington, Massachusetts have expressed(17) a deep willingness to explore and demonstrate new methods regardless of cost. Burlington has recently suspended roadway salting practices when a study(17-19) indicated that their well water chloride concentrations could exceed the recommended limit of 250 mg/l(20,21) if salting was continued. It should also be pointed out that experience, operational data, and knowledge of environmental effects are lacking for the substitute chemical deicers.

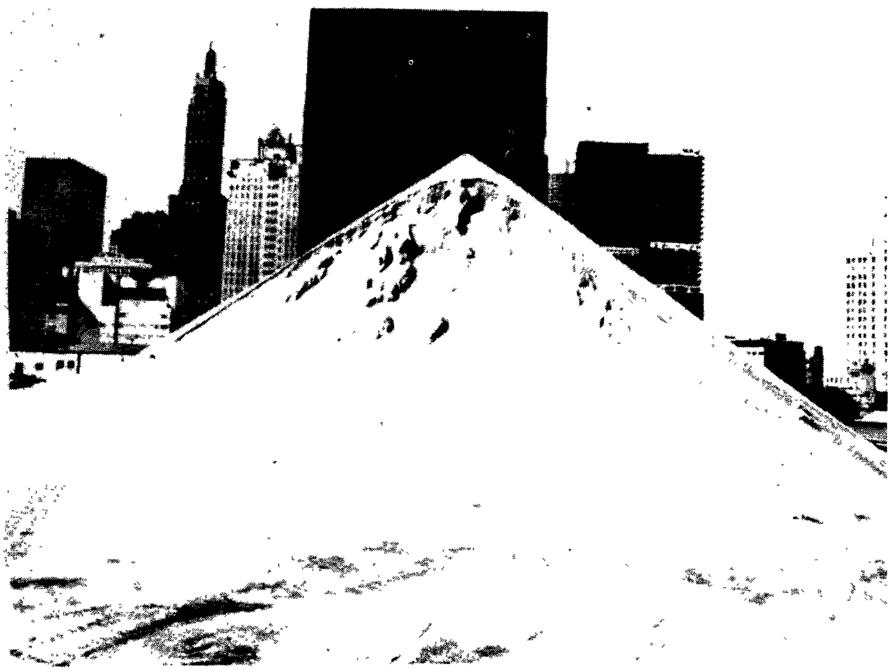
SECTION VI

SALT STORAGE

Salt storage is needed for sustaining highway deicing operations, but too frequently these facilities, which concentrate great quantities of salt, become a major contributing source of local ground and surface water salt contamination. Because of water supply contamination, desirability of better product handling, and aesthetic improvements, many communities have turned to covering of salt piles, enclosed structures, and the diversion of collection of salt-laden drainage(22,23). Typical open salt storage areas in Chicago and Milwaukee are shown in Figures 3 and 4. Figures 5 and 6 illustrate covered salt stockpiles in New York City and Toledo, Ohio, which again from a water pollution control standpoint, are highly preferred over open storage.

Example sketches of the types of salt storage facilities most frequently used in the United States are illustrated in Figures 7 to 19. It is noted that construction costs as given for these storage facilities were prepared around 1965, and are undoubtedly somewhat below current estimates. The more expensive structures are often reported to be the least expensive to use depending on local climate, amounts of stored materials, type of equipment available, and services.

Fitzpatrick(24) of the Ontario Department of Highways has described a dome-like structure or "beehive", as shown in Figure 20, which is now being used to store large quantities of sand-salt mixtures in the Province. The "beehive" is rather unique in storing up to 5,000 cubic yards of sand-salt under one roof with a clear span free of posts, poles or pillars. The structure has a 100 foot base diameter and is 50 feet high. Trucks, front-end loaders and other equipment, as shown by Figures 21 and 22, can easily move about the structure for loading and unloading thus alleviating the pollution effects from spillage in open areas. Costs are reported around $5.00-$6.00 per ton of sand-salt mixture stored (approximately equal to $3.50 per square foot of floor area)(24).



Courtesy of city of Chicago, Illinois

FIGURE 3
Open salt storage pile, downtown Chicago, Ill.

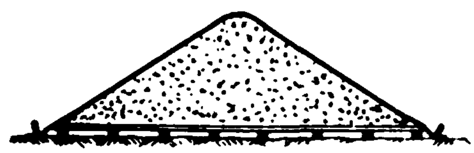
FIGURE 4
Open salt storage pile, Milwaukee, Wis.
estimated quantity 41,000 tons

FIGURE 5
Moving salt by front-end loader inside enclosed storage structure

FIGURE 6
Covered salt stockpile located adjacent to the Maumee River in Toledo, Ohio

FIGURE 7

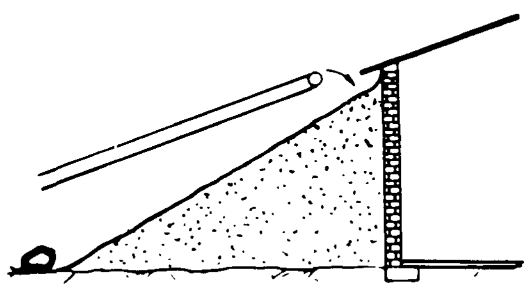
Approx. Construction Cost $3 to $5 per ton of capacity



Rock salt can easily be stored outdoors. This shows a rectangular-conical pile of bulk salt covered by a tarpaulin held down by stakes. The platform is approximately 30' square and is composed of 3" planks held up by 4" by 4" wood sills. It will hold approximately a 40-ton minimum carload of bulk salt.

FIGURE 8

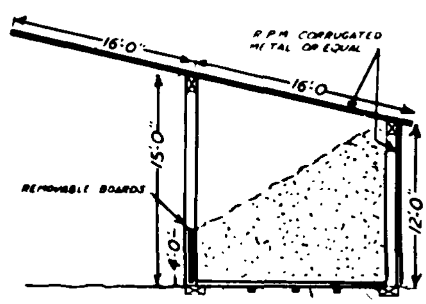
Approx. Construction Cost $3 to $5 per ton of capacity



Rock salt may also be stacked against a garage or shed wall. Here a portable conveyor stacks it. The pile is covered by a tarpaulin and anchored at the lower end by large rocks.

FIGURE 9

Approx. Construction Cost $3 to $5 per ton of capacity

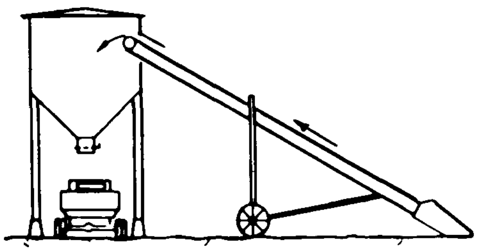


Courtesy of the Salt Institute, Alexandria, Va.

Open bin storage like this is favored by many Ohio communities, and the dimensions shown here are given to scale. The roof has a very large overhang in order to protect the open salt from the weather. Trucks are backed up to the bins and the salt is partly dumped and partly shoveled in. It is removed by shoveling into trucks, or portable conveyors may be used.

FIGURE 10

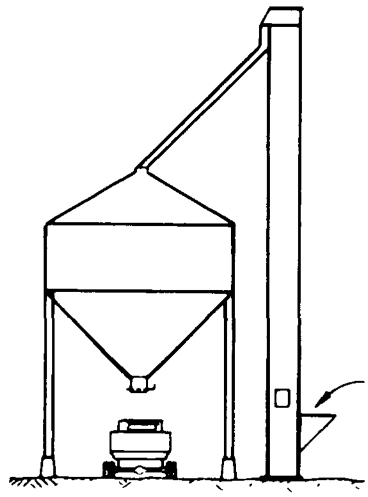
Approx. Construction Cost
$50 to $75 per ton of capacity



Standard steel bins like those used by contractors for cement, sand and gravel provide excellent rock salt storage space. Dump trucks feed salt into the portable conveyor, which carries it up to the bin.

FIGURE 11

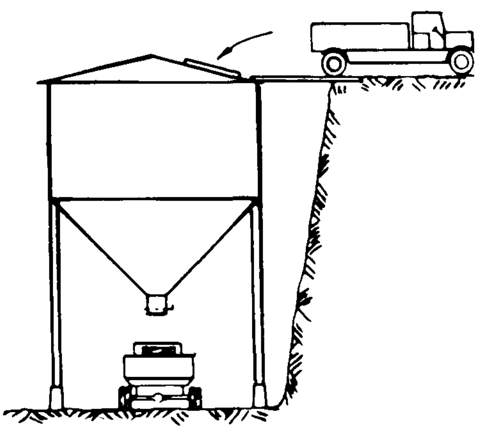
Approx. Construction Cost
$50 to $75 per ton of capacity



The same type of bin as that shown in Figure 10, except that a vertical chain and bucket elevator is used.

FIGURE 12

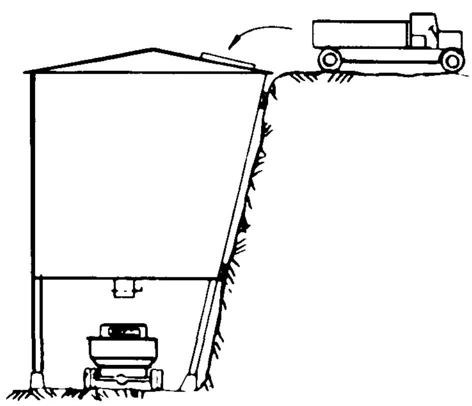
Approx. Construction Cost
$50 to $75 per ton of capacity



In hilly communities the bin may be placed close to a hillside to facilitate loading.

FIGURE 13

Approx. Construction Cost
$50 to $75 per ton of capacity

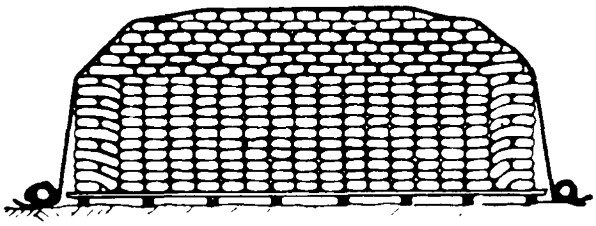


This variation on the bin in Figure 12 follows the contour of the hill.

Courtesy of the
Salt Institute,
Alexandria, Va.

FIGURE 14

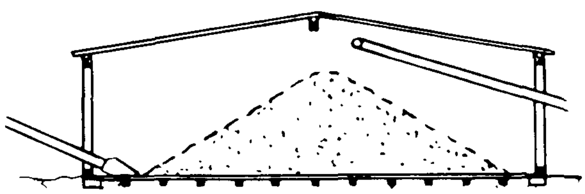
Approx. Construction Cost $15 to $20 per ton of capacity



Many communities use this method of storing bags of rock salt outdoors. The sketch shows 50 tons of bags placed on a platform about 30' wide with the bags many layers deep. The planks are 3" and supported by 4" by 4" sills. The bags are covered by a tarpaulin held down by rocks. Note the method of piling bags on the outside of the pile. Trucks are apt to bump into the pile while backing up for loading, and it is important that the stacking be in such a way that the bags stay firmly in place or else fall inward.

FIGURE 15

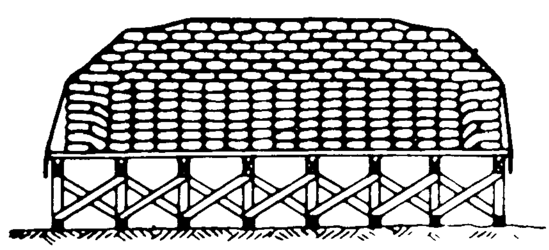
Approx. Construction Cost $10 to $30 per ton of capacity



Bulk salt stored under a shed. The salt is loaded in by a portable conveyor, which is also used for getting it out and onto trucks for distribution.

FIGURE 16

Approx. Construction Cost $20 to $30 per ton of capacity



This piling arrangement, similar to that in Figure 14 features a platform about 3' off the ground in order to facilitate loading onto trucks. Under these conditions, the storage is not over 40 tons of salt as a rule. The tarpaulin is held in place by tying underneath to the posts.

Courtesy of the
Salt Institute,
Alexandria, Va

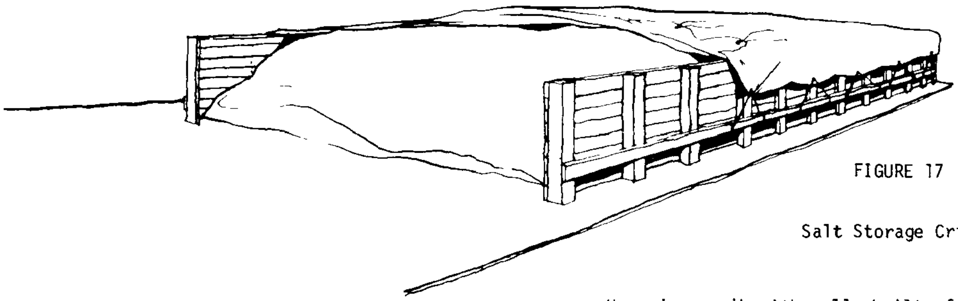


FIGURE 17

Salt Storage Crib

Here is a crib with walls built of 2 x 6 tongue and grooved creosote treated material. Posts are railroad ties set three feet apart on center. Note the 2 x 4 cleat nailed to crib wall posts as tie-down for tarpaulin or other covering.

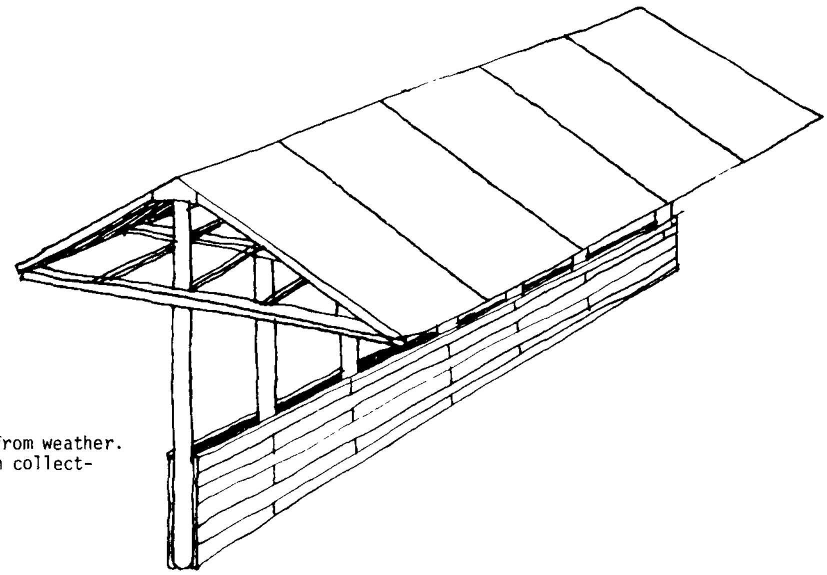
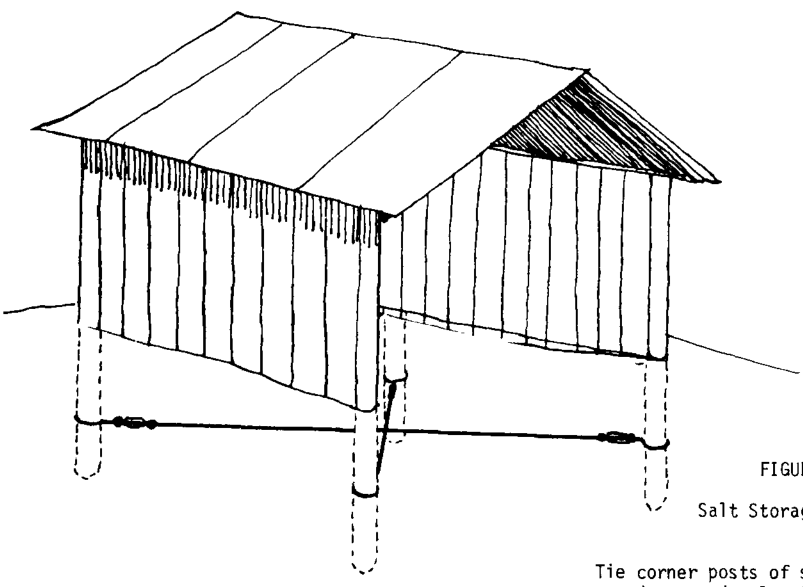


FIGURE 18

Salt Storage Shelter

Umbrella structure protects material from weather. Panel on both sides keeps salt from collecting around posts.



Courtesy of the Salt Institute, Alexandria, Va.

FIGURE 19

Salt Storage Building

Tie corner posts of storage buildings together with underground galvanized cables with turnbuckles.

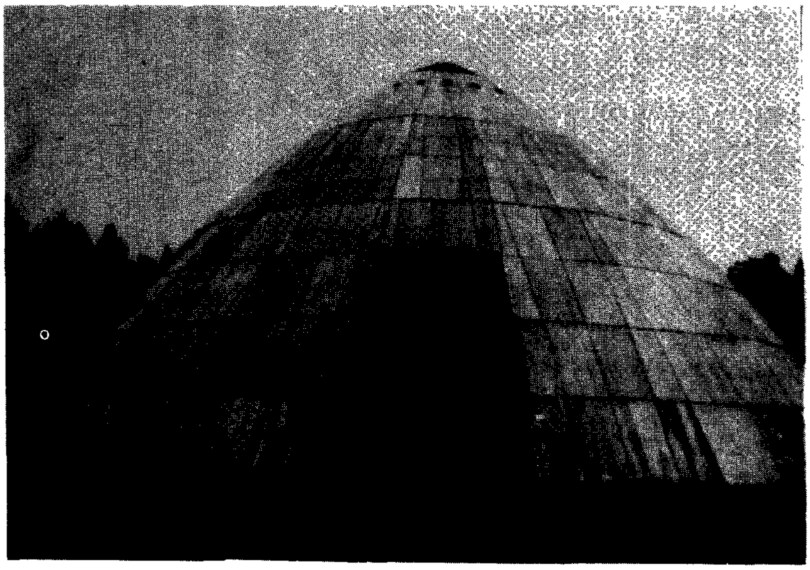


FIGURE 20

The "Beehive" - Salt Storage Structure; note air vents at top

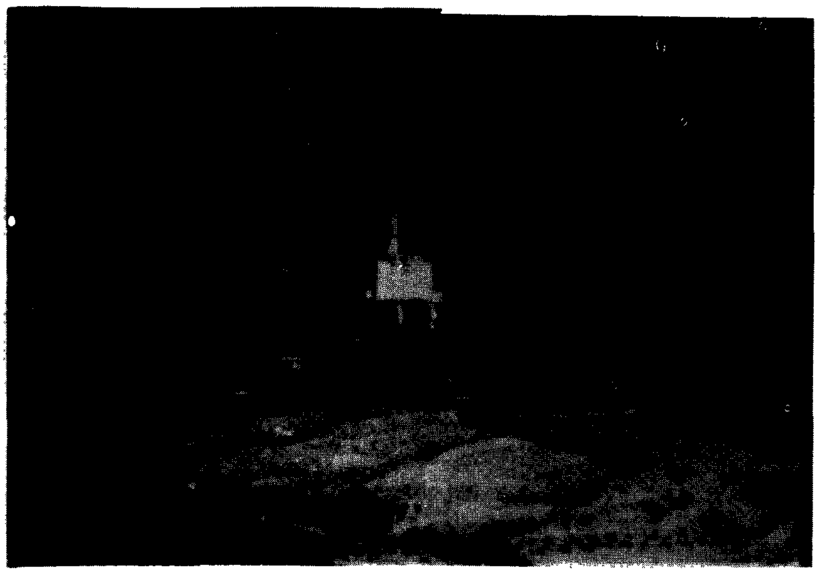


FIGURE 21

The "Beehive" - Method of loading; first stage by truck and dozer

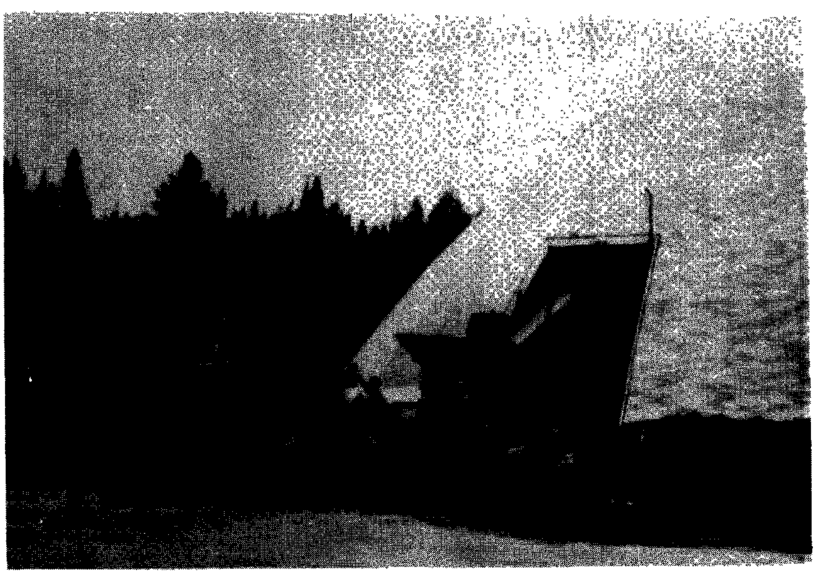


FIGURE 22

The "Beehive" - Method of loading; second stage by conveyor

SECTION VII

ENVIRONMENTAL EFFECTS FROM DEICING COMPOUNDS

Runoff, Sewage, and Surface streams

Street runoff from the melting of ice and snow mixed with chloride salts, finds its way via combined and sanitary sewers to the local sewage treatment plant and then to the streams; and also via storm sewers to nearby receiving waters. Daily chloride loads were shown to be 40 to 50 percent higher for winter months as compared to summer months in municipal sewage at Milwaukee, Wisconsin(12,25). During days of heavy snow-melt, daily chloride loads were three-fold the normal summertime loads. Calculations(10) show that 600 pounds of salt when applied to a one-mile section of roadway 20 feet wide containing 0.2 inches of ice, will produce an initial salt solution of 69,000 (at 10°F) mg/l to 200,000 (at 25°F) mg/l. Street runoff samples collected from a downtown Chicago expressway in the winter of 1967 showed chloride contents from 11,000 to 25,000 mg/l(26,27). Table V illustrates some high chloride concentration values found in runoff.

At Milwaukee, on January 16, 1969, extremely high chloride levels of 1,510 to 2,730 mg/l found in the Milwaukee, Menomonee, and Kinnickinnic Rivers, were believed directly attributable to deicing salts entering these streams from highway snow melt(23). Table VI contains the Milwaukee results. Meadow Brook in Syracuse, New York contained chloride concentrations usually in the range of 200 to 1,000 mg/l, but frequently exceeded a few thousand mg/l(29). For example, a sample in December showed about 11,000 mg/l chlorides in the Meadow Brook watershed(27). From the limited data available on streams, increasing chloride trends are evident for some large rivers in the U.S.(10). Wintertime highway runoff eventually running into freshwater streams and natural or man-made lakes or ponding areas may have adverse effects upon water life in the future(10,24).

The dumping of extremely large amounts of accumulated snow and ice from streets and highways, either directly or indirectly into nearby water

TABLE V

HIGH CHLORIDE VALUES IN RUNOFF

Location	Source	Date	Chlorides (mg/l)	Reference
Chippewa Falls, Wisc.	Highway	1956-1957	10,250	Schraufnagel (12)
Madison, Wisc.	Street	1956-1957	3,275	Schraufnagel (12)
Lake Monona Wisc.	Snow Pile	1956-1957	1,130	Schraufnagel (12)
Chicago, Ill.	JFK Expressway	1966-1967	25,100	Schraufnagel (26,27)
Des Moines, Iowa	Cummins Pkwy. Storm Drain	1958-1969	2,720	Henningson, et al. (28)

TABLE VI

SPECIAL RIVER SAMPLING, MILWAUKEE SEWERAGE COMMISSION, January 16, 1969[a/]

Location	Water Temperature (°C)	Chlorides (mg/l)
Kinnickinnic River at Chase Avenue	10.0	2,005
Menomonee River at 13th St. and Muskego	10.5	200
Menomonee River at 70th and Honey Creek Pkwy.	5.0	2,730
Milwaukee River at Silver Spring Road	4.0	2,680
Milwaukee River at Port Washington Road	6.5	1,510

a/ Records received from the Milwaukee Sewerage Commission, May 1970(25).

bodies could constitute a serious pollution problem. These deposits have been shown(30) to contain up to 10,000 mg/l sodium chloride, 100 mg/l oils, and 100 mg/l lead. The latter two constituents attributable to automotive exhaust. Figure 23 shows a dumping operation.

Farm Ponds and Lakes

Effects of highway salts upon farm ponds and as a cause of induced stratification in lakes have been described by various investigators. A 1966-1968 survey of twenty-seven farm ponds along various highways in the State of Maine showed that road salts have strong seasonal influence on the chloride level of these waters, and that salt concentrations were increasing yearly(10,26,31,32). Density stratification of chlorides was observed in Beaver Dam Lake at Cumberland, Wisconsin(12); in First Sister Lake near Ann Arbor, Michigan(33); and Irondequoit Bay at Rochester, New York(34), all three cases attributed to salt runoff from nearby streets entering these lakes. It has also been estimated that highway salts contribute 11 percent of the total input of waste chlorides entering Lake Erie annually(10,35). Sodium from road salts entering streams and lakes may additionally serve to increase existing levels of one of the monovalent ions essential for optimum growth of blue-green algae, thereby stimulating nuisance algal blooms(36,37).

Recent investigations(38) have brought attention to the hazardous potential of sodium and calcium ion exchange with mercury tied up in bottom muds. This could release highly toxic mercury to the overlying fresh waters. Undoubtedly other poisonous heavy metals can also be released in this manner.

Deicing Additives

Special additives present within much of the highway salts sold today may create pollutional problems(39) even more severe than caused by the chloride salts(40). Ferric ferrocyanide and sodium ferrocyanide are commonly used to minimize the caking of salt stocks(12). The sodium form

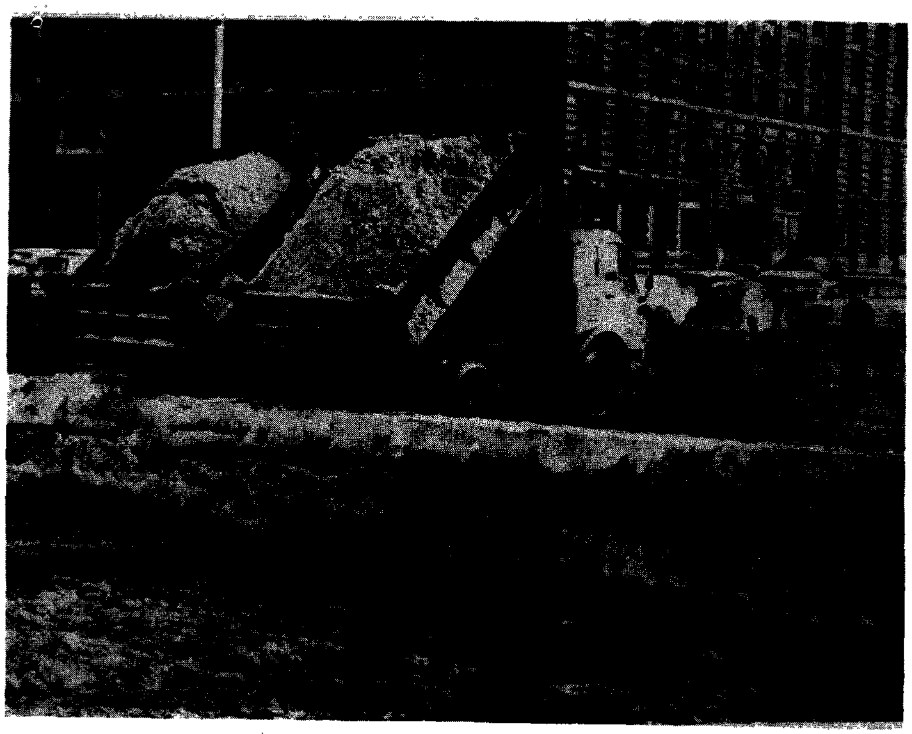


FIGURE 23

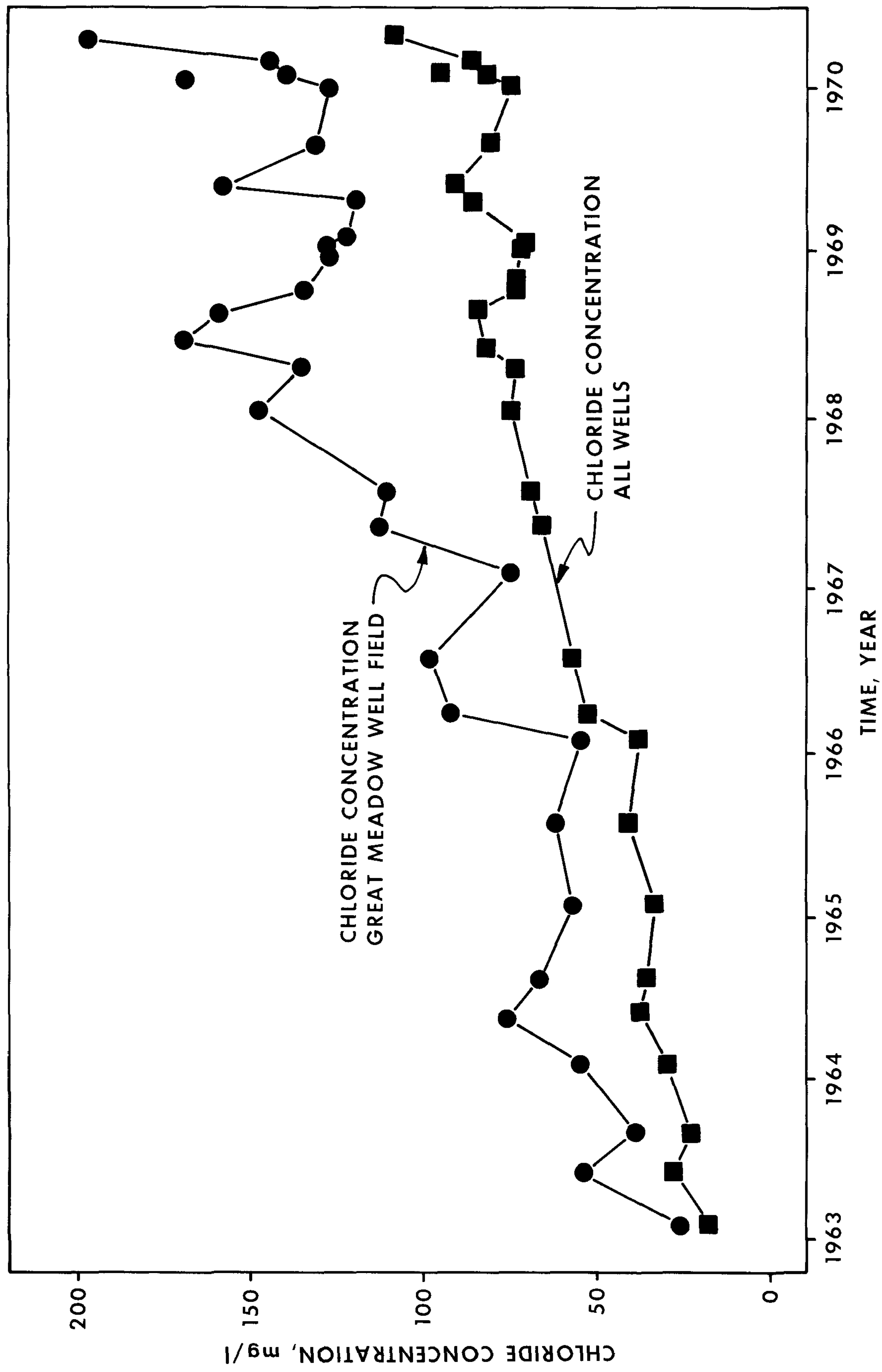
Dumping snow into nearby waterway

in particular, is quite soluble in water, and will generate cyanide in the presence of sunlight(10). Tests by the State of Wisconsin showed that 15.5 mg/l of the sodium salt can produce 3.8 mg/l cyanide after 30 minutes(10,12). Maximum levels of cyanide allowed in public water supplies range from 0.2 to 0.1 mg/l(20,41). Chromate and nutritious phosphate(10, 12) additives are used in deicers as corrosion inhibitors(10,12,40). As with cyanide, chromium is a highly toxic ion(40), and limits permitted in drinking and other waters are in the same low range(20,41). During the winter of 1965-1966 in the Minneapolis-St. Paul area, snow melt samples showed maximum levels of 24 mg/l sodium chromate, 1.7 mg/l hexavalent chromium, and 3.9 mg/l total chromium(40).

Ground and Surface Water Supply Contamination

Serious groundwater pollution has occurred in many locations due to the heavy application of salts onto highways and inadequate protection given to salt storage areas(6,10,17-19,31,32,42-56). The State of New Hampshire up to 1965, is reported to have replaced more than 200 roadside wells, due to contamination by road salts. Some of these wells had contained in excess of 3,500 mg/l chlorides(10,49). In Manistee County, Michigan, a roadside well located 300 feet from a highway department salt storage pile, was found to contain 4,400 mg/l chlorides(10,43). Tastes and odors in domestic water supplies in Connecticut have been traced to chlorides and sodium ferrocyanide originating from salt storage areas(51). Within Massachusetts, salt increases have been noted in the water supplies of some 63 communities(19,42,57), and various supplies have been abandoned at least in part due to road salting and salt storage piles(17-19,42,50, 52,53,57).

The previously cited Town of Burlington, Massachusetts conducted a study(17,18) indicating area wells are becoming increasingly high in chlorides as shown in Figure 24. If this chloride concentration were to increase at the rate shown, water supplied by these Burlington wells could soon exceed the upper limit of 250 mg/l chloride established by the U.S. Public Health Service(20), a condition which could possibly force closing



Courtesy of the town of
Burlington, Mass.

CHLORIDE CONCENTRATION OF WELLS IN THE BURLINGTON, MASSACHUSETTS AREA 1963-1970

FIGURE 24

of wells. It should be emphasized that a desirable concentration of chlorides is considered to be 25 mg/l or less(21) and that the American Heart Association(10,19,58,59) recommends water containing more than 20-22 mg/l of sodium (59 mg/l sodium chloride) should not be used when patients are on diets with an intake of sodium restricted to less than 1,000 mg/day(59). The normal adult intake of sodium is about 4,000 mg/day(10).

Other specific cases of water supply contamination in Massachusetts merit attention. The Town of Becket in 1951 found the water in one of its wells had drastically increased in chloride content to about 1,360 mg/l attributable to a salt storage pile located uphill from the well(54). Private and public water supplies in the Weymouth, Braintree, Randolph, Holbrook, Auburn, and Springfield areas were among those believed to be affected by highway salts, in Massachusetts. Large salt storage piles located at Routes 128 and 28 in Randolph, and located alongside the Blue Hill River, were suspected of introducing contamination into Great Pond, which serves as water supply for Braintree, Randolph, and Holbrook. Water supplies in Tyngsboro and Charlton were similarly experiencing salt increases, and two wells in Charlton were likely to be abandoned(55). Also, in the general Boston area, snow removal and disposal practices are cited as contributing to heavy salt content in the Mystic Lakes(56).

On the subject of industrial water use, Schraufnagel(12,49) found that chlorides have been responsible for the corrosion of various metals including stainless steels. Schraufnagel also cites an industry statement that "increasing the salinity average above the then 40 to 50 mg/l, or lengthening the periods of high salinity, would increase corrosion of all metals used in the handling system". McKee and Wolf in 1963(60), in their extensive review of the literature summarized chloride tolerances for various industries as follows: food canning and freezing - 760 mg/l; carbonated beverages, food equipment washing, and paper manufacturing (Kraft) - 200 to 250 mg/l; steel manufacturing - 175 mg/l; textiles, brewing, and paper manufacturing (soda and sulfate pulp) - 60 to 100 mg/l; and dairy processing, photography and sugar production - 20 to 30 mg/l(10, 60). Other reviews on water quality needs for industry including chloride limits are also available(61,62).

Vehicular and Roadway Damage

Road salts not only promote vehicular corrosion, but may also affect structural steel, house sidings, and other property(6,49,63-73). It has been previously estimated that the private car owner pays for corrosion in the amount of about $100 per year(65). Deicers may cause appreciable damage to highway structures and pavements, particularly those constructed of Portland cement(6,69,70). Even though air-entrained concrete is reported superior to non air-entrained concrete in its resistance to salts, it is preferrable that neither form be exposed to road salts for at least one year, after being poured(6,69,70). Detrimental effects from deicing salts have been reported(49,73) on various underground utilities, such as cables and water mains.

Soil, Vegetation, and Trees

Widespread damage of roadside soils, vegetation, and trees has been observed where there has been liberal application of road salts(10,32,46, 74-109). Most studies dealing with plant injury and death have focused on the sugar maple decline(10,87-93,95-98,109) which has occurred over a 16-State area, mostly in the New England States. Figures 25 through 28 resulting from a study conducted by the Connecticut State Highway Department(95-98,109) show the progressive deterioration of sugar maples and associated leaf damage. Figure 25 taken in 1960 depicts the condition of sugar maples on two sides of a road where longitudinal drainage is from right to left. Figure 26 depicts the condition of these maples five years later. Leaf margin burn, limb die-back, and varying degrees of defoliation are pronounced on the trees on the left receiving the impact from salt-laden drainage. These effects are more readily illustrated by Figures 27 and 28. The tree in Figure 27 on the left side of the roadway shows severe stages of deterioration, and the leaves in Figure 28 demonstrate severe leaf-margin burn. It is important to realize here, in general that until the 1960's, highway maintenance departments principally relied on abrasives as opposed to salt(3).

FIGURE 25

Relatively healthy Sugar Maples,
Photographed 1960, Route 17, Durham-
Middletown line, Conn.

FIGURE 26

Same trees as above - those on
left exhibiting salt damage
photographed 1965

Courtesy of E. F. Butto
State of Conn. Dept. o
Transportation

FIGURE 27

Close-up of Sugar Maple exhibiting pronounced damage, Route 17, Durham-Middletown line, Conn.

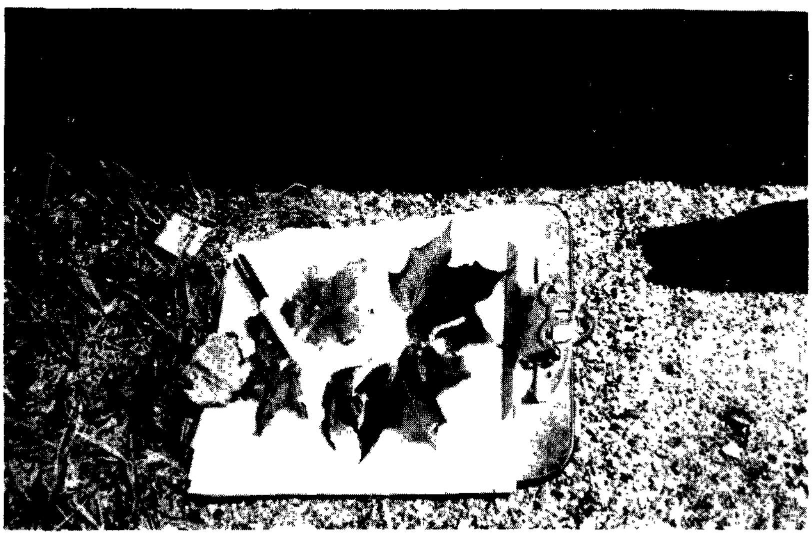


FIGURE 28

Healthy (right) vs. damaged Sugar Maple leaves, from right and left side of Route 17, respectively, Durham-Middletown line, Conn.

Courtesy of E. F. Button, State of Conn. Dept. of Transportation

Tables VII through XI give relative salt tolerances of various fruit crops, vegetable crops, field crops, grasses, forage legumes, trees, and ornamentals. It is hoped that this information may be used by highway authorities and others in selecting roadside plants and vegetation.

TABLE VII

SALT TOLERANCE OF FRUIT CROPS 1/

Tolerant	Moderately Tolerant	Sensitive
Date palm	Pomegranate	Pear
	Fig	Apple
	Olive	Orange
	Grape	Grapefruit
	Cantaloup	Prune
		Plum
		Almond
		Apricot
		Peach
		Strawberry
		Lemon
		Avacado

1/ Original Source, Bernstein, L., 1965(101).

TABLE VIII

SALT TOLERANCE OF VEGETABLE CROPS 2/

Tolerant	Moderately Tolerant	Sensitive
Garden beet	Tomato	Radish
Kale	Broccoli	Celery
Asparagus	Cabbage	Green bean
Spinach	Caulifower	
	Lettuce	
	Sweet corn	
	Potato	
	Sweet potato-yam	
	Bell pepper	
	Carrot	
	Onion	
	Pea	
	Squash	
	Cucumber	

2/ Original Source, Bernstein, L., 1959(102).

TABLE IX

SALT TOLERANCE OF FIELD CROPS 3/

Tolerant	Moderately Tolerant	Sensitive
Barley	Rye	Field bean
Sugar beet	Wheat	
Rape	Oats	
Cotton	Sorghum	
	Sorgo (sugar)	
	Soybean	
	Sesbania	
	Broadbean	
	Corn	
	Rice	
	Flax	
	Sunflower	
	Castorbean	

3/ Orignial Source, Bernstein, L., 1960(103).

TABLE X

SALT TOLERANCE OF GRASSES AND FORAGE LEGUMES[4/]

Tolerant	Moderately Tolerant	Sensitive
Alkali sacaton	White sweet clover	White dutch clover
Saltgrass	Yellow sweet clover	Meadow foxtail
Nuttall alkali-grass	Perennial ryegrass	Alsike clover
Bermuda grass	Mountain brome	Red clover
Tall wheatgrass	Harding grass	Ladino clover
Rhodes grass	Beardless wildrye	Burnet
Rescue grass	Strawberry clover	
Canada wildrye	Dallis grass	
Western wheatgrass	Sudan grass	
Tall fescue	Hubam clover	
Barley	Alfalfa	
Birdsfoot trefoil	Rye	
	Wheat	
	Oats	
	Orchard grass	
	Blue gamma	
	Meadow fescue	
	Reed canary	
	Big trefoil	
	Smooth brome	
	Tall meadow oatgrass	
	Milvetch	
	Sourclover	

4/ Original Source, Bernstein, L., 1958(104).

TABLE XI

SALT TOLERANCE OF TREES AND ORNAMENTALS[5/]

Tolerant	Moderately Tolerant	Poorly Tolerant
Common matrimony vine	Silver buffalo berry	Black walnut
Oleander	Arbor vitae	Little leaf linden
Bottlebrush	Spreading juniper	Barberry
White acacia	Lantona	Winged euonymus
English oak	Golden willow	Multiflora rose
Silver poplar	Ponderosa pine	Spiraea
Gray poplar	Green ash	Artic blue willow
Black locust	Eastern red cedar	Viburnum
Honey locust	Japanese honey suckle	Pineapple guava
Osier willow	Boxelder maple	Rose
White poplar	Siberian crab	European hornbeam
Scotch elm	European black currant	European beech
Russian olive	Pyracantha	Italian poplar
Squaw bush	Pittosporum	Black alder
Tamarix	Xylosma	Larch
Hawthorne	Texas privet	Sycamore maple
Red oak	Blue spruce	Speckled alder
White oak	Douglas fir	Lombardy poplar
Apricot	Balsam fir	Red maple
Mulberry	White spruce	Sugar maple
	Beech	Compact boxwood
	Cotton wood	Filbert
	Aspen	
	Birch	

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SELECTED WATER RESOURCES ABSTRACTS

INPUT TRANSACTION FORM

1. Report No.	EPA-R2-73-257
2.	**W**

Title: Water Pollution and Associated Effects from Street Salting

5. Report Date

6.

8. Performing Organization Report No.

Project No.

Author(s): Richard Field, Hugh E. Masters, Edmund J. Struzeski, Jr., Anthony N. Tafuri

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16. Abstract This report comprises a state-of-the-art review of highway deicing practices and associated environmental effects.

The bare pavement policy has resulted in a great increase in the use of deicing salts. They are more efficient and economical than abrasives. However, there is excessive application leading to environmental problems.

Besides chemical melting, various methods for deicing exist. Some of these are, stationary and mobile thermal melting units, alternate deicing compounds, snow adhesion reducing pavements, electromagnetic energy for ice shattering, and drainage systems designed to capture snowmelt for treatment or control.

Salt storage facilities often become a major contributing source of local groundwater and surface water salt contamination. Coverage of salt piles is becoming more prevalent. Types of enclosed structures are illustrated, and cost considerations given.

High chloride concentration levels have been found in roadway runoff. The special additives in deicing salts may create more severe pollutional problems than the chloride salts. Serious groundwater contamination has occurred in many locations, for example, Maine, Massachusetts, New Hampshire, and Michigan. Widespread damage of roadside soils and vegetation has been observed in areas of liberal salt usage.

Areas of future research are also indicated in this report.

17a. Descriptors Environmental damages, hydrophobic substances, highway deicing, groundwater contamination, plant tolerances, public water supplies, salt storage, vehicular corrosion, water pollution effects, wintertime highway runoff, snow removal practices.

17b. Identifiers Stormwater Runoff

17c. COWRR Field & Group

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