WATER POLLUTION AND ASSOCIATED EFFECTS FROM STREET SALTING

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ABRIDGMENT

•MOST of the sodium chloride and calcium chloride (hereafter called "salt" or "road salt") used for deicing purposes eventually has a detrimental effect on our environment. The high levels of salt in our drinking water and the effect of the salt on the flora adjacent to highways and roadways have produced doubts about the heavy use of salt to provide "bare pavement".

The "bare pavement" policy of highway maintenance is popular because it is an easy guide for highway crews and because most people believe that it reduces wintertime accidents. The problem with this policy, however, is that is specifies the minimum of salt needed but not the maximum and that it spoils motorists by leading them to expect "June travel in January".

When skidding is the possible cause of an accident, the highway department is at once blamed, regardless of other important possible causes. Because of this, foremen tend to salt heavily and early, even though statistics do not clearly show a positive correlation between road salting and accidents. Several researchers have suggested that heavy salting may even increase or worsen accidents by giving drivers a false sense of security. Also, a bare pavement, especially on bridges and ledge cuts, in cold weather can develop a thin sheet of ice that is invisible to the motorist. Winter road safety may depend more on driver attitudes and behavior than on road conditions.

A 1971 EPA report, Environmental Impact of Highway Deicing, focuses on the characteristics of snowmelt runoff and its effect on the environment. This report also covers snow removal operations and the effects of deicing salts on roadside vegetation, vehicles, and highway structures. Some of these topics are covered briefly here.

Currently about 9 to 10 million tons of sodium chloride, 0.3 million tons of calcium chloride, and 11 million tons of abrasives are used annually. Highway salting rates range from 400 to 800 pounds of salt per mile of highway per application, and many roads annually receive more than 50 tons of salt per mile.

Prescribed application rates vary, but it is acknowledged that, however high or low the prescribed rate, highway crews often exceed the levels of salting recommended by the management. This is due to fickle weather, public demands for snow-free roads, lack of precision spreaders, and poor handling techniques.

Poor methods of loading salt onto trucks and improper calibration and operation of snow control equipment often lead to excessive salt use. New spreading mechanisms (e.g., one that will spread salt in a restricted path or one that will give a constant spread rate geared to road speed) and improved handling practices can minimize environmental problems and save money without impairing wintertime road maintenance.

Deicing salts are often stockpiled in open areas without suitable protection, and if covers exist they are often not properly fastened. The resulting salt-laden drainage

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often has easy access to nearby water supplies. Treatment of the drainage and the use of covered dome-like structures, like the one called the "beehive", could eliminate salt storage pollution dangers.

Large amounts of accumulated snow and ice, some containing up to 10,000 mg/litre of sodium chloride, 100 mg/litre of oils, and 100 mg/litre of lead, are dumped into nearby waters, or else the snow melts and then runs off and enters the body of water via the sewer system. In Milwaukee, during days of heavy snowmelt runoff, daily chloride loads in municipal sewage were 3 times the normal summertime loads.

A 1966-1968 survey of 27 ponds along various highways in Maine showed that road salts have strong seasonal influences on the chloride level and that these levels are increasing yearly. In addition, the sodium from road salts entering streams and lakes can overstimulate the growth of blue-green algae. Sodium and calcium ion exchange with mercury could, under special sediment conditions, release highly toxic mercury or other heavy metals to the overlying fresh waters.

Ferric ferrocyanide and sodium ferrocyanide, common additives in road salt, are soluble in water and can generate cyanide in the presence of sunlight: 15.5 mg/litre of sodium ferrocyanide can produce 3.8 mg/litre of cyanide after 30 minutes, as compared with public health limits of 0.1 to 0.2 mg/litre. Further research is needed to establish the ultimate fate of these cyanides in the environment.

Groundwater pollution by salt has caused some wells in New Hampshire to contain more than 3500 mg/litre of chlorides, as compared with a U.S. Public Health maximum of 250 mg/litre. Relatively low concentrations of sodium in drinking water can exacerbate hypertension, heart disease, and kidney and liver ailments, diseases that affect many Americans.

Road salt can cause vehicle corrosion and may affect structural steel, house sidings, and other property as well as damage highway structures and pavements. Underground utilities, such as cables and water mains, may also sustain damage.

Widespread damage to roadside soils, vegetation, and trees has been attributed to liberal application of road salt. Sugar maples, especially in New England, have deteriorated extensively within a 5-year period. Leaf margin burn, limb dieback, and varying degrees of defoliation are noticeable even to an unobserving eye.

The EPA has initiated 4 projects in an attempt to better understand and control the road salt problem.

The first project was a study (1) that highlighted the need for more information on the effects of salt on the environment and man-made structures to allow accurate cost-benefit analyses of alternate approaches. Alternatives considered were pavement heating, a snowplow with compressed air, and a brush and blower system. Salting is still considered the most economical method of snow and ice control, but, as also suggested in the study, research is now under way to identify an inexpensive hydrophobic or icephobic (water or ice repellant) substance that would reduce ice adhesion when applied to the pavement (the second project). Economic analyses of salt damage and alternate methods are also being further explored (the third project).

The fourth project involved 3 independent projects. The first will determine by survey of best current practices the methods of optimum salt use. It will include an estimation of the minimum amount of deicing chemicals necessary for safe traffic flow under varying weather conditions, guidelines for application, and instrumentation and suggestions for legislation on salt use. The second aims at developing a practical guide for salt storage and handling. The third will examine the ecological effect of dumping large quantities of snow from streets and highways into water bodies or water supply watersheds. The chloride level will be monitored at several points and samples will be tested for nitrogen and nitrates, sodium, phosphorous, lead, mercury, chromium, oxygen demand, oil and grease, and various solids.

Together these projects will produce an accurate evaluation of the damage and associated costs of chemical deicing with respect to the environment, vehicles, and highway structures. Continued excessive use of salt will, of course, increase the damage; but high speeds, tight commuting schedules, public expectations, and highway department habits make a ban impractical.

Since it must be used for the present, salt should at least be used as efficiently and

carefully as possible. Several state and local governments, including Minnesota, Vermont, and Massachusetts, have recognized this and through legislation have attempted to improve present practices. More research is needed in several fields to avoid the dangers that may result from a hasty, simplistic solution to this problem.

It would be good for us all to keep in mind a slogan of the Connecticut Highway Research Department: "Remember, if a little bit of salt is good, more is not necessarily better!"

REFERENCE

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DISCUSSION

Richard Fenton, Environmental Protection Administration, City of New York

Those of us who have been trying to develop more solid basic data on the quantities of chemicals needed by operating personnel welcome the interest of the Environmental Protection Administration in this area of winter highway maintenance. Perhaps as a result of these EPA studies we can devise a cooperative research program and get answers to questions that have nagged us for decades.

With respect to the report itself, the most startling comment was that there is no conclusive evidence that the use of salt has made winter travel safer. I do not know what evidence would be considered conclusive. Anyone who has attempted to drive on packed snow or ice knows that it takes a longer distance to stop a car on such surfaces than on bare pavement. Braking distances on different surfaces are easily measured to determine how many additional feet are necessary to stop on ice or snow-covered surfaces versus bare pavement. It is not only the longer stopping distance that is troublesome, but also the fact that there is a loss of control. That a car may go sideways or in a direction other than a straight line is particularly vexing and dangerous. Thus, I believe it is only common sense for operating personnel who have the responsibility to make the roadways safe to strive for a bare pavement. It is the safest roadway condition.

Salt is a common substance, perhaps one of the commonest in continuous use from before recorded history to the present. In New York City, for example, we have been able to obtain it for many years in large quantities at a price of less than 1 cent per pound. There is not much else you can buy at that price. When there is an effective substance at that price level, operating officials will certainly want to examine carefully any suggestions for changes in procedures.

That rock salt, or almost any other substance that is effective on snow and ice, could cause some environmental damage if improperly used is not a surprising finding. Salt is common in our diets, but how many are aware that about 4 tablespoons is a lethal dose? I think the report does not recognize fully the problems faced by line supervisors, who must make the roadways passable as rapidly as possible so that people and goods move freely and winter storms cause a minimum adverse impact on a community's economy.

With respect to salt storage sites as sources of environmental damage, there is little excuse for that today. Present knowledge is adequate to isolate such piles from the environment.

With respect to anti-caking additives, particularly the ferrocyanides, these have been a substantial boon to highway salt users. A prudent operating agency, because of lower cost and easier delivery, would ordinarily purchase its salt in advance of the winter season and store it at strategic locations ready for use. Because the weather fluctuates, there have been times in New York City, for example, when we have had a relatively mild winter. This resulted in carrying over much of the stored salt for use

during the following winter. Thus, it was not unusual to have salt stored for as long as 18 months before it was used. In pre-additive days, it was also typical for substantial caking to occur, requiring the use of pneumatic drills to break up the salt into large chunks before use. The large chunks of salt would then be crushed under the wheels or tread of a tractor before being loaded into a spreader. With that kind of operation, calibrating a salt spreader would, of course, become meaningless, since particle sizes were unknown and erratic.

In the early 1950s we began a series of storage tests in New York City, some on a large scale—using 100 tons of salt at a time in abandoned coal silos—and some on a smaller scale—using upended, large-diameter sewer pipe to simulate a silo. We tested the common anti-caking substances, such as cornstarch, silica gel, and 3 or 4 other substances. None worked when stored for a period of 24 months in covered vertical storage with good protection from the elements. Then, in cooperation with a major salt producer, we tested a ferrocyanide. It worked. The significance of vertical storage is that salt spreaders can be loaded rapidly by gravity when speed is important in fighting a snowstorm. Further, in urban areas, where real estate is expensive, vertical storage requires less land area than horizontal storage. About a dozen years ago, the ferrocyanides came into common use and revolutionized salt storage by virtually eliminating the caking of salt in covered storage. Thus, it made practical the use of calibrated spreaders, which made it, at least theoretically, possible to spread a predetermined quantity.

Certainly any potential side effects should be carefully studied, as suggested in the EPA report. I would like to add another comment in relation to such studies. Storm water from coastal cities along the eastern seaboard drains into the Atlantic Ocean. The potential problems for the urban coastal cities may be significantly different from those of inland communities.

With respect to effects on water supplies, the studies in Massachusetts I have seen that indicated a sharp rise in chloride levels seem to be relatively few in number and where the wells adjoined haphazard storage piles or were close to major highways. The general water supply in the snow belt should be monitored and the chloride data published periodically in journals usually read by public works officials so that all concerned may have ready access to the facts.

With respect to the corrosion of vehicles, we conducted such studies in the early 1950's in New York City. In these studies, plates made of the same steel as commonly used for auto bodies were fastened to the underside of city vehicles that operated in salt-free areas as well as in areas using salt. Some plates were also placed on the roofs of public buildings to determine how much corrosion might be attributed to atmospheric conditions. Our findings were that about one-half to two-thirds of the corrosion of the plates could be attributed to atmospheric conditions. These tests were done before undercoating was widely available and had become a common preventive measure adopted by many motorists.

With respect to damage to roadway surfaces, well over 90 percent of our surfaces are asphalt or are unpaved and thus are not affected by salt. It has been a requirement for many years that all exterior concrete in New York City be made with air-entrained concrete. Further, when our local building code was revised about 10 years ago, air-entrained concrete was made a requirement for the interior concrete floors of garages to eliminate damage from salt tracked in on tires.

With respect to underground utilities, it should be noted that naval architects have been designing for a saltwater environment for a long time. Perhaps those who have responsibilities for subsurface utility design should review what is done on shipboard to minimize corrosion. In some of the subsurface facilities we studied in New York City, we found that no provision had been made for the drainage of storm water. One of the local utilities relied on a truck-mounted pumper, which emptied the standing water about once a year. This was for installations that generated much subsurface heat, which no doubt evaporated much of the storm water. However, if any salt were present, obviously the salt solution would become more concentrated as the evaporation proceeded. In addition, all other things being equal, corrosion is greater as the temperature rises. For that kind of subsurface utility design, how much blame can be

reasonably attributed to a public works agency using salt to make the roadways safe? Further, many of these utility installations were in the gutter areas where maximum inflow would occur rather than in the relatively sheltered sidewalk areas.

With respect to anti-corrosion additives, we also ran corrosion tests, using the aforementioned steel plates at the same time as the other tests were being conducted, in a test area where we used an additive. Our findings were that it was useless under our field conditions. Further, we found that the additive seemed to have a slight tendency to cake the salt somewhat more quickly than would otherwise occur.

Salts that are soft and that crush readily in handling create a high content of fine particles, and these are less desirable than salts that are harder and resist degradation: The more fines, the greater the tendency to cake. The marine salts are in the category of soft salts, and in past years we were reluctant to use them in New York City because of their poor storage characteristics, among other reasons. Further, it is apparent that spreading a predetermined quantity of the more easily degradable substances would be much more difficult than with the harder rock salt. In addition, the fines would dissolve on the surface of a thick layer of packed snow or ice, forming a slippery brine film that would diminish traction. Thus, a more dangerous condition would probably result than the original packed snow or ice.

With regard to the effects on soil and vegetation, in a congested urban community with paved streets and sidewalks there would be a minimum of observable effects.

With respect to the recommendations in the report, I would like to point out a few basic factors that face operating officials in coping with storms. To begin with, weather forecasting is still far from a precise science. In our city, there are sometimes substantial differences in depth of snowfall and temperature between one end of town and the other. In a storm where the average fall may be, say, 5 in., it would not be unusual to find variations of 2 to 3 in. in depth in locations several miles apart. Nor is it unusual to find sleet and icy rain in one part of town and just rain in another part, when the average temperature is at the freezing point. Thus, the amount of salt to be spread must be left to local supervisory discretion.

The temperature during a storm is critical in determining salt use, but so is the temperature immediately following the storm. If the forecast is for rising temperatures, then less salt would be needed than if the forecast is for falling temperatures. Since there is uncertainty in any forecast, the prudent public works official must make adequate allowances in the quantity of salt to be spread. Thus, I suggest that more accurate local forecasts are essential to a reduction in salt use.

The second basic problem faced by a public works official is how much salt should be spread. It may be a surprise to many that we do not have a very solid foundation of experimental data on which to base a judgment on the theoretical minimum amounts needed. Almost all of the studies I have reviewed are based on laboratory tests on ice in ice-cube-type trays. These ice-cube-tray experiments do not in my judgment completely simulate snow, which is a more elusive substance. However, ice-cube-tray tests are readily conducted and are easily reproducible, so they are quite convenient. However, we should bear in mind that ice is not snow and such tests do not have, among other things, warm automobile tires churning and mixing the snow and salt. If we are to determine the minimum salt needed, then there is an obvious need to conduct tests on snow with simulated traffic, as well as to bring in other relevant factors.

The third basic problem that confronts an operating official is to be able to spread on the roadways, with as much precision as possible, the minimum quantity that should be put there to provide a safe roadway. There are two subproblems involved here, as I see it. The first subproblem is to have salt of a uniform particle size distribution, so that we are dealing with the same substance in all snow operations, including the calibration of the spreaders. Unfortunately, this is not always possible. As noted earlier in relation to marine salts, rock salt, too, tends to form more and more fine particles as it is handled. Thus, the minimum amount of handling between the mine and the roadway would be necessary to ensure uniformity. If salt cakes in storage and has to be crushed in the maintenance yard before it can be put into a spreader, then the particle size distribution will be so variable that the calibrations of the spreaders would have no real significance. This is of major importance if environmental effects are to be minimized.

The second subproblem is to have reliable salt spreaders that can spread a predetermined quantity with due allowances for traffic conditions and other variables. It is encouraging that in the last quarter century of my personal observations there has been a decided improvement in equipment available for this purpose.

Frank O. Wood, Salt Institute, Alexandria, Virginia

We also welcome the interest of the EPA in this subject, and we are pleased to have this opportunity to comment on the EPA report.

The detrimental effect of salt additives is mentioned. One class of additives is the anti-caking agents such as ferric ferrocyanide, also known as Prussian blue, and sodium ferrocyanide, also known as yellow prussiate of soda. Salt for highway use is treated with 50 to 250 ppm of these additives. This is equivalent to 0.1 to 0.5 lb of anti-caking agent per ton of salt.

A few common items in which Prussian blue is used are household bluing, blueprints, blue-black ink, and carpenter's chalk. Sodium ferrocyanide is approved by the Food and Drug Administration (CFR 121.1032) as an anti-caking additive in table salt based on exhaustive tests wherein no evidence of toxicity was demonstrated at 500 ppm. Sodium ferrocyanide is therefore not toxic at any of the concentrations that would be encountered. Although laboratory work has shown that cyanide can be released from low levels of this compound by sunlight, no evidence has ever been found that would indicate that this phenomenon can occur under field conditions. Furthermore, this original laboratory research is being looked into more carefully, and a report is expected in the near future.

The report also names chromate and phosphate additives as being detrimental. We will not argue this point, but would like to state that these additives are no longer being used in highway salt.

It is true that highway salt can have a detrimental effect on roadside soils over a period of years. However, it has been shown that this effect can be reversed with gypsum (1).

We have conducted our own study regarding the chloride levels of water supplies throughout the United States and Canada. In Table 1 we find that the water supplies of cities selected at random have increased from 10.6 ppm chloride in 1947 to 17.7 ppm in 1971. Although this is a 66 percent increase, it is not serious when you consider that the Public Health Drinking Water Standards recommend a limit of 250 ppm chloride.

The chloride level of Lake Erie has also increased to 23 ppm. However, only 11 percent of this increase is attributed to deicing salts (2).

With regard to automobile corrosion, a report to be released by the National Association of Corrosion Engineers (3) states, "It has been widely quoted that corrosion damage devalues the automobile by about $100 annually. The widespread use of this number is regrettable because it is not derived on the basis of economic study. The $100 annual loss was simply estimated and should not have been construed in any way as being quantitative or semi-quantitative." Furthermore, comparison of trade-in values that appear in the publication by the NAD Used Car Guide Company shows that the annual difference in automobile values between the Northeast, where salt is used, and the Southeast, where it is almost never used, is approximately $4.50 per vehicle per year. Therefore, if there are other losses due to corrosion, these show up as repairs but do not affect trade-in values.

Many reports, including the EPA report, discuss the necessity for doing research on alternate deicing chemicals. Although there is always room for research, this subject has been thoroughly investigated (3, 4). With regard to alternates to chemical deicing, one report estimates that to install pavement heating on an Interstate highway would increase the construction costs by a factor of 8 (5).

With regard to underground utilities, the NACE Task Group Report (3) concludes: "Underground installations may suffer accelerated corrosion from salt brine seepage through the soil and through structural openings. Improved materials and coatings are being used extensively to mitigate underground corrosion."

Table 1.

Cities	Average Annual Chloride (ppm)					
	1947	1952	1957	1962	1967	1971
Atlanta, Georgia						1.0
Buffalo, New York				2.3	2.7	2.6
Chicago, Illinois	5.2	6.4	5.7	6.9	7.9	9.1
Cleveland, Ohio	20.0	20.1	20.6	24.0	27.2	23.5
Denver, Colorado	17.8	28.1	17.8	25.8	16.1	12.6
Detroit, Michigan	8	8	7	8	10	8
Hartford, Connecticut	2.4	2.4	2.4	3.4	5.0	6.0
Houston, Texas						
Indianapolis, Indiana	12	13	15	21	33	41
Los Angeles, California	31	26	31	28	27	28
Milwaukee, Wisconsin	4.3	5.0	5.6	6.8	8.0	8.5
Minneapolis, Minnesota	1.08	2.5	3.3	3.9	5.8	6.19
Montreal, Canada	14	20	22	24	25	28
New York, New York						
Oklahoma City, Oklahoma				117	111	112
Philadelphia, Pennsylvania				14.8	20.6	22.5
Phoenix, Arizona				146	121	181
Pittsburgh, Pennsylvania	25	23	25	23	21	19
Portland, Maine	1.5	1.5	2.5	2.5	4.3	3.5
Quebec, Canada	5	5	5	5	6	8
Rochester, New York			18.6	19.1	19.1	20.4
San Francisco, California	1.1		2.6	2.9	4.0	4.3
Seattle, Washington	2.7	0.6	1.8	2.2	2.4	4.4
Springfield, Massachusetts	1.6	1.8	2.1	5.8	13.6	17.0
Toronto, Canada	17.9	20.1	22.3	24.0	25.5	29.2
Washington, D.C.	5.0	3.78	7.0	10.0	10.9	11.9
Worcester, Massachusetts						
Average	10.6	11.7	12.3	14.0	15.6	17.7

The salt industry has often been accused of not making available full information on marine salts. If this situation has existed in the past, I am sure that it does not exist today among our members. This information is also available from other sources (6, 7).

The EPA report mentions an article by Feick, Horne, and Yeaple (8). We investigated this report and found that the soil was artificially contaminated with mercury (it contained approximately 2,900 ppm mercury versus approximately 150 ppm in the worst of naturally contaminated soils) and was treated with saturated brine (approximately 26 percent versus stream concentrations that would be in the parts per million range of chloride). These experiments were later repeated by the original authors using badly contaminated natural soils and brines up to saturation. It was found that mercury would not be released under these conditions, and the authors published their findings in the letters to the editor section of the July 13, 1973, issue of Science.

These comments are not given with the idea of being critical of the original EPA report but are for the purpose of supplying further information, some of which has been released quite recently or is in the process of being released.

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