

ROAD SALT USE AND THE ENVIRONMENT

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•USE of dry salt in the United States increased from just over 4 million tons in 1935 to more than 19 million tons in 1969. In 1935 more than 55 percent of all salt used was evaporated, whereas in 1969 only 30 percent was evaporated; the remainder was rock or solar salt used primarily for ice and snow control, special chemical processing, and water conditioning. If the present salt use patterns hold true in future years, it appears likely that 7 million tons of evaporated and 22 million tons of rock salt may be needed by 1980 to satisfy all demands. Projections of established trends indicate that about 60 percent of all salt consumed in 1980 may be rock salt applied to northern roads.

At the present time, salt use cannot be seriously restricted; it is far too essential in snow and ice control, and there are no readily available substitutes. Alternative materials generally are prohibitive in cost and may have much worse environmental effects than salt.

However, as more salt is required for winter maintenance of streets and highways, there have been localized incidences of water pollution, mostly in the vicinity of large, poorly located or improperly covered salt piles. Such pollution must be kept to a minimum in the future if maximum benefits from de-icing salts are to be maintained.

THE NATURE OF ROAD SALT POLLUTION

Most recorded incidences of serious road salt pollution have occurred along arterial roads and streets near major centers of population or in the vicinity of large, uncovered salt storage piles. In areas of large exposed salt accumulations, salt is readily dissolved in the precipitation that falls during those months when salt is present, and this salt is carried by runoff water to nearby surface water courses or surficial ground-water aquifers. Chloride concentration in runoff water may vary considerably from storm to storm depending primarily on the quantity of salt available and weather conditions before and after application. If the snow cover from an individual storm melts and runoff occurs prior to the next snowfall, in all probability that runoff will contain in solution practically all of the road salt that had been applied before the snow melted. This is due to the fact that salt is very soluble in water and in solution is in a very stable form. The recommended application rate for salt is 500 lb per two-lane mile of road. An average total per storm may be as much as 1 ton of sodium chloride per mile of two-lane highway, which could result in runoff from such an occurrence of several hundred ppm pounds of runoff water. If, on the other hand, no runoff occurs during the entire winter snowfall period, early spring runoff would be expected to carry in solution all of the salt applied during that winter. The chloride concentration of such runoff water might be considerably less than that of the first example because of additional dilution made possible by precipitation that fell as rain after the salting season ended.

A meaningful order-of-magnitude evaluation of runoff chloride concentration per storm or salting season in any given area can be made providing the total winter precipitation, the number of ice storms and snowstorms, and the quantity of salt applied per storm and per season are known. An illustration of one method of evaluation used in Illinois is shown in Figure 1. The approximate number of salting days is obtained by adding the number of snow and ice days extrapolated from the contour lines shown in Figure 1a, and the average precipitation during the salting season is estimated from those average totals shown for the various regions of the state. These values, and the

total tons of sodium chloride used per mile of two-lane road per salting period, are entered into the graph shown in Figure 1b to obtain a rough estimate of the chloride concentration that can be expected to be contained in runoff water leaving the road or street right-of-way at any given point. In cases where the exact quantity of road salt applied is not known, a reasonable estimate of this value usually can be made using the salt industry recommended application rate of 1 ton per mile of two-lane road per storm.

It should be pointed out that the graph in Figure 1b is designed for a 100-ft right-of-way. Also, in compiling this graph the assumption was made that all snow or ice falling on the entire right-of-way would be available from dilution of the road salt applied only on the two-lane paved surface. Thus, the chloride concentration values obtained from Figure 1b must be considered as that concentration to be expected in runoff water flowing in roadway ditches not receiving overland flow from adjacent private lands that have not been salted. Naturally, further dilution will occur after the runoff leaves the highway right-of-way.

Runoff chloride concentrations obtained from the graph in Figure 1b must be adjusted if the right-of-way width is other than 100 ft. If the case in question is for only a 40-ft right-of-way, the value shown in Figure 1b would have to be divided by 0.4. By the same token for a 200-ft right-of-way, the value from Figure 1b would have to be divided by 2.0 to obtain the proper runoff chloride concentration value. As an example, assume that 10 tons of sodium chloride were applied to a two-lane, 60-ft right-of-way in an area that had a total of 10 in. of precipitation during the salting period. The values in Figure 1b show that for a 100-ft right-of-way the runoff chloride concentration should be about 450 ppm and that for the 60-ft right-of-way in question the concentration should be $450 \text{ ppm} \div 0.6 = 750 \text{ ppm}$.

After salt-laden runoff leaves a road right-of-way following thaw periods, it enters nearby streams, turbulent flow action of the current usually blends and dilutes the salty runoff almost immediately, and, even in cases where only slight mixing occurs, the bulb of salty water generally flows downstream out of the area of application in only a few hours or days. In groundwater reservoirs, on the other hand, little if any dilution and mixing with native groundwater occur because of the laminar, nonturbulent flow conditions that prevail in such earth materials. Several months may be required for the salty recharge to percolate only a few hundred feet through an aquifer to some nearby discharge point such as a river, lake, or pumping well.

Surface Water Pollution

Road salt pollution of streams usually is observed first as an abrupt salt level increase in the stream during major spring thaw periods. This increase, which may peak and begin to recede in less than a week, is caused primarily by direct overland flow of high salt-content water from the drainage basin into the water course. Recession in stream salt content, characterized by several secondary reversals of ever-diminishing magnitude during subsequent spring and early summer rains, generally reaches and fairly well maintains a constant base level during late fall and early winter of each year. If the stream receives significant flow from adjacent shallow groundwater reservoirs adversely affected by road salt pollution, this relatively subdued effect usually is discernible only by a persistent increase in yearly minimum chloride levels over base chloride levels recorded prior to the beginning of heavy road salt use within the drainage basin.

The nature of overland runoff and groundwater chloride pollution derived primarily from rock salt sources is shown in Figure 2. Yearly maximum chloride levels in the Illinois River at Peoria generally occur between January and March following the major period of spring thaw. From this yearly peak, chloride concentration levels recede to a yearly minimum (base level) usually by August. Base level chloride concentrations (Fig. 2) generally reflect the salt pollution level of groundwater outflow to a stream. Obvious persistent increases in yearly maximum and minimum chloride levels, as well as a corresponding increase in the mean salt concentration level in the stream, appear to closely parallel the graph of rock salt use for snow and ice control within the state.

Figure 1. Method of evaluating runoff chloride concentration: (a) precipitation during salting period and number of salting days per year and (b) probable average chloride concentration in right-of-way runoff.

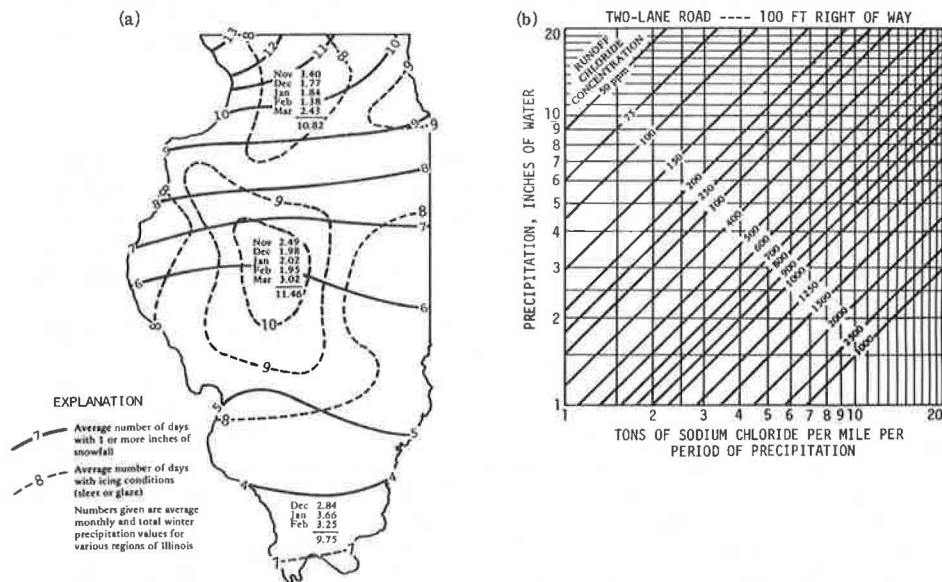
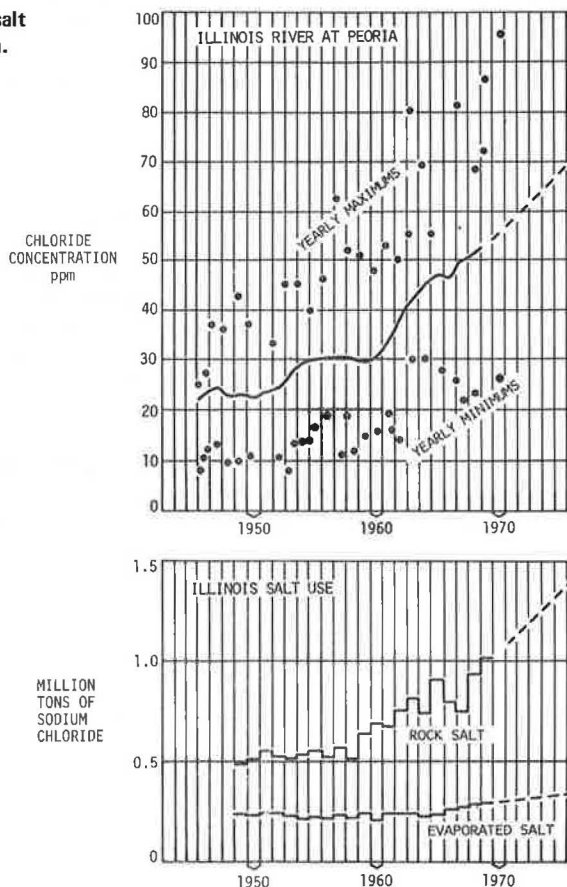


Figure 2. Total salt use in Illinois and salt concentration in Illinois River at Peoria.



A direct correlation is not possible from the data shown in Figure 2 because the Illinois River basin above the Peoria gauge receives flow from only about 25 percent of the total land area of Illinois. However, when it is considered that approximately 75 percent of the state's population live in this part of Illinois, the seemingly excellent correlation inferred from these data may prove to be real once additional salt use data are assembled.

Groundwater Pollution

Salt-laden runoff from poorly protected salt piles or heavily salted arterial roads and streets enters surficial aquifers with precipitation recharge in the early spring just after the ground thaws. Sometimes such pollution may move overland several hundred feet on impermeable clay or shale before entering surficial aquifers through overlying permeable beds of silt or sand in areas where the impermeable formations are missing.

If the salty recharge water enters an aquifer within the cone of influence of a pumping well, in time it will move through the aquifer to that well as shown in Figure 3a. In unpumped aquifers, the salty water moves through the water-bearing material to some nearby surface water body (Fig. 3b), blends with water from that stream, and perhaps leaves the area undetected several months or years after its initial entry into the aquifer. The only evidence of its entry usually is a persistent yet subtle rise in base chloride levels of that stream as is apparent in the Illinois River yearly minimum chloride level (Fig. 2). An example of de-icing salt pollution effects in a developed surficial aquifer at Peoria in west-central Illinois illustrates this point.

In recent years, periodic cyclic increases in the chloride content of groundwater from several industrial and municipal wells at Peoria have been traced to calcium and sodium chloride used by the city of Peoria for winter street de-icing. The aquifer in this area is a very permeable sand and gravel formation about 60 ft thick contained in a partially buried bedrock trough associated with the present-day Illinois River Valley. The upper part of the water-bearing material lies at or near land surface over much of the southern part of Peoria.

Recharge to the aquifer is derived primarily from precipitation and from the Illinois River through recharge pits and by induced infiltration through the bed of the stream. A significant quantity of additional recharge is received from adjoining glacial drift or shallow bedrock aquifers and from street storm runoff through leaks in the old brick sewer system that serves this portion of town.

Graphs of groundwater chloride concentrations in some of the affected wells (Fig. 4) show two sources of salt pollution. Prior to 1959, the source of pollution proved to be sodium chloride wastewater from a packing plant located in the vicinity of wells D and C. Pollution from the packing plant entered the aquifer through leaky brick sewers. Chloride levels in the aquifer receded for a time after the plant was abandoned in 1959 but then began to increase following the location of a large salt storage facility about 2,000 ft north of the old packing plant. Cyclic increases in salt concentration evident since about 1960 have been attributed to this salt pile. Some of the pollution from this source enters the aquifer through the leaky brick sewers in this part of the city; a significantly large quantity also is carried to the aquifer with precipitation recharge in the vicinity of the salt storage facility. Because wells A and B are situated adjacent to the salt pile, they receive a greater concentration of the high chloride content recharge and at an earlier time than do other, more distant wells. The exact reverse of this was true when the packing plant waste in the vicinity of wells C and D was the primary pollutant.

Salt storage at this location began in 1955. Initially, salt was merely piled on the ground, but in time a concrete slab base and tarpaulin cover were used to protect the salt piles from the weather. A Peoria Street Department garage, including partially enclosed concrete salt storage bins covered with a permanent roof, was constructed in 1963. The concrete-slab floor of these bins extended out beyond the roof line by about 5 ft until about 1967 when a 30-ft floor slab extension was added. Salt generally was stored in the bins for an average of 120 days, from about November through February.

Figure 3. Nature of salt movement near surface sources.

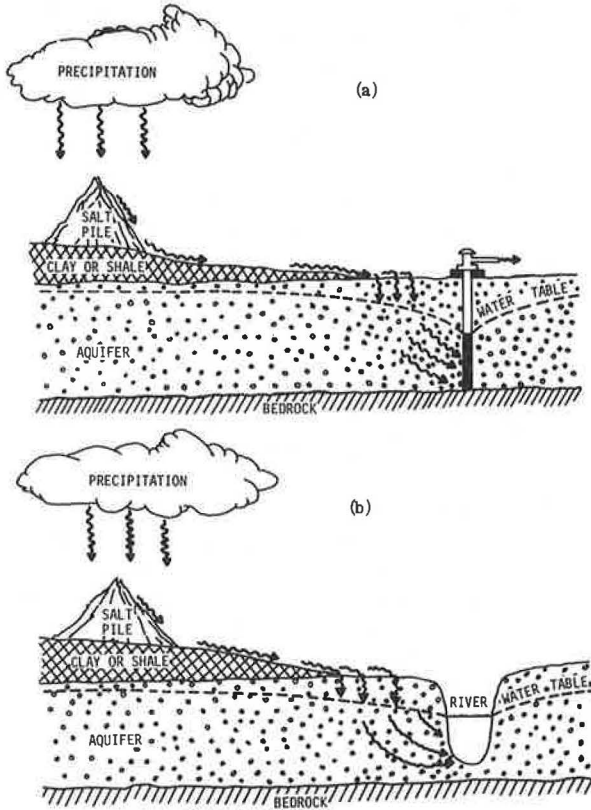
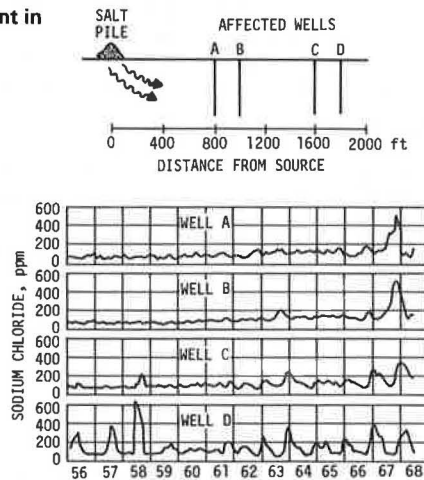


Figure 4. Changes in chloride content in part of shallow aquifer at Peoria.



After 1960, the total quantity of salt stored during any given year ranged between 2,000 and 3,000 tons. This material consisted of a 4:1 mixture of sodium and calcium chloride. Prior to about 1965 little if any salt remained in the bins during the summer months. However, following the winter of 1965-66, there was a sizable carry-over of salt each year. It is estimated that the yearly carry-over during 1966, 1967, and 1968 was 175, 500, and 350 tons respectively. During an inspection of the storage bins in July 1968, it was observed that the land surface was practically covered with salt precipitate for a distance of several feet beyond the concrete-slab floor. It was also observed at this time that small trickles of salt-saturated water were flowing from some of the storage bins into the brick-lined storm sewers that underlie this property.

In recent months this particular salt storage facility has been abandoned, and salt pollution from that source is abating. However, a new privately owned salt storage pile in the general area has begun to seriously pollute another nearby well field. Although a detailed investigation of this new salt pollution source has not been completed, data thus far obtained indicate that no impermeable bottom pad was provided at the site; this permitted leachate of concentrated brine to enter the aquifer beneath the facility. It is significant to note that, in this particular case, the salt pile reportedly always has been protected from precipitation by some kind of impermeable cover.

POLLUTION CONTROL

In the cases discussed, as in practically every incident of road salt pollution that has occurred in the past, several primary controlling factors seem to have always been ignored or at least not considered in their proper perspective. Some of the more important of these are that road salt is very soluble in water, in solution it is very stable, in high enough concentrations salt is a pollutant, and dilution is about the only economical solution to salt pollution. If we consider these and other factors previously discussed, it follows that minimal water pollution effects from road salt use can be realized only if salt is wisely stored, handled, and applied.

Storage Facilities

Siting—Ideally, a salt storage site should be readily accessible to major points of need and to the transportation systems that supply and use it. The site should be located away from homes and factories to avoid damage caused by salt dust. It should be situated on relatively flat yet well-drained ground that is easily protected from overland runoff. Also, the site should be mantled by impermeable deposits of shale or clay thick enough to effectively seal any underlying water-bearing formations from possible pollution from the salt storage area.

From a pollution standpoint, considerable geohydrologic exploratory work may be needed to prove the acceptability of a potential storage site prior to the actual construction of the salt storage facility. Such work usually is justifiable, if considered in the light of possible adverse effects on nearby water supplies and the potential costs of storage facility relocation that might arise if actual pollution damages ever occurred in the future. In this regard, it is always advisable when a site is being considered to obtain a few shallow groundwater samples for chemical analysis. Such background data may prove to be invaluable from a legal standpoint in cases of unjust groundwater pollution accusations that sometimes arise following the installation of a new salt storage facility.

Desirable Construction Features—After a proper site has been selected, only the most functional, economical, and pollution-free storage facility possible should be constructed. "The Snow-Fighter's Salt Storage Handbook" published by the Salt Institute contains much helpful information concerning salt storage facilities. This handbook should be consulted before a facility is designed or constructed. The following discussion, which primarily considers pollution control, is intended as a supplement to that publication.

Salt storage facilities generally considered best from a pollution standpoint are listed below in their relative order of desirability:

1. Permanent structure with doors,
2. Permanent structure with open face positioned away from prevailing winds,
3. Three-sided concrete or wood bunker with permanent or temporary cover, and
4. Canvas, vinyl, polyethylene, or plastic-laminated burlap enclosures.

In all of these facilities, a structurally adequate and waterproof base pad is considered mandatory. The pad should be large enough to contain all salt, including scatter that might occur during loading and unloading operations, and strong enough to support the weight of the salt plus that of any salt handling equipment that might be used. The total thickness of the storage and loading pad depends largely on subgrade conditions and the pad material used. Bituminous or reinforced concrete pads in storage areas served by large trucks and loading equipment may have to be 12 or more inches thick. Concrete pads should be constructed with air-entrained cement and treated with linseed oil, mineral spirits, tung oil, or an equally effective sealant. Convex crown pads should be used so that brine does not collect or flow under the pile. The pad should be sloped 1 to 2 percent for drainage control; slopes much steeper than this make salt handling equipment unstable and for this reason are not recommended.

Experience indicates that conical piles should be avoided because they are difficult to cover. Instead, windrow storage is recommended.

Uncovered salt storage piles should not be tolerated, except perhaps at small-volume outpost areas for short periods of time. Even those should not be stocked until after the ground is frozen in the fall, and all salt should be removed before the spring thaw. All primary salt storage facilities should have a waterproof cover that will provide continuous isolation of precipitation from stored salt. All of the salt placed in storage at such sites must be covered promptly and must remain covered until it is removed for distribution or spreading. By so doing, maximum protection of the environment is ensured, and the moisture content of the salt will be minimized, thereby guaranteeing that subsequent caking and freezing will be slight. Furthermore, stockpiled dry salt is capable of holding large amounts of moisture acquired from the air or from precipitation entering through leaky covers, thereby lessening the quantity of brine runoff that normally might occur.

When salt is removed from covered storage, it should be taken from only one end so that exposure of the pile to the weather is minimized. And at the finish of each loading day, routine maintenance of the pile should include sweeping the work area clean of salt, pushing all scattered salt to the middle of the work face as the pile is reshaped, and finally covering the pile completely until its next period of use.

A two-ditch water and brine collection system surrounding the base and loading pad of salt piles is advisable in cases where nearby water supplies may be adversely affected. In such cases, an outside ditch is provided to divert unpolluted overland runoff from adjacent land and precipitation that strikes the covered area into some nearby storm sewer or natural drainage way. An inner sealed ditch and leakproof brine holding vault is located inside the freshwater ditch work to permit capture and storage of any brine that may originate from the pile or salt handling area. Sufficient width between the two ditches must be provided to permit placement of an effective anchoring system for the cover material. Brine storage vaults usually are positioned as far as possible away from the work face of the pile, and each vault is equipped with a self-priming pump capable of efficiently filling tank spreader equipment.

Salt Handling Equipment—One of the primary complaints received from people who load, unload, or move salt is that readily available equipment usually is not designed to handle salt easily and quickly without excessive scatter and waste. New, specialized salt handling equipment definitely appears to be needed, especially a compact and efficient conveyor assembly patterned after the conveyor machinery used on self-loading salt boats.

Salt Spreading

Rock Salt—Spreading equipment currently available for road snow and ice control generally uses the old fertilizer-disk spinner principle on tailgate or hopper spreaders. With this type of equipment, road salt waste and resulting water pollution easily can

occur unless extreme care is taken in calibrating and operating the spreader equipment and the truck.

Spreader calibration often is done prior to the salting season by using dry rock salt of a certain particle size. However, at times during storms only high-moisture content salt with perhaps a different particle-size distribution may be available for spreading, and this material may not flow at the same rate of consistency as the dry salt formerly used. This sometimes causes excessive salt application that could result in water pollution. Even if dry salt is available, spreader equipment must be continually checked to ensure that proper calibration is maintained.

The speed of the spreader engine and truck also must be maintained at the correct rate if salt waste is to be minimized. In some of the newer equipment now on the market these factors are largely automatically controlled if accurate calibration is maintained. However, throughout the country many salt spreader trucks still are equipped with mechanical controls that rely on the driver for these functions, and the chances for possible operator error are great. Wasteful salt use caused by operator error always must be of major concern to those responsible for maintaining maximum salt benefits and minimum salt pollution. In most cases of this type, wise salt use and conservation practices generally are understood and adhered to by engineers and supervisory personnel of state, county, and city highway maintenance departments. Unfortunately, most maintenance personnel actually handling or spreading the salt usually are not made fully aware of possible harmful effects of the salt they use. For this reason, informing this ever-changing group of people should be a major and never-ending undertaking using all available means of communication.

Research and development of more efficient, economical, and dependable rock salt spreading equipment should be expedited. The equipment developed should be capable of distributing the minimum quantity of salt required for maximum de-icing benefits regardless of what the moisture content of the salt or the speed of the spreading motor or truck is. Equipment and methodology for applying road salt in the form of brine rather than rock salt also should be developed for use where applicable. Such application appears to be most worthwhile for the disposal of brine derived from pollution control measures employed at large salt storage facilities.

Brine—Rock salt's ability to melt ice and snow can be greatly enhanced by the concurrent use of brine. This is normally accomplished by placing a small tank of brine on spreader trucks and discharging it at the spinner as it is distributing rock salt. The rate of application is approximately 10 gal of brine per ton of salt. Accelerated ice melting can also be achieved when brine is sprayed over the open truckload of salt prior to spreading. In this method, care must be taken to ensure that the moisture content of the truckload is not made excessive by the addition of the brine. If the brine collected in the sump is in excess of the amount needed to fill the tanks on spreader trucks or the amount sprayed on open truckloads, this excess could be used on secondary roads or streets where salt is not ordinarily spread.

Agencies that apply brine directly to icy road surfaces should do so with caution and should make sure that all brine applied is concentrated and is spread often enough to prevent a refreeze. Brine concentration should not exceed a specific gravity of 1.178. At higher concentrations, precipitation of the salt and subsequent caking or plugging in storage tanks, pumps, metering equipment, piping, and discharge orifices will occur. Brine applications should be confined to the centerline of crowned roadway sections and to the high side of superelevated curve sections. The rate of application should be approximately 175 gal of concentrated brine per mile. Such application can be accomplished by use of a straight discharge pipe that drains directly to the pavement or a spray bar attachment provided with additional holes at the extreme end of the traffic side of the spray bar. Tank trucks normally used for watering new landscape plantings, gravel stabilization, or asphalt placement can be converted to brine spreaders in the wintertime. Corrosion on such vehicles is not appreciably more than on any other equipment handling dry chemicals, if the vehicles are thoroughly flushed with clean water after each use. Rusting problems can be minimized by proper cleaning and oil coating of the equipment at the end of each salting season. In flushing operations, care must be taken to ensure that resulting wastewater will not become a serious pollutant.

SUMMARY

Any actions taken to minimize road salt pollution must of necessity be closely coordinated. Problems involved are far too complex and encompass too many areas of speciality to permit any one discipline to solve them alone. Scientists such as geo-hydrologists and chemical engineers and salt producers, equipment manufacturers, and salt consumers all must work together if a quick, workable solution to this problem is to be attained.

One of the first steps taken should be to inspect existing and proposed salt storage sites to determine the pollution potential of each site and to devise means of pollution prevention or elimination if the inspections prove such actions to be necessary. As a general rule, uncovered salt storage piles should never be tolerated. Storage facilities always should include a watertight pad strong enough to support the weight of the salt and salt handling equipment and a waterproof system of ditches and sumps at the edge of the storage pad to catch and hold for future use any brine outflow from the pile.

Concurrent with salt storage site pollution control measures, research and development of more efficient, economical, and dependable salt handling and salt spreading equipment should be expedited. A small-scale adaptation of the handling equipment used on self-unloading salt boats is especially needed for waste-free fast loading and unloading operations at most salt storage facilities. Also needed is spreading equipment capable of distributing the minimum quantity of salt required for maximum de-icing benefits regardless of the moisture content of the salt or the speed of the spreading equipment. Equipment and methodology for applying road salt in the form of brine rather than rock salt also should be developed for use where applicable. Such application appears to be especially worthwhile for the disposal of brine derived from pollution control measures employed at large salt storage facilities.

After salt pile sources of pollution have been eliminated and the best possible salt handling and spreading equipment is commonly available, concerted efforts should be directed toward correcting wasteful and improper salt handling or application practices of major salt users such as highway maintenance departments. Wise salt use and conservation practices generally are understood and adhered to by engineers and supervisory personnel in these departments. However, the maintenance personnel actually handling and spreading road salt usually are not made fully aware of possible harmful effects of the salt they use. For this reason, informing this group of people should be a major and never-ending undertaking that makes use of all available means of communication.

It is imperative that all people concerned with the processing, distribution, or use of de-icing salt work together to ensure maximum benefits from this essential product without causing adverse effects that could lead to bans or restrictions on its use. If everyone in the field does his part, water pollution from de-icing salt use can be held within acceptable limits for a long time to come.

REFERENCES

1. Dickinson, W. E. Snow and Ice Control—A Critical Look at Its Critics. Highway Research Record 227, 1968, pp. 48-49.
2. Dickinson, W. E. Deicing Salts and the Environment. Public Works, Dec. 1971, pp. 54-56.
3. Storm Water Pollution From Urban Land Activity. Environmental Protection Agency, Water Pollution Control Research Series 11034FLK07/70, 1970.
4. Environmental Impact of Highway Deicing. Environmental Protection Agency, Water Pollution Control Research Series 110400KK06/71, 1971.
5. Fitzpatrick, J. R. Beehives Protect Snow Removal Salt and Prevent Water Pollution. The American City, Sept. 1970, pp. 81-83.
6. Hanes, R. E., Zelazny, L. W., and Blaser, R. E. Effects of Deicing Salts on Water Quality and Biota—Literature Review and Recommended Research. NCHRP Rept. 91, 1970.
7. Kyser, J. O. Brine Solution Removes Stubborn Ice. Public Works, Jan. 1971, pp. 67-68.

8. Mammel, F. A. We Are Using Salt—Smarter. *The American City*, Jan. 1972, pp. 54-56.
9. *The Snowfighter's Handbook—A Practical Guide for Snow and Ice Control*. Salt Institute, Alexandria, Va., 1967.
10. *The Snowfighter's Salt Storage Handbook*. Salt Institute, Alexandria, Va., 1968.
11. *Proceedings of the Street Salting—Urban Water Quality Workshop*. State Univ. of New York College of Forestry at Syracuse, 1971.
12. Walker, W. H. Salt Piling—A Source of Water Supply Pollution. *Pollution Engineering*, July-Aug. 1970, pp. 30-33.
13. Walker, W. H. Road Salt Pollution. *Ground Water Age*, Nov. 1970
14. Walker, W. H. Limiting Highway Salt Pollution of Area Water Supplies. *Rural and Urban Roads*, March 1971, pp. 71-72.
15. Wood, F. O. The Role of Deicing Salts in the Total Environment of the Automobile. Presented at NACE Symposium, March 1970.
16. Wood, F. O. Salt—The Universal De-Icing Agent. *Proc. Street Salting—Urban Water Quality Workshop*, State Univ. of New York College of Forestry at Syracuse, 1971.