Road Salt in the Environment

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ABSTRACT

The increasing use of salt for the control of snow and ice accumulation on the roads in winter has resulted in concern about its impact on the environment. The Institute for Environmental Studies therefore has established a coordinated approach to the study of the associated problems through the involvement of researchers, together with municipal engineers and politicians.

The impact of salt on the environment is examined in terms of water quality in streams and wells. It is found that some biota are not affected, but rising levels of sodium may be a threat to potable water supplies. Vegetation subjected to salt spray from roads may be substantially damaged through dieback of the foliage and absorption through the roots, although some species are more salt-resistant than others.

Close attention to policies governing the demands for chemical clearing of roads as well as management of the salt distribution system are shown to be effective ways of reducing the amount of salt entering the environment and a methodology for assuring successful coordination of these efforts is described. The legal liability of agencies responsible for winter and road maintenance is examined through actual case histories describing vehicle accidents as well as environmental damage.

The relationship between safety, mobility and the presence of snow on the roads is explored through a study of vehicle accidents in Toronto during the winter months. This particular work is of a continuing nature and interim results are discussed.

INTRODUCTION

In Ontario, the most commonly used chemical for controlling snow and ice on roads and highways is sodium chloride. During the last 30 years, consumption in the Great Lakes Basin has risen to its present level of about 2.8 million tons per year (Vallentyne, 1979) and there is some indication that it will stay at approximately this level. The number of variables that govern its application make it difficult to estimate future use accurately.

It is proposed here to survey some of the environmental concerns raised in past years over the widespread use of salt and other chemicals for clearing snow and ice from the roads. From these concerns we may conclude that there is a legitimate need for measures to be taken to reduce the usage of salt wherever feasible, but at the same time, it should be recognized that its elimination is not yet possible. The technique for environmental management, therefore, becomes of key importance. It is essential that much of the adversary atmosphere surrounding some of the issues be dispelled so that they may be considered rationally and objectively. In this paper we examine not only the scientific findings but also the very nature of research and information exchange.

It is obvious to all that the social and economic development in Canada, as in any industrialized country, is vitally dependent upon transportation and the continuous availability of a network of passable roads and highways which make this possible. The length and severity of Canadian winters make the task of maintaining the roads free from ice and snow a major as well as costly venture. Vehicular traffic densities on these roads have continued to increase during the last 30 years, and this in turn has been interpreted as a demand for "bare pavement" conditions the year around. As a result, we have seen a growing use of chemicals wherever temperatures permit their application to control ice formation and build-up on the roads.

PATHWAYS

The mechanics and techniques used in applying salt to the roads are well-known, even though not widely agreed upon, and need no further clarification here. However, once the salt has been spread, it immediately becomes a detectable chemical in the environment and there are a number of pathways it can follow in passing through the environment. Each pathway is affected by the presence of excessive (over natural background levels) salt concentrations, and together they constitute a substantial environmental impact.

Airborne

Dry or powdered salt may blow about and migrate considerable distances downwind. Similarly, as a brine solution, salt can be splashed by vehicles and transported as a fine spray to adjacent fields and vegetation. It has been estimated that as much as 10 percent of the salt applied can become airborne, although the amount is more frequently near one percent.

Waterborne

Concurrently, the brine solution formed on the roads can enter surface water courses through road drainage systems and from there move into the hydrologic cycle. A study at the University of Toronto (Paine, 1979) indicated that half of the salt applied to the Don River watershed (at Toronto) apparently failed to reach the river as measured at the river's point of discharge into Lake Ontario. Examinations of similar phenomena in the Boston area (Huling and Hollocher, 1972) and at Chicago (Wulkowicz and Saleem, 1974) suggest that it takes more than one year to remove the salt applied to the watershed. Thus we are faced with the real possibility of a salt accumulation over a period of several years somewhere in the watershed ecosystem.

Groundwater

In tests conducted along Maine highways (Hutchinson and Olson, 1967), it was also found that sodium concentrations at a depth of 6 inches near the edge of the road increased by four to eight times the normal or background value after two or three years. In locations where salting had taken place over a period of 18 years, sodium levels 8 times greater than normal were found up to 45 feet from the highway (Hutchinson and Olson, 1967).

The accumulations of chloride in the soil followed a similar pattern, but the actual amounts are much lower. Examination of the vertical profile confirms that salt levels are highest at the surface, although the distribution can be greatly affected by the compaction and permeability of the soil. Summer rains tend to leach the salt away gradually. However, the authors of one such study observed that the amount of salt retained in the upper 4.6 m in autumn ranged from 15% to 55% of the amount of salt applied during the previous season (Toler and Pollock, 1974).

Thus a proportion of the salt applied to the roads joins the surface runoff and eventually percolates through the soil layers to enter underground aquifers. The actual amounts of salt moving in this way are highly variable, being dependent upon soil permeability, ground cover, ground surface gradients, etc. Time lags are similarly variable.

Surface Waters

North American researchers have established a correlation between road salting and elevated chloride levels in surface waters. Studies in Toronto (Scott, 1976) and Syracuse (Hawkins, 1971) have revealed that sodium concentrations in streams may increase 50-fold during the spring runoff, and there is little doubt that the source is road salt. Small lakes and rivers are the most seriously affected, since the volumes of larger water bodies appreciably dilute the levels of sodium and chloride. Perhaps one of the most interesting impacts of increased salinity in lakes is the gradual suppression of seasonal mixing (Hawkins and Judd, 1972). The resultant stratification produces a reduction in dissolved oxygen in the lower strata due to the reduced solubility of oxygen in waters high in dissolved solids. This, together with the stress of saline water, causes the gradual elimination of animals living in the benthic layer. This reduced oxygen in the water also affects the fish population.

High sodium concentration in streams could result in the increased liberation of mercury and other heavy metals from the sediment in the stream bed. The process is similar to that which occurs in a domestic water softener, where calcium is displaced in the regenerative process. This process, of course, requires very high salt concentrations.

EFFECTS

Health

The potential risk to ground water sources makes it extremely important that we protect ourselves against contamination in every possible way. In Ontario, for example, well over one hundred communities depend upon ground water for their supplies of drinking water (National Inventory of Municipal Waterworks, 1981).

High concentrations of chloride create a taste and therefore a warning of a possible health hazard to the users. Even so, it is possible for concentrations to become sufficiently high to create a health hazard for bottle-fed infants. On the other hand, sodium content is not presently regulated by maximum acceptable concentrations in most parts of the world, and the role of excess sodium in the disease "hypertension" is a contentious issue. Because this disease affects some 2 million Canadians (Canadian Heart Foundation), low sodium diets are fairly common. For this reason, the Canadian "Drinking Water Guidelines" (issued in 1978) suggest that the appropriate health authorities be notified if the sodium concentration of a potable water supply exceeds 20 mg/l, which is a level of concern for persons on a strict (500 mg/day) low sodium diet.

A limited study of private well water supplies (Joy, 1979) north of Toronto indicated that more than half of the wells tested had sodium concentrations in excess of this figure. Indeed, some 19% had concentrations greater than 100 mg/l and 6% were above 250 mg/l. The evidence relating these unusually high levels to the application of road salt is purely circumstantial, but it is clear that there is movement of salt from some source into the aquifer. At the present time, sodium content is not routinely measured in most potable water supplies. Its growing presence in the environment and the potential threat to health suggest greater attention is warranted. Most of the literature dealing with the impact of road salt on ground water supplies is site-specific.

Soil and Vegetation

Extensive salt infiltration into the soil lowers its fertility and affects its ability to support desirable plant growth. Both sodium and chloride are toxic at various concentrations to vegetation, although threshold concentrations vary according to the plant species. Injury to roadside vegetation occurs primarily in two ways—directly, by the splashing of brine on to branches and leaves, and indirectly, by absorption of salts through the roots in both summer and winter. The former results in quite obvious foliar damage such as leaf burn, defoliation, die-back and browning. In high concentrations the salt may be taken up passively due to diffusion and depolarization of the root membrane, allowing cytoplasmic salt to equilibrate with the external medium. At this point, membrane selectivity fails and nutrients flow out of the root. Certain salt resistant plants have developed natural mechanisms to deal with the excess of salt and can be found in coastal zones affected by salt ocean spray. It is noteworthy that more salt is accumulated in the winter and by older tissue. It has also been observed that "hardiness" to cold is reduced by an increased accumulation of salt, although the mechanism has not yet been determined. Generally speaking, conifers are particularly vulnerable to salt spray because the photosynthesis process continues throughout the winter months, whereas deciduous trees are most affected by salt in the soil.

Wildlife

Roadside brine has sometimes proved to be a fatal attraction for certain species of wildlife. Moose in particular have a seasonal dietary demand for sodium (Best et al., 1977) due to horn growth in males and lactation in females. Thus they are attracted to the brine pools which form in melting snow along the salted roads and create a traffic hazard.

Corrosion

Corrosion represented well over half of the total costs to Americans from road salting, as determined by two studies (Murray and Ernst, 1976; Brenner and Moshman, 1976). Numerous other investigations related to vehicle corrosion lead to the conclusion that about 50% of the corrosion occurring in automobile parts could be attributed to the regular use of salt on the roads. Similarly, highway structures deteriorate more rapidly because the presence of road salt can increase the number of freeze-thaw cycles under certain temperature and salt concentration regimes, thus leading to cracking of the concrete in bridge decks (Gillott, 1978). Then salt, slush and water penetrate the cracks and accelerate corrosion of the reinforcing steel bars.

CONTROL

From all of the foregoing, one can clearly see that there is extensive literature on case histories and specific instances where a linkage is firmly established between the spreading of road salt and certain environmental consequences. At the same time salt emerges as one of the most useful and effective chemicals for clearing roads and highways of snow and ice. The protagonists of each point of view (for and against salt) can create a highly polarized issue, whereas the practical resolution of such problems must incorporate elements of both extremes. Thus we have the classical situation where professional intervention must endeavour to limit the destructive aspects of environmental impact while simultaneously realizing the benefits from mobility of transportation stemming from the use of salt on the roads. The aim at this point is, therefore, to provide balanced, practical advice to the decision-makers, that is to say, those persons who act for the public both as stewards of resources and providers of public services.

Research Approach

At the Institute for Environmental Studies for the last few years a research process has been underway involving a "study group" and a "working group." The study group examines a generic environmental problem and shakes out of it a set of rather well-defined environmental or resource related problems that lend themselves to transdisciplinary or multi-phased research.

Both the working and study groups comprise those members of the academic staff, students and scientists from government, the private sector or industry that have a committed interest in the subject area and some training, education, talent or skill that they can bring to bear on developing a solution to the problem. The secret is commitment, knowledge and skill. All of these properties are evaluated by the hardest judges of all, the peers in the working group.

A working group will typically include a broad range of disciplines. Interpersonal compatibility is essential for the group to work together. Compatibility of this kind is never present spontaneously; rather it must grow out of mutual respect as it develops. The defensive jargon must be dropped and an understanding of the roles of other specialists must be appreciated.

Such a group now represents a set of resources that could be set loose after the appropriate gestation period to provide a myriad of solutions to the problem(s).

The process began by having the members of the working group learn of the environmental effects of releasing salt. This was done in the form of a workshop where the municipal and provincial road maintenance supervisors from some 26 municipalities were invited to share their experiences. This process developed a mutual respect and eliminated the suspicion that some theoretical academics would try to impose some hopelessly impracticable solution.

Discussions revolved around the question of applying to a highway the appropriate amount of salt, sand and/or other chemicals (and no more), for the purposes of maintaining safe passage of vehicular traffic in winter conditions. Any discussion of techniques must accommodate the views of the operators.

In the provision of a public service, the policy issues are decided by elected representatives, so any changes in the level of service provided must involve the politicians responsible for establishing policy and answerable to the public. Any question of experimentation must be acceptable to both the operators and the politicians.

The next step is to present information on some of the known environmental problems. The mere presence of the political and executive players indicates a cooperative attitude, and a far more convincing case can be presented for change of policy or practice in such a setting than could possibly be achieved in the largest conference or convention that one could imagine. In this setting the intervenors (operators and politicians) are sensitized to the message. The confidence is built and a mutual respect obliges each group to play their role, taking account of the other peoples' views.

The political and executive participants were then invited to propose what steps they might take individually to reduce the environmental problems outlined. That group, having outlined their respective plans (experiments), had a considerable commitment to make their experiment work, since it was not just some wild dream of an academic or theoretician. At this stage, it was important to retain objectivity and avoid any exaggerations.

Reconvening the participants after the winter season is over allows for the success (and failure) stories to be exchanged. This, of course, permitted the less courageous experimenter to plan more boldly for the following year. This process is seen as an ongoing event with some element of competition as well as the most important element of all, the education process. Fortunately, the process of reducing environmental impact, in this case, also reduces the winter maintenance budget, which is dear to the hearts of the public and the politician.

In such a scenario everyone is learning from everyone else and from the experience of the experiment. Even an experiment that fails will result in a level of education and understanding which could not be achieved in a more esoteric setting.

Output

The time period during which this consultative process could be operative is flexible. It might be expected that after 5 years a code of practice would emerge with major policy changes implemented and accepted by the public. Perhaps the most important aspect does not lie in the operational sphere but rather in ensuring that the circles of interest, concern and information continue to expand. This will occur only through concerted and managed efforts of the major participants.

Legal Considerations

The setting in which the environmental aspects of road salting are portrayed represents a common juxtaposition of responsibilities for the decision-makers. There is, however, a further dimension that must receive consideration and that relates to the legal implications, particularly with respect to liability. In Canada, the legal basis for treating municipal or provincial liability for improper or inadequate application of road salt deals almost entirely with vehicle accidents. There is a substantial body of case law in this respect, and an examination suggests that the courts are at present reluctant to impose liability upon municipalities and provinces for vehicular accidents caused by inadequate or improper application of road salt unless gross (extreme) negligence is proven (Adamache and Bickenbach, 1980). With regard to environmental damage, municipalities and provinces could be held liable for deterioration in water quality, property damage, lost income and damage to health caused by pollution due to the application and storage of road salt. However, there have been no cases of this specific nature in which a decision has been reached, although two cases are presently in progress in Ontario (Adamache and Bickenbach, 1980).

Curiously, the relationship between road surface conditions in winter and the safety and mobility of vehicle traffic is of great complexity and has not been clarified in any objective fashion. A study along these lines has been initiated by the Institute but has not yet proceeded far enough to draw any inferences.

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