ATTACHMENT

4.5.A. RESEARCH PROJECT R-18-0 INTERIM REPORT (USGS-MDPW-003) "EFFECT OF DEICING CHEMICALS ON SURFACE AND GROUNDWATER" (PRELIMINARY GUIDELINES FOR ESTIMATING CHLORIDES), ie. THE "TOLER ANALYSIS"
RESEARCH PROJECT R-18-0 INTERIM REPORT (USGS-MDPW-003) "EFFECT OF DEICING CHEMICALS ON SURFACE AND GROUNDWATER" (PRELIMINARY GUIDELINES FOR ESTIMATING CHLORIDES), ie. THE TOLER ANALYSIS

The "Toler Analysis" is a predictive methodology that can be used to determine potential chloride concentrations in surface and groundwater from existing and anticipated salt applications on adjacent highways. The methodology was originally developed in 1974 by Larry Toler of the United States Geological Survey. The New York State Department of Health standard for chloride in drinking water is 250 mg/kg as found in the State Sanitary Code, Subpart 5-1 (see VI. - Attachment C). Past and present use of the "Toler Analysis" demonstrates quantitatively that NYSDOT highway construction projects, and subsequent maintenance operations, rarely approach this standard.

There are no general requirements by NYSDEC, FHWA or USEPA to use the "Toler Analysis". However, NYSDOT Regions should consider using the methodology whenever:

* the project is located within a Federal Sole Source Aquifer Project Review Area, within the recharge area of a NYSDEC designated Primary Water Supply or Principal Aquifer Area, or there are public or private drinking water supply wells within 200 meters, of the project and one or more of the following conditions apply:

* a Section 1424(e) review is required;

* there is high public interest/opposition to the project;

* an EIS is required for the project;

* the Aquifer overburden material is moderately to highly permeable;

* the water table is close to the surface (a shallow aquifer);

* the recharge of the aquifer is moderately to highly dependant upon direct precipitation on the recharge area; and/or

* the project involves constructing a new road or adding additional travel lanes to an existing road.
EFFECT OF DEICING CHEMICALS ON SURFACE AND GROUND WATER

(PRELIMINARY GUIDELINES FOR ESTIMATING CHLORIDES)

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The contents of this report reflect the views of the U. S. Geological Survey which is responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policy of the Department of Transportation. This report does not constitute a standard, specification or regulation.

* * *

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**Title and Subtitle**

EFFECT OF DEICING CHEMICALS ON SURFACE AND GROUND WATER

(Provisional guidelines for estimating chlorides)

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**Supplementary Notes**

This report is in partial fulfillment of the requirements of agreements 2485 and 2764, Research Project R-18-0 "Effects of Deicing Chemicals upon Surface and Ground Water".

**Abstract**

Tentative methods are proposed for estimating effects on surface water and ground water resulting from applications of highway deicing salts. For surface water, the method requires estimates of the drainage area of a basin, runoff from the basin, and amount of deicing salt to be applied. One year of record at three stations was used to substantiate the record. For ground water, the method involves defining the cone of depression and upgradient areas of a producing well or wells, estimates of deicing salt to be applied in this area, and pumping record of the well or wells. The ground-water method is unsupported by field data. Both methods should be compared with alternate methods whenever possible.

**Keywords**

Deicing chemicals, chlorides, highway salt, surface water, ground water, concentration

**Distribution Statement**

Limited to governmental agencies having interest in subject matter only. Not for public distribution.
Preliminary guidelines for estimating concentration of chloride in water resulting from application of highway deicing salts

by L. G. Toler

INTRODUCTION

Use of sodium and calcium chloride salts for melting ice and snow on highways is common in the northern States. In Massachusetts, statewide use of these salts--95 percent sodium chloride and 5 percent calcium chloride--on State--maintained highways, increased from 26,000 tons in 1954-55 to 231,000 tons of 1971-72. During the winter of 1972-73, the trend of salt usage by the Massachusetts Department of Public Works was reversed. Due to better spreading practices and a mild winter only 150,000 tons of salt were applied to State-maintained highways. Similar amounts of salt were probably applied to streets by cities and towns. Much of the salt applied is carried off highways in meltwater or is plowed, along with snow, to the adjacent unpaved area. Meltwater from the highway and salt-laden snowbanks flows overland to streams or percolates through the ground to the water table.

Dispersion of these salts in the environment may have detrimental effects on soil, vegetation, aquatic life, and water supply. Because of these potential detrimental effects, dispersion of salts must be considered in Environmental Impact Statements for all highway construction projects. There are currently no guidelines for assessing environmental effects of highway deicing salts. Guidelines are urgently needed so design engineers would have a simplified method to identify and assess potential problems which may develop from use of deicing salts and to indicate that some measures should be taken during design to minimize any adverse effects.
Such measures might include diversion of highway runoff away from sensitive areas such as water-supply wells or reservoirs, relocation of highways away from sensitive areas, selection of alternate routes, or possibly a decision not to build a highway.

The U. S. Geological Survey, financed by the Federal Highway Administration, through the Massachusetts Department of Public Works, is assessing the effects of deicing salts on ground and surface waters. The Federal Highway Administration, through the Massachusetts Department of Public Works, has asked the Geological Survey to furnish some tentative basic procedures which can be incorporated into their Environmental Impact Statement guidelines for minimum consideration to be given potential effects of highway deicing salts.

PROCEDURES

It is desired to have some procedure by which to estimate the concentrations of the deicing salts to be expected in water at any point downgradient from a proposed highway. The stepwise procedure would be to:

1. Estimate the total amount of salt expected to enter the hydrologic system in a given period of time.

2. Estimate the amount of water in the system available to dilute the salt concentrations during the same period of time.

3. Compute the concentrations of salt (chloride, sodium, and calcium) on the basis of (1) and (2) above.
4. Compare the results in (3) with the existing water quality of the body of water under study to obtain the net change to water quality.

5. Compare (3) and (4) above with current water-quality standards and present and anticipated future needs of the water users.

6. On the basis of the above analysis, determine a course of action so that significant damage to the environment is avoided.

Two types of concentrations might be evaluated:

1. The average annual concentration.

2. The "peak" concentration which might be expected to occur for specified short periods during the year.

Because chloride is affected little by interactions with soil and water, it will be the constituent evaluated. Calcium and sodium enter into base exchange and adsorption reactions with soil minerals and organic material and their dispersion is much more complex. The concentration of chloride should provide a basis for estimating potential calcium and sodium concentrations based on stochiometric relations with chloride.

SURFACE WATER

The average annual concentration of doling salt in streamflow may be estimated by the following procedure:

1. Pick the sensitive point in a stream basin to be evaluated. Typical choices may be (a) a reservoir or potential reservoir site or (b) a stream near a wellfield.
2. Delineate the drainage area of the basin upstream from the sensitive site.

3. Determine the lane miles of roadway to be in the basin upstream from the sensitive point.

4. Estimate the tonnage of salt to be spread in the basin. The highway departments maintain records of statewide averages per lane mile and district averages per lane mile.

5. Estimate the average annual runoff from runoff maps, precipitation maps, nearby gaging stations, or precipitation stations.

6. If runoff is determined in inches, the annual average concentration may be estimated as follows:

\[
\text{Tons salt per lane mile} \times \text{number of lane miles} \times 13.79 = \text{Concentration of salt as sodium chloride, in milligrams per liter}
\]

If concentration of chloride only is desired, use a factor of 8.37 instead of 13.79.

7. If runoff is in average cubic feet per second per square miles:

\[
\text{Tons salt per lane mile} \times \text{number of lane miles} \times 1.02 = \text{Concentration of salt as sodium chloride, in milligrams per liter}
\]

If concentration of chloride only is desired, use a factor of 0.61 instead of 1.02.

The above calculations assume all salt applied is diluted by all runoff and all salt enters the stream. Conditions such as these would be approached after an equilibrium is reached in a basin and salt that enters the ground with recharge is carried in natural ground-water discharge to streams.
Preliminary data are available for three stations for the 1972 water year where chloride was estimated from specific conductance measurements. The following table indicates measured concentrations comparable with calculations by the above method.

<table>
<thead>
<tr>
<th>Basin</th>
<th>Drainage area (square miles)</th>
<th>Lane miles</th>
<th>Average chloride concentration (milligrams per liter)</th>
<th>Background</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Measured Calculated (INCLUDES BACKGROUND)</td>
<td></td>
</tr>
<tr>
<td>Boulder Brook</td>
<td>1.6</td>
<td>6.2</td>
<td>35 37</td>
<td>10</td>
</tr>
<tr>
<td>Nashoba Brook</td>
<td>12.7</td>
<td>43.3</td>
<td>38 35</td>
<td>unknown</td>
</tr>
<tr>
<td>Walker Brook</td>
<td>3.0</td>
<td>6.9</td>
<td>24 18</td>
<td>unknown</td>
</tr>
</tbody>
</table>

Calculations were made using average runoff maps (Knox and Nordenson, 1955) and statewide average salt-application rate for 1971-72 of 23.8 tons per lane mile.

Data on the background concentration of chloride are available only for the Boulder Brook site. At Boulder Brook the 10-mg/l (milligram per liter) background is probably partly due to salting of town roads within the basin. This background would be the "existing" water quality in step 4 of the procedures. The measured values include the background concentration.

The "peak" concentrations for specified periods during the year would logically appear to have some relationship to the average annual concentration. The amount the concentration of chloride varies about the average depends on how well it is dispersed in the hydrologic system. In large drainage basins, the number of highways would be greater than in small basins, and the distance much of the chloride would travel to reach the sensitive site would be greater. The effect of a greater chance to disperse in larger drainage basins is to decrease the variation.
in the concentration of chloride about the average concentration.

Preliminary data from the above three stations indicate the drainage area of the basin may enable one to predict the ratio of "peak" concentrations for specified periods of time to the average annual concentration.

Data from the three stations are summarized in the following table and are shown on figure 1.

<table>
<thead>
<tr>
<th>Basin</th>
<th>Drainage area (square miles)</th>
<th>Chloride concentration (milligrams per liter)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Average annual</td>
</tr>
<tr>
<td>Boulder Brook</td>
<td>1.6</td>
<td>35</td>
</tr>
<tr>
<td>Walker Brook</td>
<td>3.0</td>
<td>24</td>
</tr>
<tr>
<td>Nashoba Brook</td>
<td>12.7</td>
<td>31</td>
</tr>
</tbody>
</table>

The estimated average annual concentration can be obtained from the formulas and the answers used with figure 1 to obtain estimated maximum daily and maximum monthly concentration.

GROUND WATER

The complexities of ground-water hydrology make it difficult to generalize guidelines for estimation of the effects of highway salting on water supplies. It should be emphasized that each case is unique and should be regarded as such when evaluating any effects. The urgent need for guidelines prompts the suggestion of the following minimal approach if no other is available.
Figure 1.--Relationship of drainage area to concentration ratios.
A proposed highway near an existing well is probably the most sensitive situation and the one that will be considered here. As much information as is available about the wellfield should be acquired. Materials logs, water levels, and pumping records may be available from the owner. The extent of the aquifer and of the cone of depression of the water table should be determined. All salt applied within the cone of depression, or hydraulically upgradient from it, would eventually be pumped from the well. If the salt is assumed to move through the ground in discrete annual slugs, then some estimation of the annual average concentration could be made.

Consider a wellfield with a cone of depression of such extent that half a mile of 4-lane highway passes over the cone of depression. If salt is applied at a rate of 25 tons per lane mile and the wellfield pumps 1 mgd (million gallons per day):

\[1\text{ mgd} = 3.65 \times 10^8 \text{ gallons per year}\]
\[= 1.52 \times 10^6 \text{ tons per year}\]

2 lane miles of highway at 25 tons per lane mile = 50 tons
50 tons in \(1.52 \times 10^6\) tons = 33 parts per million salt
\[= 20 \text{ parts per million chloride}\]
In considering a potential aquifer, the same considerations would prevail. All the salt applied on the recharge area for the aquifer may possibly percolate to the water table and move away from the highway in the downgradient direction. Under conditions of no pumping, the salt would be diluted as it moves from the highway by dispersion and by recharge to the aquifer from precipitation. Preliminary data from test sites indicate that at 1,000 feet from the highway under conditions of no pumping, the increase in concentration of chloride may be very small. However, pumping would lower the water table and increase the gradient toward the well and 1,000 feet may very likely be an unsafe distance. A potential well site should be evaluated the same as that of an existing well.

CONCLUSION

Tentative methods are proposed for estimating effects on water resources of application of highway deicing salts. The methods are based on very limited data and should be used to obtain only gross estimates of chloride concentrations in water resulting from application of sodium and calcium chloride salts to highways. It is imperative that preparers of environmental impact statements consider these methods as a minimal consideration and, whenever possible, will compare results obtained with results from alternate methods or data from case histories.
REFERENCES


U.S. Weather Bureau, Climatological data summaries, by geographical sections.
SUPPLEMENTAL GUIDANCE FOR "TOLER ANALYSIS" APPLICATION

Some paradoxical results from using the interim report "Effects of Deicing Chemicals on Surface and Groundwater" have demonstrated the need for more explanation about the techniques and their limitations. The basic assumption in the technique is that salt concentration in the soil reaches a peak after a period of about five years of normal application during the winter. Subsequently, the amount of salt washed from an area and into surface and groundwater equals the amount applied to the highway system in that area during the same period.

IDENTIFICATION OF WATER SUPPLY SOURCES AND USERS

All potable water supply sources within 500 feet of location alternatives and all public water supplies (pumping sites and reservoirs) within the study corridor should be identified. Sensitive users (industry, recreation, hatcheries, etc.) within one-half mile downstream of the proposed highway discharge points should be identified.

APPLICATION OF THE EQUATIONS FOR GROUND WATER

The technique for considering chloride levels in wells (Toler report, page 9) should only be used after consultation with representatives of the Soils Mechanics Bureau. Because subsurface conditions in New York State are generally not simple enough to apply the Toler method, geologic studies might be required before a method of evaluation could be agreed upon. The Soil Mechanics Bureau will attempt to assist in the determination.

APPLICATION OF THE EQUATIONS FOR SURFACE WATER

In using the equations in paragraph 6 and 7 on page 4 of the report, the following should be considered.

1. Equation, Paragraph 6, page 4

\[ \frac{T \times M}{I \times A} \times K = C \]

- \( T \) = Tons of salt per lane mile
- \( M \) = Number of lane miles
- \( I \) = Inches of runoff (annual inches of rain x 0.4)
- \( A \) = Drainage area in square miles
- \( K \) = 8.37 if concentration of chloride is desired
- 13.79 if concentration of sodium chloride is desired
- \( C \) = Annual average concentration in milligrams per
liter (PPM)

2. Equation, Paragraph 7, page 4

\[
\begin{align*}
\frac{TXM}{RXA} & \quad X \quad k = C \\
T & \text{ = Tons of salt per lane mile} \\
M & \text{ = Number of lane miles} \\
R & \text{ = Runoff in cubic feet per second per square mile (see below)} \\
A & \text{ = Drainage area in square miles} \\
k & = 0.61 \text{ if concentration of chloride is desired} \\
& = 1.02 \text{ if concentration of sodium chloride is desired} \\
c & \text{ = Annual average concentration in milligrams per liter}
\end{align*}
\]

Runoff \( R \) in annual average cubic feet per second per square mile should be used. The highest runoff values from measured hydrologic data and from culvert design computations should not be used. These values will give generally poor and inaccurate results.

**DETERMINATION OF SALT APPLICATION RATE (T)**

The average application rate in New York State appears to be between 7 and 10 tons per lane mile per year with local application rates reaching 20 to 25 tons per lane mile at high density traffic locations. When reliable salt application rate data is not readily available for the watershed under study, as is often the case, the quantity of 10 tons per lane mile per year can be used in computing the levels of chlorides that might be anticipated.

**DETERMINATION OF RUNOFF VALUE (I AND R)**

Information concerning flow rates and the amount of precipitation in a basin can sometimes be obtained from the Department of Environmental Conservation (DEC) and the United States Department of the Interior, Geological Survey (USGS). Information is often available in the USGS publication, "Water Resources Data for New York, Surface Water Records." However, it should be noted that DEC and USGS do not always have information available for the watershed under study.
DETERMINATION OF THE TOTAL LEVELS OF CHLORIDES

The results obtained from the equations should be added to measured background concentrations (which should include the concentrations from other highways within the watershed) to determine the final concentrations to be expected.

Background levels of chloride concentrations can sometimes be obtained from the Department of Environmental Conservation Regional Offices or the Department of Environmental Conservation Central Office, Division of Pure Waters which maintains a data bank on monitored streams within the state.

SHOCK LOADS

An estimated level of shock load (sudden high concentrations of short duration) for chlorides can be estimated by multiplying the final concentrations by 2.0.

EVALUATION OF RESULTS

The current standard for chloride is 250 milligrams per liter in areas where there are relatively "simple" systems of surface and subsurface water supplies and no sensitive users. In special cases where there are complex systems of surface and subsurface water supplies and sensitive users within one-half mile of the proposed highway discharge points the Soil Mechanics Bureau can provide assistance in determining possible effects; usually, the equations should not be directly applied without detailed knowledge of the stream flow. Assistance should be obtained by written request to the Regional Soils Engineer to investigate specific systems within the proposed project area.

CONCLUSION

After completing the evaluation, the possible effects of any additional levels of chloride should be considered in context with other possible water quality impacts of the project and the Region within which the increased levels are to occur. Considering the change in levels of pollutants in conjunction with these two factors should ensure that an adequate delineation of possible water quality impacts of a proposed project is included in the Environmental Impact Statement.