

ANALYSIS OF THE EFFECTS OF ROAD SALT ON WATER QUALITY IN THE NORTHERN UNITED STATES

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National Water-Quality Assessment Program, Principal Aquifer Data Synthesis

Problem Maximum Chloride Concentrations in Ground Water

The use of sodium chloride as a deicing chemical on paved areas has increased dramatically in the northern United States since the 1950's. Sales of sodium chloride for highway deicing have increased from 591,000 tons in 1950 to more than 19 million tons in 2003. Concern has been growing about the effects of deicing chemicals on ground-water and surface-water supplies and aquatic habitats.

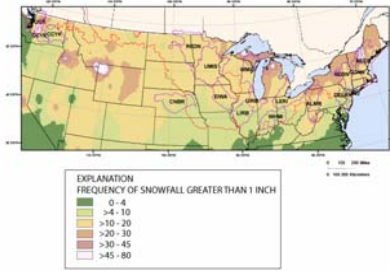
Objectives

- Describe concentrations of ions related to deicing chemicals (sodium, chloride, other ions) in urbanized shallow aquifers and in urban streamflow
- Relate concentrations to regional application rates, land use, hydrogeology and climatic factors.
- Describe water-type and the potential changes to overall water chemistry due to input of sodium chloride.
- Determine if ground-water discharge to streams is a major contributor of road deicing chemicals relative to annual load



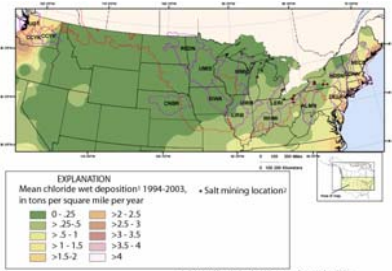
Less than 2 percent of the drinking water-supply wells sampled contained concentrations of chloride in excess of USEPA Secondary Maximum Contaminant Level of 250 mg/L. About 2.3 percent of the monitoring wells sampled had chloride concentrations in excess of 250 mg/L.

Snowfall Frequency



Snowfall frequency is an indirect measure of the need for winter road deicing. The frequency of snowfall events greater than 1 inch over the glacial aquifer system in the lower 48 states ranges from about 4 to almost 80 events per year. Data interpolated from National Climatic Data Center 1971-2000.

Mean Wet Deposition of Chloride 1994-2003



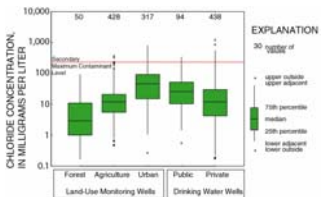
The wet deposition of chloride was averaged from gridded data available from the National Acid Deposition Program, 1994-2003. This yield represents a small part of the yield shown below.

The Glacial Aquifer System



The U.S. Geological Survey, through the National Water-Quality Assessment (NAWQA) program, is in the process of conducting regional assessments of principal aquifers in the United States, based on data collected beginning in 1991. The glacial aquifer system is the largest principal aquifer in areal extent and for ground-water use for public supply in the United States (Warner and Arnold, 2005).

Chloride Concentrations in Ground Water



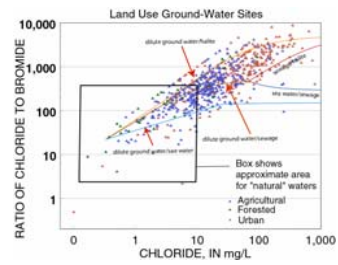
Explanatory Variables

Regression Model to Predict natural log (Chloride Concentrations) in Urban Ground Water

- ☐ Frequency of >1 inch snowfall
- ☐ Percent of 500-m buffer that contains roads
- ☐ Percent of 500-m buffer that has hydric soil
- ☐ Recharge rate
- ☐ Mean air temperature

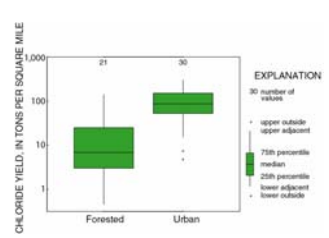
A multiple-linear regression model was used to determine ancillary factors that predict the natural log of chloride concentrations in ground water. The significant variables are shown above.

Sources of Chloride in Ground Water



Chloride was plotted against the chloride:bromide ratio by mass to help understand the sources of chloride. Binary mixing curves were generated using end-members (Granato 1996; Davis and others, 1998; Jagucki and Danner, 2001) for dilute ground water, sea water, and sewage. The results of this analysis indicated that chloride originated from mixed sources in agricultural areas, and that chloride in most urban wells was dominated by halite dissolution, but often contained some chloride that may be derived from sewage.

Chloride Basin Yields



Chloride loads were computed using USGS "S-Loader" based on Runkel and others (2004). Yields of chloride were much larger in urban basins, some with point-source discharges. Wet deposition of chloride was typically less than 4 tons/square mile in the study area. When converted to equivalent NaCl and divided by the total length of roads in each basin, total outputs from basins are similar to typical application rates of 10-30 tons per road mile.

Monitoring Sites



Maximum Chloride Concentrations in Streams

Explanatory Variables

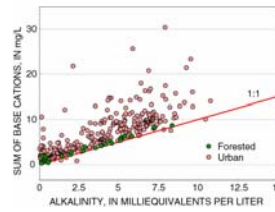
Regression Model to Predict natural log (Maximum Chloride Concentration) in Urban and Forested Surface Water sites

- ☐ Percent Urban Land
- ☐ Potential Evapotranspiration
- ☐ Percent Dunne Overland Flow

Major ion data were analyzed for 51 basins dominated by urban or undeveloped land. Twelve basins contained municipal point-source discharges. The recommended chronic aquatic criteria (U.S. Environmental Protection Agency, 1980) concentration of 230 mg/L was equaled or exceeded at 9 sites, and the recommended acute criteria of 860 mg/L was equaled or exceeded at 5 sites. The majority of the samples with concentrations higher than the recommended criteria were collected during the winter months, and are likely associated with snow-melting events.

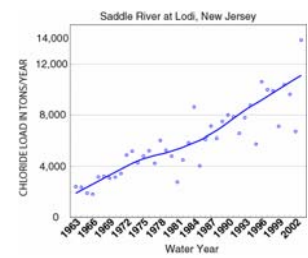
A multiple-linear regression model was used to determine ancillary factors that predict the natural log of the maximum chloride concentration measured at 51 urbanized or forested basins.

Base Cation Concentrations in Ground Water by Land Use



This plot similar to those created by Rhoads and others (2001), shows the relation between alkalinity and the sum of base cations. In waters affected only by mineral-weathering reactions, samples would likely fall on the 1:1 line or be shifted slightly left of the line due to acid deposition. The urban samples that deviate from the 1:1 line contain excess base cations due to urban inputs including road-deicing salts, and also the release of base cations due to cation exchange of sodium for calcium, magnesium, or potassium.

Trends in Chloride Load



In some cases, streams with long-term water-quality records had obvious increases in chloride load with time.

References
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