Chloride in Surface Waters and Groundwaters of Illinois

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Chloride ($\text{Cl}^-$) Properties

• Non-toxic to humans, but too much imparts salty flavor
  – U.S. secondary drinking water standard: 250 mg/L
• Can be toxic to aquatic life at levels as low as ~200 mg/L
  – USEPA chronic criterion recommendation: 4-day average of 230 mg/L, once every 3 yrs
  – Acute criterion recommendation: 1-hour average of 860 mg/L, < once every 3 yrs
• Reduce biodiversity
  – Salt-tolerant species out-compete
Chloride Properties (cont.)

- Corrosive
  - Chloride ions are the major cause for the corrosion of steel reinforcement in concrete
  - Deicing salts: road repair costs estimated at $200 to $450 million/yr (1991 report)
- Can accelerate corrosion of metallic pipes and structures
Natural Sources of Chloride to Illinois Waters

- Mineral dissolution
  - Halite (NaCl); very soluble
- Atmospheric deposition
- Natural brine discharge
Chloride Contamination: Anthropogenic sources

Sewage & Septic

Fertilizer (KCl)

Road Salt
## Estimated Chloride Fluxes in Illinois

<table>
<thead>
<tr>
<th>Source</th>
<th>Total Flux (Mg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treated Wastewater: MWRDGC</td>
<td>175,000</td>
</tr>
<tr>
<td>Treated Wastewater: Remainder of state</td>
<td>125,000</td>
</tr>
<tr>
<td>Atmospheric</td>
<td>18,000</td>
</tr>
<tr>
<td>Road Salt</td>
<td>471,000</td>
</tr>
<tr>
<td>Water Conditioning Salt</td>
<td>135,000</td>
</tr>
<tr>
<td>Fertilizer (KCl)</td>
<td>373,000</td>
</tr>
<tr>
<td>Livestock</td>
<td>139,000</td>
</tr>
<tr>
<td>Lake Michigan withdrawals</td>
<td>34,000</td>
</tr>
<tr>
<td>Groundwater withdrawals</td>
<td>28,000</td>
</tr>
<tr>
<td>Oil-Field Brines (1% leakage)</td>
<td>23,000</td>
</tr>
</tbody>
</table>
## Concentrations for Potential Sources of Cl⁻ Samples from Illinois

<table>
<thead>
<tr>
<th>Source</th>
<th>$Cl^-$ (mg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Livestock manure</td>
<td>517 - 1980</td>
</tr>
<tr>
<td>Septic discharge</td>
<td>91 - 504</td>
</tr>
<tr>
<td>Treated wastewater</td>
<td>113 - 291</td>
</tr>
<tr>
<td>Agricultural tile drain</td>
<td>10 - 18</td>
</tr>
<tr>
<td>Agricultural soil water</td>
<td>5 - 21</td>
</tr>
<tr>
<td>Precipitation</td>
<td>0.01 - 1.8</td>
</tr>
<tr>
<td>Pristine soil water</td>
<td>0.7 - 1.6</td>
</tr>
<tr>
<td>Road salt runoff</td>
<td>1572, 8930</td>
</tr>
<tr>
<td>Background (base flow)</td>
<td>&lt; 15</td>
</tr>
</tbody>
</table>
Chloride in Surface Water in Illinois

• Lakes
Lake Michigan (USEPA)
Lake County

Data courtesy M. Adam, Lake Co. PHD
Chloride in Surface Water in Illinois

- Lakes
- Rivers
  - ISWS, USGS and MWRDGC data
Summary of Cl\textsuperscript{−} in Illinois River

• Headwaters for Illinois R. in Chicago region
• Cl\textsuperscript{−} concentrations generally highest in Chicago, generally decrease downstream
• Wastewater signature can be seen far downstream from Chicago, especially at low flow
• Seasonal effects
  – e.g., slug of Cl\textsuperscript{−} in late winter/spring

Median Cl- Values (1990-1992) USGS Stations

Samples every 4-6 weeks
Seasonal Cl⁻ concentrations
(MWRDGC Data)
Trends in Cl- Concentrations: USGS Stations (since 1984)

Various periods of record

42 Positive
19 No Trend
15 Negative
35 of 41 sites monitored since 1975 had significant positive trends
Chloride in Illinois River at Peoria

Annual U.S. Highway Salt Sales (million tons)

Chloride in Groundwater in Illinois

- Bedrock Aquifers
  - Cambrian-Ordovician
  - Silurian-Pennsylvanian
- Sand & Gravel Aquifers
- In confined aquifers, Cl$^-$ from natural sources
- All things being equal, the older the groundwater, the higher the Cl$^-$
Chloride in Bedrock Aquifers

Cambrian-Ordovician

Silurian-Pennsylvanian
Chloride in Oil Field Brines

Silurian-Pennsylvanian

Cl^- (mg/L)
- <1000
- 1000-5000
- 5000-10,000
- 10,000-20,000
- 20,000-30,000
- 30,000-40,000
- 40,000-50,000
- 50,000-60,000
- 60,000-70,000
- 70,000-80,000
- 80,000-90,000
- >90,000
Chloride in Sand & Gravel Aquifers

Wells < 50 ft deep
Chloride in the Mahomet Aquifer
Lake Calumet (south Chicago)
shallow monitoring wells

[1991]
Trends in Cl\textsuperscript{-} Concentrations in Shallow Aquifers: Chicago Region

Summary of Results

• Pre-1960 Cl\textsuperscript{-} < 20 mg/L in ~85% of all samples
• Cl\textsuperscript{-} concentrations increasing since the 1960’s
• Outer collar counties have greatest increases

All Data in 6 County Region

The image shows a box plot graph with the y-axis labeled as $Cr$ (mg/L). The graph compares data from different time periods (<1950, 1950-1960s, 1970s, 1980s, 1990-2005) with two distinct depth categories: <100 ft and 100-200 ft. The medians are indicated by numbers within the graph:

- <1950: Median 8, 5
- 1950-1960s: Median 9, 7
- 1970s: Median 22, 9
- 1980s: Median 36, 12
- 1990-2005: Median 36, 17
Individual Public Supply Wells

55% have positive trends; >60% in DuPage, Will, Kane
37% > 1 mg/L/yr; 12% > 4 mg/L/yr
Effects of Increased Chloride in Water Resources

• Increased treatment costs for drinking water
• Increased costs due to corrosion
• Loss of use of some water resources
• Ecological costs?
  – 7 of 13 streams in Milwaukee area exhibited toxicity to *Ceriodaphnia dubia* and *Pimephales promelas* due to road salt runoff