Changes in Shallow Groundwater Quality in the Chicago Region in the Past 50 Years

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Introduction

Population and infrastructure are growing rapidly in the Chicago, Illinois, metropolitan area. Population is projected to increase from 8 million in 2005 to more than 10 million by 2030. Most of the growth is occurring in counties west and south of Chicago, such as Kane, McHenry, and Will, where populations may double in that period. Demand for water is also increasing substantially. Shallow bedrock and overlying sand and gravel aquifers are expected to be the main water sources to meet the increased demand in the Chicago region.

Unfortunately, shallow aquifers are vulnerable to surface contamination, and there are many potential sources of contamination in urban and suburban areas, including landfills, sewage treatment plants, industrial effluents, atmospheric deposition, septic fields, gasoline storage tanks, and road runoff. The list of potential contaminants is enormous, including various organic compounds, toxic metals, chloride (Cl^-), sulfate, and nitrogen (nitrate, ammonium).

Chloride is a particularly useful indicator of aquifer contamination. Although not a primary threat to human health, elevated levels of Cl^- make water non-potable and thus there is a secondary drinking water standard of 250 milligrams per liter (mg/L). Chloride is a common contaminant that behaves conservatively in the environment (i.e., does not react and thus is transported at the same velocity as water) and has numerous sources in urban areas.

Where Cl^- concentrations exceed background (prior to 1950) levels of 15 mg/L in shallow groundwater in Illinois (Panno et al., 2006), human contamination is almost always to blame. Human sources of Cl^- include road-salt runoff, septic and sewage effluent, and landfill leachate. Road salt, which was applied in earnest beginning in the 1960s, has been linked to groundwater degradation in many areas that have snowy climates. Once in groundwater, Cl^- and other contaminants can persist for long periods due to slow travel times.

With the likelihood that shallow aquifer use will increase in coming decades, it is critical to determine if the water quality of these aquifers is being degraded. Kelly and Wilson (2008) examined historical shallow groundwater quality data to characterize temporal and spatial changes in water quality in the Chicago metropolitan area. This document summarizes the trends in Cl^- concentrations from that report.

Procedures

Data from six counties in northeastern Illinois were considered: Cook, DuPage, Kane, Lake, McHenry, and Will, totaling an area of approximately 3700 square miles. The shallow aquifers in this region consist of bedrock and overlying unconsolidated glacial deposits. The shallow bedrock aquifers in northeastern Illinois are primarily Silurian and Ordovician fractured dolomites. Glacial deposits overlie the bedrock throughout the entire region, and are thickest in northwestern McHenry County and generally thinnest in central DuPage and Cook Counties and northern and western Will County. Sand and gravel deposits within the glacial materials can provide moderate to large groundwater supplies. The study was limited to wells no more than 200 feet deep to focus on the aquifers most vulnerable to surface contamination.

Groundwater quality data were obtained primarily from a database maintained by the Illinois State Water Survey (ISWS). At the time of this study, the database contained chemical analyses for more than 4600 samples from private and public supply wells less than 200 feet deep in the six-county Chicago region, collected between 1906 and 2005. The data were analyzed using several statistical tests, and trend analysis was conducted on 242 wells from which multiple samples had been taken over several years. The effects of geology and land use were evaluated using well construction and geospatial data.

Results and Discussion

The median Cl^- concentration of all samples in the data set steadily increased from 6 mg/L prior to 1950 to nearly 20 mg/L in samples from 1990 to 2005, and each 10-year time period had significantly greater concentrations than the previous time period. The greatest increases were found in the western collar counties, DuPage, Kane, McHenry, and, to a lesser extent, Will County to the south. In DuPage County, the median value of Cl^- increased from 4 mg/L prior to 1950 to 101 mg/L in 1990-2005 (Figure 1).

The percentage of samples from public supply wells with elevated Cl^- concentrations has been increasing with time (Table 1). Of samples collected before 1970, about 80 percent had Cl^- concentrations less than 15 mg/L, the maximum natural background concentration. Only about 3 percent and 1 percent of samples had concentrations greater than 50 and 100 mg/L, respectively. Since then, the number of samples with elevated Cl^- concentrations has increased. Of samples collected after 1990, 37 percent had concentrations < 15 mg/L and 38 percent and 14 percent had concentrations exceeding 50 and 100 mg/L, respectively. In the shallowest wells (< 100 feet), the percentages of samples with elevated Cl^- concentrations were even higher, exceeding 50 and 100 mg/L in 66 and 34 percent of samples, respectively.

Individual Wells

Chloride concentrations are plotted versus time for some individual public supply wells in Figure 2. More than half of the wells analyzed (133 of 242) had significant increasing trends in Cl^- concentrations (Table 2). Lake County had the lowest percentage of wells with increasing Cl^- trends. Kane County had the highest percentage with increasing trends, but wells in DuPage County generally had the most rapidly increasing trends. The shallowest wells (< 100 feet) had significantly greater trends compared to deeper wells (100-200 feet), but many deeper wells had large increases in Cl^- concentrations as well.

Table 1. Chloride concentrations in public supply wells as a function of time showing median values and percentages of samples less than 15 mg/L and exceeding 50 or 100 mg/L.

	Median (mg/L)	*< 15 mg/L*	*≥ 50 mg/L*	*≥ 100 mg/L*
< 100 feet				
< 1950	10	69%	2%	0%
1950-1960s	10	71%	3%	0%
1970s	24	36%	19%	4%
1980s	39	16%	39%	11%
1990-2005	87	16%	66%	34%
100-200 feet				
< 1950	4	95%	0%	0%
1950-1960s	6	82%	3%	1%
1970s	8	66%	11%	2%
1980s	12	53%	22%	5%
1990-2005	25	40%	34%	12%
All				
< 1950	6	87%	1%	0%
1950-1960s	7	79%	3%	1%
1970s	10	60%	13%	3%
1980s	17	46%	25%	6%
1990-2005	29	37%	38%	14%

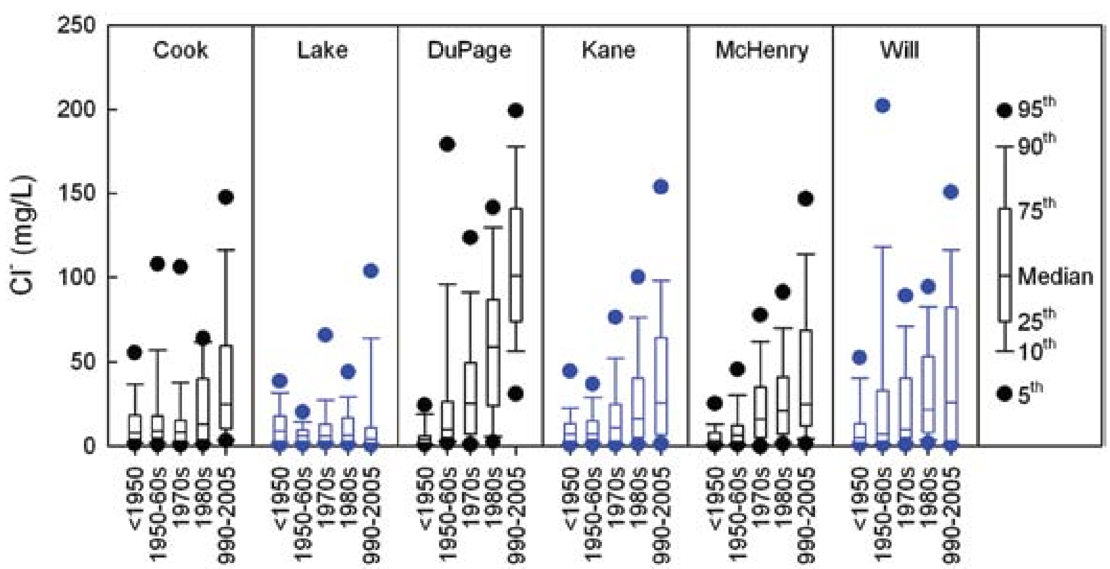

Figure 1. Box-and-whisker plots showing changes in Cl- concentrations with time for each county in the Chicago region. Data for wells < 200 feet deep. Median and various percentile values shown in plots.

In theory, the greater the thickness of low permeable till overlying an aquifer, the better it should be protected from surface contamination and thus the lower the Cl^- concentrations. This was, in fact, observed; wells beneath relatively thin till deposits (< 100 feet) had significantly greater increasing trends in Cl^- concentrations than wells beneath thick till deposits (> 100 feet).

Sources of Chloride

Road salt is the largest potential source of Cl^- in the region, and the start of increasing trends in Cl^- concentrations (around 1960) coincides with the rapid expansion of road salt application around that time. In an average winter, the Illinois Department of Transportation uses nearly 150,000 tons of road salt in the six-county region, with counties and municipalities applying approximately the same amount (Keseley, 2006). Although there are other potential sources of Cl^- to groundwater, such as septic system discharge, evidence suggests that road salt is the major source in the Chicago region. For example, Kelly and Roadcap (1994) measured Cl^- concentrations in excess of 1000 mg/L in several shallow monitoring wells installed along the uncurbed Interstate-94 in south Chicago, including two

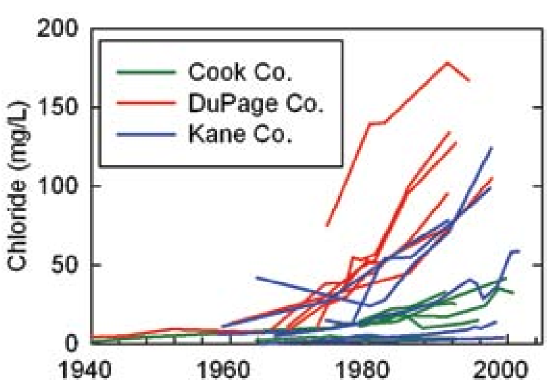

Figure 2. Chloride concentrations vs. time for selected individual public supply wells in Cook, DuPage, and Kane Counties.

Table 2. Percentages of individual wells with multiple samples having significant positive trends for Cl- and increases greater than 1 and 4 mg/L/yr.

County	*Significant positive trend*	*> 1 mg/L/yr*	*> 4 mg/L/yr*
Cook	45%	31%	7%
DuPage	60%	63%	28%
Kane	71%	36%	5%
Lake	39%	22%	4%
McHenry	55%	38%	15%
Will	62%	31%	8%
TOTAL	55%	37%	12%

exceeding 3500 mg/L. Chloride concentrations also have been increasing since the 1950s in the Illinois River waterway (which includes the Des Plaines River and Sanitary & Ship Canal in Chicago). The highest concentrations and most rapid increases have occurred in winter and early spring, suggesting that road salt runoff is the major source; septic discharge would not be expected to have seasonal variability (Panno et al., submitted).

Spatial Variability

The western and southern collar counties have the greatest increases in Cl^- concentrations in the past 50 years. Shallow aquifers in these areas tend to be more vulnerable to contamination than in Cook and Lake Counties because sand and gravel aquifers are generally thicker and closer to the surface, especially in McHenry and Kane Counties. Wells with the greatest Cl^- concentrations are often found in areas where aquifers are within 50 feet of the surface, although there were no consistent statistically significant differences between data from areas with shallow aquifers versus those without. It thus appears that the presence or absence of shallow aquifer material is not the sole control on Cl^- concentrations.

In Kane and Will Counties, most wells with low Cl^- concentrations are in the western and southern sections, respectively, where there is less urban and suburban development (Figure 3). For example, concentrations of Cl^- are significantly greater in the eastern third of Kane County compared to both the western and central thirds. As residential and road development pushes westward in Kane County, shallow aquifers, which are generally within 50 feet of the surface, will become more likely to be contaminated by human activities. Cook and Lake Counties also tend to have relatively low Cl^- concentrations, even though urban and residential development began earlier here than in the western and southern collar counties. This may be due to the fact that most major roads in Cook and Lake Counties are curbed.

Curbing diverts runoff into storm water sewers, limiting groundwater recharge by contaminated surface water. Some collar counties have less curbing than others; for example, about 10 percent of roadways in Will County and 6.5 percent of county road miles in Kane County are curbed. In contrast, in DuPage County, which is more urbanized than Will or Kane Counties, more than 60 percent of roadways are curbed, and Cook and Lake Counties undoubtedly have higher curbing percentages than DuPage County. The lesser amount of curbing in the western and southern collar counties thus could allow more contaminated runoff to recharge the shallow aquifers.

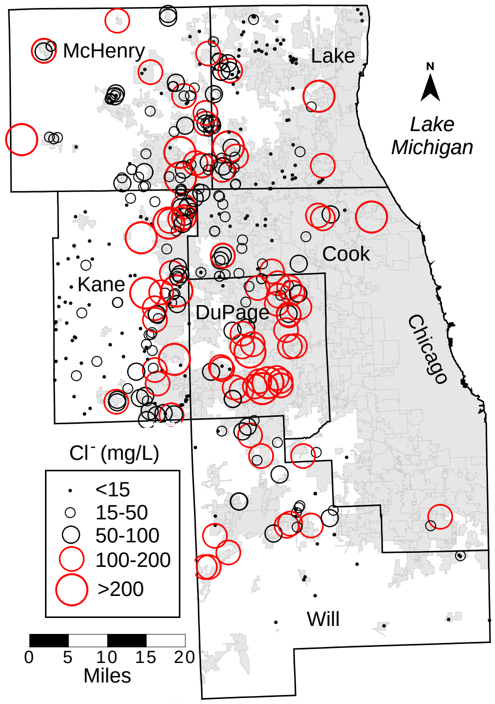

Figure 3. Chloride concentrations for samples from 1998-2004. Light gray area shows Chicago city limits and other incorporated municipalities.

Conclusions

Shallow groundwater quality in the Chicago metropolitan area has degraded at least since the 1960s, as indicated by increasing levels of Cl^-, especially in the collar counties (DuPage, Kane, McHenry, and Will). Groundwater quality in the Chicago region reflects an interplay between natural hydrogeology and human activities. There are shallower and more significant sand and gravel deposits in the western collar counties, but groundwater quality in shallow aquifers in rural parts of these counties is generally good. It thus appears that land use, primarily in the form of road salting, is the major factor affecting Cl^- concentrations in the collar counties.

In Cook and Lake Counties, however, lower Cl^- concentrations and rates of change cannot be attributed to lower rates of road salt application. Because most roadways in Cook and Lake Counties are curbed, saline runoff in these counties is channeled to storm water retention and is thus less important as a source of aquifer recharge than in the collar counties. This is an important point, as recently water resource managers have developed a consensus that a goal of storm water management should be to maximize infiltration and minimize runoff. If the quality of the recharge to groundwater is poor, then fixing one problem (storm water runoff) may produce another (decreasing groundwater quality).

Most areas in this region have probably not yet seen maximum concentrations of Cl^- because of slow groundwater travel times in the region (on average less than 3 feet per year). Even if all sources of pollution were stopped immediately, it is likely that peak groundwater concentrations of Cl^- and other surface-derived dissolved contaminants will be higher in the future than they are now. Although water quality of shallow aquifers has degraded and likely will continue to degrade given the ongoing and projected development in the Chicago metropolitan area, these aquifers will still be critical to meeting future water needs. Measures that could be taken for long-term protection of shallow groundwater quality include delineation and protection of well capture zones and use of alternative road deicing procedures.

References

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