Report for 2004ME27B: Evaluating scope and trends for decreasing base cations (and increasing diluteness)

- Other Publications:
  - Rosfjord, C., J.S. Kahl, K. Webster, C. Loftin, S. Nelson, 2004. Poster: A 20-Year Re-evaluation of Trends in a Statistical Population of Lakes in the Northeastern U.S. Maine Water Conference, Augusta, ME, April 2004.
- unclassified:
  - Rosfjord, C., J.S. Kahl, K. Webster, C. Loftin, S. Nelson, 2004. Poster: A 20-Year Re-evaluation of Trends in a Statistical Population of Lakes in the Northeastern U.S. Graduate Student Expo, University of Maine, Orono, ME, April 2004.

Report Follows

Abstract

In 1984, the Environmental Protection Agency conducted the Eastern Lake Survey (ELS-I) to assess the overall status of lakes in the east, with particular attention to the relationship between acid deposition and pH. In 1986, a statistical subset of the ELSI lakes, consisting of 145 lakes in the northeast, was re-sampled for ELS-II. Since the 1986 sampling, the Clean Air Act Amendment (CAAA) of 1990 resulted in reductions in sulfate emissions. The goal was to improve the biologically relevant chemistry of surface waters. In 2004, we re-sampled the 145 Northeastern lakes on the 20th anniversary of their original sampling. The data produced by the 2004 re-sampling allow for assessments of biologically relevant chemical trends in a wide range of lakes. Of particular interest are trends in base cation concentrations, the by-products of weathering reactions that produce acid neutralizing capacity (ANC) of surface waters and buffer against acid inputs. The lack of response of surface water pH to increase despite declines in acid deposition has been attributed to a concurrent decline in surface water base cation. Our objectives are to address long-term chemical trends in a wider chemical range of lakes while enhancing the statistical coverage of the northeastern region by using the ELSII sub-population. Trends in base cations have largely been studied in the most sensitive low ANC (<25 µeq/L) waters with few anthropogenic influences outside of atmospheric deposition. Chemical trends in high ANC lakes (>100 µeq/L) with greater anthropogenic influences are poorly understood. This research found base cation concentrations declined in a wide range of ANC waters in remote lakes in the northeast. However, lakes affected by road salt have generally experienced increases in base cation concentrations over the past 20 years. This information will allow for assessment of the CAAA and its effectiveness in increasing pH in surface waters through reductions in sulfate emissions. Additionally, this research has important implications for designing future assessments of changes in water chemistry resulting from changes in emissions.

Summary

In response to the Clean Air Act Amendments of 1990, decreases in emission of sulfur dioxide have lead to decreases in deposition of sulfate and subsequent decreases in surface water concentrations of sulfate. In the ELS-II population, sulfate decreased in over 90% of the population with an average decrease from 110.8 µeq/L in 1984 to 85.9 µeq/L in 2004. Regionally there were some differences in declines in sulfate, with the greatest decreases in the Adirondacks and the smallest decreases in Maine. Nitrate also decreased in approximately 75% of the population with average decreases from 1.94 µeq/L in 1984 to 1.13 µeq/L in 2004.

Base cations Ca and Mg showed considerable variation between lakes affected by road salt and lakes unaffected by road salt. In the high Cl population, over 85% of the lakes increased in Ca and Mg with an average increase of +62.30 µeq/L/20yr. In the low Cl group, over 70% of the lakes experienced decreases in Ca and Mg with an average decrease of -6.89 µeq/L/20yr Ca+Mg. For the purposes of this paper, it is assumed that high Cl lakes do not represent changes in lake chemistry resulting from changes in atmospheric deposition. Ca and Mg also showed variation between ANC classes. Within the low Cl group, lakes in the lower ANC classes showed greater decreases in Ca+Mg than did lakes in the higher ANC class.

Despite average decreases in Ca+Mg in low Cl lakes, there were average increases in ANC in low Cl lakes, indicating the importance of declines in sulfate to ANC. Nearly 90% of the ANC class I/low Cl lakes experienced increases in ANC over the 20 years with an average increase from -1.66 µeq/L ANC in 1984 to 7.82 µeq/L ANC in 2004. Approximately 80% of the ANC class II/low Cl experienced increases in ANC with an average increase from 61.99 µeq/L in 1984 to 68.70 µeq/L in 2004.

Nearly 80% of the ANC class I in the low Cl group experienced increases in EqpH with an average change of +0.25 pH units/20yr. This brought the average EqpH for ANC class I/low Cl from 5.56 in 1984 to 5.81 in 2004. There were, however, average decreases in EqpH for ANC class II and class III.

Concentrations of total aluminum decreased in approximately 90% of the population. Changes in total Al differ by ANC class, with ANC class I experiencing the greatest average decrease in total Al of -73.64 µg/L/20yr.

Approximately 86% of the population experienced increases in DOC with an average increase of +1.51 mg/L from 4.05 mg/L in 1984 to 5.56 mg/L in 2004. There are regional differences in changes in DOC. Maine experienced the greatest increase in DOC out of the 5 regions with an average increase from 4.46 mg/L in 1984 to 6.94 mg/L in 2004.

These 20 year trends are summarized in Fig. 5.22, 5.23, and 5.24.

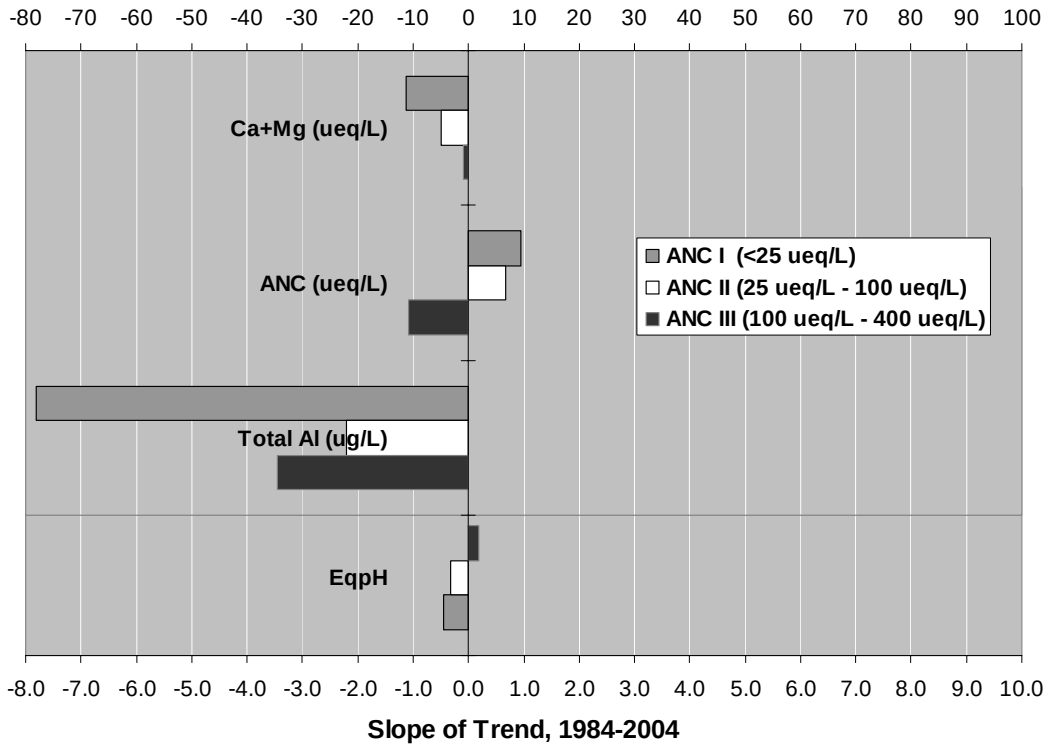

Figure 22. Average trends in the low chloride group, 1984-2004.

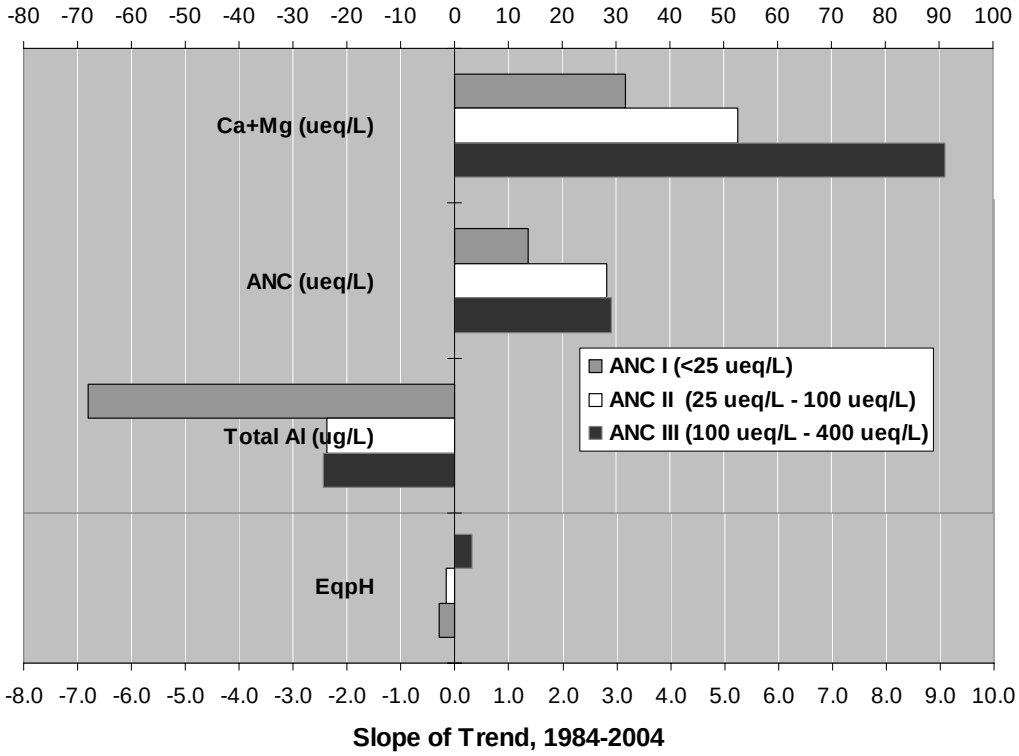

Figure 23. Average trends in the high chloride group, 1984-2004.

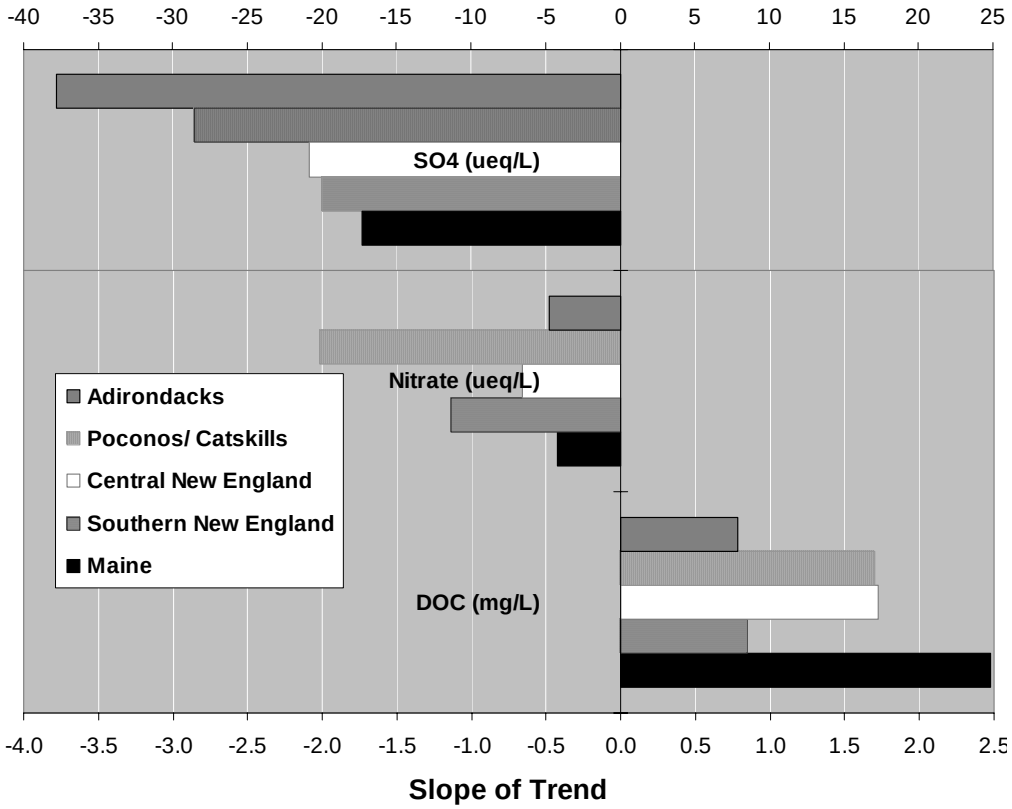

Figure 24. Regional trends in sulfate (µeq/L), nitrate (µeq/L) and DOC (mg/L), 1984-2004

Conclusions

Many of these trends indicate recovery from acid deposition and the success of the Clean Air Act Amendments. Decreases in emissions of sulfur dioxide due to the passage of the CAAA have clearly resulted in decreases in sulfate concentrations in surface waters. Decreases in the acid anion sulfate have resulted in an increase in ANC and an increase in pH, particularly in low ANC systems. Both ANC and pH are indicators of biological conditions and increases in these parameters indicate potential biological recovery in the most sensitive surface waters. Additionally, total Al had considerable decreases,

especially in low ANC lakes. Due to the toxic affects of Al on gilled organisms, decreases in total Al is an important indicator of recovery from acid deposition.

However, there are some trends which indicate that recovery from acid deposition may take longer than expected. Decreases in the base cations Ca+Mg, particularly in low ANC lakes, result in a diminished ability of surface waters to neutralize acid inputs. It is likely that increases in ANC over the 20 years would be more considerable had base cations not decreased during this time. Furthermore, due to increases in DOC, there are additional sources of acidity in many northeastern lakes.

Regionally, the Adirondacks appear to be making the greatest headway in recovery. The Adirondack region has the greatest average decrease in sulfate, the greatest average increase in EqpH, and the greatest average decrease in total Al. Conversely, Maine has the smallest average decrease in sulfate, the smallest average increase in ANC, the greatest average decrease in EqpH, and the smallest average decrease in total Al. Interestingly, the Adirondack region has the greatest average decrease in Ca+Mg while Maine has the greatest average increase in Ca+Mg. This indicates that while base cation may contribute to the acid neutralizing capacity of surface waters, changes in base cation concentrations are not driving recovery in northeastern suface waters.

The prevalence of road salt in northeastern surface waters proved to be a confounding factor when analyzing the effects of the CAAA on surface waters. The majority of the lakes in this study (56%), were affected by elevated concentrations of Cl, presumably

from road salt. While Ca+Mg had average decreases in low Cl lakes, 85% of the high Cl lakes experienced average increases in Ca+Mg.