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Short communication

Changes in base cation deposition across New York State and adjacent New England following implementation of the 1990 Clean Air Act amendments

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Abstract

To reduce atmospheric deposition, in 1990 Congress passed amendments to the Clean Air Act requiring electric utility power plants to decrease emissions of sulfur dioxide and nitrogen oxides, with Phase I beginning in 1995. We analyzed precipitation volume, wet deposition, and concentration of the sum of base cations measured at 12 National Atmospheric Deposition Program sites in Massachusetts, New Hampshire, New York, and Vermont. We compared five-year means prior to and following passage of the amendments and for five years after the implementation of Phase I. Whereas only one of the monitoring stations recorded a decline in base cation deposition, three sites out of the 12 showed a decline in base cation concentration. None of the sites exhibited a significant change in precipitation volume. Continued deposition of base cations may help to reduce the detrimental effects of acidic deposition. © 2002 Elsevier Science Ltd. All rights reserved.

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1. Introduction

Atmospheric deposition of acidifying ions has the potential to disrupt the structure and function of terrestrial and aquatic ecosystems (e.g. Raynal et al., 1982; DeHayes et al., 1999; Carreiro et al., 2000). This syndrome of responses can predispose ecosystems to damage from other stresses (McLaughlin and Percy, 1999) resulting in severe disruption.

To reduce acid deposition, Congress enacted legislation to reduce potentially damaging emissions of sulfur and nitrogen. In 1990, amendments to the Clean Air Act became a law requiring electric power utility plants to reduce emissions of sulfur dioxide and nitrogen oxides through allowance trading of permitted total amounts of

waste gases (United States General Accounting Office, 2000). Phase I of this plan began in 1995 requiring a subset of United States power plants to limit their emissions of sulfur in an effort to stem the threat to ecosystems posed by acidic deposition.

We sought to determine the effect of implementation of this legislation on the atmospheric deposition of base cations across New York State and adjacent New England. Likens et al. (2001), who characterized the deposition of sulfate, indicated the need to assess atmospheric depositional patterns of base cations as well as acidifying ions. In this analysis, we analyze wet deposition of calcium, magnesium, potassium, and sodium. Atmospheric deposition of base cations can reduce the acidifying effects of nitrate and sulfate deposition by augmenting lost stores of base cations (Hultberg and Ferm, 1995). Such supplementation of base cation stores cannot, however, reverse base cation leaching until acidic deposition has been ameliorated.

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Our objective was to quantify changes in ion deposition across New York State and adjacent New England from 1985 to 1999. As a result of projected declines in emissions of base cations in connection with the Clean Air Act Amendments, we predicted that base cation deposition has decreased across the region.

2. Methods

We accessed data of the National Atmospheric Deposition Program/National Trends Network for these analyses (National Atmospheric Deposition Program (NRSP-3)/National Trends Network, 2000). Sites examined were MA08 Quabbin Reservoir, NH02 Hubbard Brook, NY08 Aurora Research Farm, NY10 Chautauqua, NY20 Huntington Wildlife, NY52 Bennett Bridge, NY65 Jasper, NY68 Biscuit Brook, NY98 Whiteface Mountain, NY99 West Point, VT01 Bennington, and VT99 Underhill. These monitoring stations represent sites with continuous deposition records since at least 1985 and are sufficiently inland to minimize confounding effects of marine input (Ollinger et al., 1993).

Ions examined were calcium, magnesium, sodium, and potassium. We analyzed five-year means in precipitation volume and the sum of base cation deposition ($\text{kg ha}^{-1} \text{yr}^{-1}$) and concentration ($\mu\text{eq l}^{-1}$) for the time periods 1985–1989, 1990–1994, and 1995–1999. These time periods represent those prior to the 1990 legislation, between passage and implementation of Phase I, and post-implementation, respectively. Means within a site were compared using Analysis of Variance (ANOVA). Specific differences were isolated using Tukey's HSD. We used ANOVA instead of the linear models used by Lynch et al. (1995, 2000) since the predicted values through which a change in deposition could be assessed are subject to the assumption of constant non-anthropogenic trends in deposition.

In order to assess the overall temporal trend in ion concentrations, we performed a Seasonal Kendall τ test (SKT) on the data at all of the sites (Hirsch et al., 1982; Hirsch and Peters, 1988). This non-parametric statistical test compares concentrations among years by examining monthly averages independently to alleviate concerns of seasonal changes in concentration and has been deemed appropriate for detecting temporal trends of ion concentration in precipitation (Holland et al., 1995).

3. Results

Only NY10 showed a significant decline in base cation deposition (Fig. 1a). Base cation concentration declined significantly at NY10, NY20, and VT99 (Fig. 1b). None of the sites recorded significant changes in precipitation volume (Fig. 1c).

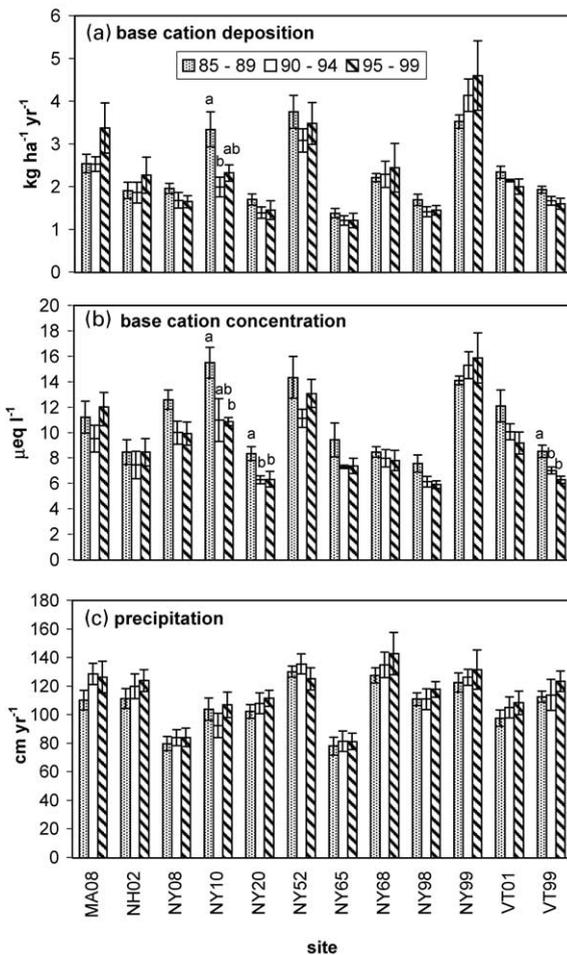


Fig. 1. Changes in base cation (a) deposition and (b) concentration and (c) precipitation across New York State and adjacent New England. Means within a site with different letters are significantly different at $\alpha = 0.05$. Error bars represent one standard error above and below the mean.

Overall, the time series analysis indicated a general 15-year trend of a decline in concentration of all ions across the region (Table 1). The exceptions were a positive trend for Na^{2+} at NH02 and NY20. Some sites recorded non-significant 15-year trends for Ca^{2+} , Na^{2+} , and K^{+} (Table 1).

4. Discussion

Few of the sites in this study had significantly decreased levels of base cation deposition and concentration (Figs. 1a and b) despite a general 15-year trend of decreased base cation concentration (Table 1). A consistent decline in concentrations could lead to a significant SKT result, yet the small absolute change

Table 1
Results of Seasonal Kendall τ analysis of trends of ion concentration ($\mu\text{eq l}^{-1}$) in precipitation (1985–1999)

Site	Ca ²⁺	Mg ²⁺	Na ⁺	K ⁺
MA08	-1.10	-0.35	-0.57	0
NH02	-0.88	-0.29	+0.19	0
NY08	-2.29	-0.60	-0.33	-0.05
NY10	-1.99	-0.61	-0.44	-0.27
NY20	-0.88	-0.29	+0.19	0
NY52	-1.95	-0.43	-0.48	0
NY65	-1.83	-0.49	-0.40	-0.04
NY68	-0.95	-0.36	-0.28	-0.08
NY98	0	-0.26	0	-0.11
NY99	-1.08	-0.12	0	0
VT01	-2.39	-0.77	-0.82	-0.14
VT99	-0.78	-0.21	-0.23	0

Value of slope is given if significantly different from zero at $\alpha=0.05$. A "0" indicates that the slope is not significantly different from zero at $\alpha=0.05$.

could still lead to the lack of significance in the ANOVAs. These results suggest that over a long term, base cation concentrations should decrease, as seen by Lynch et al. (1995), but currently the changes in base cation deposition and concentration are not large (Ito et al., 2002).

Lynch et al. (1995) found general declines in base cation concentration nationally, at broad geographic scales. In contrast, at a local depositional scale typical trends differ from the national trend. Causes of such spatial variation should be investigated.

While the current amounts of base cation deposition have not replenished base cation stocks in the Catskill Mountains of Southern New York (Burns et al., 1998; Lawrence et al., 1999), continuation of current deposition rates should help to reduce losses of these stocks. The net loss of base cations from a terrestrial system is related to the overall cycle of such ions. Inputs of base cations from atmospheric deposition replace some of those leached from soil. However, a reversal of base cation depletion in soils will occur only if acidic deposition is sufficiently reduced. Alternatively, if base cation concentration declines as suggested by the SKT results, atmospheric deposition of base cations will not be sufficient to reduce acidifying effects of atmospheric deposition. Continued monitoring and assessment of base cation deposition will be important to determine future trends in deposition of atmospherically derived base cations.

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