REGIONAL PATTERNS OF SULFUR RETENTION IN WATERSHEDS OF THE EASTERN U.S.

BARRY P. ROCHELLE
Northrop Services, Inc., 200 S.W. 35th Street, Corvallis, OR 97333, U.S.A.

and

M. ROBBINS CHURCH
Environmental Research Laboratory – Corvallis, U.S. Environmental Protection Agency, 200 S.W. 35th Street, Corvallis, OR 97333, U.S.A.

(Received December, 18, 1986; revised July 14, 1987)

Abstract. Retention of S was estimated in watersheds of the Eastern U.S. by calculating S input-output budgets for 678 lake and reservoir watershed systems in the Northeast (NE), 98 lake and reservoir and 61 stream systems of the Southern Blue Ridge Province (SBRP) and 56 stream systems of Shenandoah National Park (SNP). Budgets were determined based on estimates of deposition and output (as surface water) for each of the sites. A variety of estimates of total S deposition were used. Percent S retention is high for sites in the SBRP and SNP but is distributed around zero for sites in the NE. These findings lend support to the hypothesis that patterns exist in S retention relative to the extent of the Late Wisconsinan glaciation.

1. Introduction

Sulfur mobility in soils is an important factor affecting the response of watershed/surface water systems to S deposition associated with acidic deposition. Seip (1980) was one of the first to hypothesize that sulfate moving through watershed soil systems acts as a ‘carrier anion’ leaching positively charged ions (e.g., base cations, positively charged Al complexes and H⁺) to surface waters. Galloway et al. (1983a) and Reuss and Johnson (1985) also have discussed this concept in some detail.

Although S cycling in watersheds potentially is controlled by several processes (David et al., 1984; Swank et al., 1984; Johnson, 1984), sulfate adsorption-desorption is probably of greatest importance in most terrestrial systems (Johnson and Todd, 1983; Johnson, 1984; Fuller et al., 1985). Sulfate adsorption is influenced by several factors including content of Fe- and Al-oxides, organic matter and clay content and soil depth (Rajan, 1978; Johnson and Cole, 1980; Singh, 1984; Johnson and Todd, 1983). Also, Nodvin et al. (1986) determined that sulfate adsorption was linked to pH with adsorption increasing with a decrease in pH for mineral soils in New Hampshire having an initial pH greater than 4.0.

As noted by Seip (1980) and Galloway et al. (1983), the ability of a soil system to retain S can have important effects on the long-term acidification of surface waters. Galloway et al. (1983a) hypothesized that there were regional differences in S retention in the eastern U.S. relative to the extent of the Late Wisconsinan glaciation. They postulated that S generally was not being retained in areas north of the limit of glaciation.
but that areas south of the limit generally retained incoming S. To further examine this hypothesis, Rochelle et al. (1987) reviewed current literature concerning S input-output budgets and summarized S retention information for the U.S. and Canada. They found that, whereas most of the sites south of the limit of the last glaciation were retaining between 20 and 90% of incoming S, most of the sites north of the limit were retaining little, if any. Rochelle et al. (1987) also identified an apparent relationship between S retention and soil order, with sites dominated by Spodosols and Podzols being associated with low (or negative) net retention and the sites dominated by Ultisols and Alfisols still retaining incoming S.

We have estimated S retention for 1 yr for regional populations of three sets of surface water systems. The systems are (1) lakes (> 4 ha) in the NE, (2) lakes and reservoirs (> 4 ha) in the SBRP, and (3) streams in the SBRP. These three systems were surveyed as part of the National Surface Water Survey (NSWS) of the U.S. Environmental Protection Agency (U.S. EPA). In each case a stratified probability sampling technique was used that allows for statistical extrapolations to the entire population of systems represented by the sample. Complete descriptions of the target populations and sampling statistics are given by Linthurst et al. (1986) and Messer et al. (1986). We have computed budgets using estimates of dry S deposition at the subregional scale for the NE and examined the variation in S retention for subregional populations. We have also calculated S retention for a fourth data set – a sample of streams of the Shenandoah National Park (SNP). Although this last set was not a probability sample, it provides a useful comparison with the other three.

2. Methods

We estimated S retention in watersheds by calculating input-output budgets for 678 lake and reservoir systems in the NE, 98 reservoir and lake and 61 stream systems in the SBRP and 56 stream systems in SNP (Figure 1). Table I identifies the study sites, the chemical data available and the data sources. We calculated S retention as the difference between input minus output divided by the input.

2.1. Inputs

We computed total S inputs on an areal basis using measurements of watershed size, interpolated values of wet deposition and hypothesized scenarios of dry deposition.

2.1.1. Wet Sulfate Deposition

Wampler and Olsen (1987) used a Kriging algorithm to interpolate wet sulfate deposition for each of the NE and SBRP lake and reservoir sites and the 61 SBRP stream sites from Water Year 1984 (WY84) NADP/NTN deposition data. Precipitation averages for WY84 from precipitation stations (NOAA, National Climatic Data Center) were used in the interpolation procedure to account for precipitation volume variations within the regions.

We estimated wet deposition for the 56 SNP sites by averaging the 1981 and 1982