Atmospheric Deposition Characteristics in the Ouachita Mountains of Southeast Oklahoma

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A network of bulk precipitation collectors was established in southeastern Oklahoma to monitor the chemistry of such precipitation and to determine whether atmospheric deposition trends observed at a National Atmospheric Deposition Program (NADP) site near Clayton were representative of the commercial forest lands of southeastern Oklahoma. The field collections lasted from October 2, 1984 to October 1, 1985. There was little difference in chemistry between samples obtained at the bulk-collector network and those from the bulk collector at the NADP site; the mean pH and conductivity were 4.59 and 15.1 μmhos/cm for the network and 4.63 and 14.0 μmhos/cm for the bulk collector at the NADP site. The network's aerial coverage included two physiographic zones, the Ouachita Mountains and the Gulf Coastal Plain. Precipitation in the two zones had small but statistically significant differences in chemistry. Despite the zonal differences, the NADP station should adequately represent trends in atmospheric deposition for the commercial forest lands of southeastern Oklahoma. In a comparison of collector types, bulk-collector samples had higher pH values than wetfall samples at the coastal-plain site, but wetfall samples at the mountain site had the higher pH values. These divergent trends may have been a result of agricultural practices near the coastal-plain site.

INTRODUCTION

Southeastern Oklahoma is an area potentially sensitive to acid precipitation. Soils of the region are dominated by nutrient-poor Ultisols and Inceptisols with low cation exchange capacities. Soil parent materials are generally sandstone and shale. Waters draining from these predominantly forested, mountain landscapes are nutrient poor with very low alkalinities. The low buffering capacity of the streams is illustrated by the fact that the Kiamichi River near Big Cedar, in southeastern Oklahoma, had one of the lowest alkalinity levels of any of the 47 United States Geologic Survey Bench-Mark sites in the United States (1). No other part of Oklahoma, with the possible exception of the Wichita Mountains, is as potentially susceptible to impacts by acid atmospheric deposition as is the southeastern part of the state.

A National Atmospheric Deposition Program (NADP) monitoring station was established in 1983 near Clayton, Oklahoma to ascertain the acidity of the atmospheric precipitation in the southeastern portion of the state. The first year's precipitation data revealed that the volume-weighted pH was 4.71 (2). Precipitation is considered acid when its pH falls below 5.65 (3), the pH level determined by the carbon dioxide content of the atmosphere.

The validity of using this NADP station to characterize the precipitation for all of southeastern Oklahoma needs to be determined. The objectives of this study were (a) to determine whether data from the Clayton NADP site are representative of the commercial forest lands of southeastern Oklahoma, and (b) to compare the composition of precipitation from two types of sample collectors.

METHODOLOGY

A regional precipitation-sampling network was established in southeastern Oklahoma. This network consisted of ten bulk-precipitation-collector (bulk collector) sites located in McCurtain and Pushmataha Counties, in the southwest corner of LeFlore County, and on the eastern side of Choctaw County (Fig. 1). These collector sites were distributed over an area of approximately 6000 km² of southeastern Oklahoma. This area falls within two geologic zones-the Gulf Coastal Plain and the Ouachita Moun-

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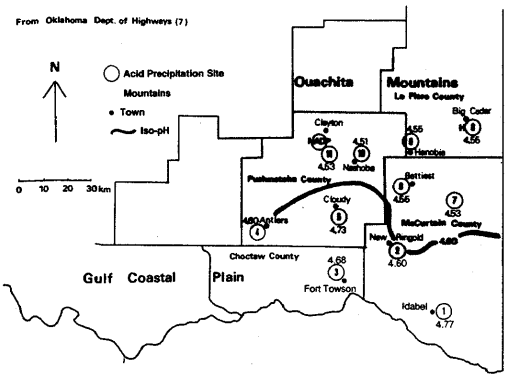

FIGURE 1. Atmospheric deposition network sites and mean annual pH values of precipitation in southeastern Oklahoma.

TABLE 1. Precipitation collection sites.

Site No.	Name	Location	Elev. (m)
1	Idabel	6 km E of Idabel	135
2	New Ringold	10 km SE of Ringold	140
3	Fort Towson	7 km NW of Ft. Towson	165
4	Antlers	0.4 km W of Antlers	160
5	Cloudy	5.6 km SW of Cloudy	195
6	Battiest	Battiest	245
7	Mt. Herman	5 km E of Mt. Herman	310
8	Big Cedar	2 km S of Big Cedar	290
9	Hanobia	1 km S of Hanobia	275
10	Nashoba	5 km E of Nashoba	215
11	Clayton	9 km SE of Clayton	335
NADP	Clayton	6 km S of Clayton	345

tains (Fig. 1). Sites one, three, and four lay within the coastal plain area, and the remaining sites were within the mountain area (Fig. 1). Sites two and five were within a few kilometers of the boundary line, and in elevation they were more like the coastal sites than the mountain sites (Table 1). Therefore, for purposes of this study, sites two and five were considered as part of the coastal plain.

Each site was equipped with a nonrecording 10-cm rain gauge and a plastic bulk collector (4). Each bulk collector consisted of a funnel, 26.5 cm in diameter, attached to a closed bucket. The funnel collected both dry deposition and liquid precipitation. The Idabel site and the Clayton NADP site were each equipped with a Belfort weighing bucket rain gauge with storm event marker and an Aerochem 301 wetfall/dryfall collector. A wetfall/dryfall collector consists of two buckets, a mechanized cover, and a moisture-sensing device. The wetfall/dryfall collector automatically uncovers the wetfall bucket and covers the dryfall bucket during precipitation; the collector then reverses the position of the cover when precipitation ends. Wetfall samples were taken from the wetfall bucket, and bulk samples were taken from bulk-collector buckets.

Wetfall and bulk samples were collected weekly, from October 2, 1984 to October 1, 1985, and analyzed the same day for pH and conductivity at a field laboratory by using an Orion Research model 601A pH meter and a YSI model 31 conductivity meter. The NADP wetfall samples were stored at ambient temperature and mailed to the NADP testing laboratory for analysis; all other samples were frozen and shipped to Oklahoma State University Forest Watershed Laboratory for determination of pH, conductivity, sulfate, and nitrate-nitrite nitrogen (henceforth referred to as nitrate). Conductivity and pH were measured as before. Sulfate concentrations were determined by the turbidimetric method; readings were taken on a Sargent-Welch turbidimeter. The cadmium reduction method was used for nitrate determinations, readings being taken on a Bausch and Lomb Spectronic 710 instrument. All the analyses were conducted according to standard methods (5). Volume-weighted means were determined by multiplying chemical concentrations by sample volumes, summing these weekly values, and dividing by the accumulated annual volume.

Statistical comparisons were made on precipitation results by using *t*-tests (6). We used the volume-weighted annual means from each site as observations. We would have used weekly values as observations, but *t*-tests require independent observations, and weekly sampling violates that protocol.

However, we used the weekly samples to determine the standard error of the mean for each site.

RESULTS AND DISCUSSION

Network

The validity of using the NADP site as a regional monitoring station was tested by comparing the bulk-collector results from the NADP site with the results from the bulkcollector network. The network samples had a mean pH of 4.59, and samples from the NADP site had a mean pH of 4.63; this is well within the network pH confidence-interval (Table 2). The NADP site produced lower nitrate, sulfate, and conductivity results than the network means, but the results from the NADP site fell well within the confidence limits of the network means (Table 2). It would appear that the NADP site is suitable for monitoring atmospheric deposition on a regional basis.

Precipitation chemistry was different for the mountain sites and the coastal plain sites. Sites six through eleven had yearly pH means clustered from 4.51 to 4.55; sites one through five had higher and more variable pH's with a range from 4.60 to 4.77 (Table 3). This difference between mountain and coastal-plain sites was significant at the .05 level (Table 2). Precipitation at the mountain sites had higher sulfate concentrations and lower nitrate concentrations than at the coastal-plain sites, but neither of these differences were statistically significant (Table 2). Precipitation at the mountain sites had significantly higher conductivity (Table 2). The significant differences between the two physiographical zones demonstrate the limitations of using a single station to monitor or represent a large or physiographically diverse area.

The 4.60 iso-pH line appears to be a rough dividing line between the two physiographic zones (Fig. 1). The pH at site five was unexpectedly high for a site located between mountains and coastal plain; this may reflect an unknown, local phenomenon.

To fully understand the potential impacts of atmospheric deposition, the total loading of pollutants and nutrients delivered to watershed surfaces must be quantified. The total yearly deposition of these ions was 3.8 kg/ha NO^-_3-N, 35 kg/ha SO_4^{2-},and 0.42 kg/ha H^+ (Table 4). These input data should be useful for assessing the significance of acidic atmospheric deposition and for future ecological research.

Sample Comparison

Wetfall collectors sample only liquid precipitation, while bulk collectors sample such precipitation plus a portion of the dryfall deposition, so different levels of hydrogen-ion concentration are expected in a comparison of the two collection systems. The bulk collector at the NADP site collected 26% more hydrogen ions than its paired wetfall collec-

TABLE 2. Samples from the NADP site compared with samples from the bulk-collector network.

Sites	n	pH	Conductivity (μmhos)	NO_3^- (μeq/L)	SO_4^{2-} (μeq/L)	Precip.[a] (cm)
Mountain	5	4.53 A[b]	15.7 A	16 A	45 A	172 A
Plain	6	4.67 B	14.4 B	17 A	44 A	152 A
Mean	11	4.59	15.1	17	44	163
[c]		4.45-4.82[c]	± 2.2[c]	± 2[c]	± 4[c]	± 4.3[c]
NADP	1	4.63	14.0	15	41	167

[a] Yearly totals

[b] Common capital letters within columns denote the absence of significant difference at the .05 level.

[c] Confidence interval for total network mean (α = .05)

TABLE 3. Mean concentrations for bulk-collector sites.

Site	pH	Conductivity (μmhos)	NO_3^- (μeq/L)	SO_4^{2-} (μeq/L)	Precip. (cm)[a]
1	4.77	13.4(1.59)[b]	15(1.7)	46(6.5)	133
2	4.60	14.9(1.65)	17(1.6)	45(5.5)	156
3	4.68	14.8(1.48)	17(1.5)	46(5.3)	140
4	4.60	14.9(1.96)	18(2.4)	40(5.3)	171
5	4.73	14.1(1.43)	17(1.7)	42(5.8)	158
6	4.55	16.2(2.21)	17(2.1)	46(7.2)	158
7	4.53	16.5(2.16)	16(1.9)	46(6.6)	153
8	4.55	14.9(1.94)	16(1.4)	45(7.0)	190
9	4.55	16.1(1.66)	16(1.6)	44(5.5)	200
10	4.51	14.5(1.83)	16(1.6)	43(7.2)	165
11	4.53	16.0(2.32)	18(2.3)	45(8.1)	166
Mean	4.59	15.1(1.83)	17(1.8)	44(6.3)	163

[a] Yearly totals.
[b] Standard error in parentheses.

TABLE 4. Annual Pollutant/ionic loads.

Site	H^+ (kg/ha)	NO_3^- kg/ha)	SO_4^{2-} kg/ha)
1	0.223	2.8	29
2	0.391	3.8	34
3	0.294	3.3	31
4	0.428	4.2	33
5	0.296	3.7	32
6	0.449	3.8	35
7	0.451	3.5	34
8	0.532	4.2	41
9	0.561	4.4	42
10	0.502	3.6	34
11	0.486	4.2	36
Mean	0.420	3.8	35

tor, whereas the bulk collector at the Idabel site collected 29% less hydrogen ions than its paired wetfall collector (Table 5). Galloway and Likens (4) conducted a study near Ithaca, New York to determine chemical differences in precipitation with relation to precipitation collector type. They found that during rainfall events the concentration of hydrogen ions was less in bulk collectors than in wetfall collectors, and this agrees with our results from the Idabel site. Galloway and Likens (4) reasoned that the concentration of hydrogen ions in bulk collectors was reduced by the mixture of wet and dry deposition. They further hypothesized that if bulk collectors sample more hydrogen ions than wetfall collectors, then both precipitation and dry deposition contribute to the total concentration of hydrogen ions. That is apparently what we observed at the NADP site.

Differences in soils and land use may explain why dry deposition increased the concentration of hydrogen ions at the NADP site and decreased it at the Idabel site. The Idabel site was located on the coastal plain near an agricultural area, while the NADP site was located in a mountainous, forested region where there was little agricultural activity. Thornton and Eisenreich (8) studied wetfall precipitation across a transect in northern Minnesota. They found that the precipitation in the forested northeastern end of the transect was more acidic, while the precipitation in the prairie-agricultural western end of the transect had lower concentrations of hydrogen ions. Thornton and Eisenreich (8) attributed the lower concentration of hydrogen ions to land use practices: Airborne calcareous soil particles, associated with agricultural practices, apparently neutralized some hydrogen ions. It would

TABLE 5. Wetfall and bulk collector comparisons.

Collector type	H^+ (μeq/L)	Conductivity (μmhos)	NO_3^- (μeq/L)	SO_4^{2-} (μeq/L)
Idabel				
Wetfall	27.6	15.6	20	51
Bulk	19.6	15.7	18	53
Percentage[a]	+29%	−0.6%	+14%	−5%
NADP—Clayton				
Wetfall	19.6	13.3	15	27
Bulk	24.7	14.7	16	43
Percentage[a]	−26%	−10.5%	−9%	−56%
System mean				
Bulk	25.7	15.0	16	44

[a] Percentage = Difference/wetfall concentration

appear that agricultural practices can affect the pH of precipitation and may have influenced our results at the Idabel site.

CONCLUSIONS

The NADP site near Clayton appears to be a suitable location for monitoring longterm trends in atmospheric deposition for the commercial forest lands of southeastern Oklahoma, despite physiographic variations within the region. The two physiographic zones, the Ouachita Mountains and the Gulf Coastal Plain, had small but statistically significant differences in precipitation chemistry. The comparison of bulk collectors with wetfall collectors was inconclusive. We speculate that atmospheric deposition at the Idabel site may have been influenced by agricultural practices.

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