Species, Part and Seasonal Differences in Sulfur Concentrations in Woody Plants

Charles T. Garten, Jr.
Savannah River Ecology Laboratory
Aiken, Drawer E 29801

INTRODUCTION

Reference data on sulfur concentrations in plants are required to evaluate the environmental impact of sulfur releases from fossil fuel combustion and industrial operations over time. Plants have been previously used as indicators of sulfur dioxide pollution and the total sulfur concentrations in lichens appear to be directly related to the degree of SO_2 air pollution (LeBLANC and RAO, 1973). Ecological considerations relating to the elemental cycling of sulfur in vegetation include seasonal variation in sulfur concentrations in plants, the degree of variation in concentrations among component parts, and the extent of species differences in sulfur levels. This paper presents data on these biological sources of variation in sulfur concentrations in woody plants.

METHODS AND MATERIALS

Component parts were sampled from three woody species inhabiting a floodplain on the lower portion of Steel Creek, a shallow coastal plain stream on the U. S. Energy Research and Development Administration's Savannah River Plant, in Barnwell County, South Carolina Leaves and twigs were sampled from hazel alder (*Alnus serrulata*) and wax myrtle (*Myrica cerifera*) during autumn (Oct. 1971), spring (April 1972) and summer (July 1972). Black willow (*Salix nigra*) trees were also sampled in summer. Individual trees and shrubs were less than 5 m tall. Surface roots were sampled in summer at a depth of approximately 15 cm. Infloresences were collected when available.

Plant parts were washed, dried at 65°C, ground with a Wiley Mill, and stored in air tight plastic vials before analysis. Sulfur analyses were performed using an automatic sulfur titrator by personnel of the Soil Testing and Plant Analysis Laboratory, Cooperative Extension Service, University of Georgia, Athens.

Bulletin of Environmental Contamination & Toxicology,
Vol. 17, No. 2

Statistical analyses were performed using the Statistical Analysis System (SERVICE, 1972). Concentrations in replicate component part samples from the same plant were averaged to give a single value for each individual. Statistical significance was indicated by $P \leq 0.05$ throughout this work.

RESULTS

Sulfur concentrations in alder and myrtle leaves differed significantly among the three seasons ($F_{2,42} = 5.8$ and $F_{2,34} = 4.8$, respectively). Concentrations in summer were less than those in autumn. Alder and myrtle twigs did not exhibit significant seasonal variation in their mean sulfur levels (Table 1). In both species, leaves had consistently greater sulfur concentrations than twigs (for alder: $F_{1,42} = 74.9$, and for myrtle: $F_{1,34} = 110.8$). The component part x season interaction was significant in both analyses but was not considered to bias the foregoing comparisons.

TABLE 1

Seasonal changes in mean sulfur concentrations (% dry weight) in leaves and twigs from two species of woody plants. Number of trees sampled are in parenthesis. Comparisons among means were made using Scheffe's test (SCHEFFE 1959).

Species	Part[1]	Spring	Summer	Autumn
Alnus serrulata	Leaf	0.118^{AB} (7)	0.091^{A} (11)	0.145^{B} (6)
	Twig	0.050^{A} (7)	0.055^{A} (11)	0.061^{A} (6)
Myrica cerifera	Leaf	0.183^{B} (8)	0.134^{A} (7)	0.173^{B} (5)
	Twig	0.081^{A} (8)	0.084^{A} (7)	0.093^{A} (5)

[1]Within a species, leaves and twigs differ significantly in concentrations in every season ($P \leq 0.05$).

[AB]Means in the same row sharing the same alphabetic superscript are not significantly different ($P > 0.05$).

Sulfur concentrations were compared among species and component parts sampled during summer (Table 2). There was a significant interaction between species and component part effects in an ANOVA ($F_{4,75} = 4.1$). Component part differences in concentrations were also found ($F_{2,75} = 22.3$). Sulfur levels in willow leaf, root and twig samples were significantly different. Myrtle leaves and twigs differed in their concentrations and myrtle root concentrations were similar to those in leaves. Sulfur concentrations in alder infloresences, from pooled summer and autumn samples, averaged 0.143 % dry weight (N = 12) and concentrations in infloresences from willow trees in summer averaged 0.185 % dry weight (N = 3).

Differences among species were also detected by ANOVA ($F_{2,75} = 9.1$). Sulfur concentrations in willow and myrtle leaves were similar and significantly greater than those in alder leaves. Myrtle and alder roots were significantly different in their sulfur concentrations. Twig concentrations were relatively invariant among species (Table 2). Variability in concentrations during summer was greatest in alders; coefficients of variation (C.V.) were 34, 43 and 70%, respectively for leaves, twigs and roots. Sulfur concentrations were least variable in wax myrtle parts (C.V. = for twigs, 14%; for leaves, 20%; for roots, 25%). Coefficients of variation for concentrations in willow roots, twigs and leaves were 18, 24, and 40%, respectively, in summer.

TABLE 2

Sulfur concentrations (% dry weight) in the component parts of three woody species during summer. Comparisons among means were made using Scheffe's test (SCHEFFE 1959 Number of trees sampled were 11 *Salix*, 7 *Myrica* and 10 *Alnus*.

Component	*Salix nigra*	*Myrica cerifera*	*Alnus serrulata*
Leaf	$0.164^{A,3}$	$0.134^{A,2}$	$0.087^{B,1}$
Root	$0.108^{AB,2}$	$0.121^{A,12}$	$0.077^{B,1}$
Twig	$0.046^{A,1}$	$0.084^{A,1}$	$0.056^{A,1}$

^{A,B,1,2}Within rows or columns, means sharing the same alphabetic or numeric superscript, respectively, are not significantly different (P > 0.05).

DISCUSSION

Plant samples in this study come from the southeastern United States where present and projected emissions of sulfur oxides from automobiles, electric power utilities and fossil fuel space heating are lower than for the northeastern part of the country (GOFFIN, 1973). Sulfur concentrations in lichens from areas of Canada with relatively high SO_2 pollution range from approximately 0.56 to 0.65 (% D.W.) as compared with 0.27 (% D.W.) from control areas (LeBLANC and RAO, 1973). The range of sulfur concentrations in the present study is similar to that reported by WOODWELL, WHITTAKER and HOUGHTON (1975), converted to % D. W., for component parts from a variety of woody species in the Brookhaven Oak-Pine Forest during summer and autumn: twigs, 0.020 to 0.098; leaves, 0.12 to 0.32; small roots, 0.056 to 0.180. Therefore, sulfur concentrations in woody species from a forest in New York are similar to those found in different woody species from South Carolina. The extent of species differences and geographic variation in sulfur concentrations in natural vegetation does not appear to be very great in the former comparison. Elevated sulfur concentrations in plants may be observable only for biota in the immediate proximity of a chronic source of atmospheric sulfur oxides.

Observed seasonal changes and component part differences in sulfur levels suggest variation due to phenology or physiology rather than varying external inputs to the vegetation. The seasonal changes in leaf sulfur concentrations are similar to those observed by BOYD (1971) in *Juncus effusus*, a herbaceous perennial, from the southeast. Decreasing sulfur concentrations from spring to summer are probably due to dilution effects from rapid increases in foliar biomass. High sulfur concentrations in autumn leaves cannot be explained from the present data although such patterns have been attributed to the increased production of new tissue in autumn. Sulfur concentrations in twigs were relatively invariant among seasons and species. For this reason, stems or twigs might be the best "indicator" sampling unit from woody vegetation for monitoring of sulfur levels in vegetation over time.

ACKNOWLEDGMENTS

This research was supported by contract AT(38-1)-819 between the U. S. Energy Research and Development Administration (formerly U. S. AEC) and the University of Georgia. I thank Dr. Kenneth McLeod for his review of the manuscript.

REFERENCES

BOYD, C. E.: Amer. Midl. Nat. 86, 28 (1971).

GOFFIN, P. L.: In, Our environment the outlook for 198(pp. 311-334 (A. J. Van Tassell, ed.). Toronto-London: Lexington Books 1973.

LeBLANC, F., and D. N. RAO: Ecology 54, 612 (1973).

SCHEFFE, H.: Analysis of variance. New York: Wiley 1959.

SERVICE, J.: A user's guide to the Statistical Analysis System. N. C. State Univ., Raleigh: Student Supply Stores 1972.

WOODWELL, G. M., R. H. WHITTAKER, and R. A. HOUGHTON: Ecology 56, 318 (1975).