Bull. Environ. Contam. Toxicol. (1988) 40:457–461

Environmental Contamination and Toxicology

Comparison of Elemental Concentrations in the Wood of Three Tree Species Growing Adjacent to an Inactive Chromium Smelter

Lynne Jordan Bowers[1] and John H. Melhuish, Jr.[2]

[1]Christian Brothers College, Memphis, Tennessee 38117 and [2]USDA Forest Service, Northeastern Forest Experiment Station, Berea, Kentucky

Studies of plant tissues have been conducted to determine the degree and spatial extent of point source pollutants (Ward et al. 1974, Tazaki and Ushijima 1977, Freedman and Hutchinson 1980, Peterson 1982, Morrison and Hogan 1986, Nyangababo 1987). Differences in accumulation rates among species have been used to identify plants which are good bioindicators of the status of specific elements in soils. A preponderance of these plant studies have used herbaceous plants or the leaves of woody plants. However, it is the woody tree bole which provides long-term storage of elements dispersed by anthropogenic sources of pollution.

Recent research indicates that the growth rings of trees may provide a temporal history of heavy metal deposition in the environment (Sheppard and Funk 1975, Symeonides 1979, Baes and Ragsdale 1981, Baes and McLaughlin 1984). The data of Baes and McLaughlin (1985) suggest the use of wood samples from conifer trees to monitor metal input to forest ecosystems. Lepp (1975) surveyed the literature concerning metal uptake and pathways in trees and hypothesized that ring porous species, such as oak, should produce the most useful data. Hanna and Grant (1962) found that in tree foliage significantly greater differences in elemental composition occurs between species on the same soil than between plants of the same species growing on different soils. Additional information is needed about differences in the elemental concentrations found in tree rings which may be related to species differences if tree rings are to be used to monitor metal deposition.

Seventeen elements were measured in wood samples taken from three tree species growing approximately 1.2 km from an inactive chromium smelter. The species sampled were: baldcypress (Taxodium distichum L. Rich.), loblolly pine (Pinus taeda L.), and Southern red oak (Quercus falcata L. Michx.).

Send reprint requests to John H. Melhuish, Jr. at the above address.

MATERIALS AND METHODS

Two cores were chemically analyzed from each of five oak trees, seven pine trees, and one core from four baldcypress trees. The oak and pine trees are located downwind from the smelter. Although the baldcypress trees are located upwind from the smelter it is assumed that the smelter's impact on these trees was comparable to the oak and pine because of their proximity to the smelter. Air inversions are common in the study area.

A teflon coated Swedish increment borer was used to remove two 5 mm cores from each tree. The borer and extractor were rinsed with a 10% solution of quarternary ammonium chloride in 2-heptanone and rinsed with acetone before insertion into the tree. This procedure removed any surface lead contamination (Baes and Ragsdale 1981). Wooden plugs were inserted into the core holes to reduce the risk of fungal invasion (Maeglin 1979). The cores were taken approximately 1.4 meters (DBH) from the ground on opposite sides of the tree. Studies of lead movement within xylem tissues suggest that metal gradients may occur within the xylem making the standardization of sampling height advisable in comparative studies (Lepp 1975). The cores were inserted into plastic straws, labeled, and placed in plastic bags to prevent contamination in transport to the laboratory.

Samples were processed immediately or frozen until surfaced to eliminate microbial growth and/or contamination as described by McLaughlin et al. (1983). Surfacing consisted of "peeling" the samples to reduce contamination and to reveal ring detail. Each specimen was examined under 10X magnification and the skeleton-plot technique of crossdating, as described by Stokes and Smiley (1968), was used to accurately date each growth ring.

Each increment core was sectioned for chemical analysis into four segments representing the time periods: 1. Pre-smelter years (1942-52), 2. Smelter years (1953-70), 3. Smelter-with-scrubber years (1971-80), 4. Post-smelter years (1981-84)

The samples were analyzed at the Northeastern Forest Experiment Station Research Laboratory in Berea, Kentucky. The wood samples were placed in a drying oven for 48 hours before grinding in a Spex Shaterbox. Then, a ground sample of 0.2 g was weighed, heated for one hour at 200 degrees centigrade and at 600 degrees centigrade for seven hours. The resulting ash was dissolved in 25 ml of 50% HCl. The HCl mixture was diluted to 50 ml with distilled water.

The samples were then analyzed with a Beckman Spectra Span 3B direct current plasma (DCP) emission spectrometer. Quality control samples (EPA and National Bureau of Standards) were used to check the standards of all elements before and after the wood samples were analyzed.

RESULTS AND DISCUSSION

The mean concentration of each element measured for the wood samples of all three species is shown in Table 1. The concentrations measured for each time period, that is, pre-smelter, smelter, smelter-with-scrubber, and post-smelter were averaged together. Thus, differences in elemental concentrations due to differences in smelter activity and growth rates were pooled in order to determine if any differences existed among species.

Table 1 indicates that the baldcypress wood sampled accumulated significantly higher ($P < .05$) concentrations of silicon, aluminum, sodium, magnesium, and boron than the pine and oak samples. The pine wood accumulated significantly higher concentrations of cobalt and chromium. The oak wood accumulated significantly higher concentrations of lead and calcium. The latter was expected as calcium accumulation in oaks has been well documented (Kramer and Kozlowski 1979).

Table 1. Mean elemental concentrations (microgram element/gram of wood, dry weight).[1/]

Element	Species		
	Baldcypress (26 samples)	Pine (50 samples)	Oak (35 samples)
Calcium	742.21	794.30	1892.91 (+)
Manganese	7.67 (-)	66.28	50.60
Silicon	459.35 (+)	243.42	206.23
Aluminum	310.52 (+)	230.19	127.00 (-)
Potassium	640.49	358.56 (-)	665.03
Zinc	36.80 (-)	139.60	136.63
Sodium	271.61 (+)	136.89	142.84
Cobalt	34.13	109.75 (+)	49.53
Magnesium	282.63 (+)	165.44	161.83
Iron (nsd)	234.67	235.72	226.66
Phosphorus (nsd)	112.68	87.14	110.29
Nickel	6.62 (-)	24.21	15.03
Titanium (nsd)	31.46	24.62	30.33
Chromium	10.36	37.69 (+)	9.65
Lead	13.18	10.35	20.16 (+)
Boron	18.22 (+)	7.62	6.88
Copper	5.67 (-)	15.92	26.18

[1/] The difference measured among species is shown in parentheses as follows:
(+) significantly higher $p < .05$
(-) significantly lower $p < .05$
(nsd) no significant difference among species

The data in Table 1 indicate that significant differences do exist among the three species studied in the concentration of elements of interest in studies of anthropogenic pollution. If trees are used to study the temporal trends in metal deposition in the environment, species should be sampled which are known to accumulate the specific element under study in the wood tissues or when possible more than one species should be sampled.

REFERENCES

Baes CF III, McLaughlin SB (1984) Trace elements in tree rings: evidence of recent and historical air pollution. Science 224:494-496.

Baes CF III, McLaughlin SB (1985) Trace metal uptake and accumulation in trees as affected by environmental pollution. Publication 2571, Environmental Sciences Div., Oak Ridge National Lab. Presented at the NATO Advanced Research Workshop on the Effects of Acidic Deposition on Forests, Wetlands and Agricultural Ecosystems, May 12-17, 1985, Toronto, Canada. 19 p.

Baes CF III, Ragsdale HL (1981) Age-specific lead distribution in xylem rings of three tree genera in Atlanta, Georgia. Environ Pollut Ser B2:21-35.

Freedman B, Hutchinson TC (1980) Pollutant inputs from the atmosphere and accumulations in soils and vegetation near a nickel-copper smelter at Sudbury, Ontario, Canada. Can J Bot 58:108-132.

Hanna WJ, Grant CL (1962) Spectrochemical analysis of the foliage of certain trees and ornamentals for 23 elements. Bull of the Torrey Botanical Club 89(5):293-302.

Kramer PJ, Kozlowski TT (1979) Physiology of woody plants. Academic Press, New York. 811 p.

Lepp NW (1975) The potential of tree-ring analysis for monitoring heavy metal pollution patterns. Environ Pollut 9:49-61.

Maeglin FR (1979) Increment cores-how to collect, handle, and use them. USDA Forest Service Res Pap FPL 25. 19 p.

McLaughlin SB, Baes CF III, McConathy RK, Sigal LL, Walker RF (1983) Interactive effects of acid rain and gaseous air pollutants on natural terrestrial vegetation. Natl. Acid Precipitation Assessment Program Effects Research Rev. Feb. 21-25, 1983. 18 p.

Nyangababo JT (1987) Lichens as monitors of aerial heavy metal pollutants in and around Kampala. Bull Environ Contam Toxicol 38:91-95.

Morrison IK, Hogan GD (1986) Trace element distribution within the tree phytomass and forest floor of a tolerant hardwood stand, Algoma, Ontario. Water, Air and Soil Poll 31:493-500.

Peterson MA (1982) The effects of air pollution and acid rain on fish, wildlife, and their habitats - introduction. U. S. Fish and Wildlife Serv., Biological Serv. Program, Eastern Energy and Land Use Team, FWS/OBS-80/40.10. 89 p.

Sheppard JC, Funk WH (1975) Trees as environmental sensors monitoring long-term heavy metal contamination of Spokane River, Idaho. Environ Sci and Technol 9:638-642.

Stokes MA, Smiley TL (1968) An introduction to tree-ring dating. The Univ of Chicago Press, Chicago. 73 p.
Symeonides C (1979) Tree-ring analysis for tracing the history of pollution: application to a study in Northern Sweden. J Environ Qual 8:482-486.
Tazaki T, Ushijima T (1977) The vegetation in the neighbourhood of smelting factories and the amount of heavy metals absorbed and accumulated by various species. pp 217-224. In: Miyawaki A, Tuxen R, Okuda S (eds) Vegetation, Science, and Environmental Protection. Maurzen Ltd., Tokyo. 576 p.
Ward NI, Brooks RR, Reeves RD (1974) Effect of lead from motor-vehicle exhausts on trees along a major thoroughfare in Palmerston North, New Zealand. Environ Pollut 6:149-158.
Received July 18, 1987; accepted November 9, 1987.