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Trace Element Content of Leaves of Desert Shrubs in South-central Washington

Abstract

Analyses of leaves of desert shrubs showed strong differences in macroelements according to species and location on the Arid Lands Ecology (ALE) site in south-central Washington. Halophytes were characterized by high levels of K, Cl, Br, Mn, and Na, and glycophytes by high levels of Ca and Mg. However, trace element content was not significantly different. Big sagebrush (*Artemisia tridentata*) leaves from Wyoming and the ALE site were not greatly different in trace element content. Natural leaf fall collections can be used to monitor changing levels of trace element content induced by coal combustion steam-electric plants.

Introduction

Measurements of the mineral content of leaves of desert shrubs growing in the shrub steppe region of south-central Washington have generally centered upon mineral cycling behavior (Mack 1977, Rickard 1965, Rickard and Keough 1968, Cline and Rickard 1974) and have been mostly concerned with the behavior of macronutrient elements and sodium rather than trace metals. In recent years considerable attention has been paid to trace metals as soil-plant contaminants because some of these are potentially toxic, and also because trace metals are released into the air in large quantities at large coal combustion steam electric plants even after pollutant suppression devices are installed (Vaughan *et al.* 1975, Turner and Strojan 1978). After many years of coal burning, trace metals can be expected to show elevated levels in soils near coal-fired plants. With elevated levels of trace metals on and mixed in the rooting substrate, elevated levels may eventually occur in the leaves of plants as the metals are moved into the root zone by leaching, freezing, thawing, and other processes.

Connor *et al.* (1976) measured trace metals in soil and big sagebrush (*Artemisia tridentata*) leaves at various distances from an operating coal-fired power plant in the Powder River Basin region of northeastern Wyoming and showed elevated levels of strontium, vanadium, and selenium in leaves; these levels were attributed to smoke stack emissions. Like many parts of the semi-arid western United States, big sagebrush is the most abundant shrub on the ALE site in Benton County, Washington.

This investigation determined the trace element content of freshly fallen leaves of four desert shrub species on the ALE site and indicates that freshly fallen leaves can be employed to monitor levels of trace metals that might result from future operation of coal-fired steam-electric power stations in the semi-arid shrubsteppe region of south-central Washington and adjacent Oregon. Historically, southeastern Washington has been relatively free from coal burning because the electrical requirements of the region have been mostly provided by hydroelectric dams and nuclear power.

Methods

Newly fallen leaves were collected in 1978 from four desert shrub species by placing non-metallic containers beneath the canopy spread of four individual plants of each species and by collecting the newly fallen leaves at monthly intervals (Rickard and Warren 1981). The leaf collections at the peak litterfall month, 2 g or more, were air dried, pooled, and homogenized by grinding to a fine powder with a Wiley Mill. Aliquots of each sample were dissolved by refluxing in a nitric/perchloric acid mixture (4:1). Analysis utilized several techniques. Argon inductive coupled plasma spectroscopy was used to analyze simultaneously for Ca, Mg, Na, K, P, Al, Ba, B, Cu, Fe, Mn, Sr, and Zn. Chromium, Co, Mo, Ni, V, Pb, and Sb were analyzed using graphite furnace atomic absorption spectroscopy. Bromium and Cl were determined by neutron activation and subsequent gamma spectroscopy. Arsenic and Se were determined by atomic absorption spectroscopy of the separated hydrides. All tissue samples were analyzed in duplicate and run concurrently with National Bureau of Standards reference biological standards.

Results and Discussion

The mineral content of newly fallen leaves of *Artemisia tridentata, Purshia tridentata, Atriplex spinosa,* and *Sarcobatus vermiculatus* is summarized in Table 1. These species

TABLE 1. Mineral content of freshly fallen leaves of desert shrubs analyzed on the month of peak leaf fall in 1978. Results are ppm dry weight.

	GLYCOPHYTES				HALOPHYTES	
	Artr		Artr	Putr	Atsp	Save
Ca	16,700		17,500	11,600	9,100	11,600
K	12,200		10,800	10,700	27,500	9,610
PO_4^3	6,820		3,680	1,970	5,500	2,420
Mg	2,450		1,460	7,100	7,850	1,490
Cl	1,510		1,770	4,630	9,500	14,400
Fe	1,420		1,250	1,300	1,200	695
Al	990		950	860	850	505
SiO_2	300		290	450	390	350
Na	250		140	170	1,190	95,000
Mn	180	(30-100)[1]	90	93	147	202
Ti	120	(70-300)	140	121	90	75
B	73	(20-30)	74	77	40	59
Sr	61	(30-200)	45	54	27	38
Ba	34	(50-150)	17	28	18	13
Zn	27	(27-55)	14	14	14	4.1
Cu	15	(15-20)	11	10	5.9	8.3
Br	15		9	46	120	555
Pb	5.0	(5-20)	8.9	12	3.1	3.9
Mo	2.3	(0.7-1.5)	2.0	2.4	6.0	1.9
V	2.0	(3-10)	2.0	2.5	2.0	1.0
Ni	1.2	(1-3)	1.4	2.2	2.0	1.4
Cr	1.1	(1.5-7)	.90	12	1.6	.70
As	.91		.42	8.3	1.4	.20
Co	.40	(0.2-0.6)	.30	.30	.30	.40
Sb	.12		.13	.95	.08	<.05
Se	.11	(0.2-1.6)	<.05	.10	.58	.55

[1]Range of values determined for big sagebrush (**Artemisia tridentata**) leaves collected in Wyoming. Data are from Connor **et al.** (1976). Data have been adjusted assuming an ash weight of 10 percent of dry weight for sagebrush leaves.

represent three plant families: Compositae (*Artemisia*), Rosaceae (*Purshia*), and Chenopodiaceae (*Sarcobatus* and *Atriplex*) and two ecological categories, glycophytes and halophytes. The halophytes were generally characterized by high levels of potassium, chloride, bromide, manganese, and sodium. *Artemisia* was characterized by relatively high levels of calcium, and *Purshia* and *Atriplex* had relatively high levels of magnesium. *Sarcobatus* was low in iron and aluminum. The trace metal content of shrub leaves was not greatly different, regardless of species or location; however, zinc was low in *Sarcobatus*, and arsenic and chromium were relatively high in *Purshia*.

To detect temporal changes in trace metal content of rangeland plants, it is desirable to sample the same individuals (non-destructive sampling) at the same time of year over many years. This procedure can reduce the inherent trace element variability associated with sampling of different plant tissues at different locations and different times of the year; it also avoids the mixing of leaves of different physiological ages.

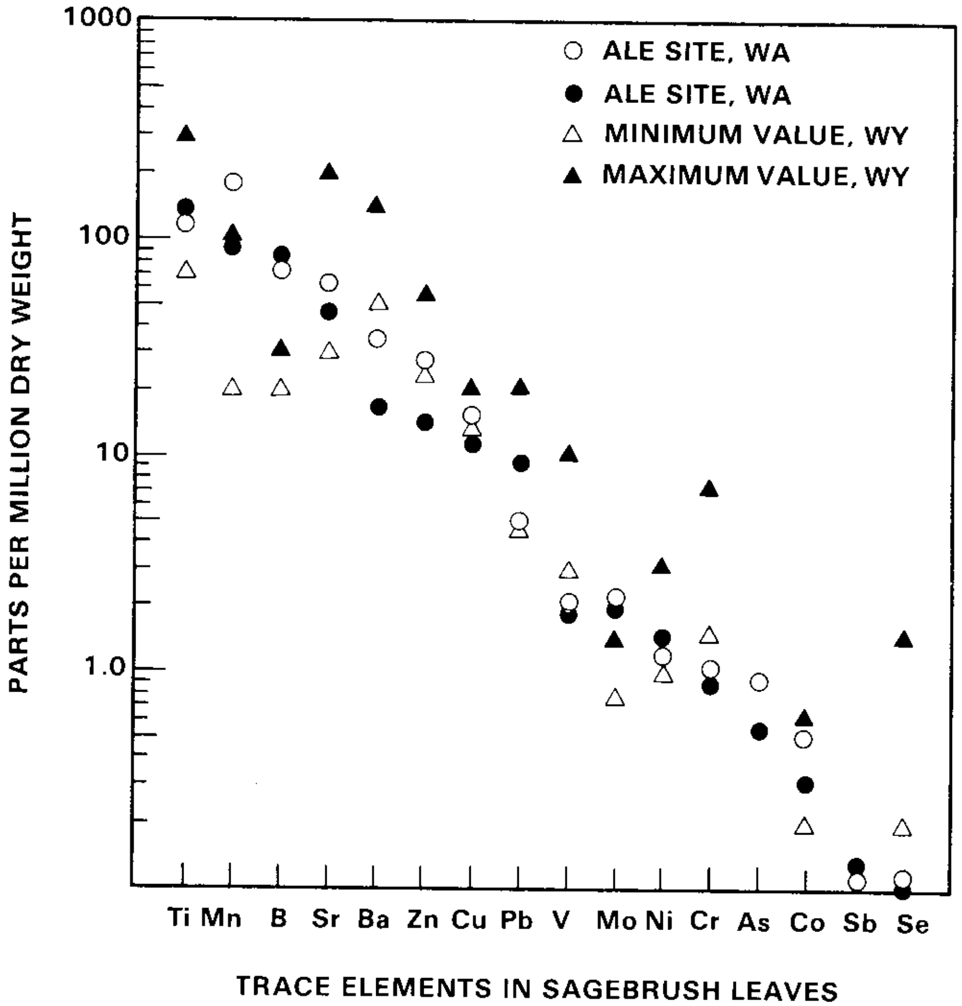

Figure 1. Trace element content of big sagebrush (*Artemisia tridentata*) leaves collected from two sites on the ALE Site, Washington, compared with minimum and maximum values from Wyoming.

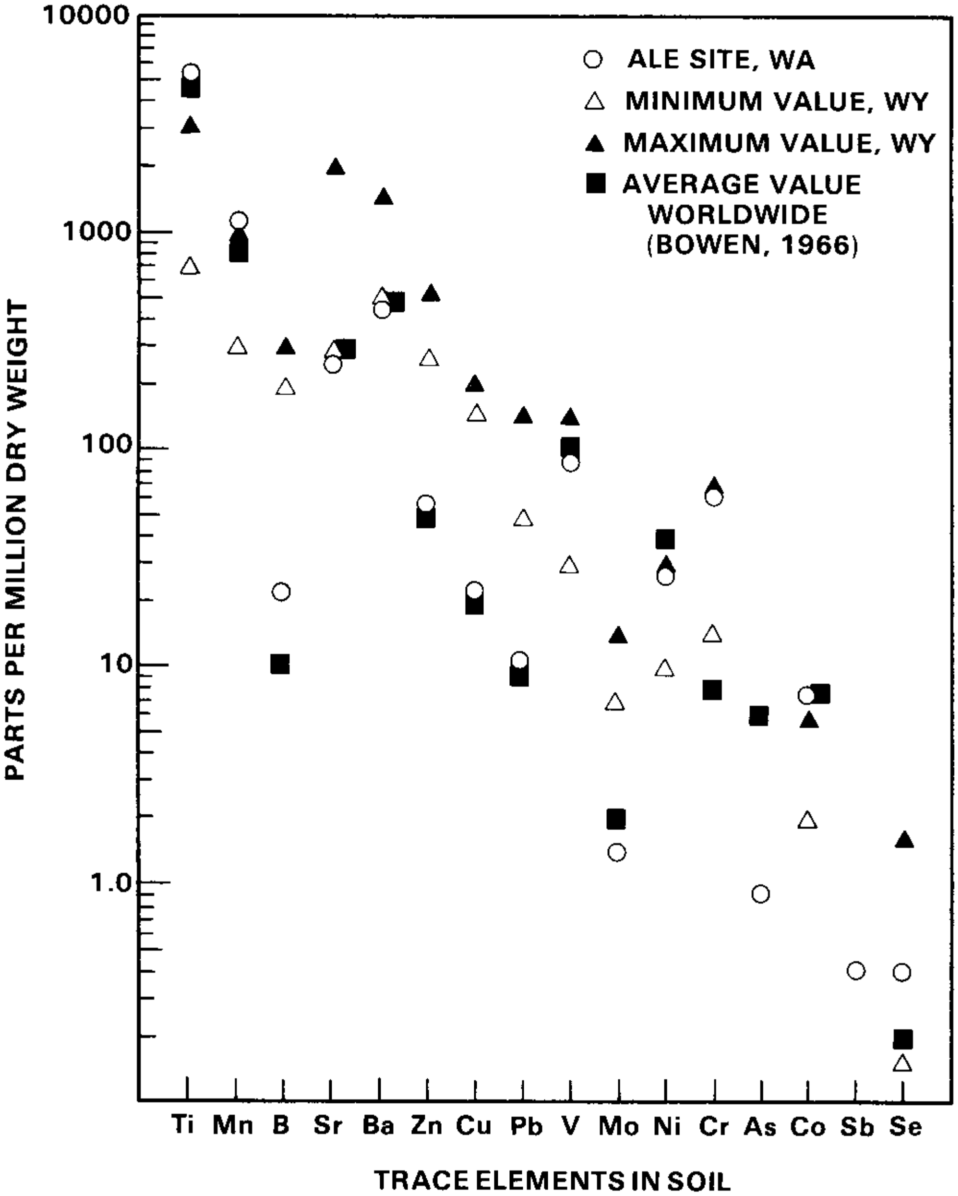

Figure 2. Trace element content of soil from the ALE Site, Washington, compared with minimum and maximum values from Wyoming.

Desert shrubs are long-lived plants, and individual mature shrubs can be expected to be available for sampling for several decades. However, desert shrubs are occasionally exposed to destruction by fire, and new sampling locations may need to be selected from time to time as losses to wildfire occur. Litterfall collectors placed beneath the shrub canopy of individual plants provides a repeatable non-destructive way to sample senescent leaves through normal leaf fall. The trace metal content of these leaves represents external (surface) retention as particulates as well as trace metals delivered internally to leaves via the soil-root-shoot pathway. Big sagebrush leaves collected from Washington and Wyoming indicate that trace metal content is not markedly different (Table 1).

Graphic presentations of trace element content of big sagebrush leaves and soil samples from Washington and Wyoming are shown in Figs. 1 and 2. When arranged in decreasing order of abundance, titanium and manganese are most abundant in sagebrush leaves and soil. Cobalt, antimony, and selenium were least abundant. In general, the same order of trace element abundance is displayed between sagebrush leaves and soil. Some of the measured trace element content in leaves probably represents surface contamination by dust. To establish whether elevated soil concentrations of trace metals can induce elevated levels of trace elements to sagebrush leaves via root uptake processes will require novel experimental procedures and designs to distinguish surface contamination from root uptake contamination (Straughan *et al.* 1981). Because big sagebrush is much more abundant in the study area than other shrub species, it seems likely that it offers the best opportunities for long term monitoring.

Acknowledgment

This work was supported by the U.S. Department of Energy under Contract DE-AC06-76RLO 1830.

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Received August 13, 1981
Accepted for publication December 4, 1981