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I. INTRODUCTION

To understand the dynamics of trace metals in desert environments requires estimates of compartment concentrations or storages (i.e., amounts of elements in soils, plants and animals), determinations of rates of flow between compartments, and estimates of rates at which materials are introduced into and irreversibly lost from the system. This report deals with measurements of amounts of trace elements in the environment surrounding Southern California Edison's Mohave Generating Station in southern Nevada, a collaborative study with Los Alamos Scientific Laboratory of trace elements in the vicinity of the Four Corners Power Plant in New Mexico, and laboratory and field experiments related to cycling of trace elements.

II. ECOSYSTEM COMPARTMENT ANALYSES

A. Standing pools of trace elements in Mohave Desert vegetation

In our last report we presented estimates of geometric mean concentrations of B, Ba, Mn, Pb, Sr and Ti in shrubs growing near the Mohave Generating Station in southern Nevada. These estimates were specific for various above-ground portions of shrubs (live stems, dead stems, leaves) and were combined with calculated standing crops to generate estimates of natural above-ground storages of elements in major species of a desert shrub community. We now extend this approach to three additional elements: Cu, Ni and Zn. Estimates of copper concentrations in tissues were based both on emission spectroscopy and atomic absorption spectroscopy. Estimates of nickel and zinc concentrations were based on atomic absorption analyses only. Table 1 gives geometric mean concentrations of these elements in above-ground parts of six shrubs. Also given are estimates of the standard errors of the geometric means.

When these concentrations were multiplied by above-ground standing crops of various tissues we obtained estimates of total above-ground storages of these three elements. Dry weight biomass estimates are given in our report of January 1, 1977 (see Table 7). Table 2 presents estimated storages of Cu, Ni and Zn, and recapitulates earlier data pertaining to six other elements.

B. Analysis of vegetation southeast of the Four Corners Power Plant, New Mexico

On September 21, 1976, Dr. Larry Wengen of Los Alamos Scientific Laboratory directed a field party, including personnel from our laboratory,

in the collection of plant samples between 8 and 121 km southeast of the Four Corners plant (see our report of January 1, 1977). These samples have been analyzed by emission spectroscopy at our laboratory and by other procedures at Los Alamos.

Plant material collected included grasses (Hilaria jamesii, Oryzopsis hymenoides), Russian thistle (Salsola iberica) and snakeweed (Gutierrezia sarothrae). Our analyses of these materials showed Cd, Co, Ni and Pb to be present at concentrations below limits of reliable measurement. Arithmetic mean concentrations of B, Mo, Sr and V ($\mu\text{g/g}$) in plant tissues are given in Table 3. These means are based on 6 or 7 samples.

We made regression analyses of concentrations of B, Mo, Sr and V in plant tissues as a function of distance from the power plant. As pointed out in previous reports, both Anderson et al. (1975) and Connor et al. (1976) have argued that significantly negative slopes of such regressions indicate possible enrichment of soil and/or vegetation by deposition from power plants. Table 4 presents the results of 24 such analyses, involving four species of plants collected 8, 12, 16, 24, 40, 72 and 121 km southeast of the Four Corners plant. The F -values test whether the slopes of the regressions differ significantly from zero. For samples of this size (6 or 7), the value of $F_{.05}$ is around 6.0. Three F -values indicate significantly negative slopes. Because two of these tests pertain to an element (Sr) which has already been implicated in the vicinity of the Dave Johnston plant in Wyoming (Connor et al. 1976) and the Mohave Generating Station in southern Nevada (Bradford et al. 1977), these results are of possible interest.

As suggested by Bradford et al., and as we shall show elsewhere in this report, there is a naturally declining geochemical gradient in soil Sr south of the Mohave station.

On March 31, Dr. Wangen visited our laboratory for a discussion of our collective findings southeast of the Four Corners Power Plant. At this time, based on LASL analyses of soil samples, Dr. Wangen's general conclusion was that all observable gradients in elemental concentrations in plants followed natural geochemical gradients as expressed in surface and subsurface soil samples. However, analyses of certain elements were still in progress. At this meeting we made comparisons of analyses of B, V, Sr and Ti in plant samples carried out at our respective laboratories (Table 5). Agreement for boron is remarkably good, and certainly acceptable for vanadium. There is a systematic difference in Sr analyses which is presently being investigated. It also appears that the two analytical procedures for titanium differed systematically, though not to as large an extent as for strontium.

C. Analysis of soils and vegetation south of the Mohave Generating Station, southern Nevada

Soil and vegetation samples were collected at sites approximately 2, 4, 6, 8, 12, 16 and 20 km south of the Mohave Generating Station on Dec. 14-15, 1976. At each site, three samples each of surface soil (0-2 cm), subsurface soil (10-20 cm) and leaves (Ambrosia dumosa, Larrea tridentata) were collected. Soil samples were prepared for chemical analysis by digestion in 4 N HNO_3 (Bradford et al 1975); vegetation preparation followed the procedure of Berry and Johnson (1966). Concentrations of Cu, Ni, Pb, Sr and Zn were determined by atomic absorption spectrophotometry;

S was determined by a sulfur analyzer utilizing a combustion iodometric procedure.

Table 6 shows average concentrations of the six elements in surface and subsurface soils. Concentrations of Pb, S and Zn were significantly higher in surface soils than in subsurface soil ($P < .05$). Although this indicates surface enrichment of Pb, S and Zn, the increase is not necessarily owing to fly ash deposition. When soil elemental concentrations were regressed on distance from the power plant, significant negatives slopes were found for S and Sr. However, similar slopes were obtained for both surface and subsurface soils, indicating natural geochemical gradients.

Concentrations of five elements in leaves of Ambrosia and Larrea are shown in Table 7. Lead concentrations were below the limits of detection in leaves. Sulfur concentrations in Ambrosia and Larrea resulted in the only significant negative slopes between leaf elemental concentrations and distance from the power plant. This negative slope for vegetation paralleled the one for soils, again implying a natural gradient.

Elemental concentration factors ($[X] \text{ leaves} \div [X] \text{ subsurface soil}$) are shown in Table 8 for Ambrosia and Larrea. Species differences are apparent for some elements. No relationship between sampling location and concentration factors was found, indicating the absence of any distance effect. There thus appears to be no biological concentration of any of these four elements by plant leaves in the vicinity of the Mohave station.

III. ECOLOGICAL PROCESSES

A. A field experiment with surface deposited fly ash and desert soil

In our last report we discussed preparations for an experiment involving the application of radioactive fly ash to desert soil. The purpose of this experiment is to measure directly some of the processes affecting redistribution of ash particles.

Fly ash from the Mohave Generating Station was activated by exposure to neutron bombardment at the UCLA School of Engineering reactor. Twenty-four samples of 7-8 g each were exposed for 16 hours to neutron fluxes of 10^{12} cm²/sec. Initial gamma spectra showed the expected large amounts of short-lived sodium isotopes, but later analyses showed amounts of ⁶⁰Co, ⁵⁹Fe and ⁴⁶Sc sufficient to tag ash for several years. Thirty days after activation 8-g samples contained about 0.15 μ C of ⁶⁰Co and 10 μ C of ⁴⁶Sc. The total amount of all gamma emitters at this time was estimated to be about 4 mC. Activated ash was taken to the Nevada Test Site on December 13, 1976.

The plan of the experiment is to distribute 8-g samples of activated ash over the soil surface, with a special retrieval device buried beneath the treated surface area. These retrieval devices are designed to 1) collect surface runoff water and suspended sediments carried away from the treated areas, and 2) permit subsequent collection of soil underlying treated areas in vertically segregated layers. Two of these devices are illustrated in Fig. 1. A device is driven into the ground so that a lip projects about 1 cm above ground surface. The lip has a notch on the downhill side from which a metal trough conducts runoff water to

a 2-liter collecting bottle. This trough is designated (A) in Fig. 1.

During February 1977 an area of one hectare was established in Jackass Flats at the Energy Research and Development Administration's Nevada Test Site. On February 15, Wood buried 29 retrievers in this area. Nine of these retrievers will serve as blanks and will underlie untreated surfaces. Twenty retrievers (in five groups of four) were buried at the corners and in the center of the study site. These were left in place for about 8 weeks, allowing some recovery of the surrounding soil. On April 10, activated ash was distributed over twenty retrieval devices. Nine were left untreated. The first collection of one group of four treated and one control device is scheduled for July 10, three months after installation. Later collections will be after six months, one year, two years and five years.

The first step in removing retrievers from the soil is to expose, with a spade, the face of the cube designated (B) in Figure 1. Then thin metal plates (C) will be driven horizontally through the soil mass surrounding the device. These plates are controlled by guides 1/2" apart. Another horizontal plate will be inserted at the top of the device to prevent loss of surface soil. Another plate (D) will be driven vertically down the face of the device opposing surface (B). The soil originally contained within the retriever will then be completely sealed in. Then the retriever is excavated and the back plate (D) is removed and a soil collecting trough (E) used to transfer soil layers into screw-cap glass jars. Amounts of radioactivity owing to ⁶⁰Co in various layers of soil from within each retriever will be determined by gamma pulse-height analysis. These counts will serve as measures of downward movement of

ash particles. Experiments with rainwater have shown that no detectable radioactivity owing to ^{60}Co is leached from activated fly ash particles.

B. Movements of cadmium, zinc and copper compounds in soil

In the previous section we described an experiment relating to the redistribution of ash particles, with particular emphasis on rates of downward movements in the soil profile. This process may have important bearing on the biological availability of elements in ash particles. Elements are also released from ash particles by chemical solution, after which dissolved compounds may be leached--independently of the fate of ash particles themselves. Rates of leaching are influenced by the particular chemical species involved and the physico-chemical constitution of the soil. Experiments are in progress to measure rates of movement of compounds of cadmium, copper and zinc in soil. The soil used in these experiments is a Hanford sandy loam with a pH of about 6.7. This soil type is derived from granitic parent material and is one of the better agricultural soils in the California central valley.

Short-lived isotopes of Cd, Cu and Zn were made by charged-particle activation using the UCLA Medical Cyclotron. These isotopes were purified and added to the surface of soil columns as nitrates, oxides and sulfides. The columns were then sequentially leached with water and EDTA or DTPA. A Picker Dyna-Scanning camera was used for real-time detection of movement and flow patterns of the metal compounds within the soil. After the initial surface adsorption, all compounds were resistant to leaching by water. Nitrates, when leached with either EDTA or DTPA, moved as a unit with the advancing front. Oxides moved

slowly and gradually trailed off in the leaching solution. Sulfides did not move with any of the applied leaching agents. This method provides a suitable technique for studying trace metal transport phenomena associated with speciation, sorption, solubilization and chelation of compounds within the soil column. Furthermore, simultaneous monitoring of movements of isotopes with disintegration energies > 0.2 MeV is possible.

C. Decomposition rates of surface litter

1. Field experiments

Litter decomposition experiments are being continued, both in the vicinity of the Mohave Generating Station and at the Nevada Test Site. We have measured weight loss in Larrea tridentata branches and twigs of Larrea and Ambrosia dumosa every three months for fifteen months at Bullhead City. These data are shown in Table 9. Weight loss to date has been slow, with average annual breakdown rates of only 6.6% (Larrea branches), 11.3% (Larrea twigs), and 10.4% (Ambrosia twigs). These slow decomposition rates reflect a combination of environmental conditions (low moisture) and the resistant nature of woody tissue. Our estimates for annual branch decomposition of 6.6% are lower than estimates of 17.1% (Swift et al. 1976) and 12-32% (Gosz et al. 1973) from more mesic environments.

Weight loss in leaves of Ambrosia dumosa, Larrea tridentata and Lycium pallidum has been measured every six weeks for 42 weeks at the Nevada Test Site using the litter bag method (Crossley and Hoglund 1962). These data are shown in Table 10. Following an initially rapid weight

loss during the first 12 weeks, decomposition slowed considerably. In this respect, weight loss followed the exponential decay model proposed by Olson (1963). The initially rapid weight loss coincided with 12 weeks of moderate rainfall (8.18 cm). After that time, only 2.52 cm of rain fell in 24 weeks. Recent rains (4.78 cm) have again coincided with accelerated weight loss. The more rapid weight loss in leaves, compared to stems and branches, is most likely due to differences in composition of the two types of tissue and the greater surface area of leaves.

At the end of these experiments, samples from all collection dates will be analyzed by emission spectroscopy and/or atomic absorption spectroscopy to obtain estimates of rates at which individual elements are released from the decomposing leaves and branches.

2. Laboratory experiments

A procedure is being developed for estimating decomposition of leaf litter under controlled laboratory conditions. Previous investigators (Oberholzer 1936, Van Schreven 1967, Sørensen 1974) have used CO_2 evolution as a measure of biological activity and organic matter decomposition. Macgregor (1972) has shown, however, that observed increases in CO_2 production following soil wetting may not imply increased decomposition, but simply the release of CO_2 from inorganic soil reserves. This is particularly true in calcareous desert soil. Our procedure involves adding known weights of leaves to glass Petri dishes which contain surface soil taken from beneath desert shrub canopies. These microcosms are then maintained at desired temperature and moisture conditions.

At the end of incubation, leaves are dried and reweighed. By using this approach we avoid the CO_2 problem and directly measure weight losses. Leaves can then also be analyzed for changes in mineral concentrations. Some preliminary data using this microcosm procedure are shown in Table 11 for Larrea and Lycium andersonii leaves which were incubated for four weeks under various environmental conditions. Several observations can be made from these initial data. First, they indicate that when moisture is present, decomposition proceeds very rapidly. Secondly, weight loss in Lycium leaves placed on fly ash amended soil was somewhat slower than on unamended soil, while weight loss in Larrea was comparable on both types of soil. Third, the replicate samples of each treatment indicate that, in most cases, the experimental error of the method is not large. Further experiments are planned using this method with various combinations of environmental conditions and fly ash amendments.

D. Uptake of elements by desert shrubs grown in ash-amended soils

Rates of movement of trace elements from desert soils amended with fly ash to plants are being examined with two desert shrubs: Lycium andersonii and Ambrosia dumosa. Data pertaining to Lycium are presented here.

Rooted cuttings of L. andersonii were planted on 14 January 1977 in desert soil to which various amounts of fly ash had been added. Nitrogen fertilizer was applied to the pots at a standard rate of $100 \mu\text{g N/g soil}$ as NH_4NO_3 at time of planting. There were five replicates with one plant per pot, and each pot contained 1500 g air-dry soil. Application rates of fly ash were 0.0, 0.2, 0.5, 1.0, 2.5, 10.0, and 20.0% by weight of soil.

On 4 May 1977, foliage from all plants was removed and plants left to continue growth. Leaves were divided into three groups: top, middle and bottom. All leaves were washed in 0.1 N HCl and water, dried, weighed and analyzed by emission spectroscopy.

Tables 12, 13 and 14 give analytical results for 13 elements. We did not measure any uptake of Cd, Pb or Ni. Lycium andersonii is a natural accumulator of Li, but leaf concentrations of this element decreased when soils contained $\geq 2.5\%$ fly ash by weight. The tabulated data show that Cu, B, Sr, and possibly Mo, are moving from treated soils into leaves of Lycium. Molybdenum is doubtful because the increase in soil pH brought about by addition of fly ash can have the same effect. Increased pH is certainly responsible for lower leaf concentrations of P and Mn. Increased concentrations of Cr and Sn were observed in plants growing in 20% fly ash-soil mixtures. We observed no evidence that elemental uptake was expressed preferentially among upper, middle and lower leaves.

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Table 1. Estimate geometric mean concentrations ($\mu\text{g/g}$) $\pm$ standard errors of the geometric means of three elements in six Mohave Desert shrubs. No analyses were made of leaves of Krameria parvifolia.

Species and tissue type	Number of samples	Cu	Ni	Zn
<u>Acacia gregii</u>				
live stems	3	11.5 ± 0.07	3.0 ± 0.15	11.1 ± 0.04
dead stems	3	27.7 ± 0.04	1.8 ± 0.13	11.9 ± 0.01
leaves	3	7.0 ± 0.06	1.6 ± 0.03	10.4 ± 0.02
<u>Ambrosia dumosa</u>				
live stems	3	12.8 ± 0.04	4.7 ± 0.08	8.9 ± 0.02
dead stems	3	12.7 ± 0.05	4.0 ± 0.08	9.8 ± 0.04
leaves	1	5.5	6.7	10.3
<u>Dalea fremontii</u>				
live stems	3	12.0 ± 0.08	4.4 ± 0.04	8.5 ± 0.04
dead stems	3	22.1 ± 0.05	4.5 ± 0.26	13.0 ± 0.04
leaves	1	4.7	4.6	12.2
<u>Hymenoclea salsola</u>				
live stems	3	9.5 ± 0.04	1.8 ± 0.15	8.5 ± 0.06
dead stems	3	14.1 ± 0.08	2.9 ± 0.04	9.4 ± 0.07
leaves	1	5.0	2.7	8.6
<u>Krameria grayi</u>				
live stems	3	14.6 ± 0.03	3.2 ± 0.09	7.5 ± 0.03
dead stems	3	16.2 ± 0.02	2.7 ± 0.30	7.6 ± 0.04
leaves		n.a.	n.a.	n.a.
<u>Larrea tridentata</u>				
live stems	3	5.6 ± 0.07	0.9 ± 0.15	5.1 ± 0.04
dead stems	3	19.6 ± 0.02	4.1 ± 0.09	7.5 ± 0.02
leaves	3	5.0 ± 0.10	4.9 ± 0.04	8.7 ± 0.01

Table 2. Estimated natural above-ground storages (g/ha) of nine elements in shrubs growing at Site 6 near the Mohave Generating Station in southern Nevada.

Species	B	Ba	Cu	Mn	Ni	Pb	Sr	Ti	Zn
<u>Acacia greggii</u>	3.3	6.9	4.1	4.9	0.5	3.5	72	6.9	2.5
<u>Ambrosia dumosa</u>	10.9	12.6	7.7	14.2	2.7	1.2	65	15.1	5.9
<u>Dalea fremontii</u>	2.5	9.3	2.8	4.9	0.9	0.4	60	5.4	2.1
<u>Hymenoclea salsola</u>	5.6	9.2	2.2	1.8	0.5	0.3	32	5.7	1.8
<u>Krameria grayi</u>	0.05	0.2	0.06	0.1	0.01	0.01	1	0.3	0.03
<u>Larrea tridentata</u>	7.4	18.9	7.6	17.9	1.2	3.9	90	23.6	4.0
Totals	29.7	57.1	24.5	43.8	5.8	6.4	320	57.0	16.3

Table 3. Arithmetic mean concentrations of four elements in plant samples collected between 8 and 121 km southeast of the Four Corners Power Plant, San Juan County, New Mexico.

Element	<u>Hilaria</u>	<u>Oryzopsis</u>	<u>Salsola</u> leaves	<u>Salsola</u> stems	<u>Gutierrezia</u> leaves	<u>Gutierrezia</u> stems
B	17.7	30.1	31.4	22.9	58.6	26.2
Sr	111	140	375	412	128	136
Mo	0.2	1.8	0.9	0.2	0.8	0.3
V	2.4	2.8	1.9	0.6	4.0	2.6

Table 4. Results of regression analyses involving concentrations of four elements in vegetation between 8 and 20 km southeast of the Four Corners Power Plant.

Element	Material analyzed	<u>n</u>	<u>r</u>	<u>F</u>
B	<u>Hilaria</u>	6	-0.67	3.2
	<u>Oryzopsis</u>	7	-0.80	8.9*
	<u>Salsola</u> leaves	6	0.45	1.0
	<u>Salsola</u> stems	6	0.34	0.5
	<u>Gutierrezia</u> leaves	7	0.64	3.4
	<u>Gutierrezia</u> stems	7	0.27	0.4
Sr	<u>Hilaria</u>	6	-0.79	6.8*
	<u>Oryzopsis</u>	7	-0.75	6.4*
	<u>Salsola</u> leaves	6	0.48	1.2
	<u>Salsola</u> stems	7	-0.46	1.4
	<u>Gutierrezia</u> leaves	7	-0.46	1.4
	<u>Gutierrezia</u> stems	7	-0.07	0.0
Mo	<u>Hilaria</u>	6	0.40	0.8
	<u>Oryzopsis</u>	7	-0.41	1.0
	<u>Salsola</u> leaves	6	-0.24	0.2
	<u>Salsola</u> stems	6	-0.56	1.8
	<u>Gutierrezia</u> leaves	7	0.09	0.0
	<u>Gutierrezia</u> stems	7	0.10	0.1
V	<u>Hilaria</u>	6	0.65	2.9
	<u>Oryzopsis</u>	7	0.73	5.6
	<u>Salsola</u> leaves	6	0.42	0.9
	<u>Salsola</u> stems	6	0.76	5.5
	<u>Gutierrezia</u> leaves	7	0.22	0.3
	<u>Gutierrezia</u> stems	7	0.18	0.2

Table 5. Comparisons of analyses of four elements in vegetation made at the UCLA Laboratory of Nuclear Medicine and Radiation Biology and Los Alamos Scientific Laboratory. Vanadium values below limit of reliable measurement are indicated by **.

Sample type	Boron		Vanadium		Strontium		Titanium	
	UCLA ¹	LASL ²	UCLA ¹	LASL ³	UCLA ¹	LASL ³	UCLA ¹	LASL ³
<u>Oryzopsis hymenoides</u>	47	54	1.8	1.8	201	117		
<u>Salsola iberica</u> ⁴	37	48	1.8	0.3	215	130		
<u>Salsola iberica</u> ⁵	24	28	**	**	407	211		
<u>Gutierrezia sarothrae</u> ⁴	47	35	**	1.3	113	68		
<u>Gutierrezia sarothrae</u> ⁵							98	128
<u>Hilaria jamesii</u>	24	20	1.6	0.1	166	60		
<u>Oryzopsis hymenoides</u>	57	62	1.6	2.0	261	168	92	93
<u>Salsola iberica</u> ⁴	24	35	2.2	0.3	584	264		
<u>Gutierrezia sarothrae</u> ⁴	63	54	3.1	3.1	171	132	153	198
<u>Gutierrezia sarothrae</u> ⁵							100	151
<u>Hilaria jamesii</u>	21	13	**	0.9	184	67		
<u>Salsola iberica</u> ⁴	22	34		0.6	185	105		
<u>Gutierrezia sarothrae</u> ⁵							68	86
<u>Hilaria jamesii</u>							64	81
<u>Oryzopsis hymenoides</u>	29	27	2.1	2.4	200	78	69	110
<u>Gutierrezia sarothrae</u> ⁴	54	56	5.3	6.1	142	205	299	489
<u>Oryzopsis hymenoides</u>	33	26	3.6	1.6	80	30		
<u>Hilaria jamesii</u>							78	74
<u>Oryzopsis hymenoides</u>							128	206
<u>Gutierrezia sarothrae</u> ⁴							480	815
<u>Gutierrezia sarothrae</u> ⁴							133	146
Means	37.1	37.8	1.8	1.6	224	126	147	215

¹ emission spectroscopy

² prompt gamma neutron activation

³ thermal neutron activation

⁴ leaves

⁵ stems

Table 6. Mean concentrations ($\mu\text{g/g}$) of six elements in surface and subsurface soils at seven distances south of the Mohave Generating Station. All means were based on three replicates.

Distance (km)	Location	Cu	Ni	Pb	S	Sr	Zn
2	surface	6.4	6.4	10.1	149	14.4	19.1
	subsurface	7.0	7.5	8.7	91	17.2	18.8
4	surface	8.3	9.6	15.4	142	31.3	28.0
	subsurface	6.0	8.1	11.9	139	42.3	18.4
6	surface	6.1	7.5	11.4	120	25.1	20.1
	subsurface	5.4	6.5	9.4	103	31.1	15.7
8	surface	5.7	7.5	10.3	123	21.0	21.0
	subsurface	4.5	6.5	7.4	100	19.5	15.9
12	surface	3.5	5.6	8.6	83	16.5	14.5
	subsurface	3.4	5.5	6.1	85	15.8	12.4
16	surface	6.3	7.8	10.7	71	11.4	25.2
	subsurface	6.4	8.1	8.9	63	10.7	25.3
20	surface	4.9	8.0	9.8	76	7.4	22.5
	subsurface	5.1	8.3	9.6	65	12.2	22.9

Table 7. Mean concentrations ($\mu\text{g/g}$) of four elements in Ambrosia dumosa and Larrea tridentata leaves at seven distances south of the Mohave Generating Station. All means were based on three samples.

Distance (km)	Species	Cu	Ni	S	Sr	Zn
2	<u>Ambrosia</u>	20.2	2.9	6600	158	11.5
	<u>Larrea</u>	13.5	3.5	6300	86	8.3
4	<u>Ambrosia</u>	15.0	1.6	5900	237	18.1
	<u>Larrea</u>	7.0	3.2	5900	143	9.0
6	<u>Ambrosia</u>	12.8	2.1	6700	271	10.6
	<u>Larrea</u>	5.1	2.1	5500	129	8.5
8	<u>Ambrosia</u>	11.0	2.9	4200	129	11.0
	<u>Larrea</u>	3.9	2.5	7200	95	8.9
12	<u>Ambrosia</u>	18.0	2.4	3200	202	14.0
	<u>Larrea</u>	8.5	3.6	5200	155	8.3
16	<u>Ambrosia</u>	21.9	2.5	3300	181	19.7
	<u>Larrea</u>	8.6	3.1	5300	109	9.2
20	<u>Ambrosia</u>	15.1	3.0	3000	139	12.9
	<u>Larrea</u>	5.0	1.5	4600	112	8.1

Table 8. Elemental concentration factors ($[X] \text{ leaves} \div [X] \text{ subsurface soils}$) for two species of desert shrubs at seven distances south of the Mohave Generating Station.

Distance (km)	Species	Cu	Ni	S	Sr	Zn
2	<u>Ambrosia</u>	2.9	0.4	73	9.2	0.6
	<u>Larrea</u>	1.9	0.5	69	5.0	0.4
4	<u>Ambrosia</u>	2.5	0.2	42	5.6	1.0
	<u>Larrea</u>	1.2	0.4	42	3.4	0.5
6	<u>Ambrosia</u>	2.4	0.3	65	8.7	0.7
	<u>Larrea</u>	0.9	0.3	53	4.2	0.5
8	<u>Ambrosia</u>	2.4	0.5	42	6.6	0.7
	<u>Larrea</u>	0.9	0.4	72	4.9	0.6
12	<u>Ambrosia</u>	5.3	0.5	38	12.8	1.1
	<u>Larrea</u>	2.5	0.7	61	9.8	0.7
16	<u>Ambrosia</u>	3.4	0.3	52	16.9	0.8
	<u>Larrea</u>	1.3	0.4	84	10.2	0.4
20	<u>Ambrosia</u>	3.0	0.4	46	11.5	0.6
	<u>Larrea</u>	1.0	0.2	71	9.2	0.4

Table 9. Mean weight losses (% $\pm$ s.e.) observed in twigs and branches of two desert shrub species near the Mohave Generating Station in southern Nevada. All means are based on four replicates.

Exposure (months)	(twigs)	(twigs)	(branches)
	<u>Ambrosia dumosa</u>	<u>Larrea tridentata</u>	<u>Larrea tridentata</u>
3	3.7 $\pm$ 0.6	1.8 $\pm$ 0.3	1.7 $\pm$ 1.1
6	5.8 $\pm$ 1.1	6.1 $\pm$ 1.2	1.3 $\pm$ 0.2
9	10.6 $\pm$ 0.8	9.5 $\pm$ 1.3	2.9 $\pm$ 0.9
12	10.4 $\pm$ 1.2	11.8 $\pm$ 1.6	6.6 $\pm$ 2.2
15	13.2 $\pm$ 1.0	11.9 $\pm$ 0.8	4.1 $\pm$ 0.3

Table 10. Mean weight losses (% $\pm$ s.e.) observed in leaf litter of three desert shrub species at the Nevada Test Site. All means are based on four replicates.

Exposure (weeks)	<u>Ambrosia dumosa</u>	<u>Larrea tridentata</u>	<u>Lycium pallidum</u>
6	29.4 $\pm$ 1.0	10.1 $\pm$ 2.9	38.6 $\pm$ 1.1
12	38.2 $\pm$ 0.6	16.3 $\pm$ 0.5	44.6 $\pm$ 2.6
18	39.0 $\pm$ 0.4	15.0 $\pm$ 1.5	43.6 $\pm$ 1.1
24	44.1 $\pm$ 1.4	19.6 $\pm$ 1.2	44.9 $\pm$ 0.8
30	41.7 $\pm$ 0.4	24.7 $\pm$ 2.1	46.7 $\pm$ 0.8
36	45.3 $\pm$ 3.3	27.0 $\pm$ 0.9	43.9 $\pm$ 1.5
42	51.2 $\pm$ 1.4	33.1 $\pm$ 1.8	52.5 $\pm$ 3.4

Table 11. Percent weight losses observed in replicate leaf litter samples of two desert shrubs after one month's exposure to various experimental treatments in the laboratory. All samples were incubated in a growth chamber at 20° C (nights) and 25° C (days).

Treatment	<u>Larrea tridentata</u>	<u>Lycium andersonii</u>
1	-0.20, 0.08	3.44, 3.01
2	4.50, 9.97	26.47, 24.15
3	32.19, 23.77	36.86, 40.83
4	24.17, 24.85	42.36, 45.95
5	46.30, 45.05	55.53, 52.42
6	36.27, 40.70	51.70, 52.66

Treatment:

- 1 control; soil moisture content unadjusted
- 2 soil moisture adjusted to 20% moisture-holding capacity (MHC) at beginning of study and again after each week of incubation
- 3 soil moisture adjusted to 20% MHC daily
- 4 soil moisture adjusted to 60% MHC at beginning of study and again after 2 weeks incubation
- 5 soil moisture adjusted to 60% MHC daily
- 6 soil amended with 10% fly ash and adjusted to 60% MHC daily

Table 12. Average concentrations of elements in upper leaves of Lycium andersonii grown in fly ash-amended desert soils. Concentrations of Ca are percents, all others $\mu\text{g/g}$.

Fly ash in soil (%)	pH ¹	Mean yield of leaves per plant (mg)	P	Ca	Zn	Cu	Fe	Mn	B	Mo	Cr	Sr	Ba	Li	Sn
0.0	7.6	230	1390	6.16	20	3.8	143	174	59	3.9	0.9	382	71	11	0.2
0.2	7.6	232	1418	7.33	11	4.3	117	95	53	4.0	1.0	456	81	13	0.6
0.5	7.6	84	1079	6.69	11	4.1	121	94	51	2.7	0.9	401	74	12	1.0
1.5	7.9	64	796	7.21	11	4.9	115	79	53	3.2	1.2	494	84	12	1.2
2.5	7.9	81	565	8.08	8	6.5	102	48	67	5.0	1.2	509	71	4	1.5
5.0	8.0	82	582	7.23	18	9.8	149	69	118	9.6	1.0	706	75	6	0.9
10.0	8.1	148	307	8.02	18	12.4	156	67	185	12.8	1.3	834	52	5	1.2
20.0	9.4	29	200	12.10	18	15.3	194	29	181	14.7	3.0	1632	76	9	1.8

¹ Before plants were put into pots

Table 13. Average concentrations of elements in middle leaves of Lycium andersonii grown in fly ash-amended soils. Concentrations of Ca are percents, all others µg/g.

Fly ash in soil (%)	Height (cm)	Mean yield of leaves per plant (mg)	P	Ca	Zn	Cu	Fe	Mn	B	Mo	Cr	Sr	Ba	Li	Sn
0.0	32	419	605	7.73	6	2.3	98	159	40	3.4	1.0	410	74	14	1.2
0.2	26	257	1054	9.32	12	3.2	77	95	49	4.4	1.1	500	94	15	1.1
0.5	25	179	766	10.21	14	3.0	81	105	55	3.3	1.1	710	101	17	0.2
1.0	16	104	814	8.20	16	4.2	90	82	66	5.2	1.0	648	100	16	0.1
2.5	15	93	624	8.22	24	5.3	79	64	90	6.5	1.1	692	76	7	0.6
5.0	15	117	383	6.61	16	7.1	115	65	112	9.4	0.9	755	66	4	0.8
10.0	10	125	263	9.44	18	11.0	181	67	180	13.1	1.3	1083	55	4	0.8
20.0	4	30	293	10.50	28	18.6	121	29	178	20.0	4.1	1350	63	5	0.5

Table 14. Average concentrations of elements in bottom leaves of Lycium andersonii grown in fly ash-amended desert soils. Concentrations of Ca are percents, all others $\mu\text{g/g}$.

Fly ash in soil (%)	Mean yield of leaves per plant (mg)	P	Ca	Zn	Cu	Fe	Mn	B	Mo	Cr	Sr	Ba	Li	Sn
0.0	227	696	10.09	8	2.5	127	211	61	3.2	1.2	743	96	15	1.1
0.2	176	796	10.56	6	3.4	173	128	48	3.8	1.4	664	95	16	1.5
0.5	89	755	7.01	5	4.1	111	71	43	2.6	1.3	449	81	14	2.1
1.0	78	400	16.11	9	3.6	158	74	52	3.8	1.5	690	96	12	1.8
2.5	125	511	8.95	11	4.3	94	60	76	5.0	1.1	680	71	6	1.6
5.0	114	504	8.54	8	7.6	264	65	120	10.0	1.3	1020	81	5	1.8
10.0	90	444	8.71	12	9.9	197	59	174	9.7	1.4	1096	62	4	2.0
20.0	24	268	8.26	11	12.9	242	27	212	13.5	4.3	1740	103	8	2.9