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CYCLING OF STABLE Cs IN A DESERT ECOSYSTEM[1]

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Abstract

Contents of stable Cs in several compartments of desert ecosystems represented at the Nevada Test Site have been determined by neutron activation. Potassium in the same compartments has also been determined and Cs:K discrimination under natural conditions has been evaluated. From compartment sizes some estimates have been made on the rates of Cs cycling through the systems. The rates were low but the stable Cs was circulating. Compartments studied include soil, several different plant species, arthropods, reptiles and mammals. The contents of Cs within compartments were in the nanogram per g of dry weight range. There appeared to be a progressive narrowing of the K/Cs ratio going from plants to reptiles and mammals. The addition of stable Cs as CsCl to a soil obtained from the Nevada Test Site resulted in leaf contents in Atriplex canescens of 0.0279, 0.580, 5.15, and 24.0 ppm per g of dry weight for application rates of 0, 5, 20, and 50 ppm

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respectively. The applied Cs was slightly more available than was the original soil Cs. One must conclude that stable Cs is freely circulated in ecosystems although at levels lower than that of K by a factor of over 100,000, and that the stable Cs will have an influence in the cycling of ^{137}Cs.

Introduction

The cycling in ecosystems of radiocesium, particularly of ^{137}Cs, is of vital importance in that many food chains which extend to man result in concentration of ^{137}Cs which in turn could be dangerous to man if the tolerance level is exceeded (Hanson 1967, Hanson and Palmer 1965, Harley et al. 1970, Rogowski and Tamura 1970, Squire and Middleton 1966, Svensson 1966, Svensson and Liden 1965). Considerable other information about ^{137}Cs cycling is available (Crossley 1967, Dahlman et al 1969, Dodd and Van Amburg 1970, Fredriksson et al 1969, Miller 1968, Olson 1965, Plummer et al 1967, Reichle and Crossley 1965, 1967, Rickard 1966, Rickard and Cline 1970, Waller and Olson 1967, Whicker et al 1965, Witkamp and Frank 1967, 1969, Wlodek 1966) but insufficient information is known about the role of stable Cs in the cycling of ^{137}Cs (Nishita et al 1960, 1965). The major purposes of this paper are to report the levels of stable Cs in various compartments of a desert ecosystem and to estimate the importance of its role in ^{137}Cs cycling.

Materials and Methods

Stable Cs was assayed by neutron activation analysis. The neutron activation techniques employed in this study were similar to those outlined by

Bowen and Gibbons (1963). The solubilization of the samples and the final determination of the induced ^{134}Cs was done using methods outlined by Harley (1970).

Duplicate plant and insect samples were run when sufficient material was available. All soil samples were run at least in triplicate. Triplicate comparator plant samples were run with each set of unknown (set contained 16 samples plus three comparators). All counting was done using a Beckman wide-beta counting system.

Stable K in soils was assayed for by counting ^{40}K by gamma-ray spectrometry. Mineral elements in biological samples were assayed with an emission spectrograph (unpublished methods of Alexander and Romney).

The samples of soils, plants, and animals were obtained from the Rock Valley area of the Nevada Test Site in 1969 and 1970. The area is an example of the northern part of the Mojave Desert.

Results and Discussion

The analysis for stable Cs and K in various components of the northern Mojave Desert ecosystem are in Table 1. The Cs content of soils varied around 4 micrograms per g of soil but that of the biological materials was mostly less than 100 nanograms per g of dry weight. The relatively high level in certain arthropods was very likely related to the presence of soil in the digestive organs of ground-dwelling species. The average K/Cs ratio in soil was 5600. The mean of the ratios for 64 samples of plant leaves was 675,000 with 285,000 for reptiles and 181,000 for mammals. The fact that the ratio was much more narrow for soil than for the biota is

probably illustrative of the unavailable nature of soil Cs to plants (Gissel-Nielsen and Andersen 1967, Hanson 1967, Nishita et al 1968, 1960) A fraction of it, however, does enter into biological cycling (Table 2).

The relationship between K and Cs in various compartments appears to be irregular (Table 1). There was a strong positive relationship between the amounts of Cs and K in soil. This is further emphasized in the distribution of K and Cs in the soil profile (Table 3). There was insufficient concentration of ^{137}Cs to contribute to the total amount present (Table 3). In contrast to the strong positive relationship between Cs and K in soil, there was a strong negative relationship between Cs and K in the mammals. The average correlation coefficient for plants was slightly negative but positive relationships were indicated for some species and negative relationships for others (Table 1). This may indicate the operation of different types of mechanisms in various species. Potassium did not seem to compete with Cs for transport in the mammals. This conclusion is based on the observation that the K/Cs ratio is narrower in mammals than in plants. If it were wider than for plants, one could have concluded that the mammal tissues could selectively transport K in preference to Cs. The process, however, seemed to be concentration rather than dilution. All mammals studied were herbivores. The negative correlation between K and Cs in the mammals may be related to competition.

Correlation coefficients were obtained for stable Cs x some mineral elements other than K for a set of plant leaves analyzed by emission spectrography. The coefficient for Cs x K was similar to that in Table 1. That for Cs x Ca was also slightly negative. There appeared to be stronger

relationships between Cs and Fe, Ti, and Al than for Cs and K or Ca. The coefficients with the heavy metals were highly positive.

To determine the effect of a stable Cs application to soil on the ability of plants to accumulate it from the soil, an experiment was conducted in which 0, 5, 20, or 50 ppm Cs as CsCl was mixed with soil collected from the Nevada Test Site. Atriplex canescens cuttings in triplicate containers were grown in the soil for 70 days. Leaf samples were taken and assayed for stable Cs by neutron activation. The mean coefficient of variation of the triplicate samples was 8.6%. The mean contents in the leaves for the 0, 5, 20, and 50 ppm application rates were 0.0279, 0.58, 5.15, and 24.0 ppm of dry weight, respectively. Although the uptake was consistent and measurable, it was only about 1/400 of what could be expected for an equivalent potassium application. A rate of K application of 50 ppm in soil would increase K contents around 1% or more of dry weight in the A. canescens plants. This would be a K/Cs for the increased uptake of around 2 million. The average K/Cs for all plants in Table 1 was 645,000. It is known that Cs is much less available from soil than is K (Nishita et al 1965). The recently applied Cs was evidently available in about the same magnitude as was the original soil Cs.

It is quite apparent then that the availability via plant roots and cycling of ^{137}Cs in ecosystems will be related to the supply of stable Cs in the soil. In some cases dilution could be expected and in other cases concentration could be expected (Nishita et al 1960, 1962) depending upon the native soil supply.

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Table 1. Contents of stable Cs and K in leaves of various plants and in other compartments of a desert ecosystem (dry weight basis).

Material	No. of samples	Cs	K	K/Cs	Cs x K
		nanograms/g	%	1000's ratio	r
Larrea divaricata leaves	12	79.7 ± 33.2	2.04 ± 0.74	256	-.402
Franseria dumosa leaves	10	73.7 ± 34.5	4.62 ± 1.06	626	+.548
Lycium andersonii leaves	10	57.4 ± 38.8	4.85 ± 1.41	845	+.368
Krameria parvifolia leaves	4	25.8 ± 14.0	2.96 ± 0.99	1147	-.133
Lycium pallidum leaves	4	54.0 ± 10.8	4.41 ± 0.98	817	-.910
Coleogyne ramosissima leaves	4	74.9 ± 32.1	1.28 ± 0.06	171	-.323
Eurotia lanata leaves	9	103.4 ± 44.2	4.07 ± 2.36	394	-.347
Grayia spinosa leaves	11	50.6 ± 25.8	9.51 ± 2.33	1879	+.180
All leaves	64	68.3 ± 37.3	4.61 ± 2.93	675	-.176
Reptiles	1	40.4	1.15	285	—
Mammals	9	50.9 ± 23.7	0.92 ± 0.13	181	-.784
Insects	8	67.0 ± 31.3	—— ——	——	——
Other arthropods	3	503.0 ± 234.8	—— ——	——	——
Soils	25	4158.0 ± 293	2.23 ± 0.49	5.4	+.715

± values are the standard deviations.

Table 2. Estimate of the amounts of stable Cs in a desert ecosystem entering into the biological cycle.

Compartment	Compartment size kg/ha	Cs g/ha	Cs Fraction of total
Soil (60 cm)	9.0×10^{6}	37,200	1.0
Exchangeable cation (60 cm)	13.5×10^{3}	50.0	0.13×10^{-2}
Plants	3000	0.21	0.56×10^{-5}
Arthropods	1.0	0.00019	0.51×10^{-8}
Reptiles	0.4	0.000016	0.43×10^{-9}
Mammals	0.6	0.000031	0.83×10^{-9}

Table 3. K, Cs, and ^{137}Cs contents in soil profiles from the Rock Valley area of the Nevada Test Site.

	A horizons	C horizons
K, mg/g soil	25.68 ± 4.45	18.83 ± 3.30
Cs, μ/g soil	4.35 ± 0.22	3.96 ± 0.03
^{137}Cs, pc/g soil	0.283 ± 0.044	0.055 ± 0.028

Table 4. Correlation coefficients for Cs vs other elements from data from leaves of 14 species of desert plants.

Factors	r
Cs x K	-.226
Cs x Ca	-.229
Cs x Fe	+.833
Cs x Ti	+.950
Cs x Al	+.738

Table 5. Cs in leaves of A. canescens following Cs applications to soil.

Cs applied	Cs in leaves[a]
ppm	micrograms/g
0	0.0279
5	0.58
20	5.15
50	24.0

([a]Average coefficient of variation was 8.6%)