
UPTAKE OF STRONTIUM BY CHAMISA (*CHRYSOTHAMNUS NAUSEOSUS*) SHRUB PLANTS GROWING OVER A FORMER LIQUID WASTE DISPOSAL SITE AT LOS ALAMOS NATIONAL LABORATORY

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ABSTRACT A major concern of managers of low-level waste burial sites is the translocation of radioactive contaminants by deep-rooted plants to the soil surface. This study investigates the uptake of strontium (⁹⁰Sr), a biologically mobile element, by chamisa (*Chrysothamnus nauseosus*), a deep-rooted shrub plant, growing over a former liquid waste disposal site (Solid Waste Management Unit [SWMU] 10-003[c]) at Los Alamos National Laboratory (LANL), Los Alamos, New Mexico. Surface soil samples (0 to 5 cm depth) were also collected from below (understory) and between (interspace) shrub canopies. Both chamisa plants growing over SWMU 10-003(c) contained significantly higher concentrations of ⁹⁰Sr than a control (background) plant—one plant, in particular, contained 3.35×10^6 Bq kg⁻¹ ash (9.05×10^4 pCi g⁻¹ ash) in top-growth material. Similarly, soil surface samples collected underneath (ave. = $4,237$ Bq kg⁻¹ dry [114.5 pCi g⁻¹ dry]) and between (ave. = 529 Bq kg⁻¹ dry [14.3 pCi g⁻¹ dry]) plants contained ⁹⁰Sr concentrations above upper limit background (30 Bq kg⁻¹ dry [0.82 pCi g⁻¹ dry]) and LANL screening action levels (>163 Bq kg⁻¹ dry [4.4 pCi g⁻¹ dry]); this probably occurred as a result of chamisa plant leaf fall contaminating the soil understory area followed by water and/or winds moving ⁹⁰Sr to the soil interspace areas. Although some soil surface migration of ⁹⁰Sr from SWMU 10-003(c) has occurred, the level of ⁹⁰Sr in sediments collected downstream of SWMU 10-003(c) at the LANL boundary was still within regional upper limit background concentrations.

KEYWORDS: radioecology, ⁹⁰Sr, plant uptake, chamisa, *Chrysothamnus nauseosus*

INTRODUCTION

Several studies have shown that vegetation growing over buried low-level radioactive waste sites at Los Alamos National Laboratory (LANL) may translocate radionuclides from the roots to above-ground plant compartments [1-3]. Deep-rooted perennial plant species like trees and shrubs were cited to be the major offenders [4, 5], and may act as conduits to other biotic [6-8] and abiotic [9-12] components

that may eventually result in a radiation dose to humans [13-16].

During a recent environmental restoration predrilling radiological surface survey in Bayo Canyon at LANL, some chamisa (*Chrysothamnus nauseosus*) shrub plants exhibited elevated beta radioactivity (Figure 1). These late-successional plants, which may root as deep as 4.1 m (13.5 ft) [17], were growing over a former liquid waste disposal structure (#TA-10-43) (Solid Waste Management Unit [SWMU] 10-003[c]) [18].

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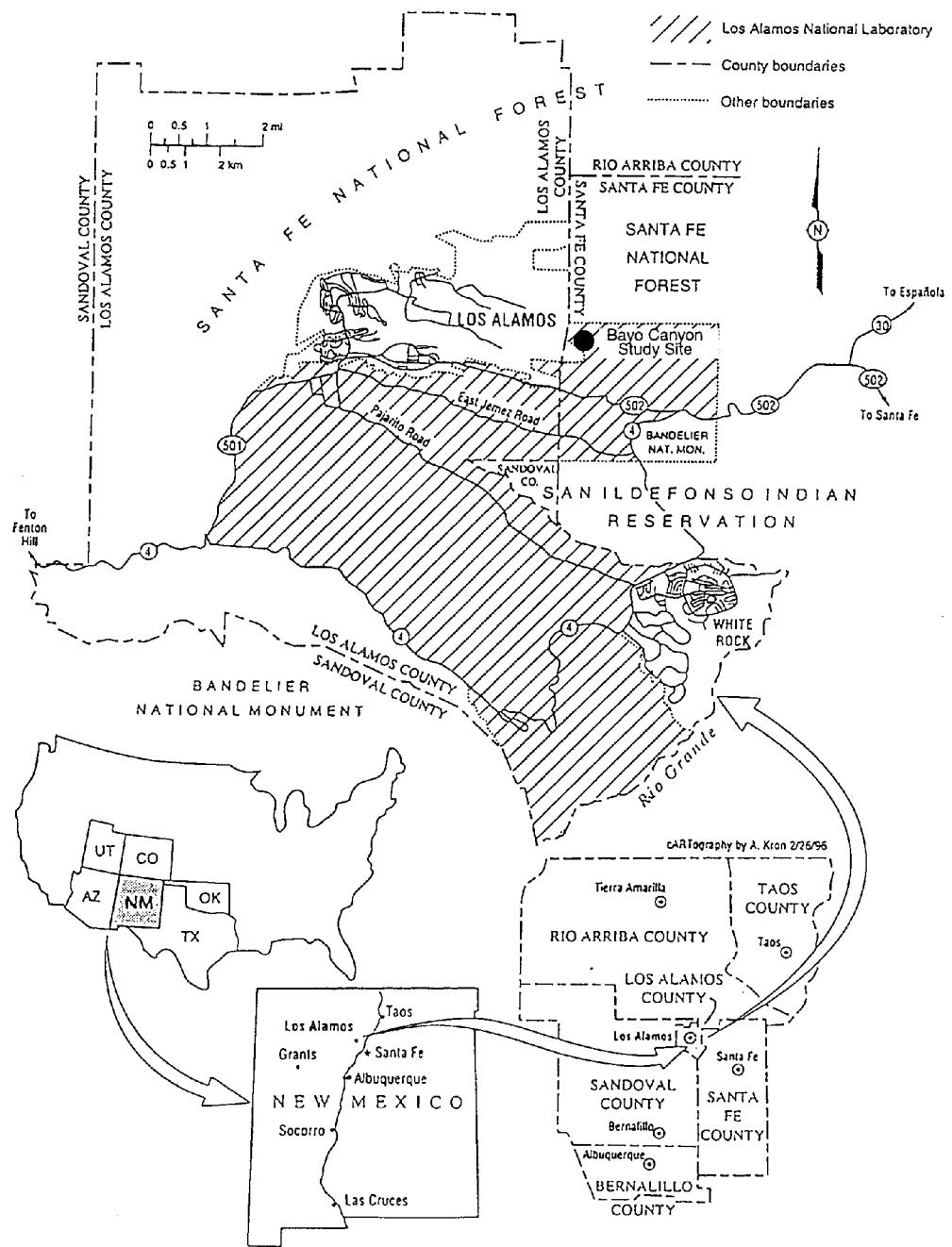


FIGURE 1. LOCATION OF THE BAYO CANYON STUDY SITE AT LANL, LOS ALAMOS, NM.

Liquid waste disposal structure TA-10-43 held lanthanum- (^{140}La) and strontium- (^{90}Sr) contaminated wastes generated by the radiochemistry laboratory (#TA-10-1) and was decommissioned and decontaminated in 1963—the structure was removed,

excavated to a depth of 5.5 m (18 ft), and backfilled with soil and building debris from other parts of the TA-10 operation [19]. In 1974, a soil subsurface investigation detected elevated levels of gross beta radioactivity near SWMU 10-003(c) [20].

Strontium-90, a beta-emitting isotope with a relatively long half-life (28 years) and a high degree of food chain mobility because of its chemical similarity to calcium (Ca), constitutes a potential long-term hazard [21]. The objective of this study was to determine the amount of ^{90}Sr uptake in deep-rooting chamisa plants from a former liquid waste disposal area and to determine the relative extent of soil-surface contamination.

PROCEDURES

Soil samples were collected underneath (understory) and between (interspace) two chamisa plant shrub canopies—those that measured the highest in beta radioactivity with field survey instrumentation—growing in Bayo Canyon with a stainless steel scoop at the 0 to 5 cm (0 to 2 in.) depth in August of 1994. Background soil samples were collected east and upwind of the site approximately 0.82 km (0.5 mi) away. At least three subsamples were collected from each zone, mixed thoroughly in a stainless steel bowl, poured into 500 ml poly bottles,

and double bagged in Ziploc containers. Similarly, plant top growth and root growth from each of the two chamisa plants were sampled by cutting the desired plant parts into 2.5 to 5.0 cm (1 to 2 in.) pieces, placing into 1 liter glass beakers, covering with tin foil, and double bagging in Ziploc containers. A background plant was also collected. All samples were transported to the Laboratory under full chain-of-custody protocols in a locked ice chest. At the Laboratory, plant samples were ashed to 500°C, transferred to labeled 500 ml poly bottles, sealed with chain-of-custody tape, and submitted along with the soil samples to an environmental chemistry group (CST-9) at LANL for the analysis of ^{90}Sr using a gas-proportional counter technique [22] and total uranium by the kinetic phosphorescence method [3].

RESULTS AND DISCUSSION

The analysis of ^{90}Sr and total uranium in chamisa plants and soils collected over SWMU 10-003(c) in Bayo Canyon at LANL and from a background area can be found in

TABLE 1. RADIONUCLIDE CONCENTRATIONS IN CHAMISA (*CHRYSOTHAMNUS NAUSEOSUS*) GROWING IN A FORMER LIQUID WASTE DISPOSAL UNIT #TA-10-43 (SWMU 10-003[C]) AT LOS ALAMOS NATIONAL LABORATORY.

Sample	^{90}Sr (Bq kg ⁻¹ ash)	Total Uranium ($\mu\text{g g}^{-1}$ ash)
SWMU chamisa plant 1		
top growth	3.35×10^6 (4.12 x 10^4) ^{ab}	0.67 (0.02)
SWMU chamisa plant 2	1.50 x 10^6 (1.85 x 10^5)	3.12 (0.62)
top growth	2.19×10^5 (2.74 x 10^4)	0.73 (0.02)
Background chamisa plant ^c	1.71 x 10^5 (2.15 x 10^4)	3.19 (0.64)
top growth	11.10 (14.8)	0.78 (0.16)
root growth	0.00 (7.4)	3.15 (0.64)

^a(+/- two counting uncertainties); values are the uncertainty in the analytical result at the 95% confidence level.

^bTo convert Bq kg⁻¹ to pCi g⁻¹, divide by 37.

^c Collected 0.82 km east and upwind of SWMU chamisa plants 1 and 2.

Tables 1 and 2, respectively.

Both chamisa plants, and especially in top-growth material, contained significantly higher concentrations of ^{90}Sr than top-growth material collected from a background chamisa plant. One chamisa plant, in fact, contained $3.35 \times 10^6 \text{ Bq kg}^{-1}$ ash ($9.05 \times 10^4 \text{ pCi g}^{-1}$ ash) of ^{90}Sr —over 300,000 times higher than the control plant. Although the amount of ^{90}Sr contamination at depth (source) is not completely known, a recent environmental restoration borehole investigation conducted approximately 0.6 to 0.9 m (2 to 3 ft) away from where the plants were collected showed $1.55 \times 10^5 \text{ Bq kg}^{-1}$ dry ($4,201 \text{ pCi g}^{-1}$ dry) of ^{90}Sr at the 4.6 (15 ft) to 4.9 m (16 ft) depth [23].

Strontium-90, a high biological mobile isotope because of its chemical similarity to Ca, is readily taken up by plants [24], and

chamisa plant roots have been shown to grow as deep as 4.1 m (13.5 ft) or more [17]. All uranium levels in top-growth and root-growth materials from chamisa plants growing over SWMU 10-003(c) were equal to uranium levels in top-growth and root-growth samples from chamisa plants collected from a background location. The higher concentrations of uranium in the roots of the chamisa plants as compared to the top-growth materials were probably due to the fact that the root samples contain more soil on the surface than does the top-growth material, which biased the analytical results.

Both understory and interspace soil samples contained ^{90}Sr at above-background concentrations; this probably occurred as a result of chamisa plant leaf fall contaminating the soil understory area followed by water and/or wind dispersal

TABLE 2. RADIONUCLIDE CONCENTRATIONS IN SOIL SURFACE SAMPLES COLLECTED UNDERNEATH AND BETWEEN CHAMISA PLANTS GROWING OVER A FORMER LIQUID WASTE DISPOSAL UNIT#TA-10-43 (SWMU 10-003[c]) AT LOS ALAMOS NATIONAL LABORATORY.

Sample	^{90}Sr (Bq kg^{-1} dry)	Total Uranium ($\mu\text{g g}^{-1}$ dry)
SWMU soil 1		
understory	7,081.8 (910.0) ^a	2.52 (0.56)
interspace	466.2 (59.2)	2.85 (1.42)
SWMU soil 2		
understory	1,387.5 (177.6)	2.60 (1.24)
interspace	592.0 (74.0)	2.54 (1.32)
Background soil ^c		
understory	3.7 (14.8)	4.83 (1.06)
interspace	51.8 (14.8)	4.98 (1.00)
RSRL ^d	30.3	4.05
SAL ^e	162.8	29.0

^a(+/- two counting uncertainties); values are the uncertainty in the analytical result at the 95% confidence level.

^bTo convert Bq kg^{-1} to pCi g^{-1} , divide by 37.

^cCollected 0.82 km east and upwind of SWMU plants/soils 1 and 2.

^dRegional Statistical Reference Level; this is the upper-limit background concentration (mean + two std dev) from Fresquez, *et al.* [30].

^eLos Alamos National Laboratory Screening Action Level from Fresquez, *et al.* [30].

contaminating the soil interspace areas. Soil collected from underneath chamisa plant #1, in fact, contained 1,914 times more ^{90}Sr than a background soil sample (3.7 Bq kg^{-1} [0.10 pCi g $^{-1}$]), which correlates very well with the chamisa plant uptake data. Interspace soil areas also contained ^{90}Sr at elevated levels ranging in concentration from 481 to 592 Bq kg $^{-1}$ dry (13 to 16 pCi g $^{-1}$ dry); the highest level was over 11 times higher than background. Moreover, both understory and interspace soil areas contained ^{90}Sr levels above the LANL screening action level (SAL) of 163 Bq kg^{-1} dry (4.4 pCi g $^{-1}$ dry) [25]. Radionuclide concentrations in soils above SALs, which are based on radiation dose levels using a risk assessment pathway computer code called RESRAD [26], initiate and require the Laboratory to further evaluate the area (i.e., site-specific baseline risk assessment, additional sampling, etc.) [27]. Although the soils data show that some migration of ^{90}Sr from the contaminated source has occurred, the levels of ^{90}Sr in sediments (3.7 Bq kg^{-1} dry [0.10 pCi g $^{-1}$ dry]) collected downstream of SWMU 10-003(c) at the Bayo Canyon/State Road 4 intersection (LANL boundary) in 1994 [28] were still within regional upper limit (background) concentrations (32 Bq kg^{-1} dry [0.87 pCi g $^{-1}$ dry]) [22]. Also, all uranium concentrations in soils collected from underneath and between chamisa plants growing over SWMU 10-003(c) were within background soil concentrations. These data correlated very well with other soil uranium background studies conducted within LANL [29] and regional off-site areas [30].

CONCLUSIONS

Deep-rooted plants like chamisa are able to translocate ^{90}Sr , a highly mobile element, from shallow low-level waste burial sites to the soil surface. Although there was some migration of ^{90}Sr from the contaminated

source, the levels of ^{90}Sr in sediments collected near the LANL boundary were within regional upper-limit background concentrations. Post revegetation management of deep-rooted plants growing in shallow low-level waste burial sites may be needed and/or biotic barriers may be required to deter plant roots from penetrating into contaminated waste materials.

ACKNOWLEDGMENT

We would like to thank John Salazar and Dale Lyons for helping with sample collection and processing. Also, thanks to Joy Ferenbaugh (graduate research assistant) and Stephanie White (undergraduate research assistant) for tabulating the data, Mary Salisbury for constructing the figure, and to Gary Allen (CST-18) and Derek Faulk (ERM/Golder) for providing site access, RFI information, and manuscript review.

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