*Radionuclide Concentrations in Soils and
Produce from Cochiti, Jemez, Taos, and
San Ildefonso Pueblo Gardens*

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RADIONUCLIDE CONCENTRATIONS IN SOILS AND PRODUCE FROM COCHITI, JEMEZ, TAOS, AND SAN ILDEFONSO PUEBLO GARDENS

by

P. R. Fresquez, D. R. Armstrong, and J. G. Salazar

ABSTRACT

Radionuclide (^3H , ^{90}Sr , ^{137}Cs , ^{238}Pu , ^{239}Pu , and total uranium) concentrations were determined in soils and produce collected from Cochiti, Jemez, Taos, and San Ildefonso Pueblo gardens. All radionuclides in soils from Pueblo areas were within or just above regional statistical (natural and/or worldwide fallout) reference levels. Similarly, the average levels of radionuclides in produce collected from Cochiti, Jemez, Taos, and San Ildefonso Pueblo gardens were not significantly different in produce collected from regional (background) locations. The effective (radiation) dose equivalent from consuming 352 lb of produce from Cochiti, Jemez, Taos, and San Ildefonso, after natural background has been subtracted, was 0.036 (± 0.016), 0.072 (± 0.051), 0.012 (± 0.027), and 0.110 (± 0.102) mrem/yr, respectively. The highest calculated dose, based on the mean + 2 std dev (95% confidence level), was 0.314 mrem/yr; this was <0.4% of the International Commission on Radiological Protection permissible dose limit for protecting members of the public.

I. INTRODUCTION

As part of the Environmental Surveillance Program at Los Alamos National Laboratory (LANL), samples of foodstuffs (produce, game animals, milk, honey, and fish) are routinely collected and analyzed for radiological constituents from surrounding communities to assess the Laboratory's impact on the human food chain. One important component of this program is the assessment of fruits, vegetables, and grains for radiological contamination—the ingestion of produce constitutes a critical pathway by which radionuclides can be transferred to humans (Nelson and Wicker 1969). Normally, radionuclide concentrations in produce collected from LANL and perimeter areas (Los Alamos townsite and White Rock/Pajarito Acres) are compared with produce samples collected from off-site regional (background) locations. Regional or background samples are collected upstream from the confluence of the Rio Grande and intermittent streams that cross Laboratory lands. These areas are also sufficiently distant from the Laboratory as to be unaffected by airborne emissions.

There are several Native American communities located in the general vicinity of LANL, and a request was made by several Pueblo Governors to assess foodstuffs on Pueblo lands for potential radiological contamination. Fruits, vegetables, herbs, pinon nuts, frogs, prairie dogs, birds, fish, deer, and elk have been suggested by the Pueblos for study. Radionuclide contents in produce (Environmental Protection Group 1995), elk (Fresquez et al. 1994a), fish (Fresquez et al. 1994b, Fresquez et al. 1995a), and bees and honey (Fresquez et al. 1994c) collected on or near several Pueblo lands have been previously reported. This study reports (1) the concentrations of various radionuclides in soils and produce collected from gardens located within and/or around four Pueblo communities: Cochiti, Jemez, Taos, and San Ildefonso, and (2) the effective (radiation) dose equivalent (EDE) to people who may consume products from these gardens.

II. METHODS

Samples of soils and produce were collected from within and/or just around Cochiti, Jemez, Taos, and San Ildefonso Pueblo areas during the 1993 growing season (Figure 1).

At each garden a soil surface subsample was collected with a 4-inch (10 cm) diameter stainless steel ring at the 0- to 2-inch (5-cm) depth. Soil subsamples were mixed in sealable plastic containers to obtain one composite sample per Pueblo area. Background samples were collected at various locations around northern New Mexico (Environmental Protection Group 1995). All soil samples were analyzed by the Environmental Chemistry Group (CST-9) for ^3H , ^{90}Sr , ^{137}Cs , ^{238}Pu , ^{239}Pu , and total uranium. All methods of soil radionuclide analysis can be found in Purtymun et al. (1987). Results are expressed as pCi/mL of soil moisture for ^3H , and on an oven-dry weight basis (dry gram) for ^{90}Sr , ^{137}Cs , ^{238}Pu , ^{239}Pu and total uranium.

Samples of produce (e.g., apples, apricots, tomatoes, cucumbers, squash, melons, pears, pumpkins, and plums) from each Pueblo area were collected and placed into labeled plastic Ziploc bags and transported back to the Laboratory in locked ice chests. Background samples were collected from the Espanola (Rio Chama and Santa Cruz River drainage area)/Santa Fe area (Environmental Protection

Group (1995). At the Laboratory, samples were washed with distilled water, towel-dried, and diced. An aliquot (≈ 100 g) from each sample was placed into 1-L beakers and heated to collect distillate (water) for ^3H analysis. The rest of the sample (≈ 1000 g) was placed into tared 1-L beakers and weighed. The beaker contents were oven-dried at 80°C for 120 h, weighed, and ashed at 500°C for 120 hrs. The sample (s) ash were weighed, pulverized, and homogenized before they were submitted with the distillate (water) sample (s) to CST-9 for the analysis of ^3H , ^{90}Sr , ^{137}Cs , ^{238}Pu , ^{239}Pu , and total uranium. All methods of radiochemical analysis of produce have been described previously (Salazar 1984). Results are expressed as pCi/mL of tissue moisture for ^3H , and on an oven-dry weight basis (dry gram) for ^{90}Sr , ^{137}Cs , ^{238}Pu , ^{239}Pu , and total uranium.

The mean radionuclide content in produce collected from each Pueblo garden was compared with produce collected from the Espanola/Santa Fe area at the 0.05 probability level using a Student's t-test. The EDE, based on a consumption rate of 160 kg (352 lb) of produce per year, was calculated using the methodology outlined in International Commission on Radiological Protection (ICRP) Publications 26 (ICRP 1977) and 30 (ICRP 1978) and the public dose conversion factors in Department of Energy report DOE/EH-0071 (DOE 1984).

III. RESULTS AND DISCUSSION

Concentrations of radionuclides in soils and produce collected from Cochiti, Jemez, Taos, and San Ildefonso Pueblo gardens during the 1993 growing season can be found in Tables 1 and 2, respectively.

All radionuclide levels, other than total uranium, in soil surface composite samples collected from Cochiti, Jemez, Taos, and San Ildefonso were within the current year's regional statistical reference level (CYRSRL) and the long-term regional statistical reference level (LTRSRL) (Table 1). Results of analyses of radionuclides (^3H , ^{90}Sr , ^{137}Cs , ^{238}Pu , ^{239}Pu , and total uranium) in soil surface samples from various locations around northern New Mexico during 1993 (Environmental Protection Group 1995) and from 1974 through 1985 (Purtymun et al. 1987) were used to establish current-year and long-term regional statistical limits, respectively, that are attributable to natural and/or worldwide fallout. The average concentration level in these samples plus twice the standard deviation of the mean was adopted as an indicator of an approximate upper-limit background.

Total uranium in soil samples collected from all of the Pueblo areas was just above the CYRSRL and the LTSRL. The difference in soil uranium concentrations between Pueblo soils and regional background soils was probably due to the fact that the

soils collected from the Pueblo gardens were from cultivated (mixed) fields, whereas the soils collected from background areas were from the surface of relatively undisturbed areas. In any case, the uranium in the garden soils was believed to be of natural origin, as the isotopic ratio of ^{235}U to ^{238}U in Cochiti (0.0081), Jemez (0.0074), Taos (0.0071), and San Ildefonso (0.0071) garden soils were within the 99% confidence level of ^{235}U to ^{238}U for naturally occurring uranium (0.0072 ± 0.0012) (Becker 1993); any values with an isotopic ratio of <0.0060 , therefore, may contain depleted uranium. Depleted uranium, a by-product of uranium enrichment processes, has been used in dynamic weapons testing at Laboratory firing sites since the mid-1940s (Becker 1992).

The average levels of radionuclides in produce collected from Cochiti, Jemez, Taos, or San Ildefonso were not significantly different from produce collected from the Espanola/Santa Fe area (Table 2). Although the concentrations of uranium in soil samples from Pueblo gardens were higher than regional statistical reference levels, the

Table 1. Radionuclides in Soils Collected from Cochiti, Jemez, Taos, and San Ildefonso Pueblo Gardens during the 1993 Growing Season.

	^3H (pCi/mL)	^{90}Sr (pCi/dry g)	Uranium (ug/dry g)	^{238}Pu (pCi/dry g)	$^{239,240}\text{Pu}$ (pCi/dry g)	^{137}Cs (pCi/dry g)
Cochiti	-0.10 (0.30) ²	0.30 ¹ (0.20)	4.22 (0.45)	0.003 (0.030)	0.005 (0.020)	0.16 (0.06)
Jemez	0.10 (0.30)	0.40 (0.20)	3.76 (0.45)	0.001 (0.030)	0.006 (0.020)	0.28 (0.06)
Taos	0.10 (0.30)	0.30 (0.20)	3.65 (0.45)	0.002 (0.030)	0.005 (0.020)	0.23 (0.07)
San Ildefonso	0.50 (0.30)	0.40 (0.20)	3.60 (0.40)	0.002 (0.030)	0.003 (0.020)	<0.08 (0.00)
CYRSRL ³	1.00	0.41	2.98	0.006	0.033	0.80
LTRSRL ⁴	7.20	0.88	3.40	0.005	0.025	1.09

¹ Numbers in bold represent detectable measurements where the analytical result was greater than two sigma (95% confidence level).

² (± 2 counting uncertainty).

³ CYRSRL (the upper-limit background concentration [mean + 2 std dev] based on data collected in 1993).

⁴ LTRSRL (the upper-limit background concentration [mean + 2 std dev] based on data collected between 1974-1986 [Purtymun et al. 1987]).

Table 2. Radionuclides in Produce Collected from Cochiti, Jemez, Taos, and San Ildefonso Pueblo Gardens during the 1993 Growing Season.¹

	³ H (pCi/mL)	⁹⁰ Sr (10 ⁻³ pCi/dry g)	Uranium (ng/dry g)	²³⁸ Pu (10 ⁻⁵ pCi/dry g)	^{239,240} Pu (10 ⁻⁵ pCi/dry g)	¹³⁷ Cs (10 ⁻³ pCi/dry g)
Cochiti						
apples	0.0 (0.6) ²	5.6 (5.6)	1.8 ³ (0.4)	8.4 (112.0)	11.2 (168.0)	-4.4 (14.0)
pumpkin	-0.1 (0.6)	38.6 (38.6)	7.3 (1.5)	19.3 (772.0)	0.0 (1158.0)	-5.7 (14.0)
tomatoes	0.0 (0.6)	65.6 (32.8)	5.1 (1.0)	49.2 (656.0)	16.4 (984.0)	-9.7 (14.4)
cucumbers	0.1 (0.6)	73.0 (58.4)	9.9 (1.9)	0.0 (584.0)	14.6 (876.0)	-4.5 (11.8)
squash	-0.1 (0.6)	13.8 (13.8)	1.7 (0.3)	6.9 (276.0)	0.0 (414.0)	-2.7 (6.0)
Mean	-0.0 (0.6) ⁴	39.0 (60.0)	5.2 (7.0)	16.8 (38.8)	8.4 (15.8)	-5.4 (5.2)
Jemez						
pears	0.5 (0.6)	6.6 (4.4)	0.7 (0.1)	4.4 (88.0)	4.4 (132.0)	-6.5 (23.2)
apples	0.3 (0.6)	8.4 (5.6)	1.0 (0.2)	8.4 (112.0)	8.4 (168.0)	-10.3 (24.4)
melons	0.0 (0.6)	99.2 (24.8)	12.4 (4.6)	24.8 (496.0)	74.4 (744.0)	-51.6 (118.8)
melons	0.4 (0.6)	86.4 (19.2)	0.4 (0.2)	19.2 (384.0)	28.8 (576.0)	-62.6 (89.8)
pears	0.2 (0.6)	20.3 (5.8)	1.0 (0.2)	11.6 (116.0)	8.7 (174.0)	6.4 (22.6)
cucumbers	0.1 (0.6)	32.1 (21.4)	5.4 (1.8)	21.4 (428.0)	21.4 (642.0)	-52.6 (109.4)
Mean	0.3 (0.4)	42.1 (80.8)	3.4 (9.4)	15.0 (16.0)	24.4 (52.4)	-29.5 (58.6)
Taos						
apples	-0.2 (0.6)	0.0 (5.4)	1.1 (0.2)	0.0 (108.0)	8.1 (162.0)	-0.0 (2.4)
pumpkin	0.0 (0.6)	30.6 (20.4)	2.6 (0.9)	10.2 (408.0)	51.0 (612.0)	-3.9 (8.2)
squash	-0.1 (0.6)	69.0 (34.0)	6.7 (1.3)	0.0 (692.0)	34.6 (1038.0)	0.5 (14.8)
tomatoes	-0.1 (0.6)	0.0 (6.0)	0.8 (0.2)	9.0 (120.0)	18.0 (180.0)	-5.0 (9.4)
apples	-0.1 (0.6)	3.7 (7.4)	1.1 (0.2)	11.1 (148.0)	7.4 (222.0)	-9.9 (12.8)
Mean	-0.1 (0.1)	20.0 (60.0)	2.4 (4.8)	6.1 (11.2)	23.8 (37.4)	-3.6 (8.5)

Table 2. (Cont.)

	³ H (pCi/mL)	⁹⁰ Sr (10 ⁻³ pCi/dry g)	Uranium (ng/dry g)	²³⁸ Pu (10 ⁻⁵ pCi/dry g)	^{239,240} Pu (10 ⁻⁵ pCi/dry g)	¹³⁷ Cs (10 ⁻³ pCi/dry g)
San Ildefonso						
squash	-0.1 (0.6)	225.5 (82.0)	6.4 (1.3)	20.5 (820.0)	20.5 (1230.0)	-1.4 (17.2)
squash	0.3 (0.6)	65.0 (26.0)	2.5 (0.5)	0.0 (520.0)	13.0 (780.0)	-6.2 (11.2)
pumpkin	-0.1 (0.6)	89.6 (22.4)	4.3 (1.8)	0.0 (448.0)	11.2 (672.0)	-1.7 (15.6)
pumpkin	0.0 (0.6)	59.4 (19.8)	2.4 (0.5)	0.0 (396.0)	9.9 (594.0)	16.6 (14.4)
plums	-0.2 (0.6)	0.0 (8.2)	2.0 (0.4)	20.5 (164.0)	213.2 (246.0)	-2.0 (3.4)
<i>Mean</i>	-0.0 (0.4)	87.9 (167.2)	3.5 (3.6)	8.2 (22.4)	53.6 (178.6)	1.1 (17.8)
Espanola/Santa Fe						
cucumbers	0.6 (0.6)	35.4 (23.6)	15.4 (3.1)	35.4 (472.0)	-23.6 (708.0)	-132.2 (123.0)
pumpkin	0.4 (0.6)	37.6 (18.8)	12.5 (2.5)	9.4 (376.0)	0.0 (564.0)	-2.1 (63.6)
squash	0.3 (0.6)	48.0 (32.0)	12.7 (2.5)	-144.0 (640.0)	-64.0 (960.0)	-46.6 (129.0)
peaches	0.5 (0.6)	20.4 (20.2)	2.8 (0.9)	40.8 (408.0)	20.4 (612.0)	0.5 (98.8)
apples	-0.1 (0.6)	3.9 (7.8)	0.5 (0.3)	0.0 (156.0)	11.7 (234.0)	0.6 (31.8)
apples	-0.1 (0.6)	3.0 (6.0)	2.1 (1.3)	3.0 (120.0)	117.0 (180.0)	-9.0 (26.0)
apricots	0.5 (0.6)	15.4 (15.5)	3.9 (1.1)	0.0 (308.0)	7.7 (462.0)	-7.6 (25.8)
apples	0.4 (0.6)	0.0 (5.6)	1.1 (0.2)	0.0 (112.0)	22.4 (168.0)	-20.0 (27.0)
plums	0.1 (0.6)	20.4 (40.8)	14.0 (2.8)	20.4 (816.0)	20.4 (1224.0)	-6.4 (18.0)
squash	0.1 (0.6)	27.8 (27.8)	5.1 (1.0)	0.0 (556.0)	27.8 (834.0)	14.3 (96.0)
<i>Mean</i>	0.3 (0.5)	21.2 (32.2)	7.0 (11.6)	-3.5 (103.4)	14.0 (91.2)	-20.8 (84.6)
CYRSRL⁵	0.8	53.4	18.6	99.9	105.2	63.8
LTRSRL⁶	16.9	75.6	38.2	35.4	67.9	690.1

¹ There are no concentration guides for produce; however, all mean radionuclide contents in produce collected from Pueblo areas were not significantly different from background using a Student's t-test at the 0.05 probability level.

² (+2 counting uncertainty).

³ Numbers in bold represent detectable measurements—where the analytical result was greater than two sigma (95% confidence level).

⁴ (+2 standard deviation).

⁵ CYRSRL (the upper limit background concentration [mean + 2 std dev] based on data collected in 1993).

⁶ LTRSRL (the upper limit background concentration [mean + 2 std dev] based on data collected between 1978 to 1993 [Fresquez et al. 1995]).

levels of uranium in produce samples collected from all of the Pueblo areas were similar to uranium concentrations in produce collected from background locations.

None of the samples collected from any of the Pueblo gardens had measureable ^3H , ^{238}Pu , or ^{239}Pu values (i.e., where the analytical value was greater than two sigma); most samples from Pueblo and background gardens, on the other hand, had measureable ^{90}Sr and uranium activity, and one sample, a pumpkin from San Ildefonso, had detectable ^{137}Cs . Of all the detectable values (^{90}Sr , ^{137}Cs , and uranium), only a few ^{90}Sr measurements exceeded the LTRSRL, however. These ^{90}Sr values were associated with melons, pumpkins, and squash collected from Jemez and San Ildefonso Pueblo gardens. Because soil ^{90}Sr concentrations from both Jemez and San Ildefonso Pueblo gardens were within background fallout levels, the elevated ^{90}Sr values in melons, pumpkins, and squash collected from these areas as compared to background was probably from cross-contamination; i.e., the samples were contaminated from other sources within the processing laboratory and/or probably were not washed very well before they were ashed for analysis. Vegetables, such as melons, pumpkins, and squash, that grow directly on the soil surface may contain a significant amount of soil residues on the underside of the fruit and may be impossible to (completely) remove.

The EDE from consuming 160 kg (352 lb) of produce from Cochiti, Jemez, Taos, and San Ildefonso Pueblo gardens, after subtracting natural background, was 0.036 (± 0.016), 0.072 (± 0.051), 0.012 (± 0.027), and 0.110 (± 0.102) mrem/yr, respectively. The highest calculated dose, based on the mean + 2 std dev (95% confidence level), was 0.314 mrem/yr (San Ildefonso); this was still $<0.4\%$ of the ICRP permissible dose limit of 100 mrem/yr from all pathways. Laboratory operations, therefore, do not result in significant, if any, doses to people that may consume produce growing in the vicinity of Cochiti, Jemez, Taos, and San Ildefonso Pueblos.

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