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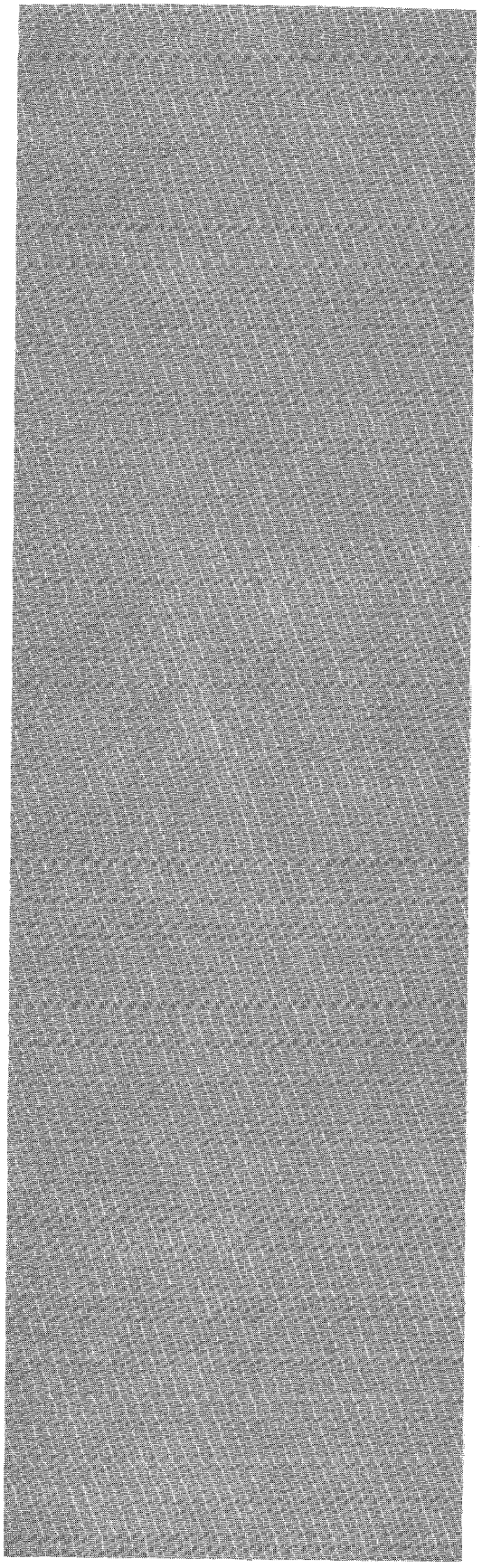

# *Tritium Concentrations in Bees and Honey at Los Alamos National Laboratory*



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# *Tritium Concentrations in Bees and Honey at Los Alamos National Laboratory*

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# TRITIUM CONCENTRATIONS IN BEES AND HONEY AT LOS ALAMOS NATIONAL LABORATORY

by

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

## ABSTRACT

**Los Alamos National Laboratory (LANL) has maintained a network of honey bee colonies at LANL, perimeter (Los Alamos townsite and White Rock/Pajarito Acres) and regional (background) areas for over 15 years; the main objective of this honey bee network was to help determine the bioavailability of certain radionuclides in the environment. Of all the radionuclides studied ($^{3}H$, $^{57}Co$, $^{7}Be$, $^{22}Na$, $^{54}Mn$, $^{83}Rb$, $^{137}Cs$, $^{238}Pu$, $^{239}Pu$, $^{90}Sr$ and total U), tritium was consistantly detected in bees and was most readily transferred to the honey. In fact, honey collected from hives located at TA-21, TA-33, TA-50, TA-53, and TA-54 and from White Rock/Pajarito Acres contained significantly higher concentrations of $^{3}H$ than regional background hives. Based on the average concentration of all radionuclides measured over the years, the effective dose equivalent (EDE) from consuming 5 kg (11 lb) of honey collected from Los Alamos (townsite) and White Rock/Pajarito Acres, after regional background has been subtracted, was 0.0186 ($\pm$0.0507) and 0.0016 ($\pm$0.0010) mrem/yr, respectively. The highest EDE, based on the mean + 2SD (95% confidence level), was 0.1200 mrem/y; this was <0.2% of the International Commission on Radiological Protection permissible dose limit of 100 mrem/yr from all pathways.**

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## INTRODUCTION

Honey bees are effective monitors of environmental pollution (Bromenshenk 1990); they forage for pollen and nector over a large area (e.g., 7 sq km) (Wallwork-Barber et al. 1982), accumulate contaminants from all three media (e.g., air, water and soil) (Bromenshenk et al. 1985), and return to a fixed location (the hive) for sampling (Simmons et al. 1990). The distribution of pesticides (Anderson and Wojtas 1986), polychlorinated biphenyls (Morse et al. 1987), heavy metals (Crane 1984), and radionuclides (Hakonson and Bostick 1976) have all been assessed using honey bee colony networks. Hakonson and Bostick (1976) found bee colonies useful in determining the bioavailability of $^{3}H$, $^{137}Cs$, and plutonium in the Los Alamos area.

Los Alamos National Laboratory (LANL) has maintained a network of beehives in potentially contaminated and noncontaminated (background) areas for over 15 years. Both bees and honey are sampled for various heavy metals and radionuclides. Of all the radionuclides studied (e.g., $^{3}H$, $^{57}Co$, $^{7}Be$, $^{22}Na$, $^{54}Mn$, $^{83}Rb$, $^{137}Cs$, $^{238}Pu$, $^{239}Pu$, $^{90}Sr$, and total U), tritiated water was most readily collected by bees and transferred to the honey. The consumption of honey constitutes one pathway by which radionuclides can be transferred to humans (White et al. 1983, Gladney et al. 1982).

This report summarizes $^{3}H$ concentrations in bee and honey collected from LANL (onsite), perimeter (Los Alamos and White Rock/Pajarito Acres) and regional (background) locations over a 15-yr period. Also, the total effective (radiation) dose equivalent (EDE) was estimated for people that may consume honey collected from perimeter areas. Honey collected from onsite hives is not available for public consumption.

## METHODS

Bee and honey samples were collected from 12 onsite (LANL), two perimeter (Los Alamos and White Rock/Pajarito Acres/TA-36) and five background locations (San Pedro, San Juan, Pojoaque, El Rancho, and/or Chimayo) (Figure 1). At each hive, approximately 500 g of forager bees and two frames of honey were collected; samples were placed into clean Ziploc bags, marked for identification, and transported to the Laboratory in locked ice chests.

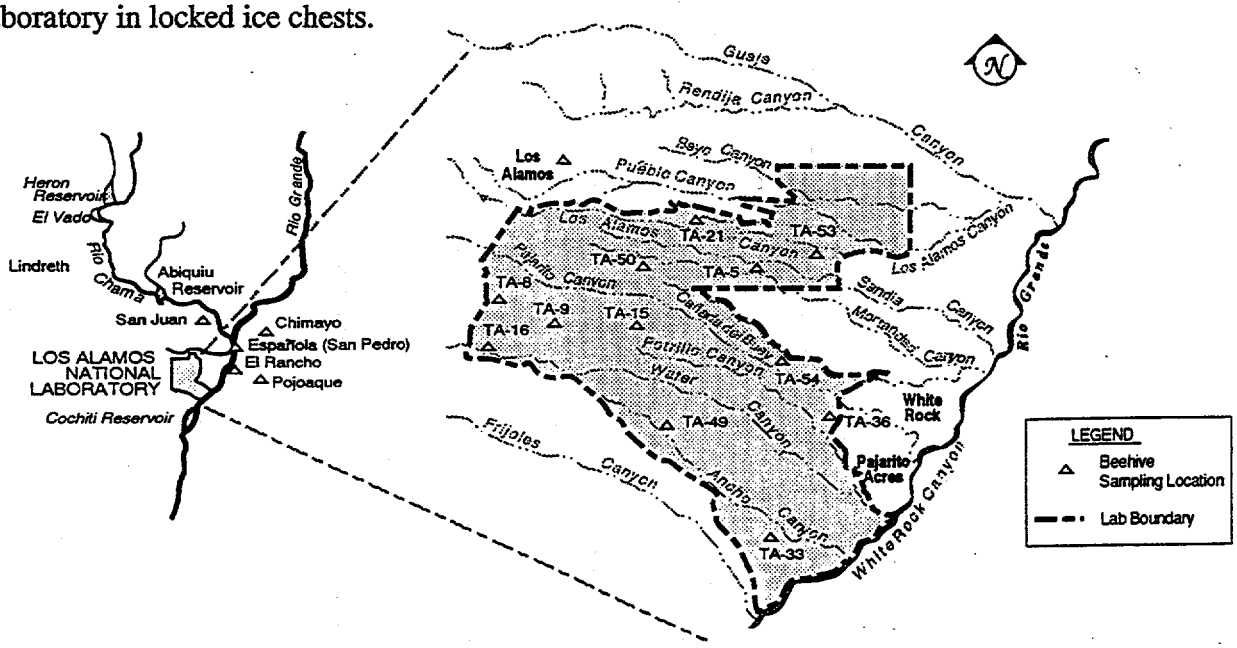


Figure 1. Locations of beehives on LANL, perimeter, and regional areas.

At the Laboratory, 5 mL of moisture was distilled from each sample, mixed with 15 mL of a scintillation solution, and counted on a scintillation counter for 50 min by the Environmental Chemistry Group (CST-9) (Salazar 1984).

Variations in mean $^{3}H$ concentrations between potentially contaminated (i.e., LANL and perimeter) and regional (background) areas were analyzed using a Student's t-test at the 0.05 and 0.01 probability level on natural log-transformed data (Gilbert 1987). All of the data used in this report was compiled from LANL Environmental Surveillance Reports 1979 to 1993.

The EDE--based on all radionuclides averaged over the years--was calculated using the methodology outlined in International Commission on Radiological Protection (ICRP) Publication 30 (ICRP 1978) and the public dose conversion factors in Department of Energy (DOE) report DOE/EH-0071 (USDOE 1984).

## RESULTS

### Honey Bees

Concentrations of $^{3}H$ in honey bees collected from LANL, perimeter, and regional (background) areas from 1982 to 1993 are presented in Table 1.

Tritium in bees collected from onsite areas ranged in concentration from 0.30 to 3,300.00 pCi/mL. Most hives on LANL lands in almost every year contained bees with $^{3}H$ above the upper limit background concentration(s), i.e., the levels were greater than the (background) mean for a particular year plus twice the standard deviation. The highest $^{3}H$ concentrations in bees were detected from hives located at the Los Alamos Meson Physics Facility (LAMPF) at TA-53 and at the radioactive waste disposal site (Area G) at TA-54. Concentrations of $^{3}H$ in bees collected from perimeter areas--Los Alamos and White Rock/Pajarito Acres--ranged from 0.10 to 1.80 pCi/mL and from 1.10 to 34.60 pCi/mL, respectively. The upper limit background concentration for $^{3}H$ in bees collected from regional (background) hives over a 12-yr period was 3.60 pCi/mL.

Based on the average concentration of $^{3}H$ over the years, bees collected from TA-5, TA-8, TA-15, TA-21, TA-33, TA-50, TA-53, TA-54, and White Rock/Pajarito Acres had a significantly higher $^{3}H$ concentration than bees collected from background areas.

### Honey

Concentrations of $^{3}H$ in honey collected from LANL, perimeter, and regional (background) areas from 1979 to 1993 are presented in Table 2.

Tritium in honey collected from on-site areas ranged in concentration from -0.20 to 7,600.00 pCi/mL. Again, $^{3}H$ concentrations in honey from most LANL hives and in most years were greater than the respective upper limit background concentration; and,

particularly at TA-53 (LAMPF) and TA-54 (Area G). Concentrations of $^{3}H$ in honey collected from perimeter locations--Los Alamos and White Rock/Pajarito Acres--ranged in concentration from 0.10 to 860.00 pCi/mL and from 0.20 to 60.00 pCi/mL, respectively. The upper limit background concentration for $^{3}H$ in honey collected from regional hives over a 15-yr period was 21.22 pCi/mL.

Overall, the concentration of $^{3}H$ in honey collected from hives located at TA-21, TA-33, TA-50, TA-53, TA-54, and White Rock/Pajarito Acres was significantly higher than background.

**Total Effective Dose Equivalent**

Based on the average concentration of radionuclides ($^{3}H$, $^{57}Co$, $^{7}Be$, $^{22}Na$, $^{54}Mn$, $^{83}Rb$, $^{137}Cs$, $^{238}Pu$, $^{239}Pu$, $^{90}Sr$, and total U) over the years (Table 3), the EDE from consuming 5 kg (11 lb) of honey collected from Los Alamos (townsite) and White Rock/Pajarito Acres, after regional background has been subtracted, was 0.0186 ($\pm$0.0507) and 0.0016 ($\pm$0.0010) mrem/yr, respectively. Although $^{3}H$ in honey collected from the Los Alamos area was not significantly different from background, a higher EDE was measured for Los Alamos than for the White Rock/Pajarito Acres area. The higher EDE in Los Alamos as compared to White Rock/Pajarito Acres was the result of one very-high $^{3}H$ result (860 pCi/mL), recorded in 1985, that increased the overall ($^{3}H$) average for Los Alamos. In 1985 the Laboratory released 8,638 Ci of $^{3}H$ to the atmosphere and 76,850 mCi of $^{3}H$ to the canyons as liquid effluents (Environmental Protection Group 1986); that, apparently, affected the Los Alamos townsite area more than the White Rock/Pajarito Acres area.

In conclusion, the highest EDE, based on the mean + 2SD (95% confidence level), was 0.1200 mrem/y; this was <0.2% of the ICRP permissible dose limit of 100 mrem/yr from all pathways. Therefore, Laboratory contributions to doses received from honey consumption, especially from $^{3}H$, pose no threat to the health and safety of the general public.

**ACKNOWLEDGMENT**

Special thanks to Belinda Harrigan for constructing the figure, and to Tim Haarmann (GRA), Dale Lyons (UGS) and Bryan Velasquez (SEED II) for compiling and tabulating the data. Also, many thanks to Robert Hayes, beekeeper, who has maintained the LANL beehive network for over 15 years.

**Table 1. Tritium concentrations (pCi/mL) in bees collected from on-site (LANL), perimeter (Los Alamos/White Rock/TA-36), and regional (background) areas between 1982 and 1993.[1]**

| | 1982 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | Mean |
|---|---|---|---|---|---|---|---|---|---|---|
| **ON-SITE (LANL)** | | | | | | | | | | |
| TA-5 | -.-[2] | 14.00 | 5.70 | 30.00 | 44.00 | 7.20 | 0.99 | 20.90 | 6.50 | 16.20** |
| | -.- | (4.00)[3] | (1.40) | (6.00) | (8.00) | (1.60) | (0.60) | (2.80) | (1.60) | (27.45)[4] |
| TA-8 | 1.80 | 7.70 | 4.70 | 0.70 | 1.80 | 3.50 | 0.53 | 14.60 | 0.60 | 3.99* |
| | -.- | (1.80) | (1.20) | (0.60) | (0.80) | (1.00) | (0.60) | (2.40) | (0.60) | (9.25) |
| TA-9 | -.- | 12.00 | 1.60 | 0.30 | 1.50 | 5.70 | 0.66 | 1.10 | 0.60 | 2.93 |
| | -.- | (2.00) | (1.20) | (0.60) | (0.60) | (1.40) | (0.60) | (0.60) | (0.60) | (8.09) |
| TA-15 | -.- | 5.30 | 2.20 | 2.30 | 780.00 | 2.40 | 5.26 | 13.10 | 6.90 | 102.18** |
| | -.- | (1.40) | (0.80) | (0.80) | (160.00) | (0.80) | (1.05) | (2.20) | (1.60) | (547.81) |
| TA-16 | -.- | -.- | 1.10 | 6.80 | 5.20 | 4.40 | 0.37 | 0.30 | 1.10 | 2.75 |
| | -.- | -.- | (0.80) | (1.60) | (1.20) | (1.00) | (0.60) | (0.60) | (0.60) | (5.31) |
| TA-21 | 3.60 | -.- | 23.00 | 6.70 | 18.00 | 19.00 | 8.15 | 16.10 | 4.90 | 12.43** |
| | -.- | -.- | (4.00) | (1.60) | (4.00) | (4.00) | (1.63) | (2.40) | (1.40) | (14.84) |
| TA-33 | 35.00 | 8.70 | 30.00 | 4.90 | 430.00 | 47.00 | 14.09 | 13.50 | 9.90 | 65.89** |
| | -.- | (2.00) | (6.00) | (1.20) | (80.00) | (10.00) | (2.82) | (2.20) | (2.00) | (274.53) |
| TA-35 | -.- | 21.00 | -.- | -.- | -.- | -.- | -.- | -.- | -.- | 21.00 |
| | -.- | (4.00) | -.- | -.- | -.- | -.- | -.- | -.- | -.- | (0.00) |
| TA-49 | -.- | -.- | 2.00 | 0.60 | 8.60 | 5.60 | 0.92 | 1.60 | 0.80 | 2.87 |
| | -.- | -.- | (0.80) | (0.60) | (2.00) | (1.40) | (0.60) | (0.80) | (0.60) | (6.10) |
| TA-50 | -.- | -.- | 3.60 | 63.00 | 190.00 | 25.00 | 1.75 | 1.70 | 15.60 | 42.95** |
| | -.- | -.- | (1.00) | (12.00) | (4.00) | (6.00) | (0.60) | (0.80) | (2.40) | (136.73) |
| TA-53 | 15.00 | 6.10 | 16.00 | 110.00 | 3,300.00 | 55.00 | 4.91 | 21.70 | 245.70 | 419.37** |
| | -.- | (1.60) | (4.00) | (20.00) | (600.00) | (12.00) | (0.98) | (2.80) | (11.40) | (2,166.06) |
| TA-54 | 38.00 | -.- | 260.00 | 130.00 | 1,800.00 | 760.00 | 24.11 | 411.80 | 54.40 | 434.79** |
| | -.- | -.- | (60.00) | (20.00) | (400.00) | (160.00) | (4.80) | (16.20) | (4.60) | (1,210.00) |

## Table 1. (Cont.)

| | 1982 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | Mean |
|---|---|---|---|---|---|---|---|---|---|---|
| **PERIMETER** | | | | | | | | | | |
| Los Alamos | 1.80 | -.- | -.- | -.- | 0.10 | -.- | -.- | -.- | 0.60 | 0.83 |
| Townsite | -.- | -.- | -.- | -.- | (0.60) | -.- | -.- | -.- | (0.60) | (1.75) |
| White Rock/ | 11.00 | 4.60 | 3.10 | 10.00 | -.- | -.- | -.- | -.- | 34.60 | 12.66** |
| Pajarito Acres/ | -.- | (1.20) | (1.00) | (2.00) | -.- | -.- | -.- | -.- | (3.60) | (25.45) |
| TA-36 | | | | | | | | | | |
| **REGIONAL (Background)** | | | | | | | | | | |
| Chimayo | 0.70 | 2.40 | 4.00 | -.- | 0.20 | 1.50 | -.- | -.- | -.- | 1.76 |
| | -.- | (1.00) | (1.20) | -.- | (0.60) | (0.60) | -.- | -.- | -.- | (3.01) |
| El Rancho | -.- | -.- | -.- | 0.40 | 0.70 | -.- | -.- | -.- | -.- | 0.55 |
| | -.- | -.- | -.- | (0.60) | (0.60) | -.- | -.- | -.- | -.- | (0.42) |
| Pojoaque | -.- | -.- | -.- | -.- | -.- | -.- | 0.61 | 0.20 | 0.80 | 0.54 |
| | -.- | -.- | -.- | -.- | -.- | -.- | (0.60) | (0.60) | (0.60) | (0.61) |
| San Juan | -.- | -.- | 3.20 | -0.20 | 0.30 | 0.70 | 0.40 | 0.10 | 0.40 | 0.70 |
| | -.- | -.- | (1.00) | (0.60) | (0.60) | (0.60) | (0.60) | (0.60) | (0.60) | (2.28) |
| San Pedro | -.- | 5.00 | 1.10 | 0.30 | -.- | 0.80 | 0.69 | 0.20 | 0.60 | 1.24 |
| | -.- | (1.40) | (0.80) | (0.60) | -.- | (0.60) | (0.60) | (0.60) | (0.60) | (3.37) |
| Mean | 0.70 | 3.70 | 2.77 | 0.17 | 0.40 | 1.00 | 0.56 | 0.17 | 0.60 | 1.12 |
| | (0.00)[4] | (3.68) | (3.00) | (0.64) | (0.53) | (0.87) | (0.30) | (0.12) | (0.40) | (2.48) |

[1] The collection and analysis of bees was not conducted between 1983 and 1985.

[2] -.- analysis not performed, lost in analysis, or not reported in the Environmental Surveillance Report(s).

[3] (±2 counting uncertainty).

[4] (±2 standard deviation).

* Significantly different from regional (background) at the 0.05 level using a Student's t-test on natural log-transformed data.

** Significantly different from regional (background) at the 0.01 level using a Student's t-test on natural log-transformed data.

**Table 2. Tritium concentrations (pCi/mL) in honey collected from on-site (LANL), perimeter (Los Alamos/White Rock/TA-36), and regional (background) areas between 1979 and 1993.**

| | 1979 | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | Mean |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **ON-SITE (LANL)** | | | | | | | | | | | | | | | | |
| TA-5 | 11.80 | 27.40 | 13.60 | 7.20 | -.-[1] | 12.00 | 10.00 | 8.40 | 7.70 | 1.00 | 1.60 | 4.90 | 0.10 | 0.80 | 0.60 | 7.65 |
| | -.- | -.- | -.- | -.- | -.- | -.- | (2.00)[2] | (2.00) | -.- | (0.60) | (0.80) | (0.60) | (0.60) | (0.60) | (0.60) | (14.78)[3] |
| TA-8 | -.- | -.- | -.- | -.- | 7.70 | 4.80 | 59.00 | 0.40 | 5.90 | 1.60 | 2.60 | 0.80 | 0.40 | 0.50 | -.- | 8.37 |
| | -.- | -.- | -.- | -.- | -.- | -.- | (12.00) | (0.80) | -.- | (0.60) | (0.80) | (0.60) | (0.60) | (0.60) | -.- | (35.95) |
| TA-9 | -.- | -.- | -.- | -.- | -.- | 1.70 | 13.00 | 4.50 | 1.00 | 0.10 | 1.40 | 0.80 | 0.20 | 29.10 | -0.40 | 5.14 |
| | -.- | -.- | -.- | -.- | -.- | -.- | (2.00) | (0.80) | -.- | (0.60) | (0.60) | (0.60) | (0.60) | (3.40) | (0.60) | (18.60) |
| TA-15 | -.- | -.- | -.- | -.- | -.- | 4.20 | 26.00 | 4.30 | 0.50 | 0.60 | 3.00 | 1.00 | 5.40 | 1.20 | 0.60 | 4.60 |
| | | | | -.- | -.- | -.- | 6.00 | (1.20) | -.- | (0.60) | (1.00) | (0.60) | (0.60) | (0.80) | (0.60) | (15.42) |
| TA-16 | 2.80 | 5.20 | 3.10 | 11.00 | -.- | -.- | -.- | -.- | 0.00 | 0.50 | 0.30 | 0.50 | 0.70 | 1.50 | 0.10 | 2.34 |
| | -.- | -.- | -.- | -.- | -.- | -.- | -.- | -.- | -.- | (0.60) | (0.60) | (1.20) | (0.60) | (0.80) | (0.60) | (6.60) |
| TA-21 | 5.80 | 5.60 | 18.20 | 9.00 | 81.00 | 29.00 | 6,200.00 | 7.50 | 14.00 | 3.90 | 31.00 | 110.00 | 9.10 | 49.90 | 12.00 | 439.07** |
| | -.- | -.- | -.- | -.- | -.- | -.- | (1,200.00) | (1.80) | -.- | (1.00) | (6.00) | (20.00) | (1.80) | (5.50) | (2.20) | (3,188.02) |
| TA-33 | 579.00 | 207.00 | 156.00 | 92.50 | 73.00 | 99.00 | 67.00 | 33.00 | 14.00 | 38.00 | 55.00 | 240.00 | 12.40 | 25.10 | -0.20 | 112.72** |
| | -.- | -.- | -.- | -.- | -.- | -.- | (14.00) | (6.00) | -.- | (8.00) | (12.00) | (40.00) | (0.66) | (3.00) | (0.60) | (294.79) |
| TA-35 | -.- | -.- | -.- | -.- | -.- | -.- | -.- | 8.40 | -.- | -.- | -.- | -.- | -.- | -.- | -.- | 8.40 |
| | -.- | -.- | -.- | -.- | -.- | -.- | -.- | (2.00) | -.- | -.- | -.- | -.- | -.- | -.- | -.- | (0.00) |
| TA-49 | -.- | -.- | -.- | -.- | -.- | -.- | -.- | -.- | 2.20 | 1.10 | 7.10 | 1.30 | 0.10 | 2.50 | 0.50 | 2.11 |
| | -.- | -.- | -.- | -.- | -.- | -.- | -.- | -.- | -.- | (0.60) | (1.60) | (0.60) | (0.60) | (1.00) | (0.60) | (4.37) |
| TA-50 | 26.70 | 17.90 | 63.50 | 17.60 | 31.00 | 12.00 | 73.00 | -.- | 11.00 | 1.30 | 7.10 | 9.10 | 1.80 | 4.30 | 2.10 | 19.89** |
| | -.- | -.- | -.- | -.- | -.- | -.- | 14.00 | -.- | -.- | (0.60) | (1.60) | (2.00) | (0.60) | (0.60) | (0.80) | (44.91) |
| TA-53 | -.- | -.- | -.- | 11.20 | 9.80 | 50.00 | 7,600.00 | 0.12 | 65.00 | 61.00 | 74.00 | 420.00 | 6.40 | 32.70 | 117.90 | 704.01** |
| | -.- | -.- | -.- | -.- | -.- | -.- | (1,600.00) | (0.02) | -.- | (12.00) | (16.00) | (80.00) | (1.20) | (3.60) | (7.20) | (4,349.29) |
| TA-54 | 9.60 | 21.40 | 27.00 | 29.40 | 29.00 | 37.00 | -.- | -.- | 92.00 | 0.20 | 370.00 | 54.00 | 95.30 | 94.70 | 238.00 | 84.43** |
| | -.- | -.- | -.- | -.- | -.- | -.- | -.- | -.- | -.- | (0.60) | (80.00) | (10.00) | (16.00) | (6.40) | (11.00) | (211.86) |

## Table 2. (Cont.)

| | 1979 | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | Mean |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **PERIMETER** | | | | | | | | | | | | | | | | |
| Los Alamos | 3.60 | 4.00 | 12.70 | 12.30 | 0.22 | -.- | 860.00 | -.- | -.- | -.- | 0.10 | -.- | -.- | -.- | 0.30 | 111.65 |
| Townsite | -.- | -.- | -.- | -.- | -.- | -.- | (180.00) | -.- | -.- | -.- | (0.60) | -.- | -.- | -.- | (0.60) | (604.84) |
| White Rock/ | 10.50 | 7.90 | -.- | 3.20 | 4.90 | 4.00 | 9.00 | 2.30 | 20.00 | 0.20 | -.- | -.- | -.- | -.- | 37.30 | 9.93* |
| Pajarito Acres/ | -.- | -.- | -.- | -.- | -.- | -.- | (2.00) | (0.80) | -.- | (0.60) | -.- | -.- | -.- | -.- | (8.60) | (22.26) |
| TA-36 | | | | | | | | | | | | | | | | |
| **REGIONAL (Background)** | | | | | | | | | | | | | | | | |
| Chimayo | 0.60 | 3.00 | 6.30 | 1.30 | 4.80 | 0.80 | 9.00 | 0.30 | 5.00 | -.- | 0.60 | 2.40 | -.- | -.- | -.- | 3.1 |
| | -.- | -.- | -.- | -.- | -.- | -.- | (2.00) | (0.80) | -.- | -.- | (0.60) | (0.80) | -.- | -.- | -.- | (5.69) |
| El Rancho | -.- | -.- | -.- | -.- | -.- | -.- | -.- | -.- | -.- | 0.30 | 0.00 | -.- | -.- | -.- | -.- | 0.15 |
| | -.- | -.- | -.- | -.- | -.- | -.- | -.- | -.- | -.- | (0.60) | (0.60) | -.- | -.- | -.- | -.- | (0.42) |
| Pojoaque | -.- | -.- | -.- | -.- | -.- | -.- | -.- | -.- | -.- | -.- | -.- | -.- | 0.30 | 0.30 | 0.50 | 0.37 |
| | -.- | -.- | -.- | -.- | -.- | -.- | -.- | -.- | -.- | -.- | -.- | -.- | (0.60) | (0.60) | (0.60) | (0.23) |
| San Juan | -.- | -.- | -.- | -.- | -.- | -.- | -.- | -.- | 0.40 | 1.60 | 0.20 | 0.40 | -0.10 | 0.70 | -0.30 | 0.41 |
| | -.- | -.- | -.- | -.- | -.- | -.- | -.- | -.- | -.- | (0.60) | (0.60) | (0.40) | (0.60) | (0.60) | (0.60) | (1.24) |
| San Pedro | -.- | -.- | -.- | -.- | 3.10 | 4.10 | 60.00 | 1.40 | 6.00 | 0.50 | -.- | 0.30 | 0.00 | 0.20 | 0.00 | 7.56 |
| | -.- | -.- | -.- | -.- | -.- | -.- | (12.00) | (0.80) | -.- | (0.60) | -.- | (0.40) | (0.60) | (0.60) | (0.60) | (37.08) |
| Mean | 0.60 | 3.00 | 6.30 | 1.30 | 3.95 | 2.45 | 34.50 | 0.85 | 3.80 | 0.80 | 0.27 | 1.03 | 0.07 | 0.40 | 0.07 | 3.95 |
| | (0.00)[3] | (0.00) | (0.00) | (0.00) | (2.40) | (4.67) | (72.12) | (1.56) | (5.97) | (1.40) | (0.61) | (2.34) | (0.42) | (0.53) | (0.81) | (17.27) |

[1] -.- analysis not performed, lost in analysis, or not reported in the Environmental Surveillance Report(s).

[2] (±2 counting uncertainty).

[3] (±2 standard deviation).

* Significantly different from regional (background) at the 0.05 level using a Student's t-test on natural log-transformed data.

** Significantly different from regional (background) at the 0.01 level using a Student's t-test on natural log-transformed data.

**Table 3. Mean radionuclide concentrations in honey collected from perimeter and regional (background) areas.[1]**

| Radioisotope | Perimeter | | Regional |
|---|---|---|---|
| | Los Alamos (Townsite) | White Rock/ Pajarito Acres | |
| $^{3}H$ (pCi/mL) | 111.65 (604.84)[2] | 9.93 (22.26) | 3.95 (17.27) |
| $^{57}Co$ (pCi/L) | 15.50 (27.40) | 95.50 (165.80) | 39.50 (122.60) |
| $^{7}Be$ (pCi/L) | 163.70 (159.00) | 47.50 (336.60) | 260.20 (624.40) |
| $^{22}Na$ (pCi/L) | 21.30 (38.80) | 20.40 (75.00) | 11.10 (64.80) |
| $^{54}Mn$ (pCi/L) | 15.80 (8.00) | 49.00 (93.60) | 32.30 (60.60) |
| $^{83}Rb$ (pCi/L) | 17.70 (13.20) | 45.30 (98.60) | 54.50 (119.00) |
| $^{137}Cs$ (pCi/L) | 26.75 (72.20) | 29.00 (66.98) | 66.65 (260.78) |
| $^{238}Pu$ (pCi/L) | 7.44 (111.60) | 5.58 (111.60) | 43.40 (78.41) |
| $^{239}Pu$ (pCi/L) | 7.44 (74.40) | -7.44 (74.40) | 0.00 (102.76) |
| $^{90}Sr$ (pCi/L) | 930.00 (1,116.00) | 930.00 (2,232.00) | 2,108.00 (3,907.00) |
| Total U (ng/g) | 2.28 (6.80) | 1.92 (4.98) | 2.34 (4.12) |

[1] With the exception of $^{3}H$, all other means between perimeter and regional (background) areas were not significantly different at the 0.05 level using a Student's t-test on natural log-transformed data.
[2] (±2 standard deviation).

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