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1983 Environmental Monitoring Report Sandia National Laboratories Albuquerque, New Mexico

MASTER

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Abstract

Sandia National Laboratories (SNL) is located south of Albuquerque on Kirtland Air Force Base. Because radionuclides are potentially released from its research activities, SNL has a continuing environmental monitoring program which analyzes for cesium-137, tritium, uranium, alpha emitters, and beta emitters in water, soil, air, and vegetation. Measured radiation levels in public areas were consistent with local background in 1983. The Albuquerque population received an estimated 0.250 person-rem from airborne radioactive releases, whereas it received greater than 49,950 person-rem from naturally occurring radionuclides.

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Abbreviations

Acronyms

ACRR	Annular Core Research Reactor
ANSI	American National Standards Institute
DOE	Department of Energy
DRCF	Dose Rate Conversion Factor
EPA	Environmental Protection Agency
IEEE	Institute of Electrical and Electronic Engineers, Inc
KAFB	Kirtland Air Force Base
MDA	Minimum Detectable Activity
MDL	Minimum Detectable Level
NBS	National Bureau of Standards
NOAA	National Oceanic and Atmospheric Science Administration
PBFA	Particle Beam Fusion Accelerator
RCG	Radiation Concentration Guide
SNL	Sandia National Laboratories
SPR	Sandia Pulsed Reactor
TLD	Thermoluminescent Dosimeter

Radioactivity Measurements

mR	milliroentgen (unit of radiation exposure)
mrem	millirem (unit of radiation dose)
person-rem	Radiation dose to population
Ci	Curie (unit of radioactivity)

Units

g	gram
ft	foot
°C	Celsius degree
m	meter
% moisture	weight percent of water
l	liter
ml	milliliter
P	statistical probability

System International Prefixes

Exponent	Prefix	Symbol
10^6	mega	M
10^3	kilo	k
10^{-3}	milli	m
10^{-6}	micro	μ
10^{-9}	nano	n
10^{-12}	pico	p
10^{-15}	femto	f
10^{-18}	atto	a

1983 Environmental Monitoring Report

Sandia National Laboratories

Albuquerque, New Mexico

Introduction

Sandia National Laboratories (SNL) is operated by Sandia Corporation, a prime contractor of the US Department of Energy (US DOE). The Corporation, which is a subsidiary of AT&T Technologies, Inc., provides service to the US Government on a non-profit, no-fee basis. The major responsibilities¹ are national security and energy projects. SNL designs the arming, fuzing, and firing systems used in US nuclear bombs and warheads. Safety, reliability, and survivability of weapon systems receive primary emphasis.

Other projects include nuclear reactor safety studies for the US Nuclear Regulatory Commission; development of safe transport and storage systems for special nuclear materials including plutonium and uranium-235; nuclear waste disposal techniques and site studies; pulsed power research; thermonuclear fusion research; solar energy research; vertical axis wind turbine research; fossil fuel and geothermal energy research.

Location of Sandia National Laboratories

SNL is located south of Albuquerque, NM, within the boundaries of Kirtland Air Force Base (KAFB), in Bernalillo County. It consists of five technical areas situated in the eastern half of the 190-km² KAFB military reservation. KAFB sits on two broad mesas that are bisected by Tijeras Arroyo, an east-west canyon. These mesas are bound by the Manzano Mountains (Cibola National Forest) to the east and the Rio Grande, a river, on the west. Elevations range from a low of 1,500 m at the Rio Grande to a high of 3,255 m at Sandia Crest, which is in the Sandia Mountains adjacent to Albuquerque. KAFB is at a mean elevation of 1,630 m.

The largest population center in Bernalillo County, and also the closest population center to KAFB, is Albuquerque, located just north of the base. The 1980 census figures² gives an Albuquerque population of 331,767. The Isleta Indian Pueblo, which borders KAFB on the south, is the next nearest population center with a 1980 census of 1,872. An estimated total population of 450,000 people live within an 80 km radius of KAFB.²

Albuquerque Climate and Meteorology

Albuquerque temperatures³ are characteristic of high altitude, dry, continental climates (Table 1). Daily temperature ranges are wide, although temperature extremes such as -18°C (0°F) and 38°C (100°F) occur infrequently. Daytime temperatures during the winter average near 10°C (50°F). Summer daytime maximum temperatures average less than 32°C (90°F) except in July. The average annual precipitation is 20 cm (8 in.); half of this precipitation occurs from July through September in the form of brief thundershowers. Winter months are quite dry with less than 5 cm (2 in.) of precipitation normally recorded. The average annual relative humidity is about 43%. (The humidity drops to less than 20% in June.)

Strong winds^{3,4} often accompanied by blowing dust occur mostly in late winter and early spring. The wind speed reaches 13.3 m/s (30 mph) for less than 48 days each year. Prevailing surface winds on KAFB are from the east.⁵ Rapid night-time ground cooling produces strong temperature inversions as well as strong drainage winds down Tijeras Canyon.

Table 1. Summary Meteorological Data for the Albuquerque Area (1941 to 1970)*

Month	Temperatures (°C)		Precipitation Normal (cm)	Mean Wind	
	Normal Daily Range Min	Max		Speed (m/s)	Direction
J	-4.7	8.3	0.76	3.6	N
F	-2.6	11.4	0.99	3.9	N
M	0.2	15.1	1.19	4.5	SE
A	5.2	21.2	1.22	4.9	S
M	10.4	26.6	1.35	4.7	S
J	15.4	31.9	1.27	4.5	S
J	18.4	33.4	3.53	4.1	SE
A	17.4	32.1	3.40	3.7	SE
S	13.7	28.6	1.96	3.8	SE
O	7.1	22.1	2.01	3.7	SE
N	-0.1	13.9	0.74	3.5	N
D	-3.9	8.6	1.32	3.4	N

*NOAA, *Local Climatological Data, Annual Summary with Comparative Data*, Albuquerque, New Mexico, 1980. The original measurements have been converted to metric units.

Hydrology and Biology in Central New Mexico

The major hydrologic⁶ surface feature in central New Mexico is the Rio Grande, which runs north-south through Albuquerque. Rio Grande water is primarily used for irrigation of agricultural crops. There are no continuously running streams on KAFB. Because of infrequent stream flow, the municipal and domestic water needs of the Albuquerque vicinity are supplied by deep wells. These wells range from 148 to 365 m in depth, with most measuring 305 m. On KAFB, the water table lies 137 m below Area V. There are indications that the ground water flows westward towards the Rio Grande in this area.

New Mexico has low precipitation, wide temperature extremes, frequent drying winds, heavy showers with erosive effects, and erratic seasonal distribution of precipitation. This semidesert southwest climate combines with the low-water availability to produce many species¹ of drought-resistant flora such as cacti. The mesa vegetation, consisting of grasses and shrubs, is illustrated in Figure 1. Figure 2 shows juniper trees and cacti that are present at the higher elevations bordering the mountains. Russian thistle (tumbleweeds) proliferate in mechanically disturbed areas.

SNL Technical Areas and Radioactive Effluents

SNL (Figure 3) consists of five technical areas and several environmental test areas. Each area has its own distinctive operations; a brief description of each area and a summary of radioactive effluent releases follow.

Area I (Figure 4), with approximately 5,000 people, has the largest population. This area is dedicated primarily to the design, research, and development of weapon systems and weapon system components. It also includes laboratories and shops used by administrative and technical staff. Generally, the only potential radioactive release from Area I is tritium (³H) from two sources; however, no ³H was released from the area in 1983.

Area II is a small facility used for explosive testing. Techniques for measuring fractures in geologic strata are developed at this facility. Small amounts of ⁸⁵Kr generated by explosive testing are vented from the earth during fracture permeation tests. There were no tests in Area II in 1983 and, therefore, no ⁸⁵Kr releases.

Figure 1. Mesa Vegetation

Figure 2. Manzano Foothills Vegetation

Figure 3. Environmental Monitoring Locations in Sandia Technical Areas I-V

Figure 4. Sandia Technical Area I

Area III is located 8 km south of Area I. It is comprised of 20 test facilities which include a sludge irradiation facility and extensive environmental test facilities (such as sled tracks, centrifuges, and a radiant heat facility). No radioactive effluents are released through normal operations in the area. The radioactive disposal site⁷ consists of two adjoining fenced areas that occupy approximately 1.6 acres. One area has been used for low-level waste disposal in five shallow trenches. Four of the trenches are no longer used and have been filled and covered with dirt. The second area has been used for classified waste disposal in 34 pits. Thirty-three of these pits have been filled and covered with a concrete cap. One pit is currently being used. Two additional pits located in the classified waste disposal area are used exclusively for natural and depleted uranium waste disposal.

Area IV is a new facility designed for inertial confinement fusion research and pulsed power research. A large accelerator, the Particle Beam Fusion Accelerator-I (PBFA-I), was completed in 1980. Gaseous tritium effluents (HT) may be generated in the fusion research. There was no radioactive release from this area in 1983.

Area V houses large electron beam accelerators, three research reactors in two reactor facilities, an intense gamma irradiation facility (using ⁶⁰Co and ¹³⁷Cs), a neutron irradiation facility (using ²⁵²Cf), and a hot cell facility. Tritium is released from the accelerators when they are used for fusion research. No tritium was released in 1983. The two research reactor facilities in Area V are quite dissimilar: the Sandia Pulsed Reactor (SPR) is an unreflected, unmoderated assembly of enriched uranium; the Annular Core Research Reactor (ACRR) is an annular core of 226 fuel elements in an open water tank. Both the SPR and ACRR air exhaust systems are equipped with particulate effluent samplers. The ACRR also has a continuous gaseous effluent monitor. The amounts of radioactivity released from either reactor in 1983 would not be detectable at the perimeter of KAFB. The reported amount of ⁴¹Ar (which is released from both reactor areas) was computed from reactor operating parameters. Neither the ACRR nor SPR releases cooling water.

SNL also has environmental test areas outside of the five technical areas. These areas are located south of Area III and in canyons on the west side of the Manzano mountains. Coyote Canyon (Figure 3) is such an area. In these remote test areas, depleted uranium is infrequently spread over limited areas during explosive testing. Operations in these areas are controlled to prevent this uranium from reaching public areas beyond the confines of KAFB.

Environmental Monitoring for Radioactive Effluents

SNL has maintained an environmental monitoring program⁸⁻¹⁹ since February 1959. The objectives of this surveillance program are to detect the release and/or migration of radioactive material from SNL operations and to determine the resulting population exposures above normal background radiation levels. The monitoring program also provides a check on the effectiveness of reactor radiological safety systems. Radioactive effluent discharges to the environment are kept as low as reasonably achievable in accordance with DOE requirements for environmental protection. Soil, vegetation, water, and air are monitored for radionuclides, primarily ¹³⁷Cs and ³H. Gross alpha and gross beta analysis are done in water samples. Soil samples are analyzed for uranium to determine the existence or spread of uranium from explosive testing.

In addition to the other elements of the monitoring program, a program was begun in 1981 which uses integrating dosimeters (thermoluminescent dosimeters or TLDs) to measure ambient levels of external penetrating radiation around each major facility. Before a facility's contribution to a population dose can be calculated (in the event of an unplanned release), a good estimate of natural background with its inherent variability must be available. Natural background radiation levels are affected by many environmental factors, including ground cover and seasonal variations in precipitation and temperature.

Sandia's non-radioactive effluent source terms consist of potential releases to the air, sanitary sewer, and ground water. While these source terms are small and the potentials for release are kept low by stringent administrative policies, we plan to upgrade the monitoring program for non-radioactive effluents during calendar year 1984. The data collected from this enhanced program will be included in future reports.

Monitoring Locations

The SNL environmental monitoring locations (Figures 3 and 5) remain essentially the same from year to year except when a facility changes its operations or its operation is discontinued. Ground water samples are collected from wells in use at the time of collection and may differ from one year to the next.

Table 2 lists the SNL environmental monitoring locations and specifies the type of sample collected (vegetation, water, soil) or presence of a TLD station for each location. Thirteen locations are on-site at SNL facilities; five are on KAFB at the perimeter or boundary; fourteen are community (or background)

sites distributed around and in Albuquerque within an 80-km radius of SNL. Water monitoring locations include six ground water locations (wells) and three surface water locations. Location 8 is a surface water sampling location on the Rio Grande upstream of the SNL facilities. It provides control data for comparison with Location 11, a downstream Rio Grande sampling location.

Sample Collection and Analysis

Samples are gathered and stored in accordance with methods described in DOE/EP-0023.²⁰ Native vegetation, soil, and water samples are collected annually at the end of the growing season. Fallout Deposition Collectors and TLDs are exchanged quarterly.

Deposition Collectors

Deposition sampling is used to measure the total amount of dry and wet deposition from the ambient atmosphere. One standard method of deposition sampling is the passive particulate fallout collector. The type of collector used at SNL is the pot collector, a 4-liter stainless steel container positioned 3 m above the ground surface.

In anticipation of a hot cell facility to be built in Area V, fallout collectors were used to monitor the environment for particulate background data in 1977. Now that the facility is completed (operations began in 1982),⁷ the data collection will continue as part of the environmental surveillance program.

Figure 5. Environmental Monitoring Locations in the Albuquerque Area

Table 2. Sandia Environmental Monitoring Locations

Location Number	Location	Description*	Sample Type**
1	Pennsylvania Ave	S	V,S,T
2	Radioactive Disposal Site	S	V,S,T
3	Coyote Canyon Control	S	V,S,T
4	Isleta Reservation Gate	P	V,S,T
5	McCormick Gate	P	V,S,T
6	Area III, SE	S	V,S,T
7	Arroyo, N Area III	S	V,S,T
8	Corrales Bridge	C	V,S,W
9	Sedillo Hill, I-40 E of Albuquerque	C	V,S
10	Oak Flats	C	V,S,T
11	Isleta Pueblo, Rio Grande	C	V,S,T,W
12	Area III Well	S	W
13	Base Well #1	S	W
14	Base Well #2	S	W
15	Base Well #14	S	W
16	Four Hills	P	V,S,T
17	Base Well #13	S	W
18	North Perimeter Rd	P	T
19	Seismic Center Gate	P	V,S,T
20	Area IV, SW	S	V,S,T
21	Bernalillo Fire Sta #10, Tijeras	C	T
22	Los Lunas Fire Sta	C	T
23	Rio Rancho Fire Sta, 19th Street	C	T
24	Corrales Fire Sta	C	T
25	Placitas Fire Sta	C	T
26	Alb. Fire Sta #9, Menaul NE	C	T
27	Alb. Fire Sta #11, Southern SE	C	T
28	Alb. Fire Sta #2, High SE	C	T
29	Alb. Fire Sta #7, 47th NW	C	T
30	Alb. Fire Sta #6, Griegos NW	C	T
31	Area II Guard Gate	S	T
32	Area V, SW Corner	S	T
33	Coyote Springs	S	V,S,W
34	Base Well #12	S	W

*S = Sandia, P = Perimeter of Sandia, C = Community

**V = Vegetation, S = Soil, W = Water, T = TLD (Thermoluminescent Dosimeters)

Four fallout collectors are positioned in Area V: one each at the NW, NE, SE, and SW corners. A fifth collector has been positioned in Area III to monitor effluents released from Area V; it is located at the predicted point of maximum mean concentration of effluents. A sixth collector, located in an Albuquerque residential area 16 km north of Area V, provides background or control data. Deposited materials from each quarterly collection are analyzed for gross alpha, gross beta, and gamma activity.

Vegetation

Native vegetation samples are randomly collected in late summer from a 9-m² area at each sample location. Since the native desert vegetation is sparse, a sample includes a mixture of species, with grass species predominating. Each sample weighs approximately half a kilogram and consists of stems and leaves representative of the species at each site. Consequently, radionuclide concentrations for vegetation include variability due to species uptake, retention, or deposition as well as location. Replicate samples consisting solely of grasses were collected at location 5 in order to estimate variability due to location. Each vegetation sample is cut and blended prior to radiochemical analysis for tritium and gamma spectrum analysis (¹³⁷Cs).

Water

Water samples are collected in acid-cleaned, plastic containers that have been rinsed in distilled water. Replicate samples of approximately 3.8 liters (one gallon) of water are collected at each water sampling location. One sample is acidified immediately to 10% by volume with 2N HNO₃ and is used for total water radiochemical analysis. The second sample is filtered immediately and the water is then acid-treated to prevent plating of any radionuclides on the container walls. A radiochemical analysis for gross alpha, gross beta, gamma spectrum analysis, uranium, and tritium are then performed on the water and filter samples.

Soil

Soil samples are randomly collected from the same 9-m² quadrat as the vegetation samples. Three samples of the top 5 cm of soil are collected and composited at each station. Each soil sample is dried, ball-milled, and sieved prior to a ¹³⁷Cs and uranium analysis.

Radiochemical Analysis

Aliquots of the vegetation samples are taken for each radiochemical analysis. One aliquot of vegetation is air-dried to reach a constant dry mass, finely ground up, and then placed in a 500-ml Marinelli beaker for gamma spectrum analysis. A 100 g sample is used for each analysis. A second 100 g aliquot of vegetation is heated with cyclohexane in a 1000-ml distillation flask and the water is collected in a Barrett trap. The water collected in the trap is analyzed for ³H with a liquid scintillation detector using a 1 ml sample volume.

Soil samples are analyzed for uranium by leaching a 2-g aliquot with mixed acids (HNO₃/HF) and diluting with water to a 10-ml volume to extract uranium and other acid-soluble metals. A 0.1-ml aliquot of acid solution is diluted to 10 ml with 2N HNO₃. Fifteen ml of aluminum nitrate and 10 ml of ethyl acetate are added and mixed for 10 min to selectively extract uranium into the organic phase. Three 0.1-ml aliquots are then fused with an NaF/LiF flux and measured by fluorescence.

Water, soil, and vegetation samples are analyzed according to ANSI/IEEE Standard 680-1978. They are analyzed for gamma-emitting radionuclides by placing approximately 450 g of water, 862 g of soil, or 100 g of vegetation in 500-ml Marinelli beakers and counting for 1,000 min by using high-efficiency, high-resolution Ge or Ge(Li) detectors and multi-channel analyzers. The detectors are calibrated and checked routinely by using either a mixed radionuclide standard obtained from the National Bureau of Standards (NBS) or by using a standard traceable to NBS. The data is analyzed by computer software developed by Canberra Industries.

Water samples are further analyzed for gross alpha-beta activity by evaporating an aliquot of water (100 ml for alpha analysis; 400 ml for beta analysis) on a 5-cm stainless steel planchet and counting for 100 min by using a low-background, gas-proportional detector. The detector is calibrated and checked routinely by using standards traceable to NBS.

Laboratory quality assurance is achieved through successful participation in Environmental Protection Agency (EPA) and DOE intercomparison programs. Table 3 gives results for 1982 gross alpha, gross beta, ¹³⁷Cs, ³H, and uranium determinations in water. Ratios comparing SNL values to quality assurance program values are included.

Table 3. 1983 Quality Assurance Results for Selected Radiochemical Analysis

Analysis pCi/l	Sample Type	Date	QA* Program	Sandia Value	Program Value	Ratio**
Gross α	Water	Jan 83	EPA	30 $\pm$ 2	29 $\pm$ 7	1.03
	Water	May 83	EPA	9 $\pm$ 2	11 $\pm$ 5	0.82
	Water	Sep 83	EPA	6 $\pm$ 1	5 $\pm$ 5	1.20
Gross β^-	Water	Jan 83	EPA	32 $\pm$ 1	31 $\pm$ 5	1.03
	Water	May 83	EPA	57 $\pm$ 4	57 $\pm$ 5	1.00
	Water	Sep 83	EPA	8 $\pm$ 2	9 $\pm$ 5	0.89
^{137}Cs	Water	Feb 83	EPA	20 $\pm$ 2	19 $\pm$ 5	1.05
	Water	June 83	EPA	—	26 $\pm$ 5	—
	Water	Oct 83	EPA	20 $\pm$ 2	22 $\pm$ 5	0.91
	Water	Mar 83	DOE	1970 $\pm$ 150	1890 $\pm$ 125	1.04
	Water	Jul 83	DOE	2010 $\pm$ 140	2390 $\pm$ 150	0.84
	Water	Nov 83	DOE	5400 $\pm$ 40	5460 $\pm$ 40	0.99
	Soil	Nov 83	DOE	1090 $\pm$ 20	1000 $\pm$ 20	1.09
^3H	Water	Jun 83	EPA	1290 $\pm$ 26	1529 $\pm$ 337	0.84
	Water	Aug 83	EPA	1600 $\pm$ 100	1836 $\pm$ 342	0.87
	Water	Oct 83	EPA	1437 $\pm$ 57	1210 $\pm$ 329	1.19
	Water	Dec 83	EPA	2554 $\pm$ 150	2389 $\pm$ 350	1.07
	Water	Mar 83	DOE	15200 $\pm$ 3900	12900 $\pm$ 3500	1.18
	Water	Jul 83	DOE	11800 $\pm$ 3500	10800 $\pm$ 2900	1.09
Uranium —	Water	Feb 83	EPA	27 $\pm$ 2	31 $\pm$ 6	0.87
	Water	Aug 83	EPA	33 $\pm$ 2	26 $\pm$ 6	1.27

*EPA—Environmental Protection Agency Environmental Systems Laboratory Quality Assurance Intercomparison Study.

DOE – Department of Energy Environmental Measurements Laboratory Intercomparison Program

**Ratio of Sandia to program value.

$\pm 1 \sigma$ Counting Errors.

External Penetrating Radiation

TLDs are placed at 25 locations. The type of TLD phosphor used is LiF in chip form. All dosimeters are placed in open areas over soil substrates 1 m above ground level. A minimum of five TLDs are placed at each location in order to get an estimate of the variability in TLD response at that location. TLDs are exchanged on a quarterly basis.

All TLDs are annealed at 400°C for 1 h prior to field placement. Transit controls are used to document additional exposure received during transit from SNL to field locations. The TLD readout equipment is calibrated by exposing TLDs to 0, 10, 20, 30, 50, and 80 mR of ^{60}Co midway through each quarterly field cycle. Ten TLDs are exposed at each level.

Monitoring Results

Table 4 gives concentrations of ^3H and ^{137}Cs in vegetation (primarily grass species) at seven SNL, four perimeter, and four community locations. Table 5 compares the mean concentrations and respective standard deviations, as well as ranges, for ^{137}Cs in vegetation for the three types of sampling locations. The ^{137}Cs concentrations ranged from less-than MDL values to 0.111 pCi/g. Only two locations had above MDL ^{137}Cs . Tritium concentrations, reported as pCi per ml of extracted water, ranged from 0.90 to 15.4 pCi/ml. [Less-than-MDL values were set equal to the MDL in the calculation of mean ($\bar{x}$) values.] The reported ^{137}Cs concentrations (Table 4) are fallout levels. Concentration differences between locations

were not statistically significant ($P < 0.01$) for the three locations for ^{137}Cs . The reported ^3H concentrations fall within the range of background ^3H concentrations for this area except at Location 2. Tritium concentrations in vegetation were higher at Sandia location 2 than at all other locations. This sampling station is in Area III at the west boundary of the radioactive disposal site. The source of tritium appears to be small amounts of atmospheric ^3H released from the radioactive disposal site. Vegetation samples were also collected at each of the four corners of the disposal site. Tritium concentrations ranged from 15.1 to 15.8 pCi/ml ($\bar{x} = 15.4$ pCi/ml, $s_x = 0.15$ pCi/ml).

Table 4. Concentrations of ^3H and ^{137}Cs in Vegetation Samples

Location	^3H pCi/ml (water)	% Moisture	^{137}Cs pCi/g (Dry)
<u>Sandia</u>			
1	0.90 ± 0.6	28.1	<0.058
2	15.4 ± 2.6	29.4	<0.087
3	4.5 ± 1.4	33.3	<0.059
6	3.7 ± 1.3	34.4	0.053 ± 0.019
7	4.5 ± 1.4	34.6	<0.043
20	3.6 ± 1.3	30.3	<0.098
33	4.5 ± 1.4	21.7	<0.056
<u>Perimeter</u>			
4	2.3 ± 1.0	27.4	<0.045
5	4.0 ± 1.3	31.0	<0.055
16	3.9 ± 1.3	40.0	<0.056
19	4.5 ± 1.4	28.6	0.111 ± 0.024
<u>Community</u>			
8	3.6 ± 1.3	50.0	<0.062
9	3.6 ± 1.3	24.4	<0.054
10	4.5 ± 1.4	40.8	<0.223
11	3.4 ± 1.2	41.7	<0.050
MDL	0.45		
$\pm 1 \sigma$ Counting Errors			

Concentrations of uranium and ^{137}Cs and ^3H in soil samples are reported in Table 6 for seven SNL, four perimeter, and four community locations. Table 7 summarizes the mean concentrations, respective standard deviations, and range of values for nuclides in each of the three types of sampling locations. Uranium concentrations ranged from 2.0 to 3.5 $\mu\text{g/g}$ and are

consistent with natural background levels. Differences between locations were not statistically significant ($P < 0.01$). The ^{137}Cs concentrations ranged from 0.060 to 0.642 pCi/g and reflect fallout levels of ^{137}Cs . Tritium concentrations ranged from 0.45 (MDL) to 11.3 pCi/ml. The 11.3 pCi/ml value was at location 2. Less-than-MDL values were set equal to the MDL in the calculation of $\bar{x}$ values. Concentration differences between locations were not statistically significant ($P < 0.01$).

Replicate samples of soil and vegetation were collected in order to get an estimate of the variability associated with each location. Table 8 lists $\bar{x}$ and s_x for the replicate samples. This estimate of variability includes both the sampling error and the analytical and counting errors. The reported ^{137}Cs levels reflect background fallout concentrations. K-40 is a naturally occurring background radionuclide as are uranium and ^3H .

Concentrations of gross α , gross β^- , ^{137}Cs , ^3H , and uranium in water are reported in Tables 9 and 10 for both total (unfiltered) water as well as filtered water and associated suspended solids. Tritium and ^{137}Cs values were all $<\text{MDL}$. Uranium values ranged from 0.0015 to 0.0074 $\mu\text{g/ml}$ and are consistent with background levels in water. Gross α and Gross β^- values were all at or near MDL values.

Tables 11 and 12 report applicable DOE radiation protection standards for uncontrolled areas. Table 12 also gives the applicable standards for controlled areas. The radiation concentration guides in Table 12 are derived from the dose standards for individuals (assuming 168 h of exposure a week). These guides are reduced by a factor of three when dealing with average populations to correct for the increased sensitivity of some portions of the population to radiation exposure.

Data from the deposition collectors is not presented since no calculations of air concentrations can be made and the data consists of a gross analysis for alpha, beta, and gamma activity. The fallout data is screened for unusual activity not attributable to natural background. No unusual activity was detected in 1983.

Table 13 gives the annual TLD dose estimates for SNL, perimeter, and community locations noted in Table 2. The mean annual external penetrating dose for all the areas was 110 mrem/yr. There was no statistically significant difference between the three areas in annual dose estimates with one exception. Location 32 in Area V was significantly higher ($P < 0.01$) than other locations with an estimated annual dose of 257 mrem. For comparison, the other SNL locations ranged from 101 to 143 mrem/yr. Location 32 was treated as a statistical outlier and was

therefore not included in the mean dose estimates. In addition, this particular location is inside a controlled area located near the HERMES-II accelerator in Area

V. The applicable DOE standard for a whole body exposure in a controlled area (occupational exposure) is 5 rem/yr (DOE 5480.1, Chapter XI).

Table 5. Mean Concentrations of ^3H and ^{137}Cs in Vegetation

Nuclide	Location	Sample Size	Concentration*		
			$\bar{x}$	s	Range
^3H pCi/ml	Sandia	7	5.30	4.63	0.9 to 15.4
	Perimeter	4	3.68	0.95	2.3 to 4.5
	Community	4	3.78	0.49	3.4 to 4.5
Total		15	4.32	2.83	0.9 to 15.4
^{137}Cs pCi/g	Sandia	7	0.065	0.020	<0.043 to <0.098
	Perimeter	4	0.067	0.030	<0.045 to 0.111
	Community	4	0.097	0.084	<0.050 to <0.223
Total		15	0.074	0.046	<0.043 to <0.223

$\bar{x}$ = mean, s = standard deviation

* ^{137}Cs <MDL values were used in calculations of $\bar{x}$

Table 6. Concentrations of Uranium, ^3H , and ^{137}Cs in Soil Samples

Location	U $\mu\text{g/g}$	^3H (pCi/ml)	% Moisture	^{137}Cs pCi/g
<u>Sandia</u>				
1	2.6 $\pm$ 0.2	0.45 $\pm$ 0.45	2.58	0.235 $\pm$ 0.021
2	2.4 $\pm$ 0.2	11.3 $\pm$ 2.3	1.69	0.515 $\pm$ 0.021
3	2.2 $\pm$ 0.2	5.4 $\pm$ 1.6	3.63	0.412 $\pm$ 0.016
6	2.1 $\pm$ 0.2	5.7 $\pm$ 1.6	3.81	0.502 $\pm$ 0.019
7	2.4 $\pm$ 0.2	5.1 $\pm$ 1.5	2.75	0.278 $\pm$ 0.015
20	2.6 $\pm$ 0.2	3.6 $\pm$ 1.3	2.69	0.513 $\pm$ 0.020
33	3.2 $\pm$ 0.2	2.7 $\pm$ 1.1	10.70	0.103 $\pm$ 0.011
<u>Perimeter</u>				
4	2.5 $\pm$ 0.2	3.2 $\pm$ 1.2	3.20	0.642 $\pm$ 0.020
5	2.0 $\pm$ 0.2	5.6 $\pm$ 1.6	1.94	0.249 $\pm$ 0.014
16	2.6 $\pm$ 0.2	3.2 $\pm$ 1.2	2.17	0.090 $\pm$ 0.012
19	2.5 $\pm$ 0.2	2.7 $\pm$ 1.1	1.63	0.060 $\pm$ 0.022
<u>Community</u>				
8	3.5 $\pm$ 0.2	4.1 $\pm$ 1.4	9.10	0.076 $\pm$ 0.012
9	2.2 $\pm$ 0.2	3.6 $\pm$ 1.3	10.10	0.432 $\pm$ 0.020
10	2.9 $\pm$ 0.2	4.5 $\pm$ 1.4	7.87	0.515 $\pm$ 0.021
11	3.5 $\pm$ 0.2	3.6 $\pm$ 1.3	1.99	0.066 $\pm$ 0.009
MDL	0.012	0.45		0.043

$\pm 1 \sigma$ Counting Errors

Table 7. Mean Concentrations of Uranium, ^{137}Cs , and ^3H in Soil Samples

Nuclide	Location	Sample Size	Concentration		
			$\bar{x}$	s	Range
Uranium ($\mu\text{g/g}$)	Sandia	7	2.50	0.36	2.1 to 3.2
	Perimeter	4	2.40	0.27	2.0 to 2.6
	Community	4	3.03	0.62	2.2 to 3.5
	Total	15	2.61	0.47	2.0 to 3.5
^{137}Cs (pCi/g)	Sandia	7	0.375	0.175	0.103 to 0.515
	Perimeter	4	0.260	0.268	0.060 to 0.642
	Community	4	0.272	0.235	0.066 to 0.515
	Total	15	0.317	0.208	0.060 to 0.642
^3H (pCi/ml)	Sandia	7	4.89	3.37	0.45 to 11.3
	Perimeter	4	3.68	1.30	2.7 to 5.6
	Community	4	3.95	0.44	3.6 to 4.5
	Total	15	4.32	2.37	0.45 to 11.3

$\bar{x}$ = Mean, s = Standard Deviation

Table 8. Determination of Sample Variability in Replicate Samples for Selected Analysis in Vegetation and Soil

Location	Sample Type	U($\mu\text{g/g}$) $\bar{x} \pm s_x$	^{137}Cs (pCi/g)* $\bar{x} \pm s_x$	^{40}K (pCi/g) $\bar{x} \pm s_x$	^3H (pCi/g) $\bar{x} \pm s_x$
5	Soil	2.00 ± 0.01	0.249 ± 0.062	13.67 ± 0.60	5.57 ± 0.38
	Vegetation	<0.0018	0.088 ± 0.020	6.56 ± 0.77	3.70 ± 0.44
6	Soil	2.10 ± 0.01	0.502 ± 0.089	15.50 ± 0.95	5.70 ± 0.30
	Vegetation	<0.0018	0.068 ± 0.014	6.15 ± 0.40	3.70 ± 0.25
7	Soil	2.39 ± 0.01	0.275 ± 0.068	13.52 ± 2.57	5.13 ± 0.41
	Vegetation	<0.0018	0.056 ± 0.011	5.00 ± 0.53	4.50 ± 0.29

*Each mean is calculated from three replicate sample values. Reported values are mean ($\bar{x}$) and standard error of the mean (s_x).

** ^{137}Cs <MDL values were used in the vegetation calculations.

Table 9. Concentrations of Gross α , Gross β^- , Uranium, ^{137}Cs and ^3H in Surface Water

Sample Type	Location No.	Location	Gross α pCi/ml	Gross β^- pCi/ml	Uranium $\mu\text{g/ml}$	^{137}Cs pCi/ml	^3H pCi/ml
Total	8	Corrales	0.0025 ± 0.0020	0.0034 ± 0.0014	0.0015 ± 0.0001	<0.0014	$<\text{MDL}$
Filtered		(Rio Grande)	0.0025 ± 0.0020	0.0023 ± 0.0014	0.0015 ± 0.0001	<0.0017	$<\text{MDL}$
Suspended Solids			0.0006 ± 0.0002	0.0012 ± 0.0005	—	—	—
Total	11	Isleta	0.0022 ± 0.0019	0.0040 ± 0.0014	0.0074 ± 0.0001	<0.0019	$<\text{MDL}$
Filtered		(Rio Grande)	0.0021 ± 0.0019	0.0015 ± 0.0013	0.0074 ± 0.0001	<0.0013	$<\text{MDL}$
Suspended Solids			0.0008 ± 0.0002	$<\text{MDL}$	—	—	—
Total	33	Coyote Springs	0.0039 ± 0.0023	$<\text{MDL}$	0.0059 ± 0.0001	<0.0020	$<\text{MDL}$
Filtered			0.0052 ± 0.0025	$<\text{MDL}$	0.0059 ± 0.0001	<0.0014	$<\text{MDL}$
Suspended Solids			$<\text{MDL}$	$<\text{MDL}$	—	—	—
MDL—Water			0.0020	0.0015	0.00015	0.007	0.45
MDL—Suspended Solids			0.0014	0.0066	—	—	—

Table 10. Concentrations of Gross α , Gross β^- , Uranium, ^{137}Cs and ^3H in Ground Water

Sample Type	Location No.	Location	Gross α pCi/ml	Gross β^- pCi/ml	Uranium $\mu\text{g/ml}$	^{137}Cs pCi/ml	^3H pCi/ml
Total	13	Base Well 1	0.0018 ± 0.0019	0.0015 ± 0.0013	0.0022 ± 0.0012	<0.0016	$<\text{MDL}$
Filtered			0.0042 ± 0.0023	$<\text{MDL}$	0.0022 ± 0.0012	<0.0014	$<\text{MDL}$
Suspended Solids			$<\text{MDL}$	$<\text{MDL}$	—	—	—
Total	12	Area III	$<\text{MDL}$	$<\text{MDL}$	0.0037 ± 0.0002	<0.0011	$<\text{MDL}$
Filtered			0.0017 ± 0.0019	0.0014 ± 0.0013	0.0037 ± 0.0002	<0.0013	$<\text{MDL}$
Suspended Solids			0.0002 ± 0.0001	$<\text{MDL}$	—	—	—
Total	14	Base Well 2	0.0031 ± 0.0021	0.0020 ± 0.0013	0.0044 ± 0.0002	<0.0012	$<\text{MDL}$
Filtered			$<\text{MDL}$	0.0027 ± 0.0014	0.0044 ± 0.0002	<0.0018	$<\text{MDL}$
Suspended Solids			$<\text{MDL}$	$<\text{MDL}$	—	—	—
Total	15	Base Well 14	0.0020 ± 0.0019	$<\text{MDL}$	0.0052 ± 0.0002	<0.0015	$<\text{MDL}$
Filtered			$<\text{MDL}$	$<\text{MDL}$	0.0052 ± 0.0002	NS	$<\text{MDL}$
Suspended Solids			$<\text{MDL}$	$<\text{MDL}$	—	—	—
MDL—Water			0.0016	0.0055	0.00015	0.007	0.45
MDL—Suspended Solids			0.0014	0.0066	—	—	—

Table 11. Radiation Protection Standards for External and Internal Exposure of Members of the Public*

Type of Exposure	Annual Dose Equivalent or Dose Commitment (rem)**	
	Based on dose to individuals at points of maximum probable exposure	Based on average dose to a suitable sample of the exposed population
Whole body, gonads or bone marrow	0.5	0.17
Other organs	1.5	0.5

*DOE 5480.1, Chg. 2, Chapter XI-5, 4-29-81.

**In keeping with DOE policy on lowest practicable exposures, exposures to the public shall be limited to as small a fraction of the respective annual dose limits as is reasonably achievable.

Table 12. DOE 5480.1 Chapter XI-1 Radiation Concentration Guides for Selected Nuclides

Nuclide	RCG—Uncontrolled Area $\mu\text{Ci/ml}$		RCG—Controlled Area $\mu\text{Ci/ml}$	
	Air	Water	Air	Water
^3H	2×10^{-7}	3×10^{-3}	5×10^{-6}	1×10^{-1}
^{41}Ar	4×10^{-8}	—	2×10^{-6}	—
^{137}Cs	5×10^{-10}	2×10^{-5}	1×10^{-8}	4×10^{-4}
Gross α^*	—	15×10^{-9}	—	—
Gross β^-	—	3×10^{-8}	—	—
U, nat**	6×10^6	6×10^{-7}	1.8×10^8	2×10^{-5}

*USEPA National Interim Primary Drinking Water Regulations (EPA-570/9-76-003).

**1 Curie of natural uranium is equivalent to 3000 kg of natural uranium. A conversion from pg to μCi may be made by multiplying $\text{pg} \times 3.3 \times 10^{-13}$.

Table 13. Thermoluminescent Dosimeter Dose Estimates

Location	Sample Size	Mean Annual Dose (mrem)		
		$\bar{x}$	s	Range
Sandia	7	112	8	101 to 143
Perimeter	5	108	5	96 to 119
Community	12	111	5	100 to 126

Public Dose Assessment

Airborne concentrations of ^{41}Ar resulting from SNL emissions are too low to be measured in public locations. These concentrations are therefore calculated by using Pasquill's atmospheric diffusion equations,²¹ estimated activity released, and assumed meteorological conditions. Dose estimates are then made at site boundaries and for the Albuquerque area population as a whole.

The following is Pasquill's Gaussian diffusion equation:

$$X = \frac{fQ}{\pi\sigma_y\sigma_z u} \exp - \left[\frac{y^2}{2\sigma_y^2} + \frac{h^2}{2\sigma_z^2} \right] \quad (1)$$

where:

- Q = source strength in curies per second
- u = mean wind speed in meters per second
- y = receptor location in meters from the plume axis
- h = source height in meters
- $\sigma_y \sigma_z$ = diffusion coefficient in meters. These coefficients are a function of distance from the release point
- f = frequency the wind blows in a given direction
- X = concentration in curies per cubic meter

A neutral (Pasquill Type D) meteorological condition is assumed. A wind speed of 4 m/s is assumed, which is compatible with Type D conditions. A conservative simplifying assumption that $y = 0$ and $h = 0$ is also made. The maximum mean time the wind blows in a given direction is 11.4% (based on 10 years of data).⁴ These parameters are used in Eq 1 to generate the effluent release data in Table 14.

Dose rates (Table 15) were then calculated by using dose rate conversion factors (DRCF) based on the Radiation Concentration Guides (RCG) given in Table 14. Albuquerque area population doses were calculated with Eq 2. Approximately 450,000 people live within an 80-km radius of the Albuquerque area. Equation 2 uses a conservative assumption that this population is uniformly distributed within an inner 20-km radius.

$$\text{Dose} = \frac{4.50 \times 10^5}{\pi(20 \text{ km})^2} \int_0^{20 \text{ km}} X \cdot \text{DRCF} \cdot 2\pi r dr \quad (2)$$

The integral in Eq 2 overestimates the ^{41}Ar dose, as it does not include the 1.83-h half-life decay of the nuclide as it traverses the 20-km radius.

Table 14. Effluent Release Data

Parameter	^{41}Ar
Release Point	Area V
X/Q at 3 km*	$3.06 \times 10^{-13} \text{ s/ml}$
X/Q at 80 km	$2.27 \times 10^{-16} \text{ s/ml}$
Activity Released	16.9 Ci
Release Rate (Q)	$0.536 \mu\text{Ci/s}$
Boundary Concentration	$1.64 \times 10^{-13} \mu\text{Ci/ml}$
RCG—for average population**	$1.3 \times 10^{-8} \mu\text{Ci/ml}$
Boundary Concentration/RCG	1.26×10^{-5}

*Release point to site boundary distance is 3 km.

**"Standards for Radiation Protection," DOE Order 5480.1.

Table 15. Site Boundary Dose Rates and Population Doses

Parameter	^{41}Ar
Site Boundary	
Boundary Dose Rate	$2.149 \times 10^{-3} \text{ mrem/yr}$
Albuquerque Area*	
Annual Population Dose	0.250 person-rem

*Albuquerque area population from 1980 census is 450,000 residents.

Conclusions

Fallout levels of ^{137}Cs were detected in vegetation. Values ranged from less than MDL to 0.111 pCi/g. No offsite tritium was detected. Soil concentrations for ^{137}Cs ranged from 0.060 to 0.642 pCi/g. Total uranium concentrations in soil ranged from 2.0 to 3.5 $\mu\text{g/g}$. These values are consistent with soil concentrations reported for soils in this area and reflect natural levels of uranium in regional soils.^{22 23}

Concentrations of ^3H and ^{137}Cs in regional surface and well waters were less than MDL. Gross alpha concentrations in well waters ranged from MDL to 0.0031 pCi/ml. Gross beta concentrations were all less than MDL in well waters. Gross alpha concentrations in surface water ranged from 0.0021 to 0.0039 pCi/ml. Gross beta concentrations in surface water ranged from less than MDL to 0.0040 pCi/ml. Uranium concentrations ranged from 0.0015 to 0.0074 $\mu\text{g/ml}$ in water samples.

External penetrating radiation doses for the Albuquerque community area averaged 110 mrem/yr. This is the natural background dose rate for the region attributable to terrestrial and cosmic radiation.

The calculated site boundary concentrations for gaseous radionuclides are less than 1% of applicable radiation protection guides. These concentrations cannot readily be measured. The estimated population dose due to the release of gaseous radionuclides

from SNL was 0.250 person-rem over the 80-km-radius Albuquerque area (Figure 5). The corresponding population dose due to natural background external penetrating radiation in the Albuquerque area (from the TLD measurements) is 49,950 person-rem. The population dose attributable to SNL operations is minute in comparison.

Figure 6 graphically gives the nuclide release trends of gaseous radionuclide emissions from SNL over the last 10 years; ^{85}Kr , ^{41}Ar and ^3H have been the major nuclides released from SNL facilities. Only ^{41}Ar was released in 1983.

Figure 6. Summary of Atmospheric Releases of ^{41}Ar , ^3H , and ^{85}Kr From Sandia-Albuquerque Facilities

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