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Abstract

We calculated potential radiological doses to members of the public who may be exposed to Los Alamos National Laboratory (LANL) operations. The population within 80 km of LANL received a collective dose of 1.6 person-rem, which is consistent with previous years. The calculated maximum off-site radiation dose to a member of the public from Laboratory sources was at East Gate and was 1.9 mrem. The calculated maximum on-site individual exposure to a member of the public is 4.2 mrem, which compares with 13 mrem in 2000. No health effects would be expected from these doses. We also concluded that there was no significant dose related to LANL activities from ingesting locally gathered food and water in Los Alamos or White Rock.

A. Overview of Radiological Dose Equivalents

Radiological dose equivalents presented here are calculated doses received by individuals exposed to radiation or radioactive material. The "effective dose equivalent" (EDE), referred to here as "dose", has been calculated using "radiation weighting factors" and "tissue weighting factors" to adjust for the various types of radiation and the various tissues in the body. The final result, measured in mrem, is a measure of the overall risk to an individual, whether from external radiation or contact with radioactive material. For example, 1 mrem of gamma radiation is effectively equivalent to 1 mrem from inhalation of plutonium.

Federal government standards limit the dose that the public may receive from Los Alamos National Laboratory (LANL or the Laboratory) operations. The Department of Energy (DOE 1993) public dose limit to any individual is 100 mrem per year received from all pathways (i.e., all ways in which people can be exposed to radiation, such as inhalation, ingestion, and direct radiation). The dose received from airborne emissions of radionuclides is further restricted by the dose standard of the Environmental Protection Agency (EPA) of 10 mrem per year, which is codified in the Code of Federal Regulations (40 CFR 61, EPA 1986). These doses are in addition to exposures from natural background, consumer products, and medical sources. Doses from public water supplies are also limited according to the Clean Water Act, either by established maximum contaminant levels for some radionuclides or by dose (4 mrem/year for man-made radionuclides, beta/photon emitters) (EPA 2000); see Appendix A.

B. Public Dose Calculations

1. Scope

The objective of our dose calculations is to report incremental (above background) doses caused by LANL operations. Therefore, we don't include dose contributions from radionuclides present in our natural environment or from radioactive fallout unless we identify LANL as the source for these radionuclides. Annual radiation doses to the public are evaluated for three principal exposure pathways: inhalation, ingestion, and direct (or external) radiation. We calculate doses for the following cases:

(1) *the entire population within 80 km of the Laboratory;*

(2) *the maximally exposed individual (MEI) who is not on LANL/DOE property (referred to as the off-site MEI);*

(3) *the on-site MEI, defined as a member of the public who is on LANL/DOE property, such as Pajarito Road;*

(4) *residences in Los Alamos and White Rock; and*

(5) *residences adjacent to Acid Canyon.*

2. General Considerations

We use the standard methods recommended by federal agencies to determine radiation doses (DOE 1988a, 1988b, 1991; EPA 1988, 1993, 1997; and NRC 1977). We begin with measurements and extend these with calculations using the standard models and methods that are used worldwide.

a. Direct radiation exposure.

Direct radiation from gammas or neutrons is measured at more than 100 locations near LANL (Chapter 4 Sections C and H). Doses above natural background are observed near TA-3, TA-18, TA-53, and TA-54.

To receive a measurable dose, a member of the public must be within a few hundred meters of the source, e.g., on Pajarito Road. At distances more than 1 km, the inverse-square law combined with scattering and attenuation in the air reduces the dose to much less than 0.1 mrem per year, which cannot be distinguished from natural background radiation. In practice, this means the only significant doses from direct radiation are on Pajarito Road, either from TA-3-130 or from TA-18. Operations at TA-3-130 ceased when this facility closed in July 2001, so the largest dose to a member of the public was from TA-18 to a person on Pajarito Road (Section C.3 of this chapter.)

To estimate the dose to the public, we combine the measurements of gamma and neutron dose with an occupancy factor. The measurements reported in Chapter 4 would apply to an individual who is at the particular location continuously, i.e., 24 hours per day and 365 days per year. We follow standard guidance and assume continuous occupancy for residences and places of business. For locations such as Pajarito Road, we multiply the measured dose by an occupancy factor of 1/16 (NCRP 1976.)

b. Airborne radioactivity (inhalation pathway).

At distances more than a few hundred meters from LANL sources, the dose to the public is almost entirely from airborne radioactive material. Whenever possible, we use the direct measurements of airborne radioactivity concentrations measured by AIRNET and reported in Chapter 4 Section A. All of these measurements result in an annual dose to a member of the public that is less than 0.1 mrem. Where local concentrations are too small to measure, we calculate the doses using the standard model, CAP88, that combines source-term information with meteorological data to estimate where the released radioactive material went.

Some of the nuclide emissions from LANSCE are not measured by AIRNET. These are measured at the stacks (Chapter 4 Section B) and the resulting doses are calculated by CAP88 (Chapter 3 Section C). Because the radioactive half lives are short, these doses decrease steeply with distance; e.g., the annual dose is 1.4 mrem at East Gate 1 km to the north of LANSCE, and is less than 0.01 mrem at a location in

Los Alamos 5 km to the west-north-west.

c. Food (ingestion pathway).

A food type is considered a potentially significant exposure pathway if it contains radioactive material that is detected above background concentrations. Measurements of the radioactive content of foods are reported in Chapter 5 and the resulting ingestion doses are summarized in Table 3-1. These measurements of radioactive content in food include background radioactivity (including man-made radioisotopes in fallout)

Table 3-1 Ingestion Doses from Foods Gathered or Grown in the Area During 2001.

			Dose per pound (mrem/lb)	1s[a] (mrem/lb)
Deer	Regional	muscle	4.1E-4	3.8E-4
		bone	**4.0E-2**	1.4E-2
	San Ildefonso Pueblo	muscle	1.1E-04	1.4E-04
		bone	**3.4E-02**	6.6E-03
	Tesuque Pueblo	muscle	1.3E-04	1.9E-04
		bone	**2.5E-02**	4.7E-03
Elk	Regional	muscle	5.1E-04	6.3E-04
		bone	5.9E-02	3.9E-02
	near LANL	muscle	6.1E-05	6.7E-04
		bone	5.2E-02	4.0E-02
Fish	Game Fish upstream		**6.0E-04**	2.9E-04
	Game Fish downstream		7.2E-04	4.6E-04
	Non-Game Fish upstream		**9.1E-04**	3.3E-04
	Non-Game Fish downstream		8.7E-04	4.4E-04
Prickly Pear	Regional		2.7E-03	4.3E-03
	Los Alamos		7.0E-03	4.1E-03
	San Ildefonso		7.1E-03	4.7E-03
Produce	Regional		2.4E-04	2.1E-04
	On LANL		1.7E-04	2.9E-04
	Los Alamos		5.0E-04	4.2E-04
	White Rock		3.9E-04	6.6E-04
	Cochiti		4.3E-04	5.2E-04
	San Ildefonso		2.8E-04	2.8E-04

[a]This column is the two-standard-deviation (2s) uncertainty. Where the dose is greater than 2s, the dose is considered statistically significant with 95% confidence and is indicated by bold text.

The general process for calculating ingestion doses is to multiply the amount of each radionuclide in a food product by a dose conversion factor for that radionuclide (DOE 1988b). We collected and analyzed many different types of food products for their radionuclide content. Table 3-1 lists the doses from ingesting unit quantities of these foods, but we did not correct them for background or regional concentrations.

The dose from consuming a pound of elk or deer bone is similar to the amounts reported in previous years, less than 0.06 mrem. This dose is almost entirely from strontium-90, which is like calcium and so concentrates in bone. The amount of strontium-90 in animals collected near LANL is not statistically different from those far from LANL, which indicates that the strontium-90 is mostly attributable to global fallout and not to LANL.

The dose from consuming a pound of fish is less than 0.001 mrem, and is also mostly from strontium-90. Because the fish downstream of LANL do not have significantly higher concentrations than fish upstream, the strontium-90 is mostly attributable to global fallout and not to LANL.

This year, local samples of prickly pear contained more strontium-90 than regional samples; however, last year's regional samples contained more than either regional or local samples this year. These fluctuations appear to be within statistical variability and do not point to LANL as the source of the strontium-90. There is also a small but measurable concentration of uranium in the prickly pear samples, but the isotopic ratios are consistent with natural uranium. We conclude that the prickly pear data do not indicate a significant dose attributable to LANL.

The dose from consuming a pound of vegetable or fruit produce from Los Alamos is estimated as about 0.0005 mrem per pound; (the statistical significance is marginal). Most of this dose is again from strontium-90, which is most likely from global fallout. Fallout is scavenged by rainfall and therefore tends to be higher in regions of higher rainfall. We conclude it is probably not attributable to LANL. Whatever the origin, the average resident of Los Alamos, who consumes 30 pounds of local produce per year, would receive an annual dose of 0.015 mrem from this produce.

In summary, we conclude that the LANL contribution to the food dose is too small to measure and is much less than 0.1 mrem per year.

d. Water (ingestion pathway).

Kraig and Gladney (Reference: David H. Kraig and Ernest S. Gladney, "Tap Water Sampling and Analysis during Calendar Year 2001 for Calculation of Radiological Dose to the Public", LA-UR-01-6643, 2001) collected 30 tap water samples: 10 from Los Alamos; 10 from White Rock; 3 from Santa Fe; 2 from Espanola; and one each from Chimayo, Dixon, El Rito, Jemez, and Pojoaque. Each sample was analyzed for tritium, strontium-90, cesium-137, uranium-234, uranium-235, uranium-238, plutonium-238, plutonium-239, and americium-241. For each radionuclide, the minimum detectable activity was sufficient to measure a potential dose less than 0.1 mrem per year.

At all locations and for all radionuclides except uranium, the doses were much less than 0.1 mrem per year. Natural uranium in the drinking water contributes a dose of about 0.1 mrem per year in Los Alamos County and somewhat more in Santa Fe and the Rio Grande valley.

In summary, we conclude that the LANL contribution to the drinking-water dose is too small to measure and is much less than 0.1 mrem per year.

d. Soil (direct exposure pathway).

We report measurements of radionuclide concentrations in surface soil in Chapter 5. These radionuclides in soil contribute to dose through the air pathway, which is evaluated in Section B.2.b; through ingestion of food, which is evaluated in Section B.2.c; and through gamma radiation, which is evaluated in Section B.2.a and is further evaluated here.

Almost all the gamma radiation from soils is from Cesium-137, which contributes less than 1 mrem per year. The other radionuclides contribute much less than 0.1 mrem per year.

Cesium-137 is a product of global fallout from nuclear weapons tests and is found worldwide in concentrations similar to those reported in Chapter 5. Two publications, Fresquez 1996 and Fresquez 1998, conclude that the concentrations reported in Chapter 5 are the result of global fallout. Fallout is scavenged by rainfall, so the concentrations are higher in regions where the rainfall is higher; and for this reason the concentrations are higher in Los Alamos County than in the Rio Grande valley. In the Environmental Surveillance report for 2000 (LA-13861-ENV) we reported a 2000 dose of 0.14 mrem from radionuclides in soil, with a reported 1 standard deviation of 0.4 mrem. This dose was calculated in the past by subtracting regional soil concentrations from local soil concentrations and modeling the net difference using a modified residential scenario. The resulting dose was very conservative, statistically not significant, and is now considered inappropriate for determining annual dose contributions to the MEI.

In summary, we conclude that the LANL contribution to dose from soil is too small to measure and is less than 0.1 mrem per year.

e. Release of Property.

The Laboratory releases surplus items of property to the general public. The requirements for release of such property are found in Laboratory Implementation Requirement LIR-402-700-01.0, “Occupational Radiation Protection. Chapter 14, Part 3. Releasing Items.” In keeping with the principle of maintaining radiation dose levels to “As Low As Reasonably Achievable,” it is Laboratory policy to not release any property with residual radioactivity. Therefore, there is no additional dose to the general public through the release of personal property for uncontrolled use by the general public.

C. Dose Calculations and Results

1. Population within 80 km

We used the local population distribution to calculate the dose from Laboratory operations during 2001 to the population within 80 km (50 miles) of LANL. Approximately 277,000 persons live within an 80-km radius of the Laboratory. We used county population estimates provided by the University of New Mexico Bureau of Business and Economic Research (BBER). These statistics are available at *http://www.unm.edu/~bber/*.

The collective dose from Laboratory operations is the sum of the estimated doses for each member of the public within an 80-km radius of LANL; for example, if two persons each receive 3 mrem the collective dose is 6 person-mrem. This dose results from airborne radioactive emissions; other potential sources, such as direct radiation, are essentially zero. We calculated the collective dose by modeling the transport of radioactive air emissions using CAP88, an atmospheric dispersion and dose calculation computer code.

The 2001 collective population dose attributable to Laboratory operations to persons living within 80 km of the Laboratory was 1.6 person-rem, which compares with 1 person-rem reported for 2000. This increased dose resulted from increased stack releases as described in Chapter 4 Section B. Tritium increased because of decommissioning TA-33 and TA-41, and also because of an unplanned tritium release from WETF on January 31, 2001. Also, LANSCE emissions increased because of changes to the 1L-target water-cooling system. Tritium contributed about 73% of the dose; short-lived air activation products such as carbon-11, nitrogen-13, and oxygen-15 from LANSCE contributed about 26%; and plutonium, uranium, and americium contributed less than 1%.

No observable health effect is expected from these doses.

2. Off-Site MEI

The off-site maximally exposed individual (MEI) is a hypothetical member of the public who, while not on DOE/LANL property, received the greatest dose from LANL operations. The location of the off-site MEI was at East Gate along State Road 502 entering the east side of Los Alamos County. East Gate is normally the location of greatest exposure because of its proximity to LANSCE. During LANSCE operations, short-lived positron emitters such as carbon-11, nitrogen-13, and oxygen-15 are released from the stacks and diffuse from the buildings. These emitters release photon radiation as they decay, producing a potential radiation dose.

As stated in the previous section and discussed in Chapter 4 Section B, the LANSCE stack emissions were larger this year as a result of changes to the 1L-target water-cooling system. Therefore, the MEI dose was 1.9 mrem this year compared with 0.64 mrem in 2000.

We model the dose from LANSCE and from the LANL stacks using CAP88, an atmospheric dispersion and dose calculation computer code. The CAP88-modeled doses were 1.4 mrem from the LANSCE stack, 0.1 mrem from LANSCE diffuse emissions, 0.1 mrem from the tritium stacks, and 0.2 mrem from other LANL stacks. To this total, we add 0.1 mrem from the radionuclides measured at the AIRNET station, although this is primarily from tritium, which has already been accounted for in the CAP88 model. (Reference: Keith W. Jacobson, 2002, “U.S. DOE Report: 2001 LANL Radionuclide Air Emissions”, LA-13957-PR (2002)).

The total annual dose, 1.9 mrem, is far below the applicable standards, and we conclude it causes no observable health effects.

3. On-Site MEI

The on-site MEI is a member of the public on Pajarito Road who passes LANL TA-18.

Dosimeters that are sensitive to neutron and photon radiation are located on Pajarito Road. We collected data continuously throughout 2001 (Chapter 4 Section C) and these data allow us to calculate doses that might have been received by members of the public. After subtracting the dose from natural background, the total dose (during 24 hours a day and 365 days a year) was 67 mrem. Following the guidance of the NCRP (NCRP 1976) we multiplied this total by 1/16 to account for occupancy; (an occupancy factor of 1/16 corresponds to an average of half an hour of exposure every 8-hour workday). This calculation indicates a maximum dose of 4.2 mrem to a member of the public during 2001.

We report this dose as a conservative upper bound of the doses that might have been received by people passing near this facility frequently. All other pathways, including CAP88 calculations for the air pathway, add less than 0.1 mrem to the calculated dose. This dose is about 4% of the DOE public all-pathway dose limit of 100 mrem.

4. Doses in Los Alamos and White Rock

In this section, we discuss the doses to residents in Los Alamos and White Rock. We used the AIRNET data (reported in Chapter 4 Section A) to calculate the average air concentrations for the 21 perimeter stations near Los Alamos and White Rock, and subtracted the concentrations at the 4 regional stations. These concentrations were converted to doses using the factors in DOE 1988b. To these doses, we added the contributions from LANSCE, calculated using CAP88 for two representative locations: 5 km west-north-west of LANSCE in Los Alamos and 6.8 km south-east of LANSCE in White Rock.

a. Los Alamos. During 2001, the measurable contributions to the dose at an average Los Alamos residence were: 0.006 mrem from LANSCE; 0.005 mrem from plutonium; 0.003 mrem from americium; and 0.003 mrem from tritium; these add to 0.017 mrem. All other nuclides contribute less than 0.001 mrem.

b. White Rock. During 2001, the measurable contributions to the dose at an average White Rock residence were: 0.009 mrem from LANSCE; 0.001 mrem from plutonium; 0.001 mrem from americium, and 0.002 mrem from tritium; these add to 0.013 mrem. All other nuclides contribute less than 0.001 mrem.

The contributions from direct radiation, food, water, and soil were discussed in Chapter 3 Section B.2; each was too small to measure and less than 0.1 mrem. Therefore, the total annual dose from all pathways was much less than 0.4 mrem.

5. Acid Canyon

The south fork of Acid Canyon was remediated from September 12 through November 9, 2001. Both the DOE Oversight Bureau of the New Mexico Environment Department (NMED) and the contractor, Washington Group International Inc. (WGII) collected air samples during the remediation activities. From these results, we calculate the dose at the nearest residence, 170 m north of the worksite.

NMED measured 3.6E-14 Ci/m^3 of transuranics (primarily plutonium-239) at a location within the roped-off work site and about 10 m north of the main work activities. This measurement was made during two work weeks of 40 hours each. We take this as the concentration for the full 336 work hours and calculate 8.7E-15 Ci/m^3 averaged over the 1392 hours from September 12 to November 9. Also, WGII measured the following transuranic concentrations averaged over 1392 hours: 2.4E-15 Ci/m^3 at 20 m, 3.3E-14 Ci/m^3 at 5 m, and 6.9E-14 Ci/m^3 at 3 m. These concentrations should be compared with the occupational standard of 6E-12 Ci/m^3 for class-Y transuranics.

These four concentrations are proportional to $x^{-1.8}$ where x is the average distance from the work activities to the air sampler. This model corresponds to the prediction by the CAP88 atmospheric-dispersion program for class-C atmospheric stability.

This model is used to predict that the average concentration at the nearest residence was 5E-17 Ci/m^3. The estimate is conservative because it applies to smooth and flat terrain, whereas the trees and canyon walls reduce the concentration. For comparison, the CALPUFF program calculated an average concentration of 2.5E-17 Ci/m^3 at the residence.

These concentrations are well below the EPA standard of 2E-15 Ci/m^3. The dose to a member of the public who breathes 5E-17 Ci/m^3 of transuranics for 1392 hours is 0.04 mrem, which is well below the 10 mrem dose limit allowed by EPA regulations.

D. Estimation of Radiation Dose Equivalents for Naturally Occurring Radiation

This section discusses the LANL contribution relative to natural radiation and radioactive materials in the environment (NCRP 1975, 1987a, 1987b).

External radiation comes from two sources that are approximately equal: cosmic radiation from space and terrestrial gamma radiation from radionuclides naturally in the environment. Doses from cosmic radiation range from 50 mrem per year at lower elevations near the Rio Grande to about 90 mrem per year in the mountains. Doses from terrestrial radiation range from about 50 to 150 mrem per year depending on the amounts of natural uranium, thorium, and potassium in the soil.

The largest dose from radioactive material is from the inhalation of naturally occurring radon and its decay products, which contribute about 200 mrem per year. An additional 40 mrem per year results from naturally occurring radioactive materials in the body, primarily potassium-40, which is present in all food and in all living cells.

In addition, members of the US population receive an average dose of 50 mrem per year from medical and dental uses of radiation, 10 mrem per year from man-made products such as stone or adobe walls, and less than 1 mrem per year from global fallout from nuclear-weapons tests (NCRP 1987a). Therefore, the total annual dose from sources other than LANL is in the range of about 300-500 mrem. The estimated LANL-attributable 2001 dose to the onsite MEI, 4.2 mrem, is about 1% this dose.

E. Effect to an Individual from Laboratory Operations

Health effects from radiation exposure have been observed in humans at doses in excess of 10 rem (10,000 mrem). However, doses to the public from LANL operations are much smaller. According to the 1996 Position Statement of the Health Physics Society (HPS 1996): “Below 10 rem, risks of health effects are either too small to be observed or are non-existent.” Therefore, the doses reported here are not expected to cause observable health effects.

G. References

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