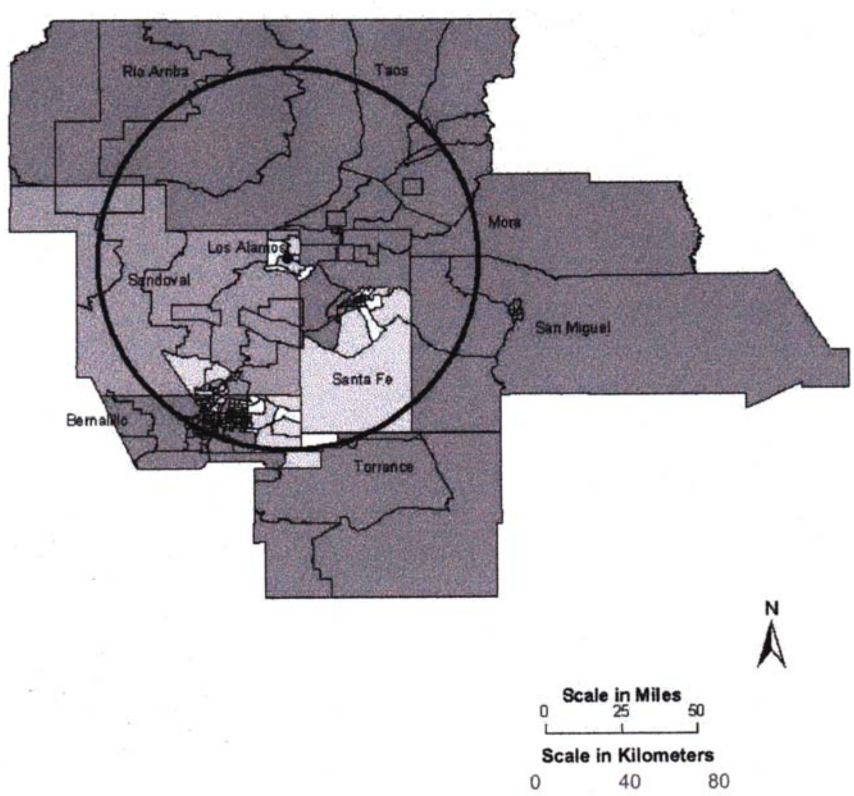
New Mexico's Right to Know:
The Impacts of Los Alamos National Laboratory Operations On Public Health and the Environment



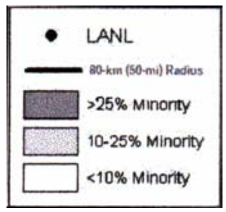
Bernd Franke
Catherine M. Richards, M.S.
Steve Wing, Ph.D., and David Richardson, Ph.D.

Prepared for Concerned Citizens for Nuclear Safety
First Technical Report
August 2003

On the Cover: Map of environmental justice demographics within a fifty-mile radius of Los Alamos National Laboratory (LANL). In 2002, minority populations comprised 30.9% of the U.S. population, 50.5% of the New Mexico population and 54.2% of the population surrounding LANL.

Source: *Draft Supplemental Programmatic Environmental Impact Statement on Stockpile Stewardship and Management for a Modern Pit Facility*, DOE/EIS-236-S2, Department of Energy/National Nuclear Security Administration, May 2003.

Key:



Concerned Citizens for Nuclear Safety
107 Cienega
Santa Fe, NM 87501
Phone: (505) 986-1973
Fax: (505) 986-0997
www.nuclearactive.org

Concerned Citizens for Nuclear Safety is a 501 (c)(3) non-profit organization that was founded in 1988 because of concerns about nuclear waste transportation through New Mexico. CCNS remains true to its mission and primary goal: to protect all living beings and the environment from the effects of radioactive and other highly hazardous materials now and in the future.

This project was supported by a grant from the Citizens' Monitoring and Technical Assessment Fund.

Table of Contents

Executive Summary

Nuclear-related activities have been continuous in Los Alamos County (LAC) since the development of Los Alamos National Laboratory (LANL) in 1943. These activities result in emissions of radionuclides into the air, discharges of radioactive liquids into canyon systems and disposal of radioactive waste in canyons and on mesa tops above the Rio Grande. Prior to the passage of stricter environmental laws in the early 1970s, less stringent approaches to and enforcement of radioactive emissions, waste disposal and monitoring of employee exposures characterized LANL's early operations. The extent to which LAC residents and LANL employees have been exposed to ionizing radiation beyond background levels remains unclear.

LANL was the first site to develop atomic weapons. Yet a complete dose reconstruction study has not been conducted at LANL. In fact, it is the last major Department of Energy (DOE) site scheduled to undergo a dose reconstruction. A dose reconstruction is a study that estimates the amount of radioactivity and chemicals to which an individual may have been exposed based on the amounts of radioactivity and chemicals released by a facility.

Workers at other DOE sites have utilized these dose reconstruction studies to support their claims under the Energy Employees Occupational Illness Compensation Program Act of 2000 (EEOICPA). To their detriment, LANL retirees and workers do not have a dose reconstruction to rely on for their EEOICPA claims.

In early 1999, the National Center for Environmental Health of the Centers for Disease Control and Prevention (CDC) began the first phase of a possible five-phase project to determine historical radionuclide and chemical releases from LANL. The project is called the Los Alamos Historical Document Retrieval and Assessment Project (LAHDRA). However, security and access has been constrained due to the May 2000 Cerro Grande Fire, the Wen Ho Lee and missing property investigations and the events of September 11th. LANL has heightened security and imposed greater limits on access to information, thereby severely hampering the CDC's work.

Despite these obstacles, the CDC's work has been very fruitful. They have found that the soil surrounding LANL may contain as much as 100 times more plutonium than was previously estimated. Furthermore, they have uncovered documents indicating plutonium levels found in autopsies of LAC residents who never worked at LANL are higher than regional background levels.

In July 2003, CDC instructed its contractors to conclude the first half of the first phase of the LAHDRA. It is uncertain if or when the project will continue. If the LAHDRA ends, LAC residents, LANL retirees and employees and those living in surrounding communities will never know the levels of radiation and chemicals to which they have been exposed.

Concerned Citizens for Nuclear Safety (CCNS) contracted with Bernd Franke, Catherine M. Richards, M.S., Steve Wing, Ph.D., and David Richardson, Ph.D. to investigate the following public health issues concerning LANL emissions:

- Historical and current emissions of radioactive materials from LANL operations into the air;
- Incidence and mortality rates for LAC residents for 24 types of cancer compared with state and national reference populations; and
- Occupational health studies of LANL employees exposed to radionuclides.

These studies focus on localized impacts at LANL and in LAC. LANL employees and LAC residents may receive the highest dose of radiation because of their proximity to the facility. Therefore, exposure of LANL employees and LAC residents may serve as an indicator of impacts to those living in the surrounding communities.

CCNS advocates preventing harm before it can happen. These reports serve as an early warning of harm to the public health and environment due to LANL operations. For example, as in dose reconstruction studies at other DOE sites, the source term estimate has been revised upwards. At LANL, the source term estimate has been doubled. Furthermore, there is increased incidence and mortality for certain cancers in LAC and the uncertainties and discriminatory nature associated with the existing LANL occupational health studies prevents full analyses of exposures. Therefore, CCNS believes that the LAHDRA project must continue in order that we may understand the source of the harm from LANL operations so that further harm may be prevented.

Based on the findings, conclusions and recommendations presented in these reports, CCNS strongly recommends that the CDC continue its LAHDRA work uninterrupted. We also strongly recommend that vulnerable populations, including children and the elderly, be included in the dose reconstruction. New Mexicans have the right to know the levels of radionuclides and chemicals to which they may have been exposed due to LANL operations. The LAHDRA and subsequent dose reconstruction project provide a vehicle for that knowledge and must continue uninterrupted.

This Executive Summary presents the findings, conclusions and recommendations resulting from these reviews and investigations.

I: A Review of Historical and Current Emissions of Radioactive Materials from LANL, by Bernd Franke, Scientific Director, ifeu - Institut für Energie und Umweltforschung, Heidelberg, Germany

Franke's investigation into historical and current emissions of radioactive materials resulting from LANL operations addresses many questions of public concern which include:

- How does currently available data on historical emissions from LANL compare with results from other DOE facilities?
- Is it reasonable to require a dose reconstruction of historical releases and an examination of subsequent health impacts?
- What conclusions can be drawn from the limited data on historical environmental monitoring?
- What issues with respect to current emissions of radioactive materials are still unresolved?

In responding to the first question, Franke utilizes data found in the February 2002 LAHDRA draft summary emissions report. Findings of the LAHDRA report include:

- The current release estimates for plutonium isotopes of 3.4 curies (Ci) are more than twice those previously estimated.
- The LANL historical plutonium emissions into the air of 3.4 Ci is about 20 times the amount of plutonium that was deposited onto the LANL site from atmospheric nuclear weapons tests, based on current estimates.
- Comparing the current LANL plutonium emission estimates with those of other DOE sites with dose reconstruction studies, the plutonium source term for LANL (3.4 Ci) is about twice that of releases from the Hanford site (1.78 Ci) and about seven times less than Rocky Flats releases (24.2 Ci).
- Comparing distances from the DOE facilities to homes and businesses, the LANL property is closer (< 1 mile) than either Hanford (15 miles) or Rocky Flats (5 miles).

In response to whether the requirement for a dose reconstruction study is reasonable, Franke demonstrates that an in-depth dose reconstruction is indeed necessary. LANL presents unique circumstances related to the lack of a final source term estimate; the existing estimate is 20 times the amount of plutonium fallout found on LANL property; and the proximity of residences and businesses to LANL facilities means that exposure is more immediate. Given that other radionuclides and toxic substances were released from LANL, there are significant uncertainties in estimating releases and subsequent exposures due to site-specific circumstances. Therefore, an in-depth dose reconstruction for LANL should be done.

Regarding the limited environmental monitoring data, Franke examines the ambient air monitoring data from the year 1972. While LANL's reported concentrations of plutonium-239/240 at most monitored on-site and off-site locations are in the expected range, the same cannot be said for the reported concentrations of plutonium-238. These exceed the expected concentrations at all locations by a factor between four and 20. The issue of plutonium-238 concentrations in ambient air at LANL is puzzling. A careful review of the quality of the air monitoring data for 1972, as well as for other years, is clearly warranted.

In response to the last question regarding current emissions, Franke generally agrees that in the year 2001, the radiation doses resulting from LANL operations were below the 10 millirem/year (mrem/yr) limit established by the Clean Air Act (CAA) 40 CFR 61, Subpart H regulation. Nevertheless, LANL was in substantive breach of its compliance obligations because of the lack of quality assurance of the data on radionuclide usage supplied by the facilities to the Meteorology and Air Quality Group.

In addition, Franke believes that one of the major problems with the Subpart H compliance definition is that the compliance limit of 10 mrem/yr effective dose equivalent only applies to a fixed location, such as a residence, school, business or office. There are many point sources in proximity to public access roads that allow travel by members of the public (sometimes called "transient receptors") to closely approach point sources, raising issues about whether these exposed receptors are covered by the compliance definition.

Many releases of radionuclide emissions are short-term and discontinuous. Short-term releases can also be expected from some of the unmonitored point sources, such as waste sites or during transportation of radioactive materials. Inhaling as few as 7.5 microcuries of plutonium would result in a dose that would be deemed noncompliant with the CAA regulations. It is uncertain whether LANL's ambient air monitoring system, AIRNET, is sensitive enough to detect such releases under certain conditions.

Franke concludes:

- The LANL historical plutonium emissions into the air of 3.4 Ci is about 20 times the amount of plutonium that was deposited onto the LANL site from atmospheric nuclear weapons tests, based on current estimates.
- The reported concentration of plutonium-238 in air in the vicinity of LANL in the year 1972 was between a factor four and 20 times higher than expected from other sources.
- The current information on historical emissions warrants a careful reconstruction of doses to members of the public, as well as an evaluation of the associated health risks.
- Visitors to the LANL site could receive an effective dose in excess of 10 mrem/yr from plutonium emissions under unfavourable circumstances (e.g., short-term emissions),

even though the emissions would be reported to be in formal compliance with 40 CFR 61, Subpart H of the CAA.

- The ability of LANL's ambient air monitoring system, AIRNET, to detect releases from unmonitored point or diffuse sources, such as waste sites, needs to be carefully analyzed.

II: An Investigation of Cancer Incidence and Mortality Rates in Los Alamos County and New Mexico 1970 – 1996, by Catherine M. Richards, M.S.

This investigation is in response to community concerns about occurrences of specific types of cancer in LAC. Richards compared LAC cancer incidence and mortality rates to New Mexico cancer incidence and mortality rates, for all races, using data from the New Mexico Tumor Registry for the 27-year time period of 1970 through 1996.

The specific aims developed for this study were to:

- Compare LAC cancer incidence rates to incidence rates calculated for a New Mexico state reference population, for all races.
- Compare LAC cancer mortality rates to mortality rates for a New Mexico state reference population, for all races.
- Determine whether any of the LAC cancer incidence and mortality rates were significantly elevated in comparison to rates observed for the New Mexico state reference population.
- Begin to assess whether any of the significantly elevated cancer rates could be attributed to ionizing radiation exposures.
- Review existing literature on ionizing radiation exposure and health risks.

The incidence rates for 24 major types of cancers were investigated. Of these 24 types of cancers, seven were significantly elevated in LAC and include: breast, melanoma, non-Hodgkin's lymphoma, ovary, prostate, testicular (significant at the 90% confidence interval) and thyroid cancers. In addition to these seven cancers, the 1993 NMDOH report also found a moderate increased incidence rate for cancer of the brain and nervous system during the mid to late-1980s. All seven of the cancers mentioned above are cancers for which claims may be filed under the EEOICPA.

Of the seven cancers, breast, melanoma, ovarian, testicular and thyroid cancers were also elevated in LAC when compared with the U.S. Surveillance, Epidemiology, and End Results Program (U.S. SEER) site data for the time period of 1991 – 1995.

Based on a review of mortality data, compiled for 24 major types of cancer, cancer mortality rates that were significantly elevated in LAC when compared to the state reference population rates include breast cancer. When comparing the LAC mortality rate for breast cancer with that of the U.S. SEER sites for the time period 1991 – 1995, the LAC mortality rate was also elevated. Additionally, LAC mortality rates for melanoma and ovarian cancers were also elevated when compared with the U.S. SEER sites.

Significant elevations in cancer for LAC residents were determined by calculating the upper and lower confidence limits for each LAC rate at the 95% and 90% confidence intervals. If the lower confidence limit for a given LAC rate was greater than the New Mexico comparison rate, the elevation was considered significant. This methodology is the same as that used by the New Mexico Department of Health (NMDOH) in their report entitled *Los Alamos Cancer Rate Study Phase I: Cancer Incidence in Los Alamos County, 1970 – 1990*.

Study limitations include the small number of observations, population mobility, difficulty in establishing cause and effect relationships and socioeconomic status and ethnicity of LAC and New Mexico. However, this study serves as a tool that can be utilized for further analysis of cancer incidence and mortality in LAC.

Richards recommends:

- Reviewing cancer registry data to investigate the increases in LAC incidence rates, compared to the New Mexico state reference population, for cancers of the female breast (50% increase), melanoma (125%), non-Hodgkin's lymphoma (48%), ovary (45%), prostate (49%), testicular (82%) and thyroid (106%).
- Reviewing cancer registry data to investigate the elevated LAC mortality rates for breast (41%), melanoma (63%) and ovarian (27%) cancers when compared with the New Mexico state reference population and the U.S. population.
- Reviewing spatial and temporal trends of cancer rates by neighborhood unit and examining the proximity of cancer cases to pollution sources.
- Conducting case reviews to establish residential history, occupational history, family disease history, other behavioral risk factors and cancer etiology.
- Conducting dose reconstruction studies by accessing LANL documents to determine potential exposures for the community of LAC.

III: A Review of Occupational Health Studies at Los Alamos National Laboratory, by Steve Wing, Ph.D., and David Richardson, Ph.D., with the Department of Epidemiology, School of Public Health, University of North Carolina

Wing and Richardson provide a critical review of occupational health studies conducted at LANL. In the review, the authors discuss the weaknesses and strengths of the studies and their capacity to address health concerns of workers and the public. They consider which employees have been included or excluded from the occupational health studies. Building on this evaluation, the authors summarize the results of LANL worker studies. Next, they interpret the LANL studies in the context of studies of workers at other nuclear facilities and other types of research into the biological effects of ionizing radiation. They conclude with a discussion of the meaning of the studies for people with health concerns and make suggestions for protection of occupational and public health.

LANL has conducted three types of occupational health studies, which are exposure, medical follow-up, and epidemiological studies. The authors describe how workers may be exposed in the industrial setting; how internal and external exposure to radiation is measured, including autopsy studies of DOE workers; and how dose reconstructions may provide quantitative estimates of exposure. One medical follow-up study of LANL workers began in 1952. The significance of such studies is unclear because of the uncertainties associated with initial exposures, choice of workers, lack of a comparison group and the low statistical power for studies of diseases of interest, such as malignancies or genetic effects. Cohort and case control epidemiological studies have been conducted at LANL.

Cohort studies identify workers from a roster of employees and follow them through time to evaluate mortality or cancer incidence using vital records or tumor registry data. However, employed persons must be healthy enough to work and receive regular income, medical insurance and other benefits. As a result, they have generally lower disease rates that may increase through exposure to occupational hazards. Their disease rates are lower than the general population, which includes people who are too ill to work and lack the benefits of regular employment, in spite of their exposures. This phenomenon is sometimes called the "healthy worker effect." Cohort studies can also be used to conduct analyses of trends in disease rates with increasing occupation exposure, sometimes called dose response studies. A case control study evaluates a specific disease in relation to exposures of interest by choosing two groups of workers, one group of disease-free controls and the other of sick workers.

Wing and Richardson found that only employees of primary contractors have been included in occupational health studies at LANL. They have included only employees of the manager and operator of LANL, the University of California (UC), and the maintenance, construction and support service workers, which are referred to as the "Zia employees." Health studies have not been conducted of employees of other contractors or subcontractors. Furthermore, most of the occupational health studies at LANL have been limited to white Anglo UC employees. Studies of the Zia workforce, which include many Hispanics and Native Americans, have been much less complete than for the UC workforce. In one study, personnel records were available for 97% of the UC workers, but only 20% of the Zia workers, and urinalysis records were available for 39% of the UC workers, but only four percent of the Zia workers.

All types of occupational health studies have limitations in design and implementation. Exposure measurements for LANL workers are limited primarily to radiation hazards. In the case of internally deposited radionuclides, estimates of body burdens and internal doses are highly uncertain and do not take into account individual differences in metabolism and retention of radionuclides. Some of the studies lack adequate follow-up to detect diseases with long latency periods. Despite serious measurement problems and a lack of exposure data for many workers and time periods, excesses of certain cancers and dose response relationships for others have been observed among workers at LANL and other DOE facilities.

Wing and Richardson recommend that given the uncertainties associated with exposures and diseases, it is important that occupational and environmental exposures to hazardous agents be minimized and that workers and the general public be involved in decisionmaking about exposure standards and health related research.

A Review of Historical and Current Emissions of Radioactive Materials from Los Alamos National Laboratory into the Air

By Bernd Franke[1]

Introduction

This report addresses questions with respect to the emissions of airborne radioactive materials, historical releases, unresolved questions regarding the current releases from Los Alamos National Laboratory (LANL).

Given the limited resources available, the review focused on questions of public concern that were raised in discussions with Concerned Citizens for Nuclear Safety (CCNS) and other members of the community:

- How does currently available data on historical emissions from LANL compare with results from other Department of Energy (DOE) facilities?
- Is it reasonable to require a dose reconstruction of historical releases and an examination of subsequent health impacts?
- What conclusions can be drawn from the limited data on historical environmental monitoring?
- What issues with respect to current emissions of radioactive materials are still unresolved?

Historical Airborne Emissions of Radioactive Materials at LANL

Since its inception during World War II in the year 1943, radioactive materials have been released into the air, water and soil as a result of LANL operations. An in-depth analysis of the effects of these releases on human health and the environment requires an accurate account of the historical emissions. The Los Alamos Historical Document Retrieval and Assessment (LAHDRA) by the Centers for Disease Control and Prevention (CDC) is the first step in this direction. The objective of LAHDRA is a systematic review of all available documents related to LANL operations and the identification of records that contribute information about releases of chemicals and radionuclides from the site between 1943 and the present.

[1] Bernd Franke is the Scientific Director for the ifeu - Institut für Energie und Umweltforschung in Heidelberg, Germany.

Plutonium Releases into the Air

The LAHDRA project is carried out by ENSR International, a global provider of environmental services to industry and government, and Shonka Research Associates, Inc. A summary report was published in February 2002 (ENSR, 2002). The LAHDRA report focuses on plutonium releases, which form the basis for the evaluation in this report. Figure 1 displays the release estimates of plutonium isotopes, the values are listed in Table 1.

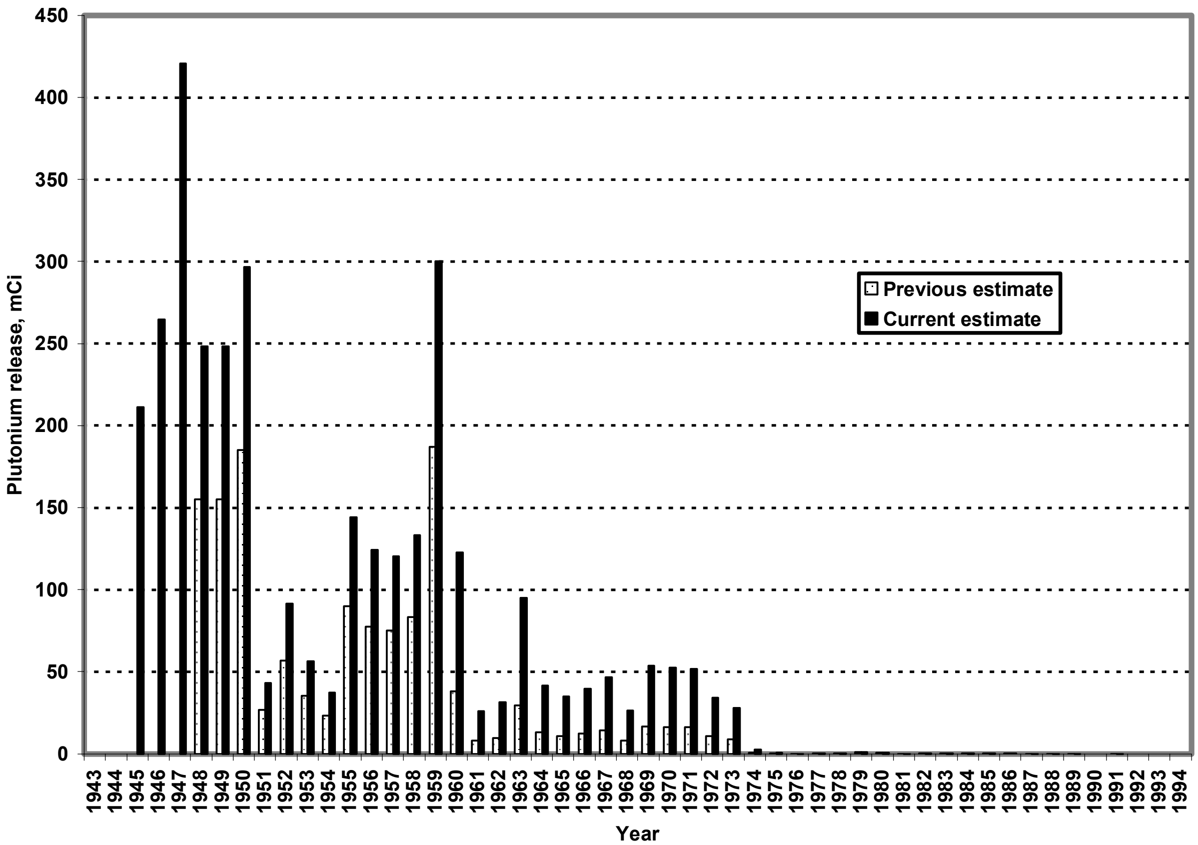


Figure 1 **Airborne releases of plutonium from LANL, 1945 – 1994 in millicuries per year (mCi/yr). Source: ESNR, 2002, p. 120**

Table 1 Airborne releases of plutonium from LANL, 1945 – 1994 in mCi/yr. Source: ESNR, 2002

Year	Previous estimate *mCi*	Current estimate *mCi*	Year	Previous estimate *mCi*	Current estimate *mCi*
1943			1970	16.42	52.65
1944			1971	16.11	51.66
1945		211.41	1972	10.69	34.28
1946		264.73	1973	8.7	27.88
1947		420.54	1974	0.79	2.55
1948	155	248.47	1975	0.25	0.79
1949	155	248.47	1976	0.07	0.07
1950	185	296.56	1977	0.13	0.13
1951	27	43.28	1978	0.11	0.11
1952	57.01	91.38	1979	1.09	1.09
1953	35.23	56.47	1980	0.75	0.75
1954	23.3	37.35	1981	0.06	0.06
1955	89.89	144.09	1982	0.11	0.11
1956	77.49	124.22	1983	0.11	0.11
1957	75.12	120.41	1984	0.14	0.14
1958	83.21	133.39	1985	0.21	0.21
1959	187.24	300.14	1986	0.21	0.21
1960	38.27	122.69	1987	0.07	0.07
1961	8.16	26.16	1988	0.07	0.07
1962	9.79	31.4	1989	0.05	0.05
1963	29.59	94.88	1990	0.03	0.03
1964	13.01	41.7	1991	0.04	0.04
1965	10.9	34.94	1992	0.01	0.01
1966	12.32	39.5	1993	0.01	0.01
1967	14.51	46.53	1994	0.01	0.01
1968	8.24	26.43			
1969	16.73	53.63	**Total**	**1,368**	**3,432**

The current LAHDRA estimate for the source term of 3.4 curies (Ci)[2] is more than twice the source term that ENSR estimated at an earlier date, while giving no further information as to when the estimate was made. Judging from the experience with source term estimates at other DOE facilities in which source term estimates were usually revised upwards, one can reasonably expect an upward revision for the LANL site as well.

[2] 1 Ci = 1 curie = 37,000,000,000 Bq (Becquerel) = 37,000,000,000 disintegrations per second.

The current estimate can be considered in several ways. One can compare the estimated releases with the fallout deposited on LANL property from atmospheric nuclear weapons tests. Based on data in the 1982 report of the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR,1982), the fallout of plutonium-239/240 from nuclear weapons tests in the northern hemisphere between 40°N and 50°N was about 1,600 picocuries[3] per square meter (pCi/m^2). Since LANL occupies 43 square miles, a total of 0.17 Ci of plutonium-239/240 is estimated to have been deposited on the LANL site from worldwide fallout using the UNSCEAR value. In other words, the current official estimate of the amount of plutonium emitted into the air by LANL is about 20 times the amount of plutonium that was deposited on the LANL site from nuclear weapons tests.

Another possibility to put the magnitude of plutonium emissions into perspective is to compare LANL's emission estimates with that of other DOE sites as shown in Table 2. The current estimate for LANL is about twice the official estimate for the Hanford site from the Hanford Environmental Dose Reconstruction Project (HEDR) for which the cumulative source term for plutonium-239/240 was estimated to be 1.78 Ci (Heeb, 1994). One should bear in mind that the Hanford site is much more remote than the LANL site; the closest offsite location is about 15 miles (24 km) east-southeast from the center of the Hanford 200 Area, whereas residential areas near LANL are less than a mile away from the source of historical emissions.

At the Rocky Flats site in Colorado, the official central estimate is 24.2 Ci, or about seven times the estimate for LANL (RAC, 1999). Whereas historical plutonium emissions were larger at Rocky Flats than at LANL, one should also bear in mind that the distance between the source of the emissions and the closest offsite area (about 5 miles) is far greater than at LANL. In addition, plutonium emissions were the only relevant source of radioactive materials at Rocky Flats, while at LANL other radioactive isotopes, such as tritium, uranium-235, uranium-238, iodine-131, cesium-137 and strontium-90, were emitted into the air as well. A careful accounting of the magnitude of historical releases of these materials into the air is still pending.

[3] 1 pCi = 1 picocurie = 1 x 10^{-12} Ci = 0.037 Bq (Becquerel) = 0.037 disintegrations per second = 2.2 disintegrations per minute.

Table 2 Comparison of historical airborne releases of plutonium from three DOE facilities

DOE Site	Plutonium Source Term	Closest distance from source to offsite area, miles	Source
Hanford, WA	1.78 Ci	~ 15 miles	Heeb (1994)
Rocky Flats, CO	24.2 Ci	~ 5 miles	RAC (1999)
Los Alamos, NM	3.4 Ci	< 1 mile	ENSR (2002)

From the above, it is concluded that a careful reconstruction of historical releases and subsequent radiation exposures is necessary at LANL. Given the different circumstances and the lack of a final estimate for LANL, a precise evaluation of the potential impacts of LANL releases is not possible at this time.

It should be noted that dose reconstructions were performed at the Hanford and Rocky Flats sites, as well as at other DOE facilities, including the Nevada Test Site. The results for the estimates of the cancer incidence risk at various DOE sites were recently compared in an article by Reed, et al. (2003). The results are shown in Figure 2 for individuals defined as the "maximum receptor" (usually at the point of maximum impact and living entirely on locally produced food) and a "typical receptor" (usually a representative individual). The largest risk was calculated for iodine-131 releases from the Hanford site. The upper bound estimate of cancer incident risk for the maximum receptor near Rocky Flats is about 1 in 10,000, mainly due to airborne emissions of plutonium-239/240. Given the fact that additional radionuclides and toxic substances were also released from the LANL site along with plutonium-239/240, and because there are significant uncertainties in estimating releases and subsequent exposures due to site-specific circumstances, it is recommended to conduct a similar in-depth evaluation for the LANL site as well.

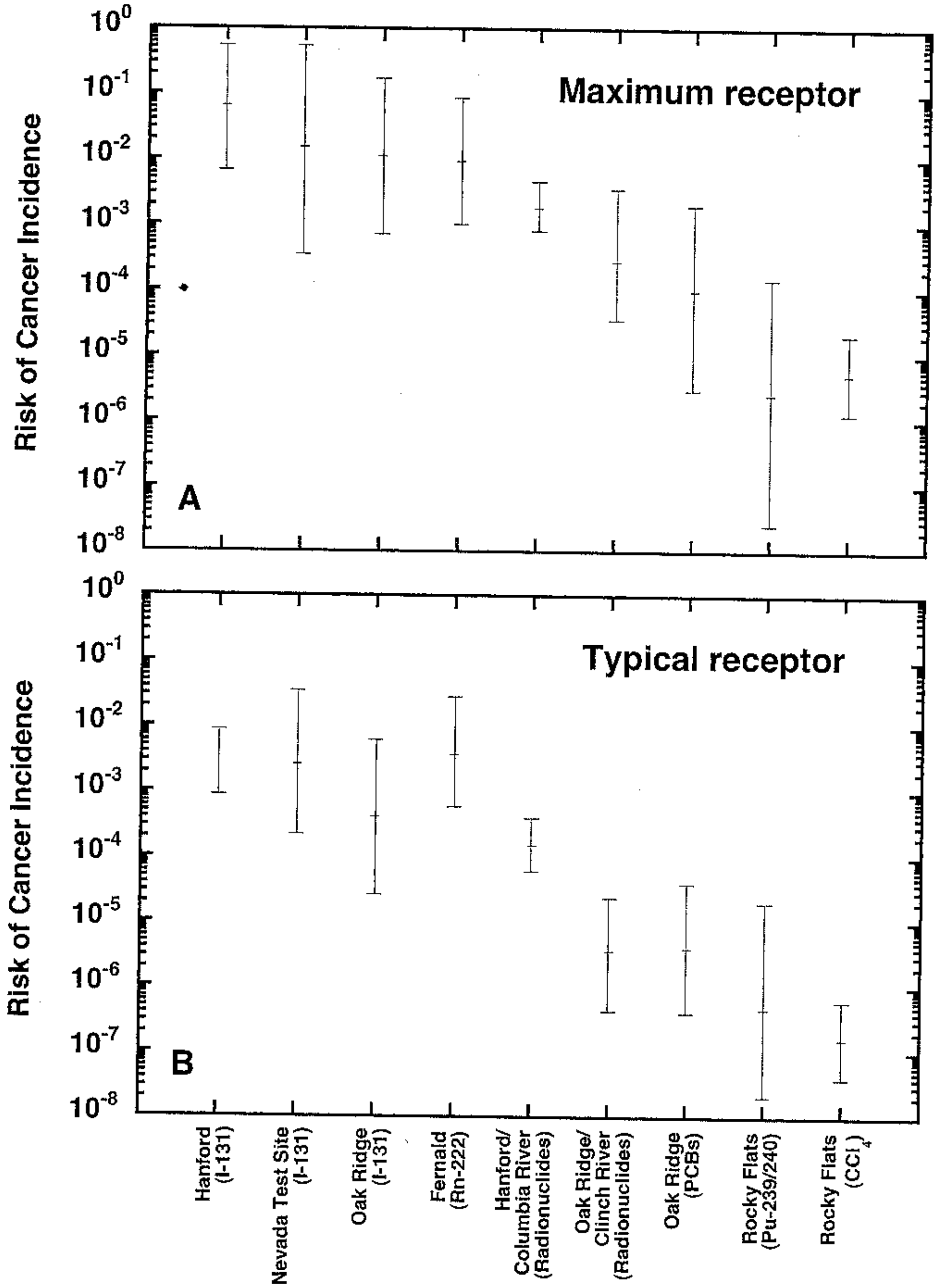


Figure 2 Excess risk of cancer incidence for representative individuals due to contaminant releases from the indicated sites for (A) a maximally exposed receptor and (B) a typical receptor, vertical lines represent 90% or 95% confidence intervals (details in Reed, et al., 2003)

Review of Selected Historical Environmental Monitoring Data for Airborne Radionuclides

The ENSR summary report contains data on concentrations of plutonium-238 and plutonium-239/240 in ambient air at various locations both onsite and offsite of LANL property in the year 1972. The reported data for annual averages is plotted in Figure 3. The highest concentrations were reported for onsite locations at Technical Area 3 (TA-3) and TA-6. At TA-6, the combined plutonium-238 and plutonium-239/240 activity was around 0.2 femtocuries[4] per cubic meter (fCi/m^3). The total plutonium emission from LANL in 1972 was estimated by ESNR to be 0.034 Ci compared to the maximum in 1947 of 0.42 Ci. Therefore, it can thus be expected that air concentrations were much larger in past years.

The expected concentration from weapons testing fallout for the year 1972 (0.04 fCi/m^3) is indicated in Figure 3, using the data that was reported for Denver in the Rocky Flats dose reconstruction (RAC, 1999). That data is shown in Figure 4 with the solid black line indicating the worldwide weapons testing fallout.

[4] 1 fCi = 1 femtocurie = 1×10^{-15} Curie.

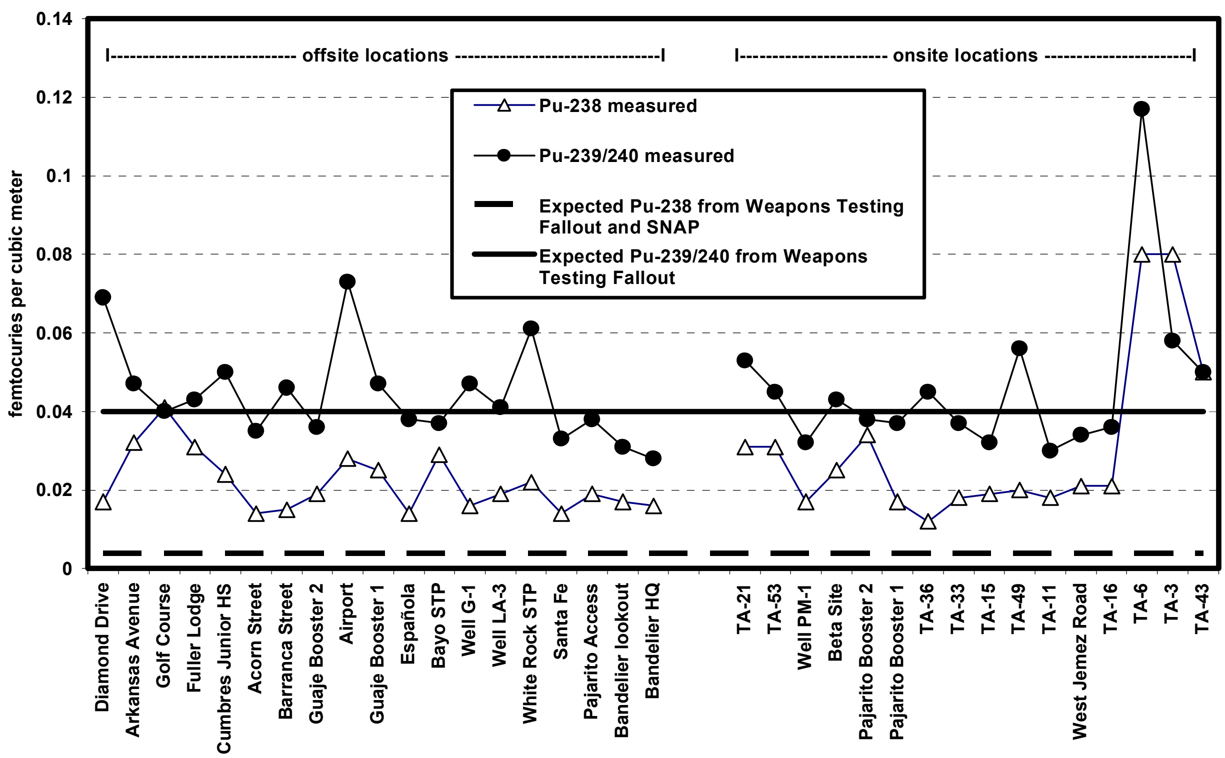


Figure 3 Activity of plutonium-238 and plutonium-239/240 in ambient air in fCi/m^3 reported by LANL for the year 1972. Source: ESNR, 2002

The expected amount of plutonium-238 can be derived from the ratio of the respective inventories in the atmosphere over the northern hemisphere. A total of 350,000 Ci of plutonium-239/240 was produced by worldwide atmospheric nuclear tests (UNSCEAR, 1982). Of this amount, about 4,000 Ci were still present in 1974 (Eisenbud, 1987). Of that, less than 80%, or about 3,000 Ci, was contained in the northern hemisphere. Hence, in 1972, the inventory in the stratosphere over the northern hemisphere was about 1% of the total production by atmospheric nuclear tests. Atmospheric nuclear tests produced much less plutonium-238, or about 9,000 Ci, of which 1% (or about 90 Ci) was present in the stratosphere over the northern hemisphere in 1972.

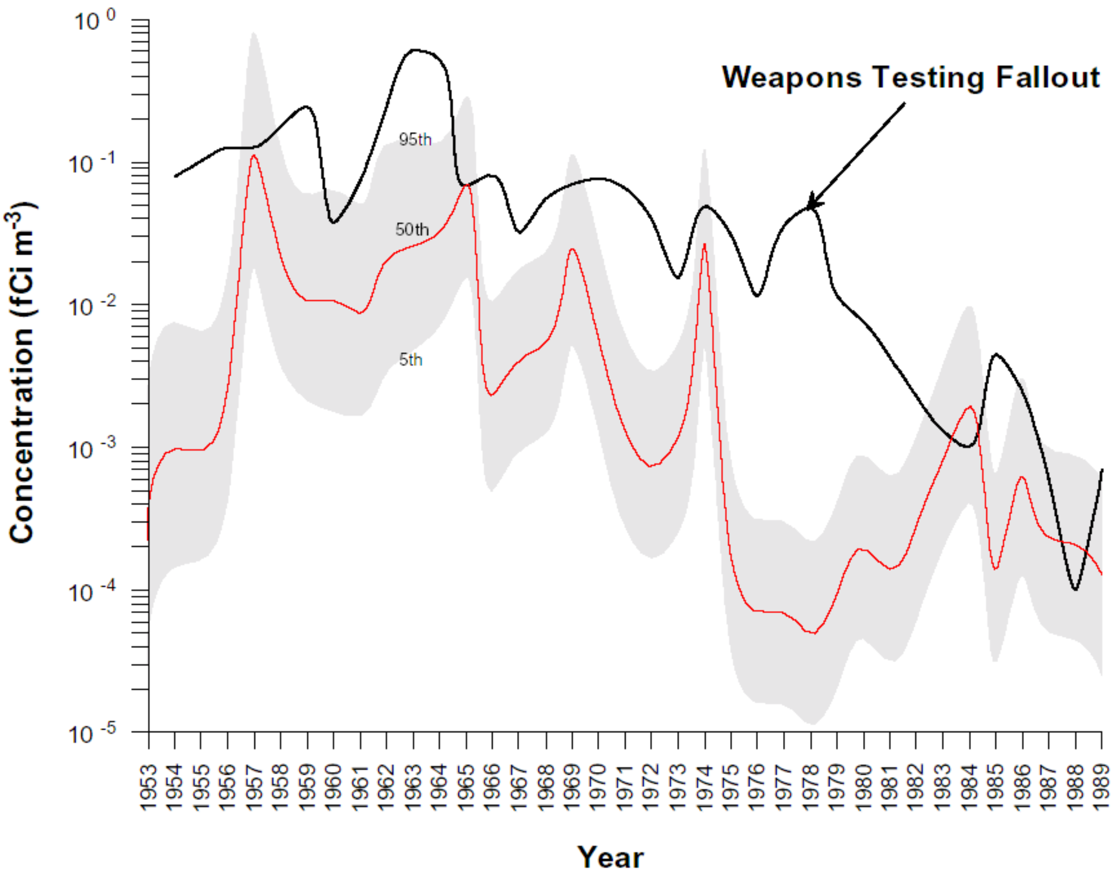


Figure 4. Estimated concentrations of plutonium-239/240 in air at Rocky Flats, fCi/m^3. The values represent estimates for the location with the highest concentrations outside the current buffer zone (east of the plant boundary along Indiana Street). Source: RAC, 1999

The major inventory of plutonium-238 in the atmosphere resulted from the re-entry of SNAP 9-A, a navigational satellite that was launched on April 21, 1964 and carried a radioisotope power generator. The satellite failed to reach orbital velocity and reentered the atmosphere over the Indian Ocean. The inventory of the source was about 17,000 Ci. In 1972, the inventory in the stratosphere over the northern hemisphere was about 300 Ci.

At first approximation, the ratio of concentrations in the atmosphere should be proportional to the stratospheric inventory. For the year 1972 in the northern hemisphere, the (plutonium-238) / (plutonium-239/240) ratio can thus be calculated (300 Ci) / (3,000 Ci) = 0.1. However, because the plutonium-239/240 air concentration from weapons testing fallout at LANL in 1972 was estimated to be 0.04 fCi/m^3, the plutonium-238 air concentration should have been 0.004 fCi/m^3.

While the reported concentrations of plutonium-239/240 at most offsite locations that were monitored by LANL are in the expected range, the same cannot be stated for the reported concentrations of plutonium-238. At all onsite and offsite locations, the reported concentrations exceed the expected concentrations by a factor between four and 20. This is also evident in the comparison of radionuclide ratios for (plutonium-238) / (plutonium-239/240). The ratios range from 0.2 to 1.4, rather than fluctuating around the value of 0.1 as one would expect, as shown in Figure 5.

This finding is quite unexpected and may be explained by major releases of plutonium-238 from LANL operations in the year 1972. The impact of LANL is indicated by the elevated concentrations at TA-3 and also in the elevated isotopic ratio. The ratio of ~1.0 for the offsite location at the golf course may indeed indicate a source upwind from that location. On the other hand, if the elevated plutonium-238 concentration was due solely to contributions from LANL, one would expect a sharper decline with distance from the site. The issue of plutonium-238 concentrations in ambient air is indeed puzzling, and a careful review of the quality of the data for 1972, as well as of data for other years, is clearly warranted.

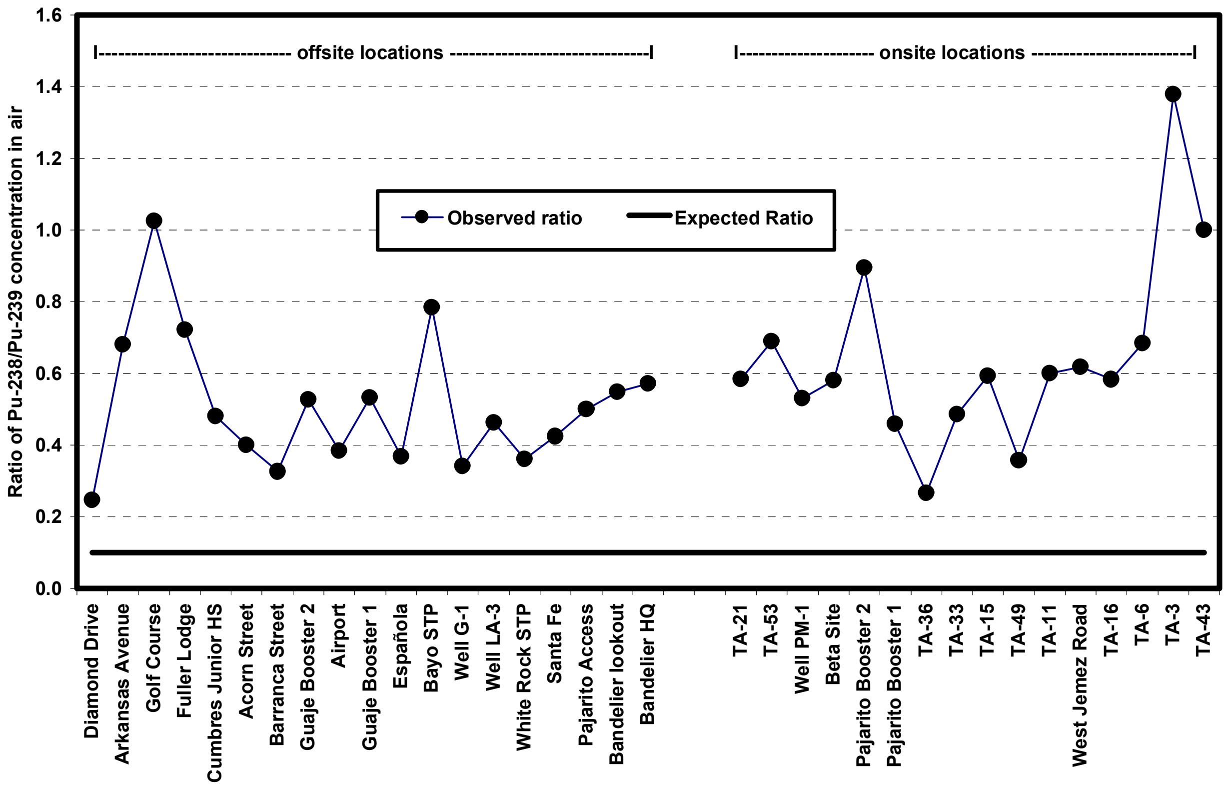


Figure 5 **Ratio of plutonium-238 and plutonium-239/240 activity in ambient air for the year 1972 at LANL**

Current Airborne Emissions of Radioactive Materials at LANL

This section of the report deals with two issues:

- Compliance requirements of the Clean Air Act, 40 CFR 61, Subpart H, and
- Radiation exposures to members of the public due to transient receptors.

Compliance with the Clean Air Act, 40 CFR 61, Subpart H

On January 21, 1997, DOE, former LANL director Siegfried S. Hecker, and CCNS reached an agreement to settle a citizens' suit concerning the status of LANL's compliance with the Clean Air Act (CAA), 40 CFR 61, Subpart H. Subpart H regulates releases of radioactivity to the atmosphere from DOE facilities. It was agreed in the settlement of the case and ordered by the U.S. District Court ordered that the Risk Assessment Corporation (RAC) would conduct a series of technical audits to evaluate LANL's compliance status as the Independent Technical Audit Team (ITAT). The first of these audits addressed whether LANL was in compliance in

1996 (Weber, et al., 1999); the second addressed LANL's compliance in 1999 (Aanenson, et al., 2000); and the third addressed LANL's compliance in 2001 (Aanenson, et al., 2002).

The Court also ordered that the audits be monitored by an independent monitoring team of the Institute for Energy and Environmental Research (IEER), Takoma Park, MD. The author was part of IEER's monitoring team; the monitoring report for the third audit was published in 2002 (Makhijani and Franke, 2002).

The ITAT concluded that LANL was in compliance with the 10 millirem[5] per year (mrem/yr) dose limit set forth in 40 CFR 61, Subpart H for the year 2001. The ITAT also found LANL to be in compliance with all other requirements of Subpart H and related Appendices. Further, the ITAT did not find any substantive technical deficiencies in LANL's compliance program. The ITAT did make some recommendations for "continued improvement" without finding that any of the areas in which these improvements were desirable constituted a substantive technical deficiency or a violation of Subpart H.

The report of the IEER monitoring team concluded:

> *IEER is in general agreement with only one of these overall conclusions of the ITAT. Despite the uncertainties and the technical deficiencies, as well as the essential lack of compliance in one area, IEER is in agreement with the ITAT regarding the 10 mrem/year dose limit compliance. This is because the maximum estimated dose is so much below 10 mrem per year (in part due to the fact that the main source of emissions, the Los Alamos Neutron Science Center (LANSCE), is not in full operation) that it is highly unlikely that the dose limit of 10 mrem per year was exceeded.*
>
> *In monitoring the audit and reviewing the final report, IEER has concluded that the ITAT should have called out four substantive technical deficiencies:*
>
> *1.) a lack of quality assurance of the data on radionuclide usage supplied by the facilities to the Meteorology and Air Quality Group (MAQ),*
>
> *2.) the problem of detecting radiologically elevated concentrations of plutonium-238 in samples in some cases,*
>
> *3.) the need to provide continuous monitoring of airborne emissions from TA-54 waste characterization activities, and*
>
> *4.) the significant uncertainties in the coverage of AIRNET stations with respect to Los Alamos North Mesa residences that justify an additional sampling station that has not been installed.*

[5] A millrem (mrem) is a measure of radiation dose. An exposure of 10 mrem/yr over 50 years would result in an increased cancer risk to an average individual of one in 2,600, using EPA's risk factors (EPA, 1994).

> *In relation to the first of these substantive technical deficiencies, IEER has also concluded that the ITAT should have found LANL to be in substantive breach of its compliance obligations under the Subpart H and related requirements under the Clean Air Act. As a result IEER finds that the main findings of the ITAT that LANL is in compliance with Subpart H and that the compliance program of LANL has no substantive technical deficiencies to be in error.*

A detailed description of the technical merits of IEER's conclusions can be found in Makhijani and Franke, 2002.

The Problem of Discontinuous Releases and Transient Receptors

One of the major problems with the compliance definition in Subpart H is that the compliance limit of 10 mrem/yr effective dose equivalent (EDE) only applies to a fixed location (a residence, school, business or office). In 2001, the closest "receptor," as these are called, was identified to be near the East Gate. This narrow definition poses a problem for the LANL site because of the following reasons:

- The LANL property is not totally fenced in as are other DOE sites (e.g., Savannah River Site).
- There are many point sources in proximity to access roads that can be frequented by members of the public.
- Many sources of radionuclide emissions are short-term and discontinuous in nature. For example, experiments conducted in laboratories can result in short-term airborne releases in batch form as compared to continuous releases from production facilities.

It is well established that past releases from several monitored stacks of the Chemistry and Metallurgy Research (CMR) building have indeed been discontinuous in nature, as a large portion of the total releases for one year occurred in less than a day. Given that the nature of LANL operations is more experimental than production-oriented, short-term releases can also be expected from at least some unmonitored point sources. In addition, there are a number of non-point sources, such as waste disposal sites, from which radioactive materials on the surface can be suspended into the air by gusty winds or fires.

This can be demonstrated by the TA-21 East area, which is suspected to contain waste materials from historical operations. Releases from a diffuse source, such as a waste site, are most likely to occur during high wind speeds (>10 miles per hour (mph)) when material can be suspended readily into air. Figure 6 shows the distributions of observations (averaged over 15 minutes) of the wind speed at the East Gate NEWNET station in August 2002 (Franke, 2002). High wind speed situations are more likely when the wind is blowing from the south-southeast. With regard to diffuse sources at TA-21 East, the wind speed/direction pattern suggests that the greatest impact to residents from such a source is likely at the North Mesa residences.

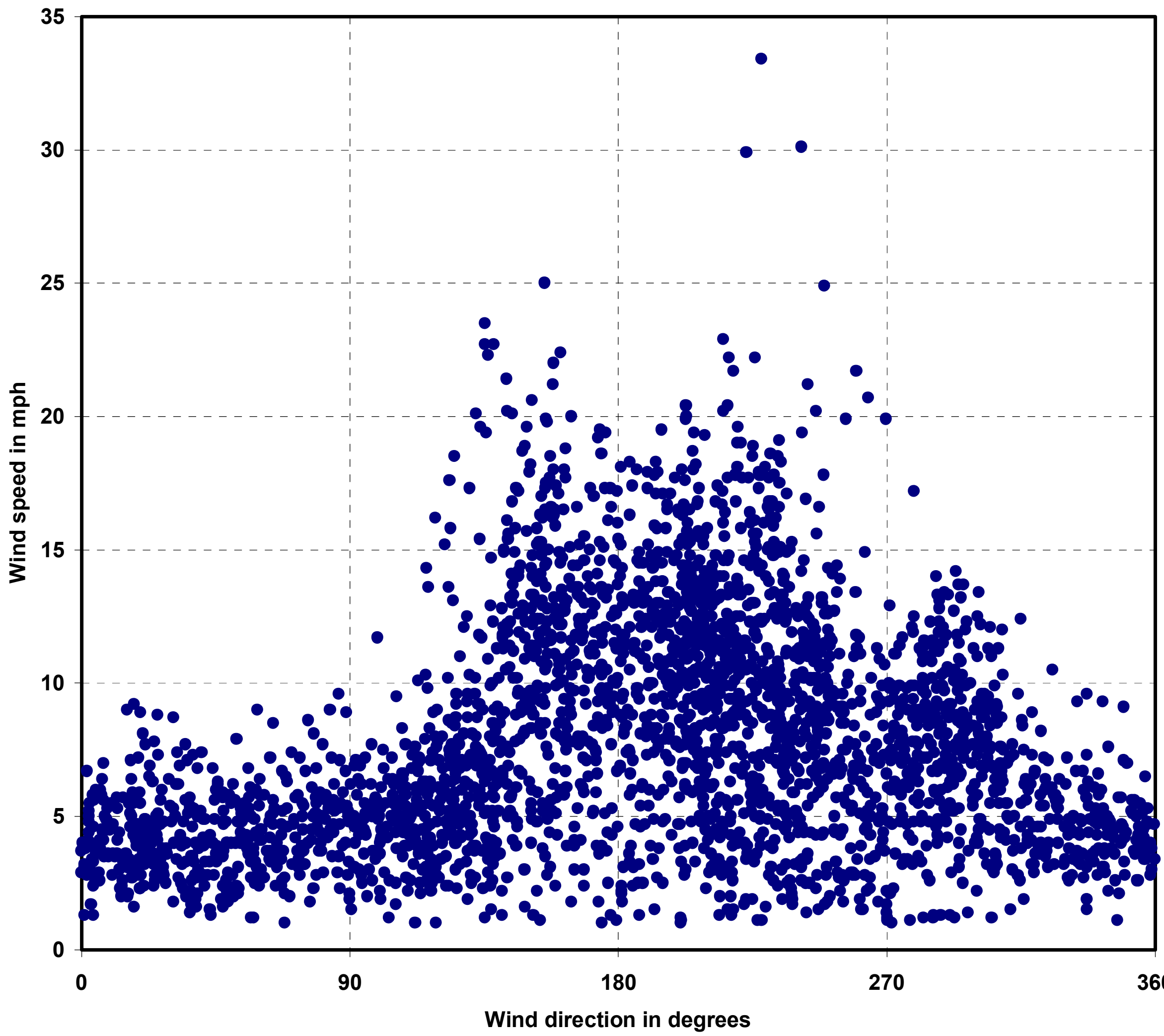


Figure 6 Wind speed as a function of wind direction at East Gate NEWNET station, August 2002 (Franke, 2002)

It is very difficult to determine the time-release function of the source term for diffuse sources with reasonable accuracy. This situation raises several questions:

- How large must a short-term release of radioactive material be in order to result in radiation exposures that exceed the 10 mrem/yr standard?
- Suppose that such a release goes undetected by stack monitoring, for example, an emission from an unmonitored source or a non-point source, such as a waste site. Would such a release be detected by the AIRNET monitoring network?

In answering the first question, dispersion calculations were performed for the following reference situation:

- A short-term release (assuming about one minute) from a source at an effective release height of 10 m (30 ft);
- An adult individual located downwind in the center of the plume where the highest concentration can be expected (plume centerline) at a distance of 50 m (150 ft.), at a normal breathing rate (about 1 cubic meter an hour (m^3/h)); and
- A release of plutonium-238 or plutonium-239/240 (medium solubility, class M) with a dose factor of 0.41 mrem/pCi (effective dose committed over a period of 50 years as a result of a single intake).

The results are shown for various atmospheric stability classes[6] for a low windspeed of 1 meter per second (m/s), which is equivalent to about 2.2 mph. The atmospheric dispersion coefficients that were used were based on dispersion experiments in Germany (Jülich and Karlsruhe). The data suggests that as little as 7.5 microcuries[7] (μCi) of plutonium would be sufficient to result in a dose that would be deemed noncompliant if the person were located at a residence or business. Furthermore, it is important to point out that the total airborne plutonium emissions from sampled stacks at LANL in 1995f were about 50 μCi (LANL, 1999). Total releases from LANL were larger because of the contribution from unmonitored point and area sources. In other words, a fraction of the reported plutonium releases from LANL, if released over a period of minutes, can be sufficient to result in an effective inhalation dose of 10 mrem if a person (e.g., a visitor passing by) happens to be present downwind near the location of the release.

[6] Stability classes describe the dispersion of a plume. The range is from class 1 (unstable; wide plume) to class 6 (very stable, narrow plume).
[7] 1 μCi = 1 microcurie = 1 x 10^{-6} Curie.

Table 3. Airborne emissions of plutonium that would result in an effective inhalation dose of 10 mrem for an adult individual who is present at a distance of 50 m at plume centerline during a short-term release from a source height of 10 m

Stability class	Wind speed m/s	Number of experimental data points	Minimum amount of activity, µCi	Median amount of activity, µCi
1	1	5	30	150
2	1	12	48	330
3	1	11	14	210
4	1	14	23	86
5	1	8	7.5	140
6	1	1		140

Is it possible to properly monitor short-term releases from unmonitored sources, such as waste sites? In such a case, radioactive material would be transported to locations where exposure of the general public could occur. Thus, the AIRNET stations would be the only way to detect the releases. Depending on weather conditions, the AIRNET stations could be located in the plume centerline or could be bypassed by the plume. A careful analysis of the sensitivity of the AIRNET system would therefore assist in evaluating whether significant exposures of short-term releases could go undetected.

Given a unit release from a source in specific weather conditions, the sensitivity of the AIRNET system can be characterized by the ratio of (maximum potential dose) / (maximum detected dose) which can be expressed as

$$\frac{D_{max}}{D_{max,\ AIRNET}}$$

where

D_{max} = effective dose received by an individual present on generally accessible locations

$D_{max,\ AIRNET}$ = effective dose detected at the maximally exposed AIRNET station

Repeating the calculations for all weather conditions allows for calculation of the conditional cumulative frequency of the ratios for a given short-term emission. If the ratio (maximum potential dose) / (maximum detected dose) is close to one, this would mean that at least one

AIRNET station is close to the maximum exposure area accessible to the general public. However, if there is a significant probability that the ratio is large, care should be exercised in converting results of AIRNET measurements into dose. A detailed evaluation is recommended because of the chance that effective doses in the one to 10 mrem range could go underreported.

It may be beneficial to proceed by evaluating one set of facilities, such as the CMR building at TA-3, Building 29, and to proceed with other sources based on the outcome of such an evaluation. This issue should be further addressed in an in-depth review.

Conclusions and Recommendations

This report identified several issues pertaining to historical and current emissions of airborne radioactive materials at LANL. The primary conclusions and recommendations are:

- Based on current estimates, the historical plutonium emissions into the air from LANL of 3.4 Ci is about 20 times the amount of plutonium that was deposited onto the LANL site from worldwide atmospheric nuclear weapons tests.
- The reported concentration of plutonium-238 in air in the vicinity of LANL in the year 1972 was a factor of four and 20 higher than expected from other sources.
- The current information on historical emissions warrants a careful reconstruction of radiation doses to members of the public and the evaluation of the associated health risks.
- Visitors to the LANL site could receive an effective dose in excess of 10 mrem/yr from plutonium emissions under unfavorable circumstances (e.g., short-term emissions), even though the emissions would be reported to be in formal compliance with 40 CFR 61, Subpart H of the CAA.
- The suitability of AIRNET to detect releases from unmonitored point or diffuse sources, such as waste sites, needs to be carefully analyzed.

References

Aanenson J.W., et al. (2000). Independent Technical Audit of Los Alamos National Laboratory for Compliance with the Clean Air Act, 40 CFR 61, Subpart H, in 1999. Risk Assessment Corporation, Neeses, SC.

Aanenson J.W., et al. (2002). Independent Technical Audit of Los Alamos National Laboratory for Compliance with the Clean Air Act, 40 CFR 61, Subpart H, in 2001. Risk Assessment Corporation, Neeses, SC.

ENSR. (2002). ENSR International. A Summary of Historical Operations at Los Alamos National Laboratory and Associated Off-Site Releases of Radionuclides and Other Toxic Materials. Los Alamos Historical Document Retrieval and Assessment Project. February 22, 2002 (available at http://www.shonka.com/ReConstructionZone/pubs/lahdradraftv2g.pdf).

Franke B. (2002). Environmental Monitoring Issues. Memorandum prepared during the monitoring phase of the "Independent Technical Audit of Los Alamos National Laboratory for Compliance with the Clean Air Act" under contract between IEER and CCNS. September 16, 2002 (in: Aanenson J.W. et al. (2002), p. C-13 to C-15).

Heeb C.M. (1994). Radionuclide Releases to the Atmosphere from Hanford Operations, 1944-1972, PNWD-222 HEDR.

LANL. (1999). Los Alamos National Laboratory (1999). Environmental Surveillance at Los Alamos during 1998. LA-13633-ENV.

Makhijani A., Franke B. (2002). Report of the Monitoring Team of the Institute for Energy and Environmental Research on the [Third] Independent Audit of Los Alamos National Laboratory for Compliance With the Clean Air Act, 40 CFR 61, Subpart H in 2001 to Concerned Citizens for Nuclear Safety, Institute for Energy and Environmental Research (IEER), Takoma Park, MD (available online at http://www.ieer.org/reports/lanl/audit3.html).

RAC. (1999). Radiological Assessments Corporation. Final Report: Technical Summary Report for the Historical Public Exposures Studies for Rocky Flats Phase II, September 1999. Neeses, SC. (available at http://www.cdphe.state.co.us/rf/rftechsummary.pdf).

Reed E.W., Thiessen K.M., Hoffman F.O., Apostoaei A.I. (2003). Comparison of Doses and Risks Obtained from Dose Reconstructions for Historical Operations of Federal Facilities that Supported the Development, Production, or Testing of Nuclear Weapons, Health Physics 84(6):687-697.

StrSchV-2001. Verordnung für die Umsetzung von EURATOM-Richtlinien zum Strahlenschutz. Bundesgesetzblatt, Jahrgang 2001 Teil I Nr.38, Ausgegeben zu Bonn am 26. Juli 2001, S. 1714-1848.

UNSCEAR (1982). United Nations Scientific Committee on the Effects of Atomic Radiation. Ionizing Radiation: Sources and Biological Effects. 1982 Report to the General Assembly, with annexes. New York, NY.

USEPA-1991. U.S. Environmental Protection Agency (1991). Risk Assessment Guidance for Superfund (RAGS), Volume I -- Human Health Evaluation Manual, Part B.

USEPA-1994. U.S. Environmental Protection Agency (1994). Estimating Radiogenic Cancer Risks. EPA 402-R-93-076 June 1994.

USEPA-2001. U.S. Environmental Protection Agency (2001). User's Guide: Radionuclide Carcinogenicity for the HEAST Radionuclide Table.

Weber J.W., et al. (1999). Independent Audit of Los Alamos National Laboratory for Compliance with the Clean Air Act, 40 CFR 61, Subpart H. Radiological Assessments Corporation, Neeses, SC.

Cancer Incidence and Mortality in Los Alamos County and New Mexico 1970-1996

By Catherine M. Richards, M.S.[8]

Introduction

This report was written in response to community concerns about occurrences of specific types of cancer in Los Alamos County (LAC). Average annual age-adjusted incidence and mortality rates per 100,000 persons for twenty-four major cancer types were calculated for LAC using data from the New Mexico Tumor Registry. The twenty-four cancer types included brain, breast, cervix uteri, colon/rectum, esophagus, gallbladder, Hodgkin's lymphoma, kidney, larynx, leukemia, liver, lung, melanoma, multiple myeloma, non-Hodgkin's lymphoma, oral/pharynx, ovary, pancreas, prostate, stomach, testis, thyroid, urinary bladder and uterine. County rates were compared to rates derived for a New Mexico state reference population, for all races, for the time period 1970 to 1996.

The cancer incidence rates that were not considered statistically significant but were elevated in comparison with the New Mexico state reference population include cancers of the brain, colon/rectum, esophagus, Hodgkin's, leukemia, and urinary bladder. The cancer mortality rates that were not considered statistically significant but were elevated in comparison with the New Mexico state reference population include cancers of the colon/rectum, kidney, liver, melanoma, non-Hodgkin's lymphoma, ovary, and pancreas.

Cancer incidence rates that were significantly elevated in LAC when compared to the state reference population rates included breast, melanoma, non-Hodgkin's lymphoma, ovary, prostate, testis (significant at the 90% confidence interval), and thyroid cancers. Cancer mortality rates that were significantly elevated in LAC when compared to the state reference population rates include breast cancer.

Significant elevations in cancers for LAC residents were determined by calculating the upper and lower confidence limits for each LAC rate at the 95% and 90% confidence intervals. If the lower confidence limit for a given LAC rate was greater than the New Mexico comparison rate, the elevation was considered significant.

Based on these findings, a second study is recommended to review the temporal and spatial trends of cancer rates by neighborhood unit. Additionally, the proximity of cancer cases to pollution sources should be evaluated. Finally, case reviews should be conducted to establish residential history, occupational history, family disease history, other behavioral risk factors, and cancer etiology.

---

[8] Catherine M. Richards, M.S., is the project coordinator for a National Institute of Environmental Health Sciences grant on Environmental Justice.

Study Objectives and Specific Aims

The primary objective of this study was to review incidence and mortality rates of LAC residents for twenty-four cancer types during the 27-year time period of 1970 to 1996.

Specific aims developed for this study were as follows:

- To compare LAC cancer incidence rates to incidence rates calculated for a New Mexico state reference population, for all races;
- To compare LAC cancer mortality rates to mortality rates calculated for a New Mexico state reference population, for all races;
- To determine whether any of the LAC cancer incidence and mortality rates were significantly elevated in comparison to rates observed for the New Mexico state reference population;
- To begin to assess whether any of the significantly elevated cancer rates could be attributed to ionizing radiation exposures; and
- To review existing literature on ionizing radiation exposure and health risks

Environmental Background

Nuclear-related activities have occurred in LAC since the development of Los Alamos National Laboratory (LANL) in 1943. These activities include both radioactive air emissions and waste disposal. Prior to the enactment of environmental laws in the 1970s, monitoring of radioactive emissions, waste disposal, and employee exposures was sporadic. At present, the extent to which LAC residents and LANL employees have been exposed to ionizing radiation beyond background levels remains unclear.

Sources and Health Risks of Ionizing Radiation

Radiation sources are both naturally occurring and manmade. Naturally occurring radiation sources include the sun (cosmic) and the earth's crust (terrestrial). People who live at high altitudes are more exposed to radiation from the sun, while people who reside in the west receive greater amounts of terrestrial radiation.

Manmade sources of ionizing radiation include nuclear fallout, fossil fuels, and medical and dental x-rays. Nuclear fallout consists of radioactive particles emitted into the air after a nuclear explosion. Nuclear explosions can occur as a result of a nuclear power plant accident or from nuclear weapons testing.

Manmade and natural sources of radiation are referred to as background radiation since the entire global population shares this burden. Non-background sources of radiation come from nuclear power plants, weapons plants, and uranium mines and from the waste created by these industries. Any of these nuclear activities can emit different radioactive isotopes including radioiodine, radiocesium, radiostrontium, tritium, and plutonium.

High doses of radiation occurring over a short time period (acute exposures) are thought to be more damaging to human health than low doses of radiation occurring over a short time span. However, low doses occurring over lengthy time periods (chronic exposures) can result in a high total or cumulative radiation dose and can lead to cancer and other diseases. The time period between radiation exposure and subsequent development of the disease is called the latency period. Much of the literature on radiation exposure and health effects is based on studies of the people who survived the atomic bomb blasts in Japan in 1945. Leukemia was the first latent disease to show up in survivors of the atom bomb blasts.

The United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) concluded, "It is now known that radiation can cause cancer in almost any tissue or organ in the body, although some sites are much more prone than others." UNSCEAR elaborates further in Annex 1 (epidemiological evaluation of radiation-induced cancer), "The inability to detect increases at very low radiation doses using epidemiological methods need not imply that the underlying cancer risks are not elevated. Rather, supporting evidence from animal studies needs to be utilized in addressing risks from low-dose and low-dose-rate exposures, while recognizing that not all molecular changes result in tumors."

Methods

This is a study of cancer incidence and mortality among residents of LAC. Average annual age-adjusted rates per 100,000 persons were calculated for the 27-year time period of 1970 to 1996 for twenty-four types of cancer. The LAC incidence and mortality rates, for all races, were compared to rates calculated for New Mexico, for all races, as referenced in the document, *Cancer in New Mexico 1970 – 1996: Changing Patterns and Emerging Trends*. Following a review of all state and LAC incidence and mortality rate data, specific cancers of concern, based on ionizing radiation literature, were selected for further analysis.

Incidence Data

Data Sources: Information regarding newly diagnosed cancers among LAC residents and residents of New Mexico, for all races, was taken from the document, *Cancer in New Mexico 1970 – 1996: Changing Patterns and Emerging Trends*, and based on cancer information obtained through the New Mexico Tumor Registry. According to the document, a case was defined as a primary malignancy diagnosed between 1/1/70 and 12/31/96 in a person who was a resident of LAC at the time of diagnosis. A similar case definition applied to the New Mexico state reference population. In referencing the document, average annual age-adjusted incidence rates, for all races, for cancer by major anatomic site among LAC residents and New Mexico residents were calculated using the direct method and standardized to the 1970 U.S. population.

Ninety-five percent and ninety percent confidence intervals were calculated for each LAC incidence rate to assess the level of statistical uncertainty. A wide confidence interval occurs as a result of low case numbers. The following equations were used to calculate 95% and 90% confidence intervals for the LAC incidence rates, respectively, LAC rate +/- (1.96*(standard error)) and LAC rate +/- (1.645*(standard error)), where the standard error is calculated as the (rate/(square root of the number of cases)). The same methodology for calculating 95% and 90% confidence intervals was used by the New Mexico Department of Health (NMDOH) in their 1993 report on cancers in LAC. Although a variety of statistical tests have been used on similar cancer data sets to determine confidence intervals, we chose to use the same method as the NMDOH to allow for a comparison of cancer incidence and mortality rate data for the time period of 1970 – 1996 with the time period of 1970 – 1990 (the time period used by the NMDOH). All negative lower confidence limits were truncated at zero. The 95% and 90% confidence interval data for incidence rates by cancer type are presented in Table 1.

Incidence rate ratios (LAC rates as the numerator and the state reference population rates as the denominator) are also presented in Table 1. These ratios illustrate the differences between the LAC rates and the state reference population rates. When the LAC rate is higher than the state reference rate, the rate ratio is greater than 1.0.

Mortality Data

Data Sources: Information regarding cancer mortality among LAC residents and residents of New Mexico, for all races, was also taken from the document, *Cancer in New Mexico 1970 – 1996: Changing Patterns and Emerging Trends*. According to the document, a cancer death is defined as a decedent who had cancer listed as the underlying cause of death on their death certificate and died between the time period of 1/1/70 and 12/31/96. Average annual age-adjusted mortality rates for all races for cancer by major anatomic site among LAC residents and New Mexico residents were calculated using the direct method and standardized to the 1970 U.S. population. The NMDOH Office of Vital Records and Health Statistics was the source used for mortality information.

Ninety-five percent and ninety percent confidence intervals were calculated for each LAC mortality rate to assess the level of statistical uncertainty. A wide confidence interval occurs as a result of low case numbers. The following equations were used to calculate 95% and 90% confidence intervals for the LAC mortality rates, respectively; LAC rate +/- (1.96*(standard error)) and LAC rate +/- (1.645*(standard error)), where the standard error is calculated as (rate/(square root of the number of cases)). Again, the calculation for the 95% and 90% confidence intervals is the same as that used by the NMDOH in their 1993 report on cancers in LAC. All negative lower confidence limits were truncated at zero. The 95% and 90% confidence interval data for mortality rates by cancer type are presented in Table 2.

Mortality rate ratios (LAC rates as the numerator and the state reference population rates as the denominator) are also presented in Table 2. These ratios illustrate the differences between the LAC rates and the state reference population rates. When the LAC rate is higher than the state reference rate, the rate ratio is greater than 1.0.

Statistical Significance

Statistical testing for elevations in the LAC rates in comparison to the state reference population rates was limited by the small number of cases (or deaths) observed for most cancers in LAC. The small case (or death) numbers resulted in wide confidence intervals for the LAC rates and a lack of statistical power to detect small to modest elevations in the LAC rates. If the lower confidence limit for a given LAC rate was greater than the state comparison rate, the elevation was considered significant and not likely due to chance alone. The same methodology for determining statistical significance was also used in a March 1993 report prepared by the NMDOH and the New Mexico Tumor Registry. Alternative statistical analysis methods could also be used such as the chi-square test (which compares the observed number of cases to that expected under an assumed Poisson distribution) and the Knox test for time-space interaction. These two types of statistical analysis methods are more typically used for descriptive epidemiologic studies.

Results

Summary: The cancer incidence rates that were not considered statistically significant, by definition above, but were elevated in comparison with the New Mexico state reference population include cancers of the brain, colon/rectum, esophagus, Hodgkin's, leukemia, and urinary bladder. The cancer mortality rates that were not considered statistically significant, by the definition above, but were elevated in comparison with the New Mexico state reference population include cancers of the colon/rectum, kidney, liver, melanoma, non-Hodgkin's lymphoma, ovary, and pancreas.

Cancer incidence rates that were significantly elevated in LAC when compared to the state reference population rates include breast, melanoma, non-Hodgkin's lymphoma, ovary, prostate, testis (significant at the 90% confidence interval), and thyroid cancers. Cancer mortality rates that were significantly elevated in LAC when compared to the state reference population rates include breast cancer.

In their March 1993 report, the NMDOH also found high incidence rates for these seven cancers for the time period, 1970 – 1990. In addition to high incidence rates for the seven cancers mentioned above, the NMDOH report also found a moderate increased incidence rate for cancer of the brain and nervous system during the mid to late-1980s. Claims compensation by the U.S. Department of Labor will be considered for all seven of the cancers mentioned above. The Energy Employees Occupational Illness Compensation Program Act of 2000 requires the U.S. Department of Labor to compensate Department of Energy employees, or their contractors, for all other cancers, with the exception of chronic lymphocytic leukemia (CLL), if on the basis of dose reconstruction modeling, the probability of causation is greater than fifty percent that the cancer was caused by occupational exposure received while working in nuclear production programs for the Department of Energy.[9] Certain workers (special exposure cohorts, e.g., workers in uranium enrichment facilities) are presumed *a priori* exposed and thus do not require a dose reconstruction to claim compensation if the individual has a qualifying illness.

Female Breast Cancer

Description and Etiology: Breast cancer is the most common form of cancer among U.S. women. Nationwide, incidence has been increasing while mortality has remained relatively constant. Epidemiologic studies have identified a number of risk factors for breast cancer. Major risk factors include family history, previous breast cancer, reproductive experience, menstrual history, socioeconomic status, and ionizing radiation.

Incidence (1970 – 1996): Breast cancer incidence in LAC women was significantly elevated when compared with the state reference population rate. LAC incidence rates were 50% higher than rates for the state reference population. However, demographic data for LAC suggests that women generally reserve childbearing for later years and exhibit higher socioeconomic status when compared with the New Mexico reference population.

Mortality (1970 – 1996): Deaths from breast cancer were significantly elevated, 41% higher, in LAC when compared with the state reference population. This elevation is cause for investigation since LAC's population is felt to have considerable access to health care facilities when compared with other areas of the state.

Melanoma

Description and Etiology: Melanoma is a cancer of the melanocytes, the skin cells that produce the dark pigment melanin. In light skinned men melanomas occur most often on the trunk. In light skinned women melanomas occur most often on the lower legs. In dark skinned people, melanomas occur most often on the palms of the hands and soles of the feet. In New Mexico, melanoma is roughly five times more common in non-Hispanic whites than Hispanic whites.

Incidence (1970 – 1996): LAC residents experienced a 125% elevation in incidence for melanoma when compared with the New Mexico state reference population. However, it should be noted that the majority of LAC's residents are non-Hispanic whites who are at a much greater risk for melanoma than Hispanic whites.

Mortality (1970 – 1996): LAC experienced more deaths (63%) due to melanoma when compared to the state reference population. However, the increased mortality rate for deaths in LAC was not statistically significant at the 95% and 90% confidence intervals.

Non-Hodgkin's Lymphoma

Description and Etiology: The non-Hodgkin's lymphomas are among the less common cancers in the U.S. Incidence generally increases with age and is higher in males than females. Etiology is not well characterized. Immunogenetic factors are important; as illustrated by the greatly increased risks that follow immunosuppression. Radiogenic origins of non-Hodgkin's lymphoma are unclear, though excess mortality has been observed in persons receiving therapeutic irradiation.

Incidence (1970 – 1996): LAC residents experienced a 48% elevation in incidence for non-Hodgkin's lymphoma when compared with the New Mexico state reference population.

Mortality (1970 – 1996): LAC experienced more deaths (26%) due to non-Hodgkin's lymphoma when compared to the state reference population. However, the increased mortality rate for deaths in LAC was not statistically significant at the 95% and 90% confidence intervals.

Ovarian Cancer

Description and Etiology: Ovarian cancer ranks second in incidence among gynecologic cancers only behind endometrial cancer. Nationally, the incidence of ovarian cancer has slightly increased since the 1940s. Childbearing is the most important known factor in reducing ovarian cancer risk, suggesting an etiologic role for hormones. The etiologic role for ionizing radiation exposure is unclear. Ionizing radiation clearly induces ovarian cancer in experimental rodents.

Incidence (1970 – 1996): LAC residents experienced a 45% elevation in ovarian cancer when compared with the New Mexico state reference population. The elevation is considered significant based on the lower confidence limits for the 95% and 90% confidence intervals of the LAC rate when compared with the state reference rate.

Mortality (1970 – 1996): LAC experienced more deaths (27%) due to ovarian cancer when compared to the state reference population, however, the increased mortality rate for deaths in LAC was not considered statistically significant at the 95% and 90% confidence intervals.

Prostate

Description and Etiology: Prostate cancer is the most commonly diagnosed cancer in U.S. males and the second leading cause of cancer deaths in males after lung cancer. Prostate cancer usually occurs in older men. The median age at diagnosis is 72 years and the median age at death is 77 years.

Suggested risk factors for prostate cancer include diets high in fat and red meat, occupational exposure to certain chemicals, and factors related to sexual activity, including certain viruses. A family history of prostate cancer in a first-degree relative doubles the risk.

Incidence (1970 – 1996): LAC residents experienced a 49% elevation in prostate cancer when compared with the New Mexico state reference population. The elevation is considered significant based on the lower confidence limits for the 95% and 90% confidence intervals of the LAC rate when compared with the state reference rate.

Mortality (1970 – 1996): LAC experienced fewer deaths due to prostate cancer when compared to the state reference population.

Testis

Description and Etiology: Testicular cancer affects younger males and is the most common malignancy diagnosed among non-Hispanic white males aged 20 – 34 years. Still it is relatively rare, accounting for only 1% of all cancers diagnosed annually in U.S. males. The strongest risk factor is a history of undescended testicle, but this is observed in only about 10% of cases. Other potential risk factors that have been suggested, including testicular trauma and injury, antecedent inguinal hernia, low birth weight and early birth order.

Incidence (1970 – 1996): LAC residents experienced an 82% elevation in testicular cancer when compared with the New Mexico state reference population. The elevation is considered significant based on the lower confidence limit for the 90% confidence interval of the LAC rate when compared with the state reference rate.

Mortality (1970 – 1996): LAC experienced fewer deaths due to testicular cancer when compared to the state reference population.

Thyroid Cancer

Description and Etiology: Thyroid cancer is a rarely diagnosed and typically nonfatal neoplasm that occurs predominantly in women. Little is known about the etiology of thyroid cancer. The higher incidence in women suggests that hormonal factors may play a role. Exposure to relatively high doses of external and internal ionizing radiation is known to cause thyroid cancer. The highest risks appear following irradiation in early childhood.

Incidence (1970 – 1996): The incidence rate of thyroid cancer in LAC is 106% that of the state reference population for the referenced time period. This elevation is considered significant and cause for continuing investigations.

Mortality (1970 – 1996): The mortality rate for thyroid cancer was lower for LAC residents than for the state reference population. Since thyroid cancer is typically non-fatal, the lower rate of thyroid cancer mortality may suggest better access to health care for the county's population when compared with the state as a whole.

Discussion

Major Findings

The cancer incidence rates that were not considered statistically significant, by definition above, but were elevated in comparison with the New Mexico state reference population include cancers of the brain, colon/rectum, esophagus, Hodgkin's, leukemia, and urinary bladder. The cancer mortality rates that were not considered statistically significant, by the definition above, but were elevated in comparison with the New Mexico state reference population include cancers of the colon/rectum, kidney, liver, melanoma, non-Hodgkin's lymphoma, ovary, and pancreas.

Cancer incidence rates that were significantly elevated in LAC when compared to the state reference population rates included breast, melanoma, non-Hodgkin's lymphoma, ovary, prostate, testis (significant at the 90% confidence interval), and thyroid cancers. Of these cancers, breast, melanoma, ovarian, testicular, and thyroid cancers were also elevated in LAC when compared with the U.S. Surveillance, Epidemology, and End Results Program (U.S. SEER) site data for the time period of 1991-1995. Additionally, though not considered statistically significant when compared to the New Mexico state reference population, the LAC incidence rate for leukemia was elevated when compared with the U.S. SEER site data for the time period of 1991-1995.

Cancer mortality rates that were significantly elevated in LAC when compared to the state reference population rates included breast cancer. When comparing the LAC mortality rate for breast cancer with that of the U.S. SEER sites for the time period of 1991-1995, the LAC mortality rate was also elevated. This is surprising given the greater access to health care for women residing in LAC. Although not considered significantly elevated when compared with the New Mexico state reference population, the LAC mortality rates for melanoma and ovarian cancers were also elevated when compared with the U.S. SEER data sets for 1991-1995.

The March 1993 NMDOH report entitled *Los Alamos Cancer Rate Study: Phase I, Cancer Incidence in Los Alamos County, 1970 – 1990, Final Report*, examined the spatial and temporal distribution of brain and nervous system, thyroid, melanoma of skin, breast, ovarian, leukemia, and non-Hodgkin's lymphoma cancers by using 5-year moving averages and by census tract. Table 3 shows the results of this analysis. The current study did not attempt to analyze incidence and mortality rates through space or time since rates were analyzed for a 27-year time period from 1970 – 1996 and by county and state level.

Study Limitations

Small Number of Observations: Literature suggests that low levels of radiation exposure cause so few additional cancers that a very large exposed population must be studied to detect the additional cancers. Therefore, an increase in cancers may not be detected in communities with populations the size of LAC, even if they are present.

For example, if radiation causes two additional cancers for every 10,000 people exposed, you would have to study a very large exposed population to begin to notice the additional cancers. If 100,000 people were exposed, only twenty additional cancers would occur and you may not recognize that these cancers were in excess of what you would normally expect.

When studying small populations, for example LAC, the small number of cancer cases results in unstable incidence and mortality rates, large confidence intervals, and a loss of determination in whether a rate is really statistically significant. To counteract this effect, information can be obtained on the local population demographics, the extent of the exposure of concern, and on other risk factors. Additionally, researchers have suggested looking at cancer incidence and mortality data at a smaller level to ascertain whether cancer clusters may exist within a neighborhood unit. This type of study is called a pre-epidemiologic study. In Woburn, Massachusetts, in the early 1980s, residents reported excess cases of childhood leukemia that were confirmed by pre-epidemiologic analysis. A rigorous epidemiologic study further validated the residents' concerns and implicated chemically contaminated drinking water as the cause.

Population Mobility: An incidence study should only measure newly diagnosed cases in a population that has been stable over time. However, the LAC population is very mobile. Nearly 25% of all 1980 county residents resided in a different state in 1975. The population mobility in LAC must be accounted for when assessing LAC cancer incidence and mortality rates. A similar problem occurs when reviewing incidence and mortality rates at the census tract level. To avoid this problem, it would be important to evaluate cases in the context of residential, occupational, and environmental exposures, family disease, and behavioral risk factor histories. Additionally, it would be useful to evaluate the proximity of cases to known exposure sources.

Cause and Effect Relationships: Cause and effect is difficult to establish when examining a group of people. For example, not everyone who smokes gets lung cancer and not everyone who gets lung cancer smokes; other variables may enter into the scenario. The same can be said of radiation exposure and cancer. Some cancers, such as colon cancer, can potentially result from exposure to high doses of radiation or colon cancer may be attributed to dietary habits or a genetic predisposition. However, lack of clear information on cause and effect does not mean that there is no risk to the surrounding population from low levels of radiation. Surveillance can help clarify cause and effect relationships through obtaining case histories on behavior, occupation, residence and family. Dose reconstruction modeling based on records obtained from LANL can also help clarify the role of environmental exposures in health outcomes, such as cancer.

Socioeconomic Status and Ethnicity of LAC and New Mexico: Certain types of cancer are more common among certain ethnic groups or socioeconomic groups. This may account for the differences in cancer rates by cancer type that we see from county to county. Some counties have a higher proportion of Hispanic or non-Hispanic whites. LAC is not typical of other counties within New Mexico; it is the most affluent county in New Mexico and it is comprised mainly of non-Hispanic whites. Additionally, access to health care is also greater in LAC than in other counties throughout New Mexico. In this study, we looked at cancer incidence and mortality rates for all races and compared LAC with New Mexico. Unfortunately, LAC does not exhibit the same proportion of ethnic categories as New Mexico, nor does it exhibit the same median household income. Note that breast, prostate and melanoma cancers are considered to be more prevalent in high-income or non-Hispanic white populations, a population that characterizes LAC.

Study Strengths

This study provides a tool that can be utilized for further analysis. Most importantly, it lists specific cancers, by anatomical site, that could be caused by ionizing radiation exposure based on information researched for cancer claims compensation. Furthermore, it illustrates the differences between LAC cancer rates and state reference population cancer rates for a large period of time, 1970 – 1996. Finally, it describes where current gaps in information exist and offers recommendations for closure of those information gaps.

Future Directions

Some of the studies referenced in this report have used descriptive epidemiology. An alternative approach might be to conduct small area analysis to determine whether cancer cases are clustered by neighborhood or in time. Although Phase I of the *Los Alamos Cancer Rate Study* did attempt to analyze both spatial and temporal trends in brain and nervous system cancer incidence rates, LAC was divided into census tracts and not into neighborhoods. By reviewing cases at a neighborhood level, one can determine the size of the population from which the cases come, the local exposure sources, and the proximity of cases to the sources of exposure. Furthermore, information can also be collected on occupation, the number of years at current residence, prior history of residence, and family disease history. Finally, without proper dose reconstruction modeling and access to LANL documents, it is virtually impossible to evaluate the environmental exposures experienced by LAC residents and whether these exposures may contribute to higher cancer incidence and mortality rates.

Recommendations

- Review cancer registry data to investigate the increases in LAC incidence rates (compared to the New Mexico state reference population) for cancers of the female breast (50%), non-Hodgkin's lymphoma (48%), melanoma (125%), prostate (49%), ovaries (45%), testis (82%) and thyroid (106%).
- Review cancer registry data to investigate the elevated LAC mortality rates (41%) for breast cancer when compared with the New Mexico state reference population.
- Review spatial and temporal trends of cancer rates by neighborhood unit and examine the proximity of cancer cases to pollution sources.
- Conduct case reviews to establish residential history, occupational history, family disease history, other behavioral risk factors, and cancer etiology.

- Conduct dose reconstruction studies by accessing LANL documents to determine potential exposures for the community of LAC.

Table 1 Cancer Incidence

Incidence	Rate	Cases	Stand. Error	95% conf. Upper limit	95% conf. Lower limit	90% conf. Upper limit	90% conf. Lower limit	Rate LAC>NM?	Difference significant at 95% CI?	Difference significant at 90% CI?
All Sites										
Los Alamos	355.90	1425.00	9.43	374.38	337.42	371.41	340.39	yes	yes	yes
New Mexico	310.30	109239.00	0.94	312.14	308.46	311.84	308.76			
Rate Ratio	1.15									
Brain										
Los Alamos	5.70	27.00	1.10	7.85	3.55	7.50	3.90	yes	no	no
New Mexico	4.80	1711.00	0.12	5.03	4.57	4.99	4.61			
Rate Ratio	1.19									
Breast										
Los Alamos	123.70	293.00	7.23	137.86	109.54	135.59	111.81	yes	yes	yes
New Mexico	82.50	15436.00	0.66	83.80	81.20	83.59	81.41			
Rate Ratio	1.50									
Cervix Uteri										
Los Alamos	5.00	11.00	1.51	7.95	2.05	7.48	2.52	no	no	no
New Mexico	11.50	2243.00	0.24	11.98	11.02	11.90	11.10			
Rate Ratio	0.43									
Colon/Rectum										
Los Alamos	37.60	144.00	3.13	43.74	31.46	42.75	32.45	yes	no	no
New Mexico	34.30	12016.00	0.31	34.91	33.69	34.81	33.79			
Rate Ratio	1.10									
Esophagus										
Los Alamos	2.50	7.00	0.94	4.35	0.65	4.05	0.95	yes	no	no
New Mexico	2.40	818.00	0.08	2.56	2.24	2.54	2.26			
Rate Ratio	1.04									
Gallbladder										
Los Alamos	0.00	0.00	0.00	0.00	0.00	0.00	0.00	no	no	no
New Mexico	2.20	754.00	0.08	2.36	2.04	2.33	2.07			
Rate Ratio	0.00									
Hodgkin's										
Los Alamos	2.50	12.00	0.72	3.91	1.09	3.69	1.31	yes	no	no
New Mexico	2.20	838.00	0.08	2.35	2.05	2.33	2.07			
Rate Ratio	1.14									
Kidney										
Los Alamos	4.00	22.00	0.85	5.67	2.33	5.40	2.60	no	no	no
New Mexico	7.40	2554.00	0.15	7.69	7.11	7.64	7.16			
Rate Ratio	0.54									
Larynx										
Los Alamos	0.90	5.00	0.40	1.69	0.11	1.56	0.24	no	no	no
New Mexico	3.20	1086.00	0.10	3.39	3.01	3.36	3.04			
Rate Ratio	0.28									
Leukemias										
Los Alamos	11.00	45.00	1.64	14.21	7.79	13.70	8.30	yes	no	no
New Mexico	9.50	3395.00	0.16	9.82	9.18	9.77	9.23			
Rate Ratio	1.16									
Liver										
Los Alamos	2.90	9.00	0.97	4.79	1.01	4.49	1.31	no	no	no
New Mexico	2.90	1012.00	0.09	3.08	2.72	3.05	2.75			
Rate Ratio	1.00									
Lung										
Los Alamos	27.60	98.00	2.79	33.06	22.14	32.19	23.01	no	no	no
New Mexico	39.20	13521.00	0.34	39.86	38.54	39.75	38.65			
Rate Ratio	0.70									
Melanoma										
Los Alamos	21.80	99.00	2.19	26.09	17.51	25.40	18.20	yes	yes	yes
New Mexico	9.70	3578.00	0.16	10.02	9.38	9.97	9.43			
Rate Ratio	2.25									

Table 1 Cancer Incidence (continued)

M. Myeloma										
Los Alamos	2.80	10.00	0.89	4.54	1.06	4.26	1.34	no	no	no
New Mexico	3.50	1217.00	0.10	3.70	3.30	3.67	3.33			
Rate Ratio	0.80									
Non-Hodgkin's										
Los Alamos	14.20	53.00	1.95	18.02	10.38	17.41	10.99	yes	yes	yes
New Mexico	9.60	3385.00	0.17	9.92	9.28	9.87	9.33			
Rate Ratio	1.48									
Oral/Pharynx										
Los Alamos	6.40	25.00	1.28	8.91	3.89	8.51	4.29	no	no	no
New Mexico	9.30	3244.00	0.16	9.62	8.98	9.57	9.03			
Rate Ratio	0.69									
Ovary										
Los Alamos	18.30	40.00	2.89	23.97	12.63	23.06	13.54	yes	yes	yes
New Mexico	12.60	2368.00	0.26	13.11	12.09	13.03	12.17			
Rate Ratio	1.45									
Pancreas										
Los Alamos	8.80	32.00	1.56	11.85	5.75	11.36	6.24	no	no	no
New Mexico	8.90	3118.00	0.16	9.21	8.59	9.16	8.64			
Rate Ratio	0.99									
Prostate										
Los Alamos	150.00	230.00	9.89	169.39	130.61	166.27	133.73	yes	yes	yes
New Mexico	100.70	15533.00	0.81	102.28	99.12	102.03	99.37			
Rate Ratio	1.49									
Stomach										
Los Alamos	4.50	16.00	1.13	6.71	2.30	6.35	2.65	no	no	no
New Mexico	8.00	2801.00	0.15	8.30	7.70	8.25	7.75			
Rate Ratio	0.56									
Testis										
Los Alamos	6.90	15.00	1.78	10.39	3.41	9.83	3.97	yes	no	yes
New Mexico	3.80	765.00	0.14	4.07	3.53	4.03	3.57			
Rate Ratio	1.82									
Thyroid										
Los Alamos	10.10	54.00	1.37	12.79	7.41	12.36	7.84	yes	yes	yes
New Mexico	4.90	1847.00	0.11	5.12	4.68	5.09	4.71			
Rate Ratio	2.06									
U. Bladder										
Los Alamos	14.90	51.00	2.09	18.99	10.81	18.33	11.47	yes	no	no
New Mexico	12.80	4477.00	0.19	13.17	12.43	13.11	12.49			
Rate Ratio	1.16									
Uterine C.										
Los Alamos	15.00	34.00	2.57	20.04	9.96	19.23	10.77	no	no	no
New Mexico	17.30	3172.00	0.31	17.90	16.70	17.81	16.79			
Rate Ratio	0.87									

Table 2 Cancer Mortality

	Rate	Cases	Stand. Error	95% conf. Upper limit	95% conf. Lower limit	90% conf. Upper limit	90% conf. Lower limit	Rate LAC>NM?	Difference significant at 95% CI?	Difference significant at 90% CI?
All Sites										
Los Alamos	128.50	446	6.08	140.43	116.57	138.51	118.49	no	no	no
New Mexico	145.60	51176.00	0.64	146.86	144.34	146.66	144.54			
Rate Ratio	0.88									
Brain										
Los Alamos	2.70	10.00	0.85	4.37	1.03	4.10	1.30	no	no	no
New Mexico	3.60	1276.00	0.10	3.80	3.40	3.77	3.43			
Rate Ratio	0.75									
Breast										
Los Alamos	32.40	69.00	3.90	40.04	24.76	38.82	25.98	yes	yes	yes
New Mexico	22.90	4330.00	0.35	23.58	22.22	23.47	22.33			
Rate Ratio	1.41									
Cervix Uteri										
Los Alamos	1.60	3.00	0.92	3.41	-0.21	3.12	0.08	no	no	no
New Mexico	3.30	618.00	0.13	3.56	3.04	3.52	3.08			
Rate Ratio	0.48									
Colon/Rectum										
Los Alamos	16.90	55.00	2.28	21.37	12.43	20.65	13.15	yes	no	no
New Mexico	15.50	5487.00	0.21	15.91	15.09	15.84	15.16			
Rate Ratio	1.09									
Esophagus										
Los Alamos	2.30	7.00	0.87	4.00	0.60	3.73	0.87	no	no	no
New Mexico	2.30	788.00	0.08	2.46	2.14	2.43	2.17			
Rate Ratio	1.00									
Gallbladder										
Los Alamos	0.00	0.00		0.00	0.00	0.00	0.00	no	no	no
New Mexico	1.50	536.00	0.06	1.63	1.37	1.61	1.39			
Rate Ratio	0.00									
Hodgkin's										
Los Alamos	0.50	2.00	0.35	1.19	-0.19	1.08	-0.08	no	no	no
New Mexico	0.80	285.00	0.05	0.89	0.71	0.88	0.72			
Rate Ratio	0.63									
Kidney										
Los Alamos	3.20	13.00	0.89	4.94	1.46	4.66	1.74	yes	no	no
New Mexico	3.10	1066.00	0.09	3.29	2.91	3.26	2.94			
Rate Ratio	1.03									
Larynx										
Los Alamos	0.00	0.00		0.00	0.00	0.00	0.00	no	no	no
New Mexico	1.00	336.00	0.05	1.11	0.89	1.09	0.91			
Rate Ratio	0.00									
Leukemias										
Los Alamos	5.10	20.00	1.14	7.34	2.86	6.98	3.22	no	no	no
New Mexico	6.10	2194.00	0.13	6.36	5.84	6.31	5.89			
Rate Ratio	0.84									
Liver										
Los Alamos	2.80	10.00	0.89	4.54	1.06	4.26	1.34	yes	no	no
New Mexico	2.70	966.00	0.09	2.87	2.53	2.84	2.56			
Rate Ratio	1.04									
Lung										
Los Alamos	18.10	60.00	2.34	22.68	13.52	21.94	14.26	no	no	no
New Mexico	32.60	11289.00	0.31	33.20	32.00	33.10	32.10			
Rate Ratio	0.56									

Table 2 Cancer Mortality (continued)

Melanoma										
Los Alamos	3.10	12.00	0.89	4.85	1.35	4.57	1.63	yes	no	no
New Mexico	1.90	691.00	0.07	2.04	1.76	2.02	1.78			
Rate Ratio	1.63									
M. Myeloma										
Los Alamos	1.30	4.00	0.65	2.57	0.03	2.37	0.23	no	no	no
New Mexico	2.50	861.00	0.09	2.67	2.33	2.64	2.36			
Rate Ratio	0.52									
Non Hodgkin's										
Los Alamos	5.80	19.00	1.33	8.41	3.19	7.99	3.61	yes	no	no
New Mexico	4.60	1614.00	0.11	4.82	4.38	4.79	4.41			
Rate Ratio	1.26									
Oral/Pharynx										
Los Alamos	2.30	8.00	0.81	3.89	0.71	3.64	0.96	no	no	no
New Mexico	2.30	790.00	0.08	2.46	2.14	2.43	2.17			
Rate Ratio	1.00									
Ovary										
Los Alamos	9.00	18.00	2.12	13.16	4.84	12.49	5.51	yes	no	no
New Mexico	7.10	1338.00	0.19	7.48	6.72	7.42	6.78			
Rate Ratio	1.27									
Pancreas										
Los Alamos	8.30	30.00	1.52	11.27	5.33	10.79	5.81	yes	no	no
New Mexico	8.20	2886.00	0.15	8.50	7.90	8.45	7.95			
Rate Ratio	1.01									
Prostate										
Los Alamos	19.50	21.00	4.26	27.84	11.16	26.50	12.50	no	no	no
New Mexico	22.60	3385.00	0.39	23.36	21.84	23.24	21.96			
Rate Ratio	0.86									
Stomach										
Los Alamos	1.80	6.00	0.73	3.24	0.36	3.01	0.59	no	no	no
New Mexico	6.00	2094.00	0.13	6.26	5.74	6.22	5.78			
Rate Ratio	0.30									
Testis										
Los Alamos	0.00	0.00		0.00	0.00	0.00	0.00	no	no	no
New Mexico	0.30	61.00	0.04	0.38	0.22	0.36	0.24			
Rate Ratio	0.00									
Thyroid										
Los Alamos	0.20	1.00	0.20	0.59	0.00	0.53	0.00	no	no	no
New Mexico	0.40	151.00	0.03	0.46	0.34	0.45	0.35			
Rate Ratio	0.50									
U. Bladder										
Los Alamos	2.00	5.00	0.89	3.75	0.25	3.47	0.53	no	no	no
New Mexico	2.70	975.00	0.09	2.87	2.53	2.84	2.56			
Rate Ratio	0.74									
Uterine C.										
Los Alamos	2.30	4.00	1.15	4.55	0.05	4.19	0.41	no	no	no
New Mexico	3.10	588.00	0.13	3.35	2.85	3.31	2.89			
Rate Ratio	0.74									

Table 3 Average Annual Age-Adjusted Cancer Incidence Rates for Sub-county Regions of Los Alamos County (LAC), All Races, 1980-1990

	Census Tract					CDP			
Site	1	2	3	4	5	Los Alamos	White Rock	LAC	NM
Non-Hodgkin's Lymphoma	18.9 (2) (0.0-45.6)	4.5 (2) (0.0-11.0)	20.4 (5) (2.2-38.7)	11.1 (5) (1.2-21.0)	16.7 (10) (6.1-27.2)	12.6 (14) (5.8-19.3)	16.7 (10) (6.1-27.2)	14.3 (24) (8.5-20.1)	11
Leukemia	1.9 (1) (0.0-5.7)	10.3 (4) (0.0-20.6)	17.5 (2) (0.0-42.2)	5.5 (3) (0.0-11.8)	11.8 (7) (2.9-20.7)	7.1 (10) (2.6-11.6)	11.8 (7) (2.9-20.7)	8.5 (17) (4.4-12.6)	9.5
Melanomas	33.8 (10) (12.4-55.2)	22 (10) (8.1-35.9)	35.8 (7) (8.7-62.9)	13.5 (6) (1.5-24.5)	21.7 (11) (8.6-34.8)	23.2 (32) (15.0-31.4)	21.7 (11) (8.6-34.8)	22 (43) (15.3-28.7)	14.5
Ovary	76.7 (9) (25.6-127.8)	19.4 (4) (0.0-38.8)	19.3 (2) (0.0-47.0)	14 (3) (0.0-30.2)	12.7 (4) (0.0-25.4)	27.4 (18) (14.5-40.3)	12.7 (4) (0.0-25.4)	23 (22) (13.2-32.8)	12.8
Breast	145.3 (28) (90.4-200.2)	120.5 (21) (67.9-173.1)	159.2 (16) (79.6-238.9)	85.3 (21) (48.1-122.5)	116 (41) (79.8-152.3)	119.8 (86) (93.9-145.6)	116 (41) (79.8-152.3)	119 (127) (97.9-140.1)	92.2
Childhood	21.9 (2) (0.0-52.8)	6.7 (1) (0.0-20.2)	0 (0) (-)	24.5 (2) (0.0-59.2)	16.9 (4) (0.0-33.9)	14.2 (5) (1.5-26.9)	16.9 (4) (0.0-33.9)	15.2 (9) (5.1-25.3)	14.8
Thyroid	16 (6) (2.9-29.1)	3.8 (2) (0.0-9.1)	5.8 (1) (0.0-17.5)	8.7 (4) (0.0-17.4)	9.3 (9) (3.1-15.4)	9 (13) (4.0-14.0)	9.3 (9) (3.1-15.4)	9.8 (22) (5.6-14.0)	4.3
Brain	7.3 (2) (0.0-17.5)	5.7 (3) (0.0-12.4)	14.2 (3) (0.0-30.6)	7.4 (2) (0.0-18.0)	8.2 (7) (2.0-14.3)	7.4 (10) (2.7-12.1)	8.2 (7) (2.0-14.3)	7.9 (17) (4.1-11.7)	5.1

Rates are for residence at diagnosis for all races per 100,000, age-adjusted to U.S. 1970 standard population; number of cases in parentheses ( ), 95% confidence limits in brackets [ ], truncated a zero.

Census tract designations:
(1) North/Barranca Mesa
(2) North Community
(3) Western Area
(4) Eastern Area
(5) White Rock

Los Alamos Census Designated Place (CDP) comprises census tracts 1 – 4;
White Rock CDP comprises censes tract 5.
Non-Hispanic White excludes two cases with unknown residence at diagnoses.
Source: New Mexico Tumor Registry

References

Athas, W. (1993). Los Alamos Cancer Rate Study: Phase I Cancer Incidence in Los Alamos County, 1970 – 1990. New Mexico Department of Health, Division of Epidemiology, Evaluation, and Planning.

Office of Epidemiology, Public Health Division, New Mexico Department of Health. (1998). Cancer in New Mexico 1970 – 1996: Changing Patterns and Emerging Trends.

Physicians Task Force on the Health Risks of Nuclear Weapons Production. (1992). Dead Reckoning: A Critical Review of the Department of Energy's Epidemiologic Research. Physicians for Social Responsibility. Washington, D.C.

Public Law 106-398. (2000).

National Academy Press. (1999) Toward Environmental Justice, Research, Education and Health Policy Needs. Washington D.C.

UNSCEAR (1982). United Nations Scientific Committee on the Effects of Atomic Radiation. Ionizing Radiation: Sources and Biological Effects. 1982 Report to the General Assembly, with annexes. New York, NY.

Occupational Health Studies at Los Alamos National Laboratory

By Steve Wing, Ph. D., and David Richardson, Ph.D.[9]

Introduction

Development, testing and production of nuclear weapons over the last 60 years has exposed workers and communities to hazardous substances. Some of these substances, including asbestos, silica and solvents, occur in many industrial settings, while others, most notably certain radioactive materials such as plutonium, are special products of the nuclear industry. Concerns about the impacts of toxic materials on workers and the public have been heightened by the nuclear industry's history of secrecy, its control over research on environmental and health consequences of weapons production, and the practice of human experimentation. Public confidence in evaluations of exposures from this industry, as well as health consequences of those exposures, has been undermined by a lack of trust in the authorities who have been responsible for creating the exposures as well as evaluating their impact.

In this report we provide a critical review of occupational health studies at Los Alamos National Laboratory (LANL), one of the first facilities built by the U.S. government as part of the Manhattan Project to develop nuclear weapons. We begin by describing the weaknesses and strengths of the studies and their capacity to address health concerns of workers and the public. We next consider who has been included and excluded from occupational health studies. Building on this evaluation, we summarize results of LANL worker studies. Next we interpret the LANL studies in the context of studies of workers at other nuclear facilities and other types of research into the biological effects of ionizing radiation. We conclude with a discussion of what the studies mean for people with health concerns and we make suggestions for protection of occupational and public health.

Types of Occupational Health Studies at LANL

Three general types of health studies of workers at LANL and other nuclear facilities can be distinguished. The first type focuses not on health and disease *per se* but on exposure to substances that could cause disease. A second type of study consists of medical follow-up of selected workers. The third type, epidemiologic studies, either compares workers' disease experience to the experience of non-workers, or evaluates whether measures of occupational exposure are related to disease rates among workers.

---

[9] Steve Wing, Ph.D., Associate Professor and David Richardson, Ph.D., Research Assistant Professor are with the Department of Epidemiology, School of Public Health, University of North Carolina.

Exposure Studies

A large number of toxic agents have been used in development and production of nuclear weapons. Work at LANL has involved use of arsenic, beryllium, asbestos, lead, organic and inorganic solvents, explosives, adhesives, and acids. Although these agents and others pose important health concerns, our review focuses on radiation hazards, which have been of primary interest in occupational health studies at LANL and other Department of Energy (DOE) facilities. The profession of health physics was created during the Manhattan Project as a response to concerns about special radiation hazards connected with development and production of atomic weapons. The primary focus of health physics in industrial settings is to minimize exposures and monitor radiation hazards in order to prevent exposures in excess of regulations.

In most industrial settings exposures of individual workers are not measured, therefore exposure levels must be inferred from information about the use of hazardous agents in particular jobs and departments, or, when available, information from monitors in work areas. However, radiation monitoring for individual workers has been conducted at many DOE facilities. Devices such as film badges and thermoluminescent dosimeters (TLDs) have been used at LANL to monitor exposures to external penetrating radiation including gamma rays, neutrons and x-rays. Although external penetrating radiation is generally easier to measure than radiation from internal radionuclide contamination, there are many problems with the use of historical monitoring records for research purposes including lack of monitoring for many workers and time periods, changes in sensitivity of dosimeters, errors in linking worker and dosimeter records, and failures in processing and reporting results.

Workers may also inhale, ingest or absorb (for example, through a wound or break in the skin) particles that emit alpha radiation, which is not detected by film badges or TLDs. Internal contamination from radionuclides such as plutonium may be assessed from tests of urine or by *in vivo* gamma spectroscopy, also referred to as whole body or lung counting. The ability of urine tests to detect internal contamination depends on the solubility of compounds, their route of entry into the body, and their rates of excretion. Therefore the accuracy of estimates of internal radiation doses depends on the quality of information about the chemical form, solubility, particle size, and route of entry of the radionuclide. The ability of urine tests to detect internal contamination also depends on the analytical method used and the completeness and frequency of monitoring.

In vivo counting works by measuring gamma emissions from the radioactive decay of particles within the body. If *in vivo* monitoring occurs infrequently, it is better suited to detection of radiological contaminants with long biological and physical half-lives than contaminants with short half-lives. Plutonium, one of the major radionuclides of concern at LANL, has low gamma emissions and is difficult to detect by *in vivo* counting. Sometimes the presence of plutonium may be inferred from the gamma emissions of other radionuclides such as americium that occur along with plutonium.

Internally deposited radionuclides can remain in the body until death, and autopsy studies of LANL workers, as well as workers at other DOE facilities, have compared plutonium body burdens estimated from autopsy tissues with estimates based on urinalysis studies. Discrepancies between these two methods can be large. Tritium, which emits beta radiation, has also been of concern at LANL and can be detected by urinalysis. Studies of internal radionuclide contamination also suffer from many of the same difficulties as studies of external radiation, including problems in sampling, laboratory processing, lack of coverage of many workers and time periods, and accuracy of record linkage.

Exposure studies are important tools for evaluating hazards in the workplace. Quantitative estimates of exposure, sometimes called dose reconstruction, can be used along with information from experimental studies of animals or epidemiologic studies of humans to estimate health risks from a given level of exposure. Of course, many assumptions are necessary to make such estimates, and they are based on averages, for example, they do not take into account an individual's susceptibility based on genetics, nutrition and other exposures. Additional problems with this approach are discussed later.

Medical Follow-up Study

A small group of plutonium-exposed LANL workers have had medical exams about every five years since they were identified for medical study in 1952. Twenty-six young healthy men working in four types of plutonium operations were chosen for study because they were judged to have the highest internal depositions of plutonium in 1944 and 1945. These men have had medical histories, physical exams, tests of vision and hearing, cardiovascular and respiratory function, blood counts, sputum cytology, urine tests, and *in vivo* counts for plutonium and other radionuclides. The vital status of this group has been monitored and cause of death information has been obtained from medical records and death certificates.

Medical follow-up of a small number of workers can assemble large amounts of clinical data. However, the significance of such studies is unclear because of uncertainties about initial exposures, choice of workers for special study, lack of a comparison group, and low statistical power for studies of diseases of interest such as malignancies or genetic effects.

Epidemiologic Studies

Two types of epidemiologic studies have been conducted at LANL - cohort and case control studies. Cohort studies identify workers from a roster of employees and follow them through time to evaluate mortality or cancer incidence using vital records or tumor registry data. Cohort studies of mortality can evaluate deaths from all types of specific causes, and cohort studies of cancer incidence can evaluate specific types of cancer.

Data collected in cohort studies can be analyzed in one of two ways. First, the observed number of deaths or cancer cases among workers can be compared to the number that would be expected if the workers had experienced the same death or disease rates as a standard population, typically the state or nation. These analyses simply address the question of whether death or disease rates of LANL workers differ from the state or the nation, and they do not consider specific occupational exposures. Employed persons must be healthy enough to work, and many, especially employees of large institutions, have regular income, medical insurance and other employment benefits. This means that industrial workers typically have low disease rates compared to populations that include people who are too ill to work and lack the benefits of regular employment. This phenomenon, sometimes called the "healthy worker effect," means that workers whose disease rates are increased by exposure to occupational hazards can have lower disease rates than the general population in spite of their exposures. Low disease or death rates among workers compared to the general population does not mean that the work environment is safe.

Cohort studies can also be used to conduct analyses of trends in disease rates with increasing occupational exposure, sometimes called dose response studies. Instead of comparing worker disease rates to a standard population, workers are divided into groups based on their occupational exposures, and disease rates for workers with higher exposures are compared to disease rates for workers with little or no exposure. The ability of dose response studies to detect effects of occupational exposures depends upon the quality of exposure measurements. When exposures are not accurately measured, workers with higher exposures may be incorrectly included in lower exposure groups, and *vice versa*, thus diluting differences between groups. In addition, accuracy of dose response studies depends on the ability to control other risk factors, such as smoking, diet, or other occupational risks, if histories of these exposures differ between workers with lower and higher levels of the occupational factor (for example, radiation) under study. The adverse effect of exposure could be obscured, for example, if workers in radiation areas were less likely to smoke than other workers (perhaps because of workplace restrictions), or if they were required to pass medical tests to work in those jobs. Although occupational cohort studies seldom have detailed data on potentially confounding exposures, they can provide important information about dose response relationships that are important to evaluating cause-effect relationships.

A second type of epidemiologic study of LANL workers is the case control study. Case control studies evaluate a specific disease in relation to exposures of interest. Occupational case control studies are conducted in order to obtain detailed exposure information for a sample of cases and controls when it would not be feasible to collect data for all workers in a cohort. First, cases of the disease are identified through death certificate or tumor registry data. Next, a group of disease-free controls is chosen. Then, records of cases and controls are compared to evaluate whether exposures to hazards at work were higher for cases than for controls. Case control studies are used to estimate risks of a particular disease associated with a variety of exposures. When quantitative information on exposures of individual workers is available, as in the case of external penetrating radiation at LANL, dose response relationships may be evaluated. Case control studies may suffer from the same problems of measurement and confounding that affect cohort studies.

Who Has Been Included in Occupational Health Studies?

Only employees of "prime contractors" have been included in occupational health studies at LANL. Since the beginning of operations, the University of California has been responsible for overall operation of the site for the DOE and its predecessor organizations, the Energy Research and Development Administration and the Atomic Energy Commission. Beginning in 1946, the Zia Company took over maintenance, construction and support services previously handled by the U.S. Army Corps of Engineers. In 1986, Pan American World Services took over the support contract from Zia, and in 1989 Pan American World Services was purchased by Johnson Controls, Inc. Maintenance, construction and support workers are referred to in this report as Zia employees. Occupational health studies at LANL have included only University of California and Zia workers; health studies have not been conducted of employees of other contractors and subcontractors.

Most occupational health studies at LANL have been limited to white Anglo employees of the University of California. Radiation monitoring, personnel and medical records for the Zia workforce, which includes many Hispanics and Native Americans, have been much less complete than records for the University of California workforce. In one study personnel records were available for 97 percent of University of California workers but only 20 percent of Zia workers, and urinalysis records were available for 39 percent of University of California workers but only four percent of Zia workers. Hispanics, non-whites and women have been excluded from a number of occupational health studies of University of California employees at LANL.

Study Findings

Our summary of occupational health studies at LANL emphasizes the direction of the results (for example, a deficit or excess of disease), biological mechanisms (for example, cancer in parts of the body where plutonium concentrates) and sample size. We do not discuss "statistical significance" because none of the studies use randomization to impart a specific meaning to these tests, and because such tests have been widely misused to interpret epidemiologic evidence.

Medical Follow-up of Manhattan Project Workers

Investigators conducting periodic medical exams of 26 white male workers exposed to plutonium during World War II at LANL have reported, for the most part, changes typical of an aging population. Some of the more highly exposed workers have elevated ratios of T-helper to T-suppressor lymphocytes, apparently due to decreased numbers of T-suppressor lymphocytes resulting from altered radiosensitivity. The clinical significance of these changes is not clear. Seven of the 26 men had died as of 1994, representing a death rate 57 percent lower than expected based on U.S. rates. Three of the seven deaths were due to cancer, including one from bone sarcoma. This case is of particular interest because bone sarcoma is rare, because plutonium deposits in the skeleton, and because bone sarcomas are a radiation-induced cancer that occurs among workers exposed to radium.

Cohort Mortality Study of Plutonium Exposed Workers

A group of 224 white male LANL workers who were estimated to have internal plutonium depositions of 10 nanocuries or more as of January 1, 1974, was followed for mortality through April, 1980. Death rates from all causes and all cancers in this small cohort were lower than expected based on U.S. rates.

Cohort Mortality Study of Zia Workers

Galke and colleagues studied workers employed by the LANL maintenance contractor. They identified a roster of 14,428 workers hired between 1946 and 1978 of whom 5,424 with adequate records were included. Approximately half of the workers were white Hispanics. Vital status was determined through 1984 for 97 percent of the workers, including 1,196 deaths. Death rates for cardiovascular disease, all cancers and lung cancers were low compared to U.S. rates, however excess deaths were observed for cancers of the stomach, liver, pancreas, bone, and leukemia. Elevated death rates were also observed for injuries and ill-defined conditions. Cancer death rates for plutonium exposed workers were about 30 percent higher than rates for unexposed workers but this finding was based on small numbers due to the lack of plutonium bioassay data for about half of the cohort.

Cohort Mortality Study of LANL Workers

A cohort mortality study of 15,727 white male University of California workers hired between 1943 and 1977 has been conducted through 1990. Average follow-up was 29 years. The death rate from all causes was 37 percent below rates for U.S. white males, and cancer mortality was 36 percent below U.S. rates. Death rates for cancer of the bone, melanoma and leukemia were similar to U.S. rates. Cancer death rates for a group of 3,775 plutonium-monitored workers were compared to rates for other workers. Death rates for all cancers were seven percent higher among plutonium workers than among other workers. Lung cancer rates were 78 percent higher among plutonium workers, based on eight observed deaths among plutonium workers. Positive dose response relationships with external ionizing radiation were observed for brain cancer and Hodgkin's disease, but not for lung cancer or cancers in general.

Cohort Cancer Incidence Study of LANL and Zia Workers

Incident cancers were ascertained from the New Mexico Tumor Registry for a group of LANL workers employed by University of California and the Zia Company between 1969 and 1978. Incident cancers among white Anglo employees were compared with the number expected based on rates for New Mexico. Among males, a 40 percent lower cancer incidence was observed in this group, primarily due to fewer than expected numbers of lung cancer. The one bone cancer observed represented a twofold excess over the expected. Five cases of lymphosarcoma and reticulosarcoma were observed where two were expected. Among females a 21 percent excess of cancer was observed. Investigators were not able to ascertain incident cancers among workers who left the state of New Mexico.

Case Control Study of Melanoma

Incident cases of malignant melanoma were included in a special case control study. These included 15 male and five female cases. Four controls were selected for each case matched for sex, ethnicity (Anglo or Hispanic), date of birth and date of first employment at LANL. Estimates of plutonium body burden, external radiation exposure and employment as a chemist or physicist were not associated with malignant melanoma.

Case Control Study of Multiple Myeloma

This study compared 98 multiple myeloma deaths and 391 age-matched controls from LANL, Hanford, Oak Ridge National Laboratory, and the Savannah River Site. Information on prior work history, smoking, medical x-rays, and potential exposure to solvents, metals, welding fumes, asbestos, ionizing and non-ionizing radiation was derived from personnel, medical, industrial hygiene, and health physics records. African Americans, men, and workers first hired before 1948 had excess multiple myeloma compared to non-African Americans, women and workers hired after 1948. Occupational exposures to external penetrating radiation and tritium at older ages (above age 40), but not exposures at younger ages, showed a dose response relationship with multiple myeloma.

Discussion and Recommendations

All the types of occupational health studies have limitations in design and implementation. Hazardous occupational exposures are difficult to measure accurately even in situations where a worker has been monitored. Exposure measures for LANL workers are limited primarily to radiation hazards. In addition to the basic problems noted above, interpretation of badge data for external radiation may be complicated by situations particular to a job or individual worker, for example when tools or equipment shield the part of the body where the dosimeter is worn from a source that is exposing other parts of the body. In the case of internally deposited radionuclides, estimates of body burdens and internal doses are highly uncertain and do not take into account individual differences in metabolism, deposition and retention. Even if exposure measures are adequate, some studies lack adequate follow-up to detect diseases with long latencies.

Dose reconstruction may be used along with risk models, as in the "probability of causation" approach, to estimate a worker's risk of disease based on occupational exposure to radiation. In addition to accurate information about historical radiation exposures, the reliability of this calculation depends on the accuracy of risk values, or dose response coefficients, used to predict the increase in disease risk. Most risk models have been based on studies of a group of survivors of the atomic bombings of Hiroshima and Nagasaki that began in 1950. High mortality in the aftermath of the atomic attacks, selective survival of persons with low sensitivity to radiation, and uncertainties in estimating doses from the bombs, including a lack of data on doses from radioactive fallout, raise serious questions about the relevance of risk estimates from this population for U.S. radiation workers. Other problems with the "probability of causation" concept come from its inability to recognize complex interactions of multiple factors in disease causation, and its lack of attention to situations in which exposure advances the time at which a person becomes sick.

Other nuclear worker studies have provided evidence of health risks from radiation exposures at levels similar to those that occurred at LANL. Excess risks in some populations are seen only when carefully considering potentially confounding factors, cancer latency and the modifying effects of age at exposure. As in the multiple myeloma case control study, some other studies of nuclear workers have suggested increased susceptibility of older workers to the carcinogenic effects of radiation exposure. The possible increased cancer risk for older workers has not been investigated in cohort studies of LANL workers. Effects of paternal occupational radiation exposures on the relative frequency of female vs. male births, still births and childhood cancers has been suggested in some other studies, but these issues have not been investigated at LANL. Further investigation of radiation health risks, as well as effects of other toxic agents, could be enhanced by involving workers and former workers in efforts to identify risky jobs and improve exposure estimates.

Risk estimation from dose reconstruction shares one problem with direct observation of risks in epidemiologic studies of nuclear workers. Both estimates represent an average of risks for many persons. In reality, an individual's risk of disease depends not only upon exposure level, but upon a myriad of factors that are particular to individuals, including genetics and historical exposures that influence susceptibility. Not only does the risk estimate depend upon accurate information at each stage of dose reconstruction and risk estimation, it represents an average whose relevance to a particular worker is uncertain. Even in the case of strong risk factors such as cigarette smoking, epidemiologic studies do a poor job of predicting who will get cancer. For these reasons, even the best health studies have limited utility for individual workers and community members concerned about individual health risks from exposures at LANL. However, these studies can contribute to identifying factors that cause disease, risks at exposure levels faced by workers or the public, and populations that are more sensitive to exposure.

Despite serious measurement problems and a lack of exposure data for many workers and time periods, excesses of certain cancers and dose response relationships for others have been observed among workers at LANL and other DOE facilities. Because workers as a group are more highly exposed than members of the general population, their experience may be considered in evaluating whether health effects might occur off site. Non-workers may be exposed because of contaminants carried home by workers, airborne emissions, water pollution, or exposures through the food chain. These exposures should in general be much lower than worker exposures, however many more people are potentially exposed. Furthermore, the general population includes children, pregnant women, older persons, and people with existing disease who may be more susceptible to hazardous agents. Direct evaluation of health effects of chronic, low-level environmental exposures through epidemiologic research is difficult because of complex exposure pathways that include air, water and food, a lack of individual exposure measurements, and migration in and out of potentially exposed areas.

Uncertainties about the health effects of exposures at LANL reflect basic limitations in knowledge about exposures and diseases. For example, unlike infectious diseases, which are classified based on their causal agents, cancers can only be classified according to the tissues they affect and the characteristics of the malignant cells. Given these uncertainties, it is important that occupational and environmental exposures to hazardous agents be minimized, and that workers and the general public be involved in decision-making about exposure standards and health related research.

References

Acquavella JF, Wilkinson GS, Wiggs LD, Tietjen GL, Key CR. (January 1983). An evaluation of cancer incidence among employees at the Los Alamos National Laboratory. Epidemiology Applied to Health Physics. Albuquerque, NM.

Acquavella J, Wilkinson G, Tietjen G, Key C, Stebbings J, Voelz G. (1983). Melanoma case-control study at the Los Alamos National Laboratory. Health Physics.

Advisory Committee on Human Radiation Experiments. Final Report, Advisory Committee on Human Radiation Experiments. (1995). US Government Printing Office. Washington, DC.

Dickinson HO, Parker L, Binks K, Wakeford R, Smith J. (1996). The sex ratio of children in relation to paternal preconceptional radiation dose: a study in Cumbria, northern England. J ournal of Epidemiology & Community Health.

Department of Epidemiology, School of Public Health, University of North Carolina. (1998). Case Control Study of Multiple Myeloma among Workers Exposed to Ionizing Radiation and Other Physical and Chemical Agents: Final Technical Report. National Institute for Occupational Safety and Health. Cincinnati, OH.

Galke W, Johnson E, Tietjen G. (1992). Mortality in an Ethnically Diverse Radiation Exposed Occupational Cohort 00404043. Los Alamos National Laboratory. Los Alamos, NM.

Gardner M, et al. (1990) Results of case-control study of leukaemia and lymphoma among young people near Sellafield nuclear plant in West Cumbria. British Medical Journal.

Greenland S. (1990). Randomization, statistics, and causal inference. Epidemiology 1:421-429.

Greenland S. (1999) Relation of probability of causation to relative risk and doubling dose: a methodologic error that has become a social problem. American Journal of Public Health 89:1166-9.

Makhijani A, Hu H, Yih K. (1995). Nuclear Wastelands: A global guide to nuclear weapons production and its health and environmental effects. MIT Press. Cambridge, MA.

Parker L, Pearce M, Dickenson H, Aitkin M, Craft A. (1999) Stillbirths among offspring of male radiation workers at Sellafield nuclear reprocessing plant. The Lancet 354:1407-14.

Richardson D, Wing S. (1999). Radiation and mortality among workers at Oak Ridge National Laboratory: Positive associations for doses received at older ages. Environmental Health Perspectives 107:649-656.

Rockhill B, Kawachi I, Colditz G. (2000) Individual risk prediction and population-wide disease prevention. Epidemiologic Reviews 22:176-80.

Salsburg D. (1985). The religion of statistics as practiced in medical journals. American Statistician 39:220-223.

Secretarial Panel for the Evaluation of Epidemiologic Research Activities. (1990). Report to the Secretary by the Secretarial Panel for the Evaluation of Epidemiologic Research Activities for the U.S. Department of Energy. US Department of Energy. Washington, DC.

Stewart A. (2000). The role of epidemiology in the detection of harmful effects of radiation. Environmental Health Perspectives 108:93-96(2000).

Voelz G, Lawrence J, Johnson E. (1997). Fifty Years of Plutonium Exposure to the Manhattan Project Plutonium Workers: An Update. Health Physics 73:611 - 619.

Voelz GL, Wilkinson GS, Healy JW, McInroy JF, Tietjen GL. (1983). Mortality study of Los Alamos workers with higher exposures to plutonium. In: 16th Mid-year Topical Meeting: Epidemiology Applied to Health Physics. Albuquerque, NM, Jan 9-13, 1983.

Wiggs LD, Johnson ER, Cox-DeVore CA, Voelz GL. (1994). Mortality through 1990 among white male workers at the Los Alamos National Laboratory: considering exposures to plutonium and external ionizing radiation. Health Physics 67:577-88.

Wing S, Richardson D, Wolf S, Mihlan G, Crawford-Brown D, Wood J. (2000). A case control study of multiple myeloma at four nuclear facilities. Annals of Epidemiology 10:144-153.

Wing S, Richardson D, Stewart A. (1999). The relevance of occupational epidemiology to radiation protection standards. New Solutions 9:133-151.

Wilkinson GS. (1992). Some pitfalls in studies of low-dose ionizing radiation: The healthy dose effect, significance questing, and exposure reductionism. PSR Quarterly 2:33-39.