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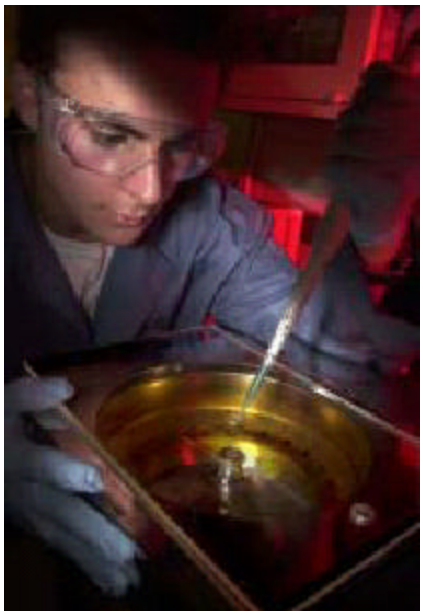
Cancer and Workers Exposed to Ionizing Radiation A Review of the Research Literature

JSI Research and Training Institute, Inc.

Cancer and Workers Exposed to Ionizing Radiation

A Review of the Research Literature



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Cancer and Workers Exposed to Ionizing Radiation: *A Review of Research Literature* is based on research conducted by Ken Silver.

The report was produced in conjunction with the JSI Center for Environmental Health Studies (JSI) by Terry Greene, Gretchen Latowsky, and Ken Silver with the assistance of Andrew Einhorn and Carol Rougvie.

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Radiation and Cancer Risk

Summary

Workers at the Los Alamos National Laboratory who may have been exposed to radiation have questions about the potential health effects of that exposure. In particular, they have voiced concern about potential links between exposure to ionizing radiation and specific types of cancer. This booklet includes the latest information from health studies of cancer risks to nuclear workers around the world. It was compiled to serve as a resource for those who have worked in nuclear industries, in particular the Los Alamos National Laboratory (LANL), their families, and communities.

Within the booklet is a series of fact sheets organized by type of cancer (bladder cancer, bone cancer, brain cancer, etc). Each fact sheet lists the findings of studies on radiation and these specific cancers. Of importance to many former employees and their families is whether the cancer has been designated under the Energy Employees Occupational Illness Compensation Program Act Of 2000 (EEOICP Act) as a "specified" cancer. Workers who had "specified" types of cancer may more easily meet the eligibility requirements for compensation, if and when "special exposure cohorts" are established at LANL.

Information is also included in the fact sheets on county rates for each type of cancer in Los Alamos and Rio Arriba counties, in which the Los Alamos National Laboratory is the major employer. High cancer rates in these counties may be an indication that occupational exposures play a role. They also may indicate a need for better health care for diagnosis and treatment.

This research overview is part of an initiative: *Worker and Community-Based Self Help on Epidemiology, Surveillance, and Compensation Rights at Los Alamos.* The project is supported by a grant from the Citizens' Monitoring and Technical Assessment Fund. It is being conducted by JSI Center For Environmental Health Studies (JSI) in collaboration with the worker organization Citizens for LANL Employee Rights (CLER) and the community-based organization El Rio Arriba Environmental Health Association (El RAEHA). The goal is to advance worker understanding and participation in important decision making. Experts invited to the community conducted a series of workshops covering such topics as occupational health and safety, epidemiology, health effects of exposure to radiation and asbestos, the role of occupational studies in setting exposure standards, and worker compensation. This report is among articles and fact sheets made available to workers and residents.

The Purpose of This Guide

For those who are impacted by cancer that may be due to employment at a nuclear facility there are few places to turn to for information that is objective and up-to-date. The concerns of exposed individuals tend to fall through the cracks of government agencies, the medical profession, and anti-nuclear groups. This guide attempts to provide useful, objective information for those who have worked in nuclear industries, in particular the Los Alamos National Laboratory (LANL). In it you will find summarized results of health studies conducted at LANL and across the world to determine whether specific types of cancer may arise from radiation exposure. Rates of cancer in Rio Arriba and Los Alamos counties are also included. This information can be of value to the broader community in efforts to best protect residents and act on health concerns.

Background:

The Energy Employees Occupational Illness Compensation Program Act of 2000 (EEOICA)

Established in recognition that Federal nuclear activities have been "ultra-hazardous" entailing "unique dangers" including recurring exposures to radioactive substances that, even in small amounts, can cause medical harm, the Energy Employees Occupational Illness Compensation Program Act (EEOICA) notes that:

> *Over the past 20 years, more than two dozen scientific findings have emerged that indicate that certain of such employees are experiencing increased risks of dying from cancer and non-malignant diseases. Several of these studies have also established a correlation between excess diseases and exposure to radiation and beryllium.*

Stating concerns over workers' lack of knowledge of the risks and frequently unmonitored exposure, Congress enacted this legislation to remedy "inadequate worker compensation" and poor agency "self-regulation."[1] This guide has information on the research leading to this act and some of the types of cancers that may be eligible for compensation.

The Lack of Information Resources

Until recently, the government has not been a valuable source of health information regarding cancer risk for individuals who may have been affected by radiation exposure.

1 ENERGY EMPLOYEES OCCUPATIONAL ILLNESS COMPENSATION PROGRAM ACT OF 2000, AS AMENDED, 42 U.S.C. § 7384 et seq. PART A — ESTABLISHMENT OF COMPENSATION PROGRAM AND COMPENSATION FUND § 7384. Findings; sense of Congress

For many years, occupational cancer risks to employees of Los Alamos and other nuclear facilities were denied by the government and its contractors. Thanks to recent policy changes these issues are finally available for review and discussion. Contributions of leaders such as Secretary of Energy Bill Richardson (1998-2001) who was willing to confront these problems head-on are uniquely valuable and very important to future protection of workers.

A wealth of research on radiation exposure and cancer risk has accumulated over the years and is on file in government agencies. Unfortunately, the information is not readily available in a format that can be useful to the general public as they seek to protect their health, obtain appropriate health care, and address concerns.

Those turning to the medical community for information about exposures and possible health effects, have often found providers unable to provide adequate assistance. Few physicians are trained in occupational medicine. Fewer still are able to undertake the legal and ethical duties that come with making a diagnosis of occupational cancer. All too frequently physicians focus solely on an individual's personal "lifestyle" factors and overlook their workplace exposures as possible causes of cancer. This can be due, in part, to the uncertainties of occupational cancer. Another factor is the time consuming process of documenting and proving a case when patients are facing medical termination or workers' compensation proceedings. Physicians need additional training, support, and leadership to recognize and respond effectively to occupational illnesses.

Nonprofit advocacy organizations have also been largely unable to meet the needs of individuals for information. While anti-nuclear and environmental organizations have played an essential role in raising society's general awareness of hazards, few of these groups are able to provide technical assistance to individuals. Moreover, the quality of information disseminated by anti-nuclear groups varies greatly.

Families sometimes rely on speculative, alternative health ideas about the health effects of radiation and chemicals when they have available to them a growing body of mainstream medical and scientific studies to help determine and address work-related illness. The information in this booklet has been prepared to provide workers and their families with objective information that they can share with their regular doctor. It may require more time and effort, but working with a mainstream doctor is an important step to obtaining quality care. In addition, an opinion based on evidence from credible research is far more valuable than an opinion from an alternative doctor when working with authorities to obtain appropriate compensation for harm.

The Problems with Epidemiology

Before reviewing the information in this booklet, it is important to consider the limitations of research on environmental exposure and human health. Studies listed in this document attempt to answer whether radiation may result in specific types of cancer. The science of studying patterns of disease in human populations to determine cause and

effect between exposures and health outcomes is called "epidemiology." Think of the term epidemics. Epidemiological studies linking exposures to human health are always extremely difficult to conduct and by nature have many limitations. Unfortunately, such studies are seldom a satisfying way of responding to worker and community concerns about cancer.

One problem with epidemiology is the stringent statistical standards scientists require before they will recognize a problem as "significant." By tradition, scientists need to be 95 percent sure that the patterns of illness observed are not due to chance. These stringent standards of proof can usually be met only in studies of very large human populations. This is the concept of statistical power. Several thousand workers may have to be studied to have even a chance of finding a "statistically significant" increase of a specific kind of cancer. Most epidemiological studies are lacking in the statistical power needed to detect small ? but real ? increases in cancer.

Yet another problem with epidemiological studies is that people are unique individuals. A group of people who work together may have similar exposures on the job, but may differ in how much they smoke, drink, eat, where they live, their genetic backgrounds, and previous job exposures. These confounding factors enter into every epidemiological study. Unlike studies of test animals, people are not caged and given known exposures. Instead they move freely in an environment with many pollutants, sometimes choosing to cause harm to themselves through lifestyle choices. Scientists have statistical methods to cope with confounding. But these methods only work when large numbers of people are enrolled in a study.

Despite these limitations, epidemiological studies are the most relevant source of information about human health risks. The studies conducted on cancer and radiation exposure have grown over the years so that a wide body of information is now available. When supplemented with new information on the biology of cancer, they can provide strong evidence as to the actual risks.

What is in This Guide?

Health Study Summaries:

This booklet is organized into a series of fact sheets on specific types of cancer: bladder cancer, bone cancer, brain cancer, etc. Each fact sheet lists the outcomes of studies on radiation and these specific cancers, ordered in relevance to LANL workers. The first listing, therefore, is of studies conducted among LANL workers themselves. Next are studies of other nuclear workers in the United States followed by studies of other nuclear workers world-wide. Finally studies of those survivors of the Atomic bomb who were exposed to radiation are listed. Further evidence is presented as to whether, in the opinion of the National Research Council, the cancer site (the bladder, the brain, etc.) has been found to be sensitive to radiation.

Regulatory Listing As Related to Radiation Exposure:

Whether the cancer has been included among the "Specified" cancers under the EEOICP Act may be of particular current relevance to families. If a "Special Exposure Cohorts" has been determined to exist at a Department of Energy site, then compensation for "Specified" cancers is a simple matter. If a special exposure cohort does not exist, then the compensation process entails additional burdens of proof. Chief among these is the need to establish a high enough level of personal exposure at the workplace to have "reasonably" caused cancer in the view of the regulatory agencies. This is determined through a complex model to recreate exposures from job histories. It is unclear how much ability workers will have to evaluate and challenge the findings of this model.

Other Risk Factors:

Listed are other risk factors for the type of cancer. These include whether the cancer is among those that may be related to smoking. This is because smoking is a major factor in several cancers. Keep in mind that if smoking is a factor, it does not rule out that radiation exposures or other workplace exposures could have contributed to the development of the cancer. In some cases, exposure to smoking and workplace hazards can combine to add or even multiply risks. This might also be true for other risk factors. Some people, for example, may be at higher risk for cancer due to their personal or family history. Such individuals may be at higher cancer risk (more susceptible) when exposed to radiation.

County Patterns of Cancer:

The fact sheets summarize the data on cancer rates in Los Alamos and Rio Arriba counties in which the Los Alamos National Laboratory is the major employer. The rates of cancer incidence (cases reported as they are diagnosed) and mortality (persons who died specifically due to having had that type of cancer) are included. The ranking of the counties from one (highest in the State of New Mexico) to thirty-third (lowest in the State of New Mexico) is provided. High rates in these counties serve as an indication that occupational exposures may play a role. They also may indicate a need for better health care for diagnosis and treatment.

Key Terms:

A few key concepts are employed throughout this booklet:

Incidence is how many people are diagnosed as having an illness. **Mortality** is how many people died from it.

Latent period for cancer is the time from when a person is first exposed to a cancer-causing substance until the disease shows up. Most cancers take at least 10 years to show up (leukemia is an exception in that it can take as little as two years). Epidemiologists make various assumptions about latency when analyzing data in health studies.

Follow-up period is the average length of time since people in the study were first exposed. For radiation-related cancer, the longer the follow-up period the more likely it is to observe an increase in cancer because of the latent period discussed above. High rates of cancer in a group of radiation workers may be lost in studies with short follow-up periods.

A dose-response relationship is one of the strongest forms of proof in health studies. In a group of workers, when the risk of cancer increases with the dose of radiation, it's a strong signal that radiation is causing that kind of cancer.

A Few More Words About...Words

Scientists use precise language. This booklet tries to do the same, but without the jargon. For readers who like a little jargon, here's the justification behind our precise choice of words.

Statistically significant is a term used to mean that the association between the health outcome and the exposure was strong enough that is was not thought to be due to chance. An asterisk (*) was placed by these findings.

Possible means that the association was on the border of being statistically significant.

Increasing is the red flag for a dose-response relationship, one of the strongest forms of proof in health studies. A dose response relationship is the relationship between the dose of radiation and the health response observed. The symbol + was used to indicate a dose-response relationship.

Race: Many worker health studies limit enrollment to "white" men. Scientifically, studying one racial group is intended to allow any effects of exposure to be seen more clearly without any influence of racial differences in genetics or other factors that may affect health. But some epidemiologists have started to question whether, in the real world, it's a form of discrimination.

This can be a source of confusion in New Mexico. When health studies use the racial label "white," it usually includes Hispanic people. In this booklet racial and ethnic terms have been omitted, except in two situations:

1) when race highlights an issue important to the community; and
2) when racial distinctions were made at the stage of analyzing the data.

People of color may have been disproportionately assigned to hazardous work, especially in years past. So it's important to consider how racial and ethnic minorities' higher exposures may have caused higher rates of illness. However, for a given dose of radiation there is no evidence that ethnic or racial groups differ in susceptibility to illness.

Technical Notes:

Possible was used in the case of a test for trend that is of borderline statistical significance; or an effect measure (SMR or SIR) of 110 or higher, but with a confidence interval (or "error bar") that includes unity (SMR=100; no difference between the exposed and comparison groups). When an increase of cancer was not statistically significant, at least five cases were required to label these as possible increases.

However, there are two exceptions. First, in studies of the LANL workforce it was important to report all observed increases, with appropriate words of caution included. Second, in studies of other workforces, it was important to convey the researchers' own interpretations. Readers may form their own opinions on the basis of the overall evidence for a specific kind of cancer.

When an increase in cancer was statistically significant, an asterisk was used to identify significance (*), the word possible was dropped.

How Communities Can Use This Information

In addition to individuals making use of the information in this booklet, the findings of these studies raise important issues that need to be addressed at the community level. These are discussed below. First is the need to address county health disparities as evidenced by high rates of cancer observed in Rio Arriba and Los Alamos County versus other New Mexico counties. Second, arguments both for and against more studies should be considered. In cases where more study would be of value, recent advancements in participatory, community-based approaches are discussed as a means to enhance their accuracy and usefulness to those affected.

The Need to Address County Health Disparities

Several kinds of cancer show rates of high incidence (cases diagnosed) and/or high mortality (deaths) that are of concern. High rates in these counties versus other New Mexico counties need to be investigated as a possible indicator of cancer impacts due to exposures at LANL. Whether or not these cancer rates are due to exposure at LANL, their patterns indicate a need for greater health care resources for early diagnosis and treatment in Rio Arriba and/or Los Alamos counties.

Hodgkin's Disease. Studies of several nuclear workforces, including LANL, have shown dose-response relationships between Hodgkin's disease and external radiation [21; 49; 67] or possible increases in death rates[50; 1; 18] or incidence.[3] Rio Arriba County ranked second in incidence and first in mortality due to Hodgkin's disease among the 33 counties in New Mexico (1970-1996). In an apparent failure in early diagnosis and treatment, the Los Alamos County's mortality ranking (sixth highest) was much worse than its ranking for incidence (twenty-fifth). Regardless of whether Hodgkin's disease is work-related, LANL is the major public institution in common to both Los Alamos and Rio Arriba counties. The Lab's resources are among those that could be applied to early diagnosis and treatment of Hodgkin's disease to improve this trend.

Multiple Myeloma. Rio Arriba County ranked highest among the 33 counties in New Mexico in mortality due to multiple myeloma (1970-1996). [33] Ionizing radiation is an accepted cause of multiple myeloma, with strong evidence available from studies of U.S. [71] and British nuclear workers.[4] State-of-the-art treatments involving transplants of bone marrow created from a person's own stem cells are available out-of-state. Access to these treatments by LANL families affected by multiple myeloma may help improve survival statistics in Rio Arriba County.

Bladder Cancer. Early detection and treatment of bladder cancer are succeeding in Los Alamos County, but failing badly in Rio Arriba County. Although ranked low in incidence of bladder cancer (twentieth), Rio Arriba County ranked highest in mortality.[33] The opposite is true in Los Alamos County: Los Alamos County ranked fifth highest in incidence but only number thirty-two in mortality. So a person is a lot more

likely to survive bladder cancer if s/he lives in Los Alamos County. As the major public institution in common to Los Alamos and Rio Arriba, LANL could help ensure that residents of Rio Arriba County enjoy the same access to medical procedures that have proven effective in saving lives on the Hill.

Testicular Cancer. While mortality is low, Los Alamos County ranks highest in the incidence of testicular cancer among the 33 counties in New Mexico (1970-1996). [33]

Other Cancers. Regardless of the cause, differences between incidence and mortality rankings indicate that Rio Arriba County also needs help with early detection and treatment of liver and cervical cancers. [33]

The Case For and Against "More Studies"

Reviewing this compilation of studies on radiation and cancer highlights the need for certain additional studies to be conducted. At the same time, it is important to recognize the many cases where more study would not be useful and where what is needed instead is action on what we already know. Both cases are discussed below, along with recommendations to make use of community-based approaches in any new studies that are conducted.

The Case Against More Studies

There are good reasons NOT to call for "more studies" of LANL worker health. Epidemiology is expensive and time-consuming. It rarely produces definitive results, for reasons noted above. Typically, epidemiologists wind up recommending "more studies." A second reason not to push for more studies is political. Proposing to "study the problem" only delays taking action on what we already know.

A third reason not to advocate for more studies is the historical lack of community benefits from carrying out costly research projects. In theory, communities should derive great benefits from interacting with outside experts. Young people should enjoy graduate research opportunities. The latest scientific knowledge should be translated into terms the community understands. And, to the extent that science brings out "the truth," government policies should then be fine-tuned to fix real problems. In reality, New Mexico communities have experienced research projects in which experts come in, collect their data, and return to their research institutions. Frequently this information is not shared with the community in a meaningful way and is not available for workers and residents to use to advocate for their own protection.

The Case For More Studies

Despite these reasons to be cautious about getting involved in health studies, important questions have been raised through studies to date of LANL workers that have not yet been answered. Those affected could benefit from additional research targeted to address these concerns.

Bone Cancer: LANL researchers conducted a study of 5,424 employees of Zia Corporation between 1946 and 1978. One striking discovery was seven cases of bone cancer, three of which were angiosarcoma of bone, "a very rare tumor." Because plutonium and other radionuclides are known to accumulate in bone, the researchers called for further investigation to determine whether the bone cancers were work-related. [15] The study also found increased death rates due to cancer of the stomach, liver, pancreas and leukemia.

A draft of the study was provided to the funding agency the National Institute for Occupational Safety and Health (NIOSH) on November 24, 1992 and was never completed. It is important to note that the study had major problems with following up with individuals over time and missing exposure records. From a roster of 14,428 workers hired by Zia between 1946 and 1978, only 5,424 had adequate records. The draft version submitted to NIOSH in November 1992 needed improved follow-up before it could be circulated for scientific scrutiny.

The Zia study should be revisited. One good reason is that LANL claims that only a single case of bone cancer has ever occurred in its workers exposed to plutonium.[17] Russian scientists studying plutonium workers have pooled bone cancers together with connective tissue cancers. [20] Doing the same at LANL could provide a partial scientific basis for addressing the concerns of families affected by leiomyosarcoma.

Brain Cancer: In 1991, concern about "environmental" brain cancer in Los Alamos grabbed media attention around the world, leading to a DOE-funded study by New Mexico state agencies. The study reached negative conclusions. [35] Meanwhile, LANL's own researchers discovered a dose-response relationship between external radiation and brain cancer deaths in LANL employees. [21] This passed almost without notice. About six to 12 brain cancer deaths, occurring between 1943 and 1990, form the basis for this discovery. This raises the obvious next questions:

* Where did they work?
* What were they exposed to?
* Did they have any work processes or operations in common?

It would be important to answer these questions and make the findings public.

Mesothelioma: This rare, fatal cancer of the chest or abdominal wall is almost always caused by exposure to asbestos. In the 1990's there were one or two cases per year of

mesothelioma among current and former LANL workers. [Department of Environmental Health Sciences, 1999] Graphs of the incidence of mesothelioma in Los Alamos and Rio Arriba counties in the 1990's are almost identical. They show sharp increases in incidence. [14] Dr. Chester Rail, a former LANL industrial hygiene engineer, has engaged in efforts to bring asbestos hazards to the attention of management as well as ongoing concerns about asbestos heavily contaminated with plutonium and other radionuclides in certain areas of the Lab.

LANL workers are not alone. Nuclear weapons employees in England have high rates of mesothelioma.[3; 29;] Back in the U.S., there were six cases of mesothelioma among the first 260 workers autopsied in the U.S. Transuranics Registry program (a registry of persons who were exposed to plutonium). [18; 78]

The families of LANL workers who died from mesothelioma need to be provided with accurate information about the kind of cancer, its cause, and their legal rights. They should not be led to believe that it was just another "lung cancer," with no definite cause. Another 23 current LANL or JCI employees have evidence of asbestosis, non-cancerous scarring of the lungs caused by asbestos exposure, on their x-rays. Another 104 current or former workers may have pleural abnormalities on their x-rays, also a sign of past exposure to asbestos.[Department of Environmental Health Sciences, 1999]

Testicular Cancer: As mentioned previously, Los Alamos County ranks highest in the incidence of testicular cancer among the 33 counties in New Mexico (1970-1996). [33] However, almost no one in the county dies from the disease. Most men in the county are employed at LANL, where they get regular medical check-ups. A study of Anglo employees showed a possible increase in the incidence of testicular cancer in men employed for at least one year between 1969 and 1978, although this was based on just three cases. [16]

A dose-response relationship between external radiation and the incidence of testicular cancer has been reported in Canadian radiation workers.[47] Men monitored for tritium in England's nuclear plants had an increased rate of death due to testicular cancer. [29]
It has long been known that plutonium is retained in the testis. We now know that plutonium's retention in the testis is longer than for other tissues. [78]

Anecdotally, three former LANL workers have expressed concerns about:

* work practices that allowed for direct gamma irradiation of the groin
* benign cysts on the scrotum
* pain in the testis, in the absence of a diagnosed illness.

All three cases were exposed to plutonium on the job at LANL.
It is time to take a closer look at the possible associations between testicular cancer and occupational exposure to external radiation.

Community-Based Research

If additional studies are conducted, new methods involving partnership with those affected can increase their usefulness. Some qualified scientists conduct their studies of workers in a "community-based" way. They do more than seek "input" from affected workers, families, and labor organizations. Citizens and their organizations are involved in every aspect of such studies. It may be due to improved input by those affected that when a community-based approach was taken to studying DOE contractor employees (at the Rocketdyne facility in California) evidence of several kinds of cancer in association with external and internal radiation was discovered. An advisory panel, which included union and community representatives along with scientific experts, conducted all of its business in public over the several years of the study. In addition to peer-reviewed publications in top scientific journals, [1; 25; 26] a non-technical booklet was distributed to explain the results of the study to the public. Such models promise a range of benefits as they improve research, serve the needs of those affected, and strengthen the community's capacity to address the problem into the future.

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Bladder Cancer and Exposure to Ionizing Radiation

Summary: There is strong evidence that bladder cancer may be associated with exposure to ionizing radiation. This evidence includes studies of nuclear workers. This is consistent with the National Research Council's finding that the bladder is sensitive to ionizing radiation. Bladder cancer is designated as a "specified" cancer under the Energy Employees Occupational Illness Compensation Program Act. Historically, incidence of bladder cancer has been high in both Los Alamos County and Rio Arriba County. Mortality has been very low in Los Alamos County and moderate in Rio Arriba County. Incidence means new cases of cancer, while mortality means deaths due to cancer. This indicates a need for improved treatment and prevention in Rio Arriba County.

What is Bladder Cancer?

The bladder is a hollow organ that stores urine. Bladder cancers may be named after the type of cell that is cancerous. For example, most bladder cancers begin in the transitional cells that line the bladder. This type of bladder cancer is called transitional cell carcinoma. (National Cancer Institute)

Findings of Human Health Research Studies

Human health research studies compare the patterns of disease among groups of people with different amounts of exposure to a suspected risk factor. Below are results reported from studies of bladder cancer among people exposed to ionizing radiation.

These studies found increases and possible increases in bladder cancer among certain groups of exposed individuals, in some cases followed over time. Statistically significant is a term used to mean that the connection between the health outcome and the exposure was strong enough that it was unlikely to be due to chance. An asterisk (*) was placed by statistically significant findings. The research included incidence studies, which look at new cases of bladder cancer. These can track health more quickly and accurately than mortality studies of deaths due to cancer. Adding to the strength of the findings is that increasing rates of bladder cancer were observed with higher doses in some studies.

Studies of Los Alamos National Laboratory (LANL) Workers

Research conducted of LANL workers provides the most direct evidence about possible relationships between a health problem and workplace exposures at LANL.

– In studies performed to date there is no reported evidence of increased rates of bladder cancer in LANL workers.

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* *Findings were statistically significant (strong evidence)*

+ *Evidence of a dose-response relationship (strongest evidence)*

Studies of Other Nuclear Workers in the United States

The next most relevant evidence comes from studies of workers in similar occupations with the same types of exposures. Listed below are studies that looked at bladder cancer and workplace exposures among nuclear workers in other parts of the United States.

- **Fernald, Ohio**: A possible increase in bladder cancer deaths was found in a study of 4,014 uranium processing workers who were employed between 1951 and 1989, and followed through 1989.[1]

- **Mallinckrodt, St. Louis, Missouri**: A possible increase in bladder cancer deaths was found in a study of 2,514 uranium processing workers who were employed between 1942 and 1966, and followed through 1993.[2]

Studies of Other Nuclear Workers World-Wide

Below are studies of nuclear workers outside of the United States that looked at bladder cancer in connection with radiation exposures.

- **Sellafield, England**: A possible increase in bladder cancer deaths was found in a study of 5,203 plutonium workers who were employed between 1947 and 1975, and followed through 1992, when compared to non-radiation workers.[3] Also, increasing rates of bladder cancer deaths were observed with increasing doses of external radiation in a study of 14,327 workers employed between 1947 and 1975, and followed through 1983. This study assumed a 15-year latent period (time after exposure for the disease to be diagnosed).[4 *+]

- **Registry of Nuclear Workers in the United Kingdom (U.K.):** Possible increasing rates of bladder cancer deaths were observed with increasing doses of external radiation in a study of 95,217 workers at major facilities in the U.K. nuclear industry.[5 +]

- **Atomic Energy Authority of U.K.:** Increased deaths due to cancer of the bladder and urinary organs (excluding kidney) were observed in a study of 21,545 radiation workers who were employed between 1946 and 1979, and followed through 1986, when compared to non-radiation workers.[6 *]

- **Obninsk, Russia (I.P.P.E.):** A possible increase in incidence of bladder cancer was found in a study of workers who were hired before 1981, and still employed between 1991 and 1997.[7]

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* *Findings were statistically significant (strong evidence)*

\+ *Evidence of a dose-response relationship (strongest evidence)*

Studies of Other Ionizing Radiation Exposures

Studies among other groups of people who were not nuclear workers can also be significant as evidence of possible increases in bladder cancer among those who have been exposed to ionizing radiation. Most other research has been conducted of people exposed to atomic bombs.

- **Atomic Bomb Survivors:** Increasing deaths due to bladder cancer were observed with increasing doses of radiation in a study of 86,572 A-bomb survivors.[8]

Other Research and Policy Findings

Is the Bladder Sensitive to Radiation?

- **Yes.** According to the National Research Council's BEIR V Committee, "radiation can cause cancer of the bladder."[9]

The National Research Council advises the U.S. government on scientific matters. Their Committee on Biological Effects of Exposure to Ionizing Radiations (BEIR) V reviewed health effects of exposure to radiation. Their findings are based mostly on studies of cancer among atomic bomb survivors, as well as on some of the available information on the biology of the body, animal studies, and other evidence. The greatest risk is at high exposure levels.

Is Bladder Cancer a "Specified" Cancer Under the Energy Employees Occupational Illness Compensation Program Act (EEOICPA)?

- **Yes.** Bladder cancer is a "specified" cancer under the EEOICPA consideration of Special Exposure Cohorts.

Policy makers have identified certain types of cancer among energy employees at nuclear facilities, including those employed at Los Alamos National Laboratory, as being potentially related to occupational exposures under the EEOICPA.

What Are Other Risk Factors for Bladder Cancer?

In considering the cancer risk from exposure to ionizing radiation at work, it is important to understand other risk factors. Below is a list of other possible risk factors for bladder cancer.

- **Tobacco.** Smoking and other tobacco use is related to bladder cancer.[10,11,12]
- **Occupation.** Some workers in other industries also have a higher risk of getting bladder cancer because of carcinogens in the workplace. Workers in the rubber, chemical, and leather industries are at risk. So are hairdressers, machinists, metal workers, printers, painters, textile workers, and truck drivers.

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* *Findings were statistically significant (strong evidence)*

\+ *Evidence of a dose-response relationship (strongest evidence)*

- **Infections.** Being infected with certain parasites increases the risk of bladder cancer. These parasites are common in tropical areas but not in the United States.
- **Medical Treatment.** The drugs cyclophosphamide or arsenic that are used to treat cancer and some other conditions raise the risk of bladder cancer.
- **Family history.** People with family members who have bladder cancer are more likely to get the disease.
- **Personal history of bladder cancer.** People who have had bladder cancer have an increased chance of getting the disease again.

These factors may add to any risk due to workplace exposure to ionizing radiation. The chance of getting bladder cancer goes up as people get older. Whites get bladder cancer twice as often as African Americans and Hispanics. The lowest rates are among Asians. Men are two to three times more likely than women to get bladder cancer.

Rates of Bladder Cancer In Exposed Counties

Los Alamos County

There have been high rates of bladder cancer incidence reported in Los Alamos County and low rates of bladder cancer mortality.

- Los Alamos County ranked fifth highest in bladder cancer incidence and very low in mortality (32nd) from 1970 to 1996 of the 33 counties in New Mexico. This is evidence of early detection and successful treatment.
- In recent years, about three to four new cases of bladder cancer has been diagnosed each year in Los Alamos County. [13,14]

Rio Arriba County

Rates of bladder cancer incidence reported in Rio Arriba County have been moderate and rates for bladder cancer mortality have been very high.

- Rio Arriba County ranked 20th in bladder cancer incidence from 1970 to 1996 of the 33 counties in New Mexico.
- Rio Arriba County ranked third highest in bladder cancer mortality from 1970 to 1996 of the 33 counties in New Mexico. [33]

Rio Arriba County's ranking for bladder cancer mortality is much worse than its ranking for bladder cancer incidence. This means that the rates of diagnosis and treatment may be low relative to the number who actually have the disease. This is a strong indication of a "health disparity" compared to Los Alamos County, where bladder cancer cases do better. More needs to be done in Rio Arriba County to detect and treat bladder cancer early.

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* *Findings were statistically significant (strong evidence)*

\+ *Evidence of a dose-response relationship (strongest evidence)*

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Bone Cancer and Exposure to Ionizing Radiation

Summary: There is moderate evidence that bone cancer may be associated with exposure to ionizing radiation. This evidence includes studies of nuclear workers exposed to ionizing radiation. Bone cancer is designated as a "specified" cancer under the Energy Employees Occupational Illness Compensation Program Act.

What is Bone Cancer?

Cancer that arises in the bone is called primary bone cancer. Bone cancer is not the same disease as cancer that spreads to the bone from another part of the body. Primary bone cancer is rare, with approximately 2,500 new cases each year in the United States. More commonly, bones are the site of tumors that result from the spread of cancer from another organ, such as the breasts, lungs, and prostate. The most common type of bone cancer is osteosarcoma, which develops in new tissue in growing bones. (National Cancer Institute)

Findings of Human Health Research Studies

Human health research studies compare the patterns of disease among groups of people with different amounts of exposure to a suspected risk factor. Below are results reported from such studies of bone cancer among people exposed to ionizing radiation.

These studies found increases and possible increases in bone cancer among certain groups of exposed individuals, in some cases followed over time. Statistically significant is a term used to mean that the connection between the health outcome and the exposure was strong enough that it was unlikely to be due to chance. An asterisk (*) was placed by statistically significant findings. Making interpretation of the findings difficult is the rarity of bone cancer. The research included incidence studies, which look at new cases of cancer. Incidence studies can track health more quickly and accurately than mortality studies of deaths due to cancer. The ZIA study of LANL workers suggested positive findings and needs to be revisited.

Studies of Los Alamos National Laboratory (LANL) Workers

Research conducted of LANL workers provides the most direct evidence about possible relationships between a health problem and workplace exposures at LANL.

Zia Study (unpublished): Possible increased deaths due to bone cancer were observed in a study of 4,942 males who were monitored for radiation while employed by Zia between 1946 and 1978, and followed through 1984. Two of the four cases of bone cancer were Hispanic men who were monitored for plutonium.

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* *Findings were statistically significant (strong evidence)*

\+ *Evidence of a dose-response relationship (strongest evidence)*

As of November 1991, a total of seven cases of bone cancer had occurred among former Zia employees. Three were angiosarcoma of bone, "a very rare tumor." LANL researchers wrote:

> "Additional work needs to be done to verify diagnoses, explore the potential for non-radiation occupational exposures, and determine whether this collection of cases of angiosarcoma of the bone is a mere curiosity or reflective of some identifiable problem."[15]

The study was never completed. No further investigation is known to have taken place.

- **UC & Zia Employees:** Possible increased incidence of bone cancer in Anglo males who were employed at least one year between 1969 and 1978. But this finding was based on just one case.[16]

- **Manhattan Project Workers:** One of the 26 workers in this small study developed bone cancer (osteosarcoma) at age 64 in 1988 and died two years later. His body burden, as measured by urine samples, was reportedly on the order of 15 to 20 nanocuries (a measure of radiation exposure) of plutonium.[17]

Studies of Other Nuclear Workers in the United States

The next most relevant evidence comes from studies of workers in similar occupations with the same types of exposures. Listed below are studies that looked at bone cancer and workplace exposures among nuclear workers in other parts of the United States.

- **Oak Ridge K-25 (unpublished):** Increased deaths due to bone cancer was found in a study of workers employed between 1945 and 1984, and followed through 1984.[18] *

- **Portsmouth, Ohio (unpublished):** Possible increased deaths due to bone cancer was found in a study of 8,887 workers employed between 1954 and 1991.[18]

- **U.S. Transuranics Registry:** One osteosarcoma was identified among 260 USTR plutonium worker autopsies.[19]

Studies of Other Nuclear Workers World-Wide

Below are studies of nuclear workers outside of the United States that looked at bone cancer in connection with radiation exposures.

- **Mayak, Russia:** Increased deaths were observed due to bone cancer in a study of workers with large body burdens (over 200 nanocuries ? a measure of radiation exposure) of plutonium who were hired between 1948 and 1958.[20] * A smaller increase in deaths due to bone cancer was observed in workers who were not monitored for plutonium. +

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* *Findings were statistically significant (strong evidence)*

\+ *Evidence of a dose-response relationship (strongest evidence)*

- **Obninsk, Russia:** Increased incidence of tumors of bone, connective tissue, skin and breast combined were observed in a study of 5,644 nuclear workers who were hired before 1981 and still employed between 1991 and 1997.[7] *

Studies of Other Ionizing Radiation Exposures

Studies among other groups of people who were not nuclear workers can also be significant as evidence of possible increases in bone cancer among those who have been exposed to ionizing radiation. Most other research has been conducted of people exposed to atomic bombs.

- **Atomic Bomb Survivors:** Possible increasing deaths were observed due to bone cancer with increasing doses of radiation in a study of 86,572 A-bomb survivors.[8]

Other Research and Policy Findings

Is the Bone Sensitive to Radiation?

Undetermined. The National Research Council's BEIR V Committee did not address the issue of bone's sensitivity to radiation, probably because these tumors are so rare.[9]

The National Research Council advises the U.S. government on scientific matters. Their Committee on Biological Effects of Exposure to Ionizing Radiations (BEIR) V reviewed sensitivity of parts of the body to radiation. Their findings are based mostly on studies of cancer among atomic bomb survivors, as well as on some of the available information on the biology of the body, animal studies, and other evidence. The greatest risk is at high exposure levels.

Is Bone Cancer a "Specified" Cancer Under the Energy Employees Occupational Illness Compensation Program Act (EEOICPA)?

- **Yes.** Bone cancer is a "specified" cancer under the EEOICPA consideration of Special Exposure Cohorts.

Policy makers have identified certain types of cancer among energy employees at nuclear facilities, including those employed at Los Alamos National Laboratory, as being potentially related to occupational exposures under the EEOICPA.

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* *Findings were statistically significant (strong evidence)*

+ *Evidence of a dose-response relationship (strongest evidence)*

What Are Other Risk Factors for Bone Cancer?

In considering the cancer risk from exposure to ionizing radiation at work, it is important to understand other risk factors. The following is a list of other possible risk factors for bone cancer.

- Children and young adults who have had radiation or chemotherapy treatments for other conditions are at greater risk.
- Adults with Paget's disease, a condition where new bone cells do not develop normally, may be at increased risk.
- A small number of bone cancers are due to heredity.

These factors may add to any risk due to workplace exposure to ionizing radiation. Bone cancers occur more frequently in children and young adults. Smoking is not believed to be related to bone cancer.

Rates of Bone Cancer In Exposed Counties

Bone cancer is so rare that the New Mexico Tumor Registry does not routinely report statistics.

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* *Findings were statistically significant (strong evidence)*

\+ *Evidence of a dose-response relationship (strongest evidence)*

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Brain Cancer and Exposure to Ionizing Radiation

Summary: There is strong evidence that brain cancer may be associated with exposure to ionizing radiation. This evidence is based upon studies conducted at Los Alamos National Laboratory, studies of nuclear workers at other sites, and others exposed to ionizing radiation. This is consistent with the National Research Council's finding that brain tissue is sensitive to ionizing radiation. There remains some scientific debate as to whether brain cancer in nuclear workers may be due to radiation or chemical exposures. Brain cancer is designated as a "specified" cancer under the Energy Employees Occupational Illness Compensation Program Act. Historically, brain cancer incidence and mortality have been among the highest in the state for Los Alamos County. Incidence and mortality in Rio Arriba County have been higher than average New Mexico county rates. Incidence means new cases of cancer, while mortality means deaths due to cancer.

What Is Brain Cancer?

Brain cancer is cancer that starts in the brain tissues. The brain is part of the body's central nervous system. Cancers that start in many other sites in the body can spread (metastasize) to the brain, but are not brain cancer. Benign tumors that are not cancer, but are still of concern, can also form in the brain. (National Cancer Institute)

Findings of Human Health Research Studies

Human health research studies compare the patterns of disease among groups of people with different amounts of exposure to a suspected risk factor. Below are results reported from such studies of brain cancer among people exposed to ionizing radiation.

All of these studies found increases and possible increases in brain cancer among certain groups of exposed workers. Statistically significant is a term used to mean that the connection between the health outcome and the exposure was strong enough that it was unlikely to be due to chance. An asterisk (*) was placed by statistically significant findings. The research was mostly mortality studies, which look at death due to brain cancer as an outcome. Incidence studies of those newly diagnosed with brain cancer can be more timely and accurate. Adding to the strength of the findings is that increasing rates of brain cancer were observed with higher doses in some studies.

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* *Findings were statistically significant (strong evidence)*

\+ *Evidence of a dose-response relationship (strongest evidence)*

Studies of Los Alamos National Laboratory (LANL) Workers

Research conducted of LANL workers provides the most direct evidence about possible relationships between a health problem and workplace exposures at LANL.

- **Mortality study up to 1990:** Research conducted at LANL (among workers up through 1990) showed evidence that the risk among workers of dying from brain cancer increased with greater amounts of exposure to external radiation measured by radiation badges (TLD).* [21]

This study presents strong evidence that was unlikely to be due to chance (was statistically significant). Supporting the evidence of a relationship, a pattern, called a dose-response trend was seen where the proportion of workers who died of brain cancer increased among those who received higher exposures. Further adding to the strength of this study is that it is based on direct personal measurements of exposure. A limitation of the study may be that is a mortality study of death from cancer rather than an incidence study of new cases.

Studies of Other Nuclear Workers in the United States

The next most relevant evidence comes from studies of workers in similar occupations with the same types of exposures. Listed below are studies that looked at brain cancer and workplace exposures among nuclear workers in other parts of the United States.

- **Fernald:** A possible increase in brain cancer deaths was observed in a study of uranium processing workers who were employed from 1951 to 1989, and then followed through 1989.[1]

- **Lawrence Livermore, California:** An increased incidence of nervous system tumors *other than brain tumors* was found in males employed between 1969 and 1980.[22]

- **Oak Ridge Y-12:** Studies observed a possible increase in brain cancer deaths in workers who were employed from 1947 to 1974. But the researchers who conducted these studies were not confident that it was due to radiation. [23, 24]

- **Rocketdyne/Atomics International, Santa Susana, California:** There was a possible increase in brain cancer deaths in workers who were monitored for internal or external radiation between 1950 and 1993, and followed to 1995.[25, 26, 27]

- **Rocky Flats, Colorado**: A Possible increase in brain cancer deaths was observed among white males who worked for at least two years from 1952 to 1979, and were followed to 1980. [28]

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* *Findings were statistically significant (strong evidence)*

+ *Evidence of a dose-response relationship (strongest evidence)*

Studies of Other Nuclear Workers World-Wide

Below are studies of nuclear workers outside of the United States that looked at brain cancer in connection with radiation exposures.

- **Three Nuclear Workforces in the U.K.:** Increasing rates of brain cancer deaths were found with increasing number of years since workers were first monitored for plutonium.[29] *

- **Sellafield, England:** A possible increase in brain cancer deaths was seen in plutonium workers when compared to non-radiation workers.[3]

Studies of Other Ionizing Radiation Exposures

Studies among other groups of people who were not nuclear workers can also be significant as evidence of possible increases in brain cancer among those who have been exposed to ionizing radiation. Most other research has been conducted of people exposed to atomic bombs.

- **Atomic Bomb Survivors:** An increasing incidence of nervous system tumors, especially schwannomas, was seen with increasing doses of radiation.[+*30] A possible increase has been observed in malignant (cancerous) and other brain tumor deaths in A-bomb survivors who were followed through 1978. There was further evidence of a dose-response trend between reconstructed exposures and the risk of death from brain cancer.[31]

Other Research and Policy Findings

Is the Brain Sensitive to Radiation?

- **Yes.** According to the National Research Council's BEIR V Committee, the tissues of the brain are sensitive to the cancer-causing effects of ionizing radiation.[9]

The National Research Council advises the U.S. government on scientific matters. Their Committee on Biological Effects of Exposure to Ionizing Radiations (BEIR) V reviewed sensitivity of parts of the body to radiation. Their findings are based mostly on studies of cancer among atomic bomb survivors, as well as on some of the available information on the biology of the body, animal studies, and other evidence. The greatest risk is at high exposure levels.

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* *Findings were statistically significant (strong evidence)*

\+ *Evidence of a dose-response relationship (strongest evidence)*

Is Brain Cancer a "Specified" Cancer Under the Energy Employees Occupational Illness Compensation Program Act (EEOICPA)?

- **Yes.** Brain cancer is a "specified" cancer under the EEOICPA consideration of Special Exposure Cohorts.

Policy makers have identified certain types of cancer among energy employees at nuclear facilities, including those employed at Los Alamos National Laboratory, as being potentially related to occupational exposures under the EEOICPA.

What Are Other Risk Factors for Brain Cancer?

In considering the cancer risk from exposure to ionizing radiation at work, it is important to understand other risk factors. Below is a list of other possible risk factors for brain cancer.

- There is scientific debate over whether brain cancer in nuclear workers is due to radiation[31] or chemicals.[24]
- Some types of brain tumors are more frequent among workers in certain industries, such as oil refining, rubber manufacturing, and drug manufacturing. Other studies have shown that chemists and embalmers have a higher incidence of brain tumors
- Researchers are studying families with a history of brain tumors to see whether heredity is a factor.

These factors may add to any risk due to workplace exposure to ionizing radiation. Smoking is unlikely to be related to brain cancer.

What Makes Brain Cancer and Radiation Exposure Difficult to Study?

There are difficulties in all human studies because one cannot determine all exposures and track all health outcomes for everyone who may have been affected. In cancer this is especially the case as the cancer may take many years to develop to the point of diagnosis and possible death (disease latency). Brain cancer research is made particularly difficult due to errors in diagnosing brain cancer. Primary cancers of many other sites in the body can spread (metastasize) to the brain. This may lead to some of these other cancers to be incorrectly thought to be brain cancer. It is important to make sure that the disease is primary brain cancer.[32]

Radiation also causes brain tumors that are not cancerous (benign). To further complicate matters, brain tumors that are cancerous (malignant) are often incorrectly classified as "benign" or "other and unspecified" tumors. A growing number of researchers believe that all brain tumors (benign *and* malignant *and* unspecified) should be counted in studies of nuclear and chemical workers.[31]

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* *Findings were statistically significant (strong evidence)*

\+ *Evidence of a dose-response relationship (strongest evidence)*

Rates of Brain Cancer In Exposed Counties

Los Alamos County

There have been high rates of brain cancer reported in Los Alamos County for both brain cancer incidence and mortality.

- Los Alamos County ranked third highest in brain cancer incidence from 1970 to 1996 of the 33 counties in New Mexico.[33]
- Los Alamos County also ranked third highest in brain cancer mortality from 1970 to 1996 of the 33 counties in New Mexico.[33]
- In the 1950's, there was a statistically significant increase in brain cancer deaths in females in Los Alamos County.[34]
- During the mid- to late- 1980's brain cancer rates in Los Alamos County were 60 to 80% higher than in the U.S. or state-wide, contributing to public concern over a cluster.[35]
- In recent years, one to two new cases have been diagnosed each year in Los Alamos County.[14]

Rio Arriba County

Rates of brain cancer reported in Rio Arriba County have been somewhat higher than average county rates for both brain cancer incidence and mortality. These higher rates may be due to chance fluctuations in area rates.

- Rio Arriba County ranked 11th in brain cancer incidence from 1970 to 1996 of the 33 counties in New Mexico.
- Rio Arriba County ranked 12th in brain cancer mortality from 1970 to 1996 of the 33 counties in New Mexico.[33]

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* *Findings were statistically significant (strong evidence)*

\+ *Evidence of a dose-response relationship (strongest evidence)*

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Breast Cancer and Exposure to Ionizing Radiation

Summary: There is strong evidence that breast cancer may be associated with exposure to ionizing radiation. This evidence includes studies of nuclear workers and others exposed to ionizing radiation. These findings are consistent with the National Research Council's determination that breast tissue is sensitive to ionizing radiation. Breast cancer is designated as a "specified" cancer under the Energy Employees Occupational Illness Compensation Program Act. Historically, breast cancer incidence and mortality have both been very high in Los Alamos County. Incidence and mortality in Rio Arriba County has been moderate to low among New Mexico counties. Incidence means new cases of cancer, while mortality means deaths due to cancer. A need exists for improved treatment and prevention in Los Alamos County.

What is Breast Cancer?

Breast cancer starts in the tissues of the breast. While mostly a disease of women, men can get breast cancer. When cancer arises in breast tissue and spreads (metastasizes) outside the breast, cancer cells are often found in the lymph nodes under the arm. Breast cancer cells may further spread to other parts of the body -- other lymph nodes and other organs, such as the bones, liver, or lungs. Other than skin cancer, breast cancer is the most common type of cancer among women in the United States. (National Cancer Institute)

Findings of Human Health Research Studies

Human health research studies compare the patterns of disease among groups of people with different amounts of exposure to a suspected risk factor. Below are results reported from such studies of breast cancer among people exposed to ionizing radiation.

All of these studies found increases and possible increases in breast cancer among certain groups of exposed individuals, in some cases followed over time. Statistically significant is a term used to mean that the connection between the health outcome and the exposure was strong enough that it was unlikely to be due to chance. An asterisk (*) was placed by statistically significant findings. The research included incidence studies, which look at new cases of breast cancer. These can track health more quickly and accurately than mortality studies of deaths due to cancer. Adding to the strength of the findings is that increasing rates of breast cancer were observed with higher doses in some studies.

***** *Findings were statistically significant (strong evidence)*

+ *Evidence of a dose-response relationship (strongest evidence)*

Studies of Los Alamos National Laboratory (LANL) Workers

Research conducted of LANL workers provides the most direct evidence about possible relationships between a health problem and workplace exposures at LANL.

- **UC & Zia Employees:** A possible increase in breast cancer incidence was observed among Anglo females who were employed for at least one year between 1969 and 1978. LANL researchers who performed the study concluded it was "not likely related to the Los Alamos work environment."[16] One male breast cancer case was reported.

- **Female Lab Employees Study:** A possible increase in breast cancer deaths was observed in white female radiation workers who were employed at least six months between 1943 and 1979, when compared to non-radiation workers (This study assumed a 25 year latency period).[36] But the researcher who conducted the study did not think it was work-related.

Studies of Other Nuclear Workers in the United States

The next most relevant evidence comes from studies of workers in similar occupations with the same types of exposures. Listed below are studies that looked at breast cancer and workplace exposures among nuclear workers in other parts of the United States.

- **Oak Ridge Y-12:** A possible increase in breast cancer deaths was observed in a study of 1,073 women first employed between 1947 and 1974, and followed through 1990.[24]

- **Women at 10 Department of Energy (DOE) Sites:** Possible increasing rates of breast cancer deaths were observed with increasing doses of external radiation in a study of 65,984 women employed at 10 DOE facilities between start-up and 1980.[37 +]

Studies of Other Nuclear Workers World-Wide

Below are studies of nuclear workers outside of the United States that looked at breast cancer in connection with radiation exposures.

- **Sellafield, England:** An increase in breast cancer deaths was found in a study of 5,203 plutonium workers who were first employed between 1947 and 1975, and followed through 1992, when compared to other radiation workers.[3 *]

- **Obninsk (IPPE), Russia**: A possible increase was observed in breast cancer incidence in a study of 2,202 females who were hired before 1981 and still employed between 1991 and 1997.[7]

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* *Findings were statistically significant (strong evidence)*

\+ *Evidence of a dose-response relationship (strongest evidence)*

Studies of Other Ionizing Radiation Exposures

Studies among other groups of people who were not nuclear workers can also be significant as evidence of possible increases in breast cancer among those who have been exposed to ionizing radiation. Most other research has been conducted of people exposed to atomic bombs.

- **A-Bomb:** Increasing female breast cancer deaths were observed with increasing doses of radiation.[8 *+] The biggest risk of breast cancer was for those who were under 15 years old at the time of exposure.[38]

Other Research and Policy Findings

Is the Breast Sensitive to Radiation?

- **Yes.** According to the National Research Council's BEIR V Committee, radiation-induced breast cancer has a minimum latent period of 10 years. The risk is greatest for persons less than 20 years old at the time of exposure.[9]

The National Research Council advises the U.S. government on scientific matters. Their Committee on Biological Effects of Exposure to Ionizing Radiations (BEIR) V reviewed sensitivity of parts of the body to radiation. Their findings are based mostly on studies of cancer among atomic bomb survivors, as well as on some of the available information on the biology of the body, animal studies, and other evidence. The greatest risk is at high levels of exposure.

Is Breast Cancer a "Specified" Cancer Under the Energy Employees Occupational Illness Compensation Program Act (EEOICPA)?

- **Yes.** Male and female breast cancers are "specified" cancers under the EEOICPA consideration of Special Exposure Cohorts.

Policy makers have identified certain types of cancer among energy employees at nuclear facilities, including those employed at Los Alamos National Laboratory, as being potentially related to occupational exposures under the EEOICPA.

What Are Other Risk Factors for Breast Cancer?

In considering the cancer risk from exposure to ionizing radiation at work, it is important to understand other risk factors. The following is a list of other possible risk factors for breast cancer.

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* *Findings were statistically significant (strong evidence)*

\+ *Evidence of a dose-response relationship (strongest evidence)*

- **Estrogen.** Evidence suggests that the longer a woman is exposed to estrogen (the estrogen hormone made by the body, taken as a drug, or delivered by a patch), the more likely she is to develop breast cancer.
- **Genetic differences.** Some people are born with differences in the cells of their bodies that may increase the risk of breast cancer.
- **Certain breast changes.** Having a diagnosis of certain unusual cell changes in breast tissue may increase a woman's risk for developing cancer.
- **Late childbearing.** Women who have their first child late (after about age 30) have a greater chance of developing breast cancer than women who have a child at a younger age.
- **Radiation therapy.** Women whose breasts were exposed to radiation during radiation therapy before age 30, especially those who were treated with radiation for Hodgkin's disease, are at an increased risk for developing breast cancer.
- **Alcohol.** Some studies suggest a slightly higher risk of breast cancer among women who drink alcohol.

These factors may add to any risk due to workplace exposure to ionizing radiation. Studies show that the risk of breast cancer increases as a woman gets older and for those with family or personal histories of breast cancer. Breast cancer occurs more often in white women than African American or Asian women. Smoking is not thought to be related to breast cancer.

Rates of Breast Cancer In Exposed Counties

Los Alamos County

There have been very high rates of breast cancer reported in Los Alamos County for breast cancer incidence and breast cancer mortality.

- Los Alamos County ranked highest in both breast cancer incidence and mortality from 1970 to 1996 of the 33 counties in New Mexico. The explanations most frequently offered are: the county population's high socioeconomic status, low birth rate, and late times of first pregnancy -- all well-documented risk factors for female breast cancer.[32, 35]
- In recent years, about 15 new cases of breast cancer have been diagnosed each year in Los Alamos County.[13]

Rio Arriba County

Rates of breast cancer incidence reported in Rio Arriba County have been moderate while breast cancer mortality has been low. Rio Arriba County:

- Ranked 22nd in breast cancer incidence and
- Ranked 29th in breast cancer mortality from 1970 to 1996 of 33 New Mexico counties.[33]

The high rates of breast cancer incidence and mortality in Los Angelos County indicate that more needs to be done in Los Angelos County to prevent and treat breast cancer.

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* *Findings were statistically significant (strong evidence)*

\+ *Evidence of a dose-response relationship (strongest evidence)*

Cervical and Uterine Cancer and Exposure to Ionizing Radiation

Summary: Moderate evidence has been recorded of a possible connection between cervical and uterine cancers and exposure to ionizing radiation. This evidence is based upon studies of nuclear workers and others exposed to ionizing radiation. The National Research Council's has not determined whether the uterus is sensitive to ionizing radiation. Cervical and uterine cancers are not designated as "specified" cancers under the Energy Employees Occupational Illness Compensation Program Act. Historically, cervical cancer incidence and mortality have been low in Los Alamos County and high in Rio Arriba County among New Mexico counties. Incidence means new cases of cancer, while mortality means deaths due to cancer. For uterine cancer, incidence has been moderate, while mortality has been very low in Los Alamos County. In Rio Arriba County, uterine cancer incidence has been moderately low, while mortality has been moderately high. These rates suggest that more needs to be done in Rio Arriba County to detect and treat cervical and uterine cancer early.

What are Cervical and Uterine Cancers?

The uterus (also known as the womb), is a hollow, pear-shaped organ that is part of a woman's reproductive system. The cervix is the lower, narrow part of the uterus. Uterine cancer is the most common reproductive cancer among women, accounting for six percent of all cancers in women in this country. Each year, about 15,000 women in the United States learn that they have cancer of the cervix. Fibroid tumors and endometriosis are conditions of the uterus that are not cancerous. (National Cancer Institute)

Findings of Human Health Research Studies

Human health research studies compare the patterns of disease among groups of people with different amounts of exposure to a suspected risk factor. Below are results reported from such studies of cervical and uterine cancer among people exposed to ionizing radiation.

The results of these studies found increases and possible increases in cervical and uterine cancer among certain groups of exposed individuals, in some cases followed over time. Statistically significant is a term used to mean that the connection between the health outcome and the exposure was strong enough that it was unlikely to be due to chance. An asterisk (*) was placed by statistically significant findings. The research included incidence studies, which look at new cases of cancer. These can track health more quickly and accurately than mortality studies of deaths due to cancer. Adding to the strength of the findings is that increasing rates of cervical and uterine cancer were observed with higher doses in some studies.

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* *Findings were statistically significant (strong evidence)*

\+ *Evidence of a dose-response relationship (strongest evidence)*

Studies of Los Alamos National Laboratory (LANL) Workers

Research conducted of LANL workers provides the most direct evidence about possible relationships between a health problem and workplace exposures at LANL.

- In studies performed to date, there is no reported evidence of increased rates of cervical or uterine cancer in LANL employees.

Studies of Other Nuclear Workers in the United States

The next most relevant evidence comes from studies of workers in similar occupations with the same types of exposures. Listed below are studies that looked at uterine and cervical cancer and workplace exposures among nuclear workers in other parts of the United States.

- **United Nuclear, Connecticut:** Increased incidence of cervical cancer was observed in a study of 594 women employed for at least six months between 1956 and 1978, and followed through 1979.[39] *

Studies of Other Nuclear Workers World-Wide

Below are studies of nuclear workers outside of the United States that looked at uterine and cervical cancer in connection with radiation exposures.

- **Nuclear Workers in Three Countries (United States, United Kingdom (U.K.), Canada):** A possible increase in uterine cancer deaths was observed with increasing doses of external radiation, assuming a 10 year latent period, in a study of 13,928 women employed before 1982.[40] +

- **Three Nuclear Workforces in the U.K.:** Increased deaths due to uterine cancer were observed in a study of 413 women who were "ever monitored" for radionuclides like Zn-65, Fe-59, Co-60 and Cr-51.[29] *

- **Atomic Energy Establishment of the U.K.:** Increased uterine cancer deaths were found in a study of 1,785 women with recorded radiation exposures who were employed between 1946 and 1979, and followed through 1986.[6] * The rate of uterine cancer increased with the amount of whole body exposure. *+ The biggest risk was for employees who were monitored for any internally-deposited radionuclide. * Most of the cases were cancer of the corpus uterus.

- **Obninsk (IPPE), Russia**: Increased incidence of uterine cancer was found in a study of 2,202 females who were hired before 1981 and still employed between 1991 and 1997.[7] *

Studies of Other Ionizing Radiation Exposures

Studies among other groups of people who were not nuclear workers can also be significant as evidence of possible increases in uterine and cervical cancer among those who have been

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* *Findings were statistically significant (strong evidence)*

+ *Evidence of a dose-response relationship (strongest evidence)*

exposed to ionizing radiation. Most other research has been conducted of people exposed to atomic bombs.

– **Atomic Bomb Survivors:** Possible increasing deaths due to uterine cancer in a study of 86,572 A-bomb survivors.[8 +]

Other Research and Policy Findings

Is the Uterus Sensitive to Radiation?

- **Unresolved.** According to the National Research Council's BEIR V Committee, the question of radiation exposure and uterine cancer is not resolved.[9]

The National Research Council advises the U.S. government on scientific matters. Their Committee on Biological Effects of Exposure to Ionizing Radiations (BEIR) V reviewed sensitivity of parts of the body to radiation. Their findings are based mostly on studies of cancer among atomic bomb survivors, as well as on some of the available information on the biology of the body, animal studies, and other evidence. The greatest risk is at high exposure levels.

Is Uterine or Cervical Cancer a "Specified" Cancer Under the Energy Employees Occupational Illness Compensation Program Act (EEOICPA)?

– **No.** Neither uterine nor cervical cancers are "specified" cancers under the EEOICPA consideration of Special Exposure Cohorts.

Policy makers have identified certain types of cancer among energy employees at nuclear facilities, including those employed at Los Alamos National Laboratory, as being potentially related to occupational exposures under the EEOICPA.

What Are Other Risk Factors for Uterine and Cervical Cancer?

In considering the cancer risk from exposure to ionizing radiation at work, it is important to understand other risk factors. The following is a list of other possible risk factors for cervical and for uterine cancer .

Cervical cancer:

– **Smoking.** The risk of cervical cancer may be increased by smoking[10] in combination with other risk factors.[41] Smoking is considered a contributory cause.[42]
– **Certain viruses.** Women who have human papillomaviruses (HPV) have a higher-than-average risk of developing cervical cancer.
– **The drug DES.** Women whose mothers were given the drug *diethylstilbestrol* (DES) during pregnancy to prevent miscarriage also are at increased risk of cervical cancer.

***** *Findings were statistically significant (strong evidence)*

+ *Evidence of a dose-response relationship (strongest evidence)*

Uterine cancer:

- **Estrogen.** Women who use the hormone estrogen without progesterone have an increased risk of uterine cancer. Long-term use and large doses of estrogen seem to increase this risk.
- **Obesity and related conditions**. High levels of estrogen may be the reason that obese women have an increased risk of developing uterine cancer. The risk of this disease is also higher in women with diabetes or high blood pressure.
- **The drug Tamoxifen.** Women taking the drug Tamoxifen to prevent or treat breast cancer have an increased risk of uterine cancer.
- **Colorectal cancer**. Women who have had an inherited form of colorectal cancer have a higher risk of developing uterine cancer than other women.

These factors may add to any risk due to workplace exposure to ionizing radiation. White women are more likely than African-American women to get uterine cancer.

Rates of Cervical and Uterine Cancer In Exposed Counties

Los Alamos County

There have been low rates reported in Los Alamos County for cervical cancer incidence and mortality. Rates of uterine cancer incidence fell in the middle of New Mexico county rates.

- Los Alamos County ranked 26th lowest in cervical cancer incidence and very low in mortality from 1970 to 1996,[33] and
- Ranked 17th lowest in uterine cancer incidence and very low in mortality from 1970 to 1996 of the 33 counties in New Mexico. [33]
- In recent years, about 2 new cases of cervical or uterine cancer have been diagnosed each year in Los Alamos County.[13, 14]

Rio Arriba County

Rates of cervical cancer reported in Rio Arriba County have been high for cervical cancer incidence and very high for mortality. Rates for uterine cancer incidence was low while cancer mortality was in the middle of New Mexico counties. These numbers suggest that more needs to be done in Rio Arriba County to detect and treat cervical and uterine cancer early.

- Rio Arriba County ranked 8th highest in cervical cancer incidence from 1970 to 1996 [33]
- Rio Arriba County ranked 3rd highest in cervical cancer mortality from 1970 to 1996[33]
- Rio Arriba County ranked 24th in uterine cancer incidence from 1970 to 1996,[33] and
- Rio Arriba County ranked 13th in uterine cancer mortality from 1970 to 1996 of the 33 counties in New Mexico. [33]

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* *Findings were statistically significant (strong evidence)*

+ *Evidence of a dose-response relationship (strongest evidence)*

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Colorectal Cancer and Exposure to Ionizing Radiation

Summary: Strong evidence has been recorded of a possible connection between colon cancer and some evidence of rectal cancer have been found in studies of exposure to ionizing radiation. This evidence is based upon studies of nuclear workers and others exposed to ionizing radiation. These findings are consistent with the National Research Council's determination that tissues of the colon and rectum may be sensitive to ionizing radiation. Colon cancer, but not rectal cancer is designated as a "specified" cancer under the Energy Employees Occupational Illness Compensation Program Act. Historically, colorectal cancer incidence and mortality have been very high in Los Alamos County and moderate in Rio Arriba County among New Mexico counties. Incidence means new cases of cancer, while mortality means deaths due to cancer. A need exists for improved treatment and prevention in Los Alamos County.

What is Colorectal Cancer?

Together, the colon and rectum form a long, muscular tube called the large intestine (also called the large bowel). Cancer that begins in the colon is called colon cancer, and cancer that begins in the rectum is called rectal cancer. Cancers affecting either of these organs may also be called colorectal cancer. (National Cancer Institute)

Findings of Human Health Research Studies

Human health research studies compare the patterns of disease among groups of people with different amounts of exposure to a suspected risk factor. Below are results reported from such studies of colorectal cancer among people exposed to ionizing radiation.

All these studies found increases and possible increases in colon and rectal cancer among certain groups of exposed individuals, in some cases followed over time. Statistically significant is a term used to mean that the connection between the health outcome and the exposure was strong enough that it was unlikely to be due to chance. An asterisk (*) was placed by statistically significant findings. The research included incidence studies, which look at new cases of cancer. These can track health more quickly and accurately than mortality studies of deaths due to cancer. Adding to the strength of the findings is that increasing rates of colon and/or rectal cancers were observed with higher doses in some studies.

Studies of Los Alamos National Laboratory (LANL) Workers

Research conducted of LANL workers provides the most direct evidence about possible relationships between a health problem and workplace exposures at LANL.

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* *Findings were statistically significant (strong evidence)*

\+ *Evidence of a dose-response relationship (strongest evidence)*

- **UC & Zia Employees:** A possible increase in colon cancer incidence was observed among Anglo males who were employed for at least one year between 1969 and 1978.(16)

Studies of Other Nuclear Workers in the United States

The next most relevant evidence comes from studies of workers in similar occupations with the same types of exposures. Listed below are studies that looked at colorectal cancer and workplace exposures among nuclear workers in other parts of the United States.

- **Lawrence Livermore, California:** Increased incidence of rectal cancer was found in females who were employed between 1969 and 1980. * [22]

- **Mound, Ohio:** Increased deaths due to rectal cancer were observed in workers who were hired during World War II.[43] *

- **Mallinckrodt, St. Louis, Missouri:** A possible increase in deaths due to colon cancer and rectal cancer were seen in a study of 2,514 uranium processing workers who were employed between 1942 and 1966, and followed through the year 1993.[2]

- **Savannah River Site:** A possible increase in deaths due to rectal cancer was found in a study of 6,687 hourly workers who were employed between 1952 and 1981 for at least 90 consecutive days.[44]

- **West Chicago (Kerr-McGee) Thorium Plant:** A possible increase in deaths due to rectal cancer was found in a study of 1,352 men who were first employed between 1940 and 1954, and followed through 1975.[45]

Studies of Other Nuclear Workers World-Wide

Below are studies of nuclear workers outside of the United States that looked at colorectal cancer in connection with radiation exposures.

- **Atomic Energy of Canada:** A possible increase in deaths due to rectal cancer was found in a study of 8,977 men who were employed between 1947 and 1985.[46]

- **Canadian Radiation Workers**: Increased incidence of colon cancer in males, and rectal cancer in males and females, was observed with increasing doses of external radiation in a study of 191,300 workers employed between 1951 and 1988.[47] *+

- **Sellafield, England**: A possible increase in incidence of rectal cancer was found in a study of 5,203 plutonium workers employed between 1947 and 1975. [3]

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* *Findings were statistically significant (strong evidence)*

+ *Evidence of a dose-response relationship (strongest evidence)*

Studies of Other Ionizing Radiation Exposures

Studies among other groups of people who were not nuclear workers can also be significant as evidence of possible increases in colorectal cancer among those who have been exposed to ionizing radiation. Most other research has been conducted of people exposed to atomic bombs.

- **Atomic Bomb Survivors:** Increasing colon cancer deaths with increasing doses of radiation in a study of 86,572 A-bomb survivors[8].*+

Other Research and Policy Findings

Are the Colon and Rectum Radiation-Sensitive Organs?

- **Yes.** According to the National Research Council's BEIR V committee, "the risks of cancer of the colon and cancer of the rectum can be increased by intensive irradiation in humans..."[9]

The National Research Council advises the U.S. government on scientific matters. Their Committee on Biological Effects of Exposure to Ionizing Radiations (BEIR) V reviewed sensitivity of parts of the body to radiation. Their findings are based mostly on studies of cancer among atomic bomb survivors, as well as on some of the available information on the biology of the body, animal studies, and other evidence. The greatest risk is at high exposure levels.

Are Colon and Rectal Cancers "Specified" Cancers Under the Energy Employees Occupational Illness Compensation Program Act (EEOICPA)?

- **Yes,** colon cancer is a "specified" cancer while
- **No,** rectal cancer is not a "specified" cancer under the EEOICPA consideration of Special Exposure Cohorts.

Policy makers have identified certain types of cancer among energy employees at nuclear facilities, including those employed at Los Alamos National Laboratory, as being potentially related to occupational exposures under the EEOICPA.

What Are Other Risk Factors for Colorectal Cancer?

In considering the cancer risk from exposure to ionizing radiation at work, it is important to understand other risk factors. The following is a list of other possible risk factors for colorectal cancer.

- **Diet.** Colorectal cancer seems to be associated with diets that are high in fat and calories and low in fiber.
- **Polyps.** Polyps are non-cancerous growths on the inner wall of the colon and rectum. Some types of polyps increase a person's risk of developing colorectal cancer.

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* *Findings were statistically significant (strong evidence)*

\+ *Evidence of a dose-response relationship (strongest evidence)*

? **Certain diseases.** Those who have been diagnosed with the rare condition of the colon, Ulcerative colitis, are at increased risk of developing colorectal cancer. Women with a history of cancer of the ovary, uterus, or breast have a somewhat increased chance of developing colorectal cancer.
? **Smoking.** There is some evidence that rectal cancer is related to smoking. But the evidence for rectal cancer is not strong or consistent. [41]

These factors may add to any risk due to workplace exposure to ionizing radiation. Those who have had family members with colorectal cancer are at higher risk.

Rates of Colorectal Cancer In Exposed Counties

Los Alamos County

There have been very high rates of colon cancer reported in Los Alamos County for colorectal cancer incidence and mortality.

- Los Alamos County ranked 3rd highest in colorectal cancer incidence and 5th highest in colorectal cancer mortality from 1970 to 1996 of the in New Mexico.
- In recent years, about 7 new cases of colorectal cancer have been diagnosed each year in Los Alamos County. [13,]

Rio Arriba County

Rates of colorectal cancer reported in Rio Arriba County have been moderate, among the middle of New Mexico counties, for cancer incidence and mortality.

- Rio Arriba County ranked 14th in colorectal cancer incidence and[13]
- Rio Arriba County ranked 19th in colorectal cancer mortality from 1970 to 1996 of the in New Mexico. [13]

The high rates of colorectal cancer incidence and mortality in Los Angelos County indicate that more needs to be done in Los Angelos County to prevent and treat colorectal cancer.

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* *Findings were statistically significant (strong evidence)*
+ *Evidence of a dose-response relationship (strongest evidence)*

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Esophageal Cancer and Exposure to Ionizing Radiation

Summary: Strong evidence has been recorded of a possible connection between esophageal cancer and exposure to ionizing radiation. This evidence is based upon studies of nuclear workers and others exposed to ionizing radiation. These findings are consistent with the National Research Council's determination that cancer of the esophagus increased in populations exposed to ionizing radiation. Esophageal cancer is designated as a "specified" cancer under the Energy Employees Occupational Illness Compensation Program Act. Historically, esophageal cancer incidence and mortality have both been moderate in Los Alamos County and in Rio Arriba County among New Mexico counties. Incidence means new cases of cancer, while mortality means deaths due to cancer.

What is Esophageal Cancer?

The esophagus is a hollow tube that carries food and liquids from the throat to the stomach. When a person swallows, the muscular walls of the esophagus contract to push food down into the stomach. Cancer that begins in the esophagus is called esophageal cancer. Esophageal cancer may be named for the type of cell that is cancerous. For example, squamous cell carcinoma or adenocarcinoma. (National Cancer Institute)

Findings of Human Health Research Studies

Human health research studies compare the patterns of disease among groups of people with different amounts of exposure to a suspected risk factor. Below are results reported from such studies of esophageal cancer among people exposed to ionizing radiation.

All of these studies found increases and possible in esophageal cancer among certain groups of exposed individuals, in some cases followed over time. Statistically significant is a term used to mean that the connection between the health outcome and the exposure was strong enough that it was unlikely to be due to chance. An asterisk (*) was placed by statistically significant findings. The research included an incidence study, which looked at new cases of cancer. These can track health more quickly and accurately than mortality studies of deaths due to cancer. Adding to the strength of the findings is that increasing rates of esophageal cancer were observed with higher doses in some studies.

Studies of Los Alamos National Laboratory (LANL) Workers

Research conducted of LANL workers provides the most direct evidence about possible relationships between a health problem and workplace exposures at LANL.

***** *Findings were statistically significant (strong evidence)*

+ *Evidence of a dose-response relationship (strongest evidence)*

- **LANL Mortality Study up to 1991:** Rates of death due to esophageal cancer were observed to increase with increasing doses of external radiation.[21 *+]

Studies of Other Nuclear Workers in the United States

The next most relevant evidence comes from studies of workers in similar occupations with the same types of exposures. Listed below are studies that looked at esophageal cancer and workplace exposures among nuclear workers in other parts of the United States.

- **Fernald, Ohio:** A possible increase in deaths due to esophageal cancer was found in a study of 4,014 uranium processing workers employed between 1951 and 1989, and then followed through 1989.[1]

- **Mallinckrodt, St. Louis, Missouri:** A possible increase in deaths due to esophageal cancer was found in a study of 2,514 uranium processing workers who were employed between 1942 and 1966, and followed through 1993.[2]

- **Rocky Flats, Colorado:** A possible increase in deaths due to esophageal cancer was found in workers with plutonium body burdens greater than 2 nanocuries (a measure of radiation exposure). However, this was based on only two cases.[28]

- **Combined Hanford, Oak Ridge and Rocky Flats:** Increasing rates of death due to esophageal cancer was found with increasing doses of external radiation in a study of 45,000 workers employed for at least six months.[48 *+]

Studies of Other Nuclear Workers World-Wide

Below are studies of nuclear workers outside of the United States that looked at esophageal cancer in connection with radiation exposures.

- **Sellafield, England:** A possible increase in deaths was found due to esophageal cancer in a study of 5,203 plutonium workers employed between 1947 and 1975, who were followed through 1992, when workers were compared to non-radiation workers.[3] A possible increase in deaths due to esophageal cancer was also found in a study of 10,157 radiation workers, who were followed through 1983. [4]

- **Canadian Radiation Workers:** A possible increased incidence of esophageal cancer from 1969 to 1988 was observed in a study of 191,300 workers who were employed between 1951 and 1988. [47]

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* *Findings were statistically significant (strong evidence)*

\+ *Evidence of a dose-response relationship (strongest evidence)*

Studies of Other Ionizing Radiation Exposures

Studies among other groups of people who were not nuclear workers can also be significant as evidence of possible increases in esophageal cancer among those who have been exposed to ionizing radiation. Most other research has been conducted of people exposed to atomic bombs.

- **Atomic Bomb Survivors:** Increasing deaths due to cancer of the esophagus with increasing doses of radiation in a study of 86,572 A-bomb survivors. [8] *+

Other Research and Policy Findings

Is the Esophagus Sensitive to Radiation?

- **Yes.** According to the National Research Council's BEIR V Committee, "[c]arcinoma of the esophagus has been observed to occur with increased frequency in several irradiated human populations."[9]

The National Research Council advises the U.S. government on scientific matters. Their Committee on Biological Effects of Exposure to Ionizing Radiations (BEIR) V reviewed sensitivity of parts of the body to radiation. Their findings are based mostly on studies of cancer among atomic bomb survivors, as well as on some of the available information on the biology of the body, animal studies, and other evidence. The greatest risk is at high exposure levels.

Is Esophageal Cancer a "Specified" Cancer Under the Energy Employees Occupational Illness Compensation Program Act (EEOICPA)?

- **Yes.** Esophageal cancer is a "specified" cancer under the EEOICPA consideration of Special Exposure Cohorts.

Policy makers have identified certain types of cancer among energy employees at nuclear facilities, including those employed at Los Alamos National Laboratory, as being potentially related to occupational exposures under the EEOICPA.

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* *Findings were statistically significant (strong evidence)*

+ *Evidence of a dose-response relationship (strongest evidence)*

What Are Other Risk Factors for Esophageal Cancer?

In considering the cancer risk from exposure to ionizing radiation at work, it is important to understand other risk factors. Below is a list of other possible risk factors for esophageal cancer.

- **Smoking.** Smoking is considered to be related to esophageal cancer. [10, 11, 12]
- **Alcohol Use**. Chronic and/or heavy use of alcohol is another major risk factor for esophageal cancer.
- **Causes of significant irritation.** Long-term irritation or damage to the lining of the esophagus can increase the risk of esophageal cancer. This may be due to factors such as if stomach acid frequently "backs up" into the esophagus or by swallowing lye or other caustic substances.

These factors may add to any risk due to workplace exposure to ionizing radiation. Esophageal cancer is more likely to occur as people get older. It is more common in men than women.

Rates of Esophageal Cancer In Exposed Counties

Los Alamos County

There have been moderate rates of esophageal cancer incidence reported in Los Alamos County for esophageal cancer and low rates of esophageal cancer mortality.

- Los Alamos County ranked 21st in esophageal cancer incidence from 1970 to 1996 of the 33 counties in New Mexico. [33]
- Los Alamos County ranked 28th in esophageal cancer mortality from 1970 to 1996 of the 33 counties in New Mexico. [33]
- In recent years, there has been less than one diagnosed each year in Los Alamos County. [13, 14]

Rio Arriba County

Rates of esophageal cancer reported in Rio Arriba County have been moderate for cancer incidence and mortality.

- Rio Arriba County ranked 15th in esophageal cancer incidence from 1970 to 1996 of the 33 counties in New Mexico. [33]
- Rio Arriba County ranked 15th in esophageal cancer mortality from 1970 to 1996 of the 33 counties in New Mexico. [33]

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* *Findings were statistically significant (strong evidence)*

\+ *Evidence of a dose-response relationship (strongest evidence)*

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Hodgkin's Disease and Exposure to Ionizing Radiation

Summary: Little evidence has been recorded of a possible connection between Hodgkin's disease and exposure to ionizing radiation. However, there is evidence from studies conducted at Los Alamos National Laboratory and other nuclear sites that suggests an increased likelihood of developing Hodgkin's disease for workers who have been exposed to ionizing radiation. The National Research Council's BEIR V committee did not address the issue of radiation-induced Hodgkin's disease. Hodgkin's disease is not a "specified" cancer under the EEOICPA. Historically, Hodgkin's disease incidence ranked among the lowest in the state for Los Alamos County but among the highest in the state for Rio Arriba County. Hodgkin's disease mortality ranked among the highest reported in the state for both counties. Incidence means new cases of cancer, while mortality means deaths due to cancer.

What Is Hodgkin's Disease?

Hodgkin's disease is one of a group of cancers called lymphomas. Lymphoma is a general term for cancers that develop in the lymphatic system. The lymphatic system is part of the body's immune system. It helps the body fight disease and infection. Hodgkin's disease, an uncommon lymphoma, accounts for less than 1 percent of all cases of cancer in this country. Other cancers of the lymphatic system are called non-Hodgkin's lymphomas. Because lymphatic tissue is present in many parts of the body, Hodgkin's disease can start almost anywhere. (National Cancer Institute)

Findings of Human Health Research Studies

Human health research studies compare the patterns of disease among groups of people with different amounts of exposure to a suspected risk factor. Below are results reported from such studies of Hodgkin's disease among people exposed to ionizing radiation.

The results of these studies found a mix of increased and possible increases in Hodgkin's disease among certain groups of exposed workers and no connection found among atomic bomb survivors. Statistically significant is a term used to mean that the connection between the health outcome and the exposure was strong enough that it was unlikely to be due to chance. An asterisk (*) was placed by statistically significant findings. Two of these studies found rates of Hodgkin's disease to increase with increasing personal exposure to radiation. The research included an incidence study, which looked at new cases of cancer. Incidence studies can track health more quickly and accurately than mortality studies of deaths due to cancer.

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* *Findings were statistically significant (strong evidence)*

\+ *Evidence of a dose-response relationship (strongest evidence)*

Studies of Los Alamos National Laboratory (LANL) Workers

Research conducted of LANL workers provides the most direct evidence about possible relationships between a health problem and workplace exposures at LANL.

- **Mortality Study up to 1991:** Increasing rates of deaths due to Hodgkin's disease with increasing doses of external radiation in a study of 15,727 men employed between 1943 and 1977, followed through 1991 (assuming either a 2- or 10-year latent period).[21 *+]

This study presents strong evidence that was unlikely to be due to chance (was statistically significant). Supporting the evidence of a relationship, a pattern, called a dose-response trend was seen where the proportion of workers who died Hodgkin's disease increased among those who received higher exposures. Further adding to the strength of this study is that it is based on direct personal measurements of exposure. A weakness of the study may be that mortality is not as good a measure of Hodgkin's disease as incidence.

Studies of Other Nuclear Workers in U.S.

The next most relevant evidence comes from studies done on workers in similar occupations facing the same types of exposures. Below are studies that observed Hodgkin's disease in possible connection with certain exposures among nuclear workers in the United States.

- **Fernald, Ohio:** Possible increase in deaths due to Hodgkin's disease in a study of 4,014 uranium processing workers employed between 1951 and 1989, followed through 1989.[1]

- **Hanford, Washington:** Increasing rates of death from Hodgkin's disease with increasing doses of external radiation in a study of 44,100 workers employed between 1944 and 1978, followed through 1986.[49 *+] However, the researchers who conducted the study did not think it was due to radiation exposure.

- **Portsmouth, Ohio:** Possible increase in deaths due to Hodgkin's disease in a study of 8,887 workers employed between 1954 and 1991.[18]

- **Oak Ridge:** Possible increase in deaths due to Hodgkin's disease in a study of 8,375 males employed for at least 30 days between 1943 and 1972, followed through 1977.[50]

- **Combined Hanford, Oak Ridge and Rocky Flats:** Increasing rates of death from Hodgkin's disease with increasing doses of external radiation in a study of 45,000 workers employed for at least six months.[48 *+]

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* *Findings were statistically significant (strong evidence)*

\+ *Evidence of a dose-response relationship (strongest evidence)*

Studies of Other Nuclear Workers World-Wide

Below are studies of nuclear workers outside of the United States that looked at Hodgkin's disease in connection with radiation exposures.

- **Sellafield, England**: Possible increased incidence of Hodgkin's disease in plutonium workers when compared to other radiation workers. [3]

Studies of Other Ionizing Radiation Exposures

Studies among other groups of people who were not nuclear workers can also be significant as evidence of possible increases in Hodgkin's Disease among those who have been exposed to ionizing radiation. Most other research has been conducted of people exposed to atomic bombs.

- **Atomic bomb Survivors**: In studies performed to date, there is no reported evidence of increased rates of Hodgkin's disease among A-bomb survivors.

Other Research and Policy Findings

The National Research Council advises the U.S. government on scientific matters. Their Committee on Biological Effects of Exposure to Ionizing Radiations (BEIR) V reviewed sensitivity of parts of the body to radiation. Their findings are based mostly on studies of cancer among atomic bomb survivors, as well as on some of the available information on the biology of the body, animal studies, and other evidence. The greatest risk is at high exposure levels.

The National Research Council's BEIR V committee did not address the issue of radiation-induced Hodgkin's disease. [9]

Is Hodgkin's Disease a "Specified" Cancer Under the Energy Employees Occupational Illness Compensation Program Act (EEOICPA)?

- **No.** Hodgkin's disease is not a "specified" cancer under the EEOIC Act consideration of Special Exposure Cohorts

Policy makers have identified certain types of cancer among energy employees at nuclear facilities, including those employed at Los Alamos National Laboratory, as being potentially related to occupational exposures under the EEOICPA.

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* *Findings were statistically significant (strong evidence)*

\+ *Evidence of a dose-response relationship (strongest evidence)*

What Are Other Risk Factors Associated with Hodgkin's Disease?

In considering the cancer risk from exposure to ionizing radiation at work, it is important to understand other risk factors. The following is a list of other possible risk factors for Hodgkin's Disease.

- Brothers and sisters of those with Hodgkin's disease have a higher-than-average chance of developing this disease.
- Epstein-Barr virus is an infectious agent that may be associated with an increased chance of getting Hodgkin's disease.

These factors may add to any risk due to workplace exposure to ionizing radiation. Hodgkin's disease occurs most often in people between 15 and 34 and in people over the age of 55. It is more common in men than in women. It is important to note that smoking is not related to Hodgkin's disease.

Rates of Hodgkin's Disease in Exposed Counties

Los Alamos County

There have been low rates of Hodgkin's disease incidence reported in Los Alamos County and high rates of Hodgkin's disease mortality.

- Ranked 25th in incidence of Hodgkin's disease and
- Ranked 6th highest in mortality among the 33 counties in New Mexico from 1970 to 1996.
- In recent years, about one case occurred every five years. [13, 14]

Rio Arriba County

There have been very high rates of Hodgkin's disease reported in Rio Arriba County for both cancer incidence and mortality.

- Ranked second highest in incidence of Hodgkin's disease and
- Ranked first highest in mortality among the 33 counties in New Mexico from 1970 to 1996. [33]

Taken together, these statistics for Los Alamos and Rio Arriba counties indicate that more needs to be done to detect and treat these cancers early.

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* *Findings were statistically significant (strong evidence)*

+ *Evidence of a dose-response relationship (strongest evidence)*

Kidney Cancer and
(and cancer of the renal pelvis)
Exposure to Ionizing Radiation

Summary: Strong evidence has been recorded of a possible connection between kidney cancer and exposure to ionizing radiation. This evidence is based upon studies conducted at Los Alamos National Laboratory, studies of nuclear workers at other sites, and others exposed to ionizing radiation. These findings are consistent with the National Research Council's determination that radiation can cause cancer of the kidneys and other urinary organs. Kidney cancer is designated as a "specified" cancer under the Energy Employees Occupational Illness Compensation Program Act. Historically, incidence of kidney cancer has been relatively low for Los Alamos County while mortality has been in the top third of New Mexico counties. Incidence and mortality due to kidney cancer in Rio Arriba County has been comparable to other NM counties. Incidence means new cases of cancer, while mortality means deaths due to cancer.

What is Kidney Cancer?

The kidneys are two organs located just above the waist, one on each side of the spine. Their main function is to filter blood and produce urine to rid the body of waste. The kidneys also help control blood pressure and regulate the formation of red blood cells. Several types of cancer can develop in the kidney. Renal cell (pelvic) cancer is the most common form of kidney cancer in adults. Wilms' tumor is the most common type of childhood kidney cancer. (National Cancer Institute)

Findings of Human Health Research Studies

Human health research studies compare the patterns of disease among groups of people with different amounts of exposure to a suspected risk factor. Below are results reported from such studies of kidney cancer among people exposed to ionizing radiation.

These studies found increases and possible increases in kidney cancer among certain groups of exposed individuals, in some cases followed over time. Statistically significant is a term used to mean that the connection between the health outcome and the exposure was strong enough that it was unlikely to be due to chance. An asterisk (*) was placed by statistically significant findings. The research included an incidence study, which look at new cases of cancer. Incidence studies can track health more quickly and accurately than mortality studies of deaths due to cancer. Adding to the strength of the findings is that increasing rates of kidney cancer were observed with higher doses in some studies.

Studies of Los Alamos National Laboratory (LANL) Workers

Research conducted of LANL workers provides the most direct evidence about possible relationships between a health problem and workplace exposures at LANL.

***** *Findings were statistically significant (strong evidence)*

+ *Evidence of a dose-response relationship (strongest evidence)*

- **Mortality Study up to 1991:** The overall rate of death due to kidney cancer was lower in white male LANL workers than in the general population, probably due to lower rates of smoking. But there were increasing rates of death due to kidney cancer with increasing doses of external radiation.*+ This was evident only when workers with body burdens of plutonium were dropped from the analysis. [21]

Studies of Other Nuclear Workers in the United States

The next most relevant evidence comes from studies of workers in similar occupations with the same types of exposures. Listed below are studies that looked at kidney cancer and workplace exposures among nuclear workers in other parts of the United States.

- **Hanford, Washington:** A possible increase in deaths due to kidney cancer was found in a study of 35,000 males who were employed between 1944 and 1972, and then followed through 1972.[51] Possible increases were also seen in a study of 44,100 workers who were followed through 1981 and again through 1986. [49, 52]

- **Mallinckrodt, St. Louis, Missouri:** Possible increasing rates of death due to kidney cancer were observed with increasing doses of external radiation in a study of 2,514 men who were employed between 1942 and 1966, and then followed through 1993. + The jobs with the greatest risk were pitchblende processing and processing of ore prior to removal of radium. [2]

- **Oak Ridge Y-12:** A possible increase in deaths due to kidney cancer was observed in a study of workers who were employed between 1947 and 1974, and then followed to 1990. [24]

Studies of Other Nuclear Workers World-Wide

Below are studies of nuclear workers outside of the United States that looked at kidney cancer in connection with radiation exposures.

- **Atomic Weapons Establishment of the U.K.:** A possible increase in kidney cancer deaths was observed in an analysis of 3,742 workers who were monitored for internal radionuclides while employed between 1951 and 1982, and then followed through 1982 (This study assumed a 10 year latent period).[53]

- **Sellafield, England:** A possible increase in deaths due to kidney cancer was seen in a study of plutonium workers, compared to non-radiation workers. [3]

- **Obninsk, Russia (I.P.P.E.):** Increased incidence of male kidney cancer was found in a study of 5,644 workers who were hired before 1981, and still employed between 1991 and 1997. [7 *]

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* *Findings were statistically significant (strong evidence)*

+ *Evidence of a dose-response relationship (strongest evidence)*

Studies of Other Ionizing Radiation Exposures

Studies among other groups of people who were not nuclear workers can also be significant as evidence of possible increases in kidney cancer among those who have been exposed to ionizing radiation. Most other research has been conducted of people exposed to atomic bombs.

- **Atomic Bomb Survivors:** Increasing deaths due to all urinary tract tumors combined were observed with increasing doses of radiation in a study of 76,000 A-bomb survivors.[54 *+]

Other Research and Policy Findings

Is the Kidney Sensitive to Radiation?

- **Yes.** According to the National Research Council's BEIR V committee, radiation can cause cancer of the kidneys and other urinary organs.[9]

The National Research Council advises the U.S. government on scientific matters. Their Committee on Biological Effects of Exposure to Ionizing Radiations (BEIR) V reviewed sensitivity of parts of the body to radiation. Their findings are based mostly on studies of cancer among atomic bomb survivors, as well as on some of the available information on the biology of the body, animal studies, and other evidence. The greatest risk is at high exposure levels.

Is Kidney Cancer a "Specified" Cancer Under the Energy Employees Occupational Illness Compensation Program Act (EEOICPA)?

- **Yes.** Kidney cancer is a "specified" cancer under the EEOIC Act consideration of Special Exposure Cohorts

Policy makers have identified certain types of cancer among energy employees at nuclear facilities, including those employed at Los Alamos National Laboratory, as being potentially related to occupational exposures under the EEOICPA.

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* *Findings were statistically significant (strong evidence)*

\+ *Evidence of a dose-response relationship (strongest evidence)*

What Are Other Risk Factors Associated with Kidney Cancer?

In considering the cancer risk from exposure to ionizing radiation at work, it is important to understand other risk factors. Below is a list of other possible risk factors for kidney cancer.

- **Tobacco use**: Research shows that smokers are twice as likely to develop kidney cancer as nonsmokers. In addition, the longer a person smokes, the higher the risk. However, the risk of kidney cancer decreases for those who quit smoking.
- **Obesity**: Obesity may increase the risk of developing kidney cancer.
- **Occupational exposure**: Studies suggest that coke oven workers in steel plants have above-average rates of kidney cancer. There is some evidence that working with asbestos, which has been linked to cancers of the lung and mesothelium (a membrane that surrounds internal organs of the body), also increases the risk of some kidney cancers.
- **Radiation therapy**: Women who have been treated with radiation therapy for disorders of the uterus may have a slightly increased risk of developing kidney cancer. Also, people who were exposed to certain radioactive substances sometimes used with diagnostic x-rays in the 1920s, have an increased rate of kidney cancer.
- **The drug Phenacetin**: Some people have developed kidney cancer after heavy, long-term use of this drug. This painkilling drug is no longer sold in the United States.
- **Dialysis treatment**: Patients on long-term use of dialysis to treat chronic kidney failure have an increased risk of developing renal cysts and renal cancer.
- **Von Hippel-Lindau (VHL) disease**: Researchers have found that people who have this inherited disorder are at greater risk of developing renal cell carcinoma, as well as tumors in other organs. (National Cancer Institute)

These factors may add to any risk due to workplace exposure to ionizing radiation.

Rates of Kidney Cancer in Exposed Counties

Los Alamos County

There have been low rates of kidney cancer incidence reported in Los Alamos County and high rates of mortality. This is an indication that more needs to be done to detect and treat these cancers early. In recent years, about one case occurred annually. [13, 14] Los Alamos County:

- Ranked 26th in incidence of kidney and renal pelvis cancer and
- Ranked 10th highest in mortality among the 33 counties in New Mexico from 1970 to 1996.[13, 14]

Rio Arriba County

There have been moderate rates of kidney cancer reported in Rio Arriba County for both cancer incidence and mortality. Rio Arriba County:

- Ranked 17th highest in incidence and
- 13th highest in mortality from kidney and renal pelvis cancer among the 33 counties in New Mexico from 1970 to 1996. [33]

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* *Findings were statistically significant (strong evidence)*

\+ *Evidence of a dose-response relationship (strongest evidence)*

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Leukemia and Exposure to Ionizing Radiation

Summary: Strong evidence has been recorded of a possible connection between forms of leukemia and exposure to ionizing radiation. This evidence is based upon studies conducted at Los Alamos National Laboratory, studies of nuclear workers at other sites, and others exposed to ionizing radiation. These findings are consistent with the National Research Council's determination that radiation can cause acute leukemia and chronic myeloid leukemia. Leukemia (except chronic lymphocytic leukemia) is designated as a "specified" cancer under the Energy Employees Occupational Illness Compensation Program Act. Historically, incidence of leukemia has been very high for Los Alamos County while mortality has been in the lowest third of New Mexico counties. Incidence and mortality due to leukemia in Rio Arriba County has been roughly comparable to other NM counties. Incidence means new cases of cancer, while mortality means deaths due to cancer.

What is Leukemia?

When leukemia develops, the body produces large numbers of abnormal blood cells. In most types of leukemia, the abnormal cells are white blood cells. There are several types of leukemia. They are grouped in two ways. One way is by how quickly the disease develops and gets worse. The other way is by the type of blood cell that is affected. Leukemia is either acute or chronic. In acute leukemia, the abnormal blood cells remain very immature and cannot carry out their normal functions. In chronic leukemia, some immature cells are present, but in general, these cells are more mature and can carry out some of their normal functions. Leukemia can arise in either of the two main types of white blood cells. When leukemia affects lymphoid cells, it is called lymphocytic leukemia. When myeloid cells are affected, the disease is called myeloid or myelogenous leukemia.

These are the most common types of leukemia:

- **Acute lymphocytic leukemia** (ALL) is the most common type of leukemia in young children. This disease also affects adults, especially those age 65 and older.
- **Acute myeloid leukemia** (AML) occurs in both adults and children. This type of leukemia is sometimes called acute nonlymphocytic leukemia (ANLL).
- **Chronic lymphocytic leukemia** (CLL) most often affects adults over the age of 55. It sometimes occurs in younger adults, but it almost never affects children.
- **Chronic myeloid leukemia** (CML) occurs mainly in adults. A very small number of children also develop this disease.

There are also other less common type of chronic leukemia. (National Cancer Institute)

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* *Findings were statistically significant (strong evidence)*

\+ *Evidence of a dose-response relationship (strongest evidence)*

Findings of Human Health Research Studies

Human health research studies compare the patterns of disease among groups of people with different amounts of exposure to a suspected risk factor. Below are results reported from such studies of leukemia among people exposed to ionizing radiation.

These studies found increases and possible increases in leukemia among certain groups of exposed individuals, in some cases followed over time. Statistically significant is a term used to mean that the connection between the health outcome and the exposure was strong enough that it was unlikely to be due to chance. An asterisk (*) was placed by statistically significant findings. The research included incidence studies, which look at new cases of cancer. Incidence studies can track health more quickly and accurately than mortality studies of deaths due to cancer. Adding to the strength of the findings is that increasing rates of leukemia were observed with higher doses in some studies.

Studies of Los Alamos National Laboratory (LANL) Workers

Research conducted of LANL workers provides the most direct evidence about possible relationships between a health problem and workplace exposures at LANL.

- **Mortality Study up to 1991:** Increasing rates of death due to lymphocytic leukemia were found with increasing doses of external radiation, assuming a latent period of two years. *+ However, all four of the cases were chronic lymphocytic leukemia (CLL) which is not thought to be caused by ionizing radiation. [21]

- **Survivors of Accidents:** Two of the security guards who were present at early criticality accidents in 1945 and 1946 developed fatal acute lymphocytic leukemia 20 to 30 years later.[55]

Studies of Other Nuclear Workers in the United States

The next most relevant evidence comes from studies of workers in similar occupations with the same types of exposures. Listed below are studies that looked at leukemia and workplace exposures among nuclear workers in other parts of the United States.

- **Fernald, Ohio:** Possible increase in deaths due to leukemia (and all blood and lymph cancers) were observed in a study of 4,014 uranium processing workers employed between 1951 and 1989, followed through 1989. [1]

- **Hanford, Washington:** A possible increase in deaths due to all blood and lymph cancers were observed in a study of 44,100 workers who were employed between 1944 and 1978. [52] A possible increase in deaths due to myeloid leukemia was observed in 35,000 men employed at Hanford between 1944 and 1972. [51]

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* *Findings were statistically significant (strong evidence)*

\+ *Evidence of a dose-response relationship (strongest evidence)*

- **Mallinckrodt, St. Louis, Missouri:** A possible increase in leukemia deaths was observed in a study of 2,514 males who were employed between 1942 and 1966, and then followed through 1993. [2]

- **Mound, Ohio:** Increase in leukemia deaths (and blood and lymph cancers) was found in a study of 3,229 males who were monitored for external radiation between 1947 and 1949, assuming a 10-year latent period (time after exposure for the disease to develop). [56 *+]

- **Oak Ridge:** A possible increase in leukemia deaths was observed in a study of 8,375 males employed at least 30 days between 1943 and 1972, and then followed through 1977. Possible increasing rates of death were seen with increasing doses of external radiation, assuming a latent period of 10 years. [50 +] For each rem (a measure of radiation dose) of exposure to external radiation, there was a 6-9% increase in the risk of leukemia. When the follow up period was extended through 1984, there was an increase in leukemia deaths in workers monitored for internal contamination. [57 *]

- **Pantex:** A possible increase in deaths due to all blood and lymph cancers was observed in a study of 3,564 males who were employed between 1951 and 1978, and then followed through 1978. [58]

- **Pooled Analysis of Nuclear Worker Studies:** For all blood and lymph cancers combined, a 20% increased risk at 1-5 rem (a measure of radiation dose) of exposure and a doubling of risk at more than 5 rem of external radiation was found across studies. [59]

- **Rocketdyne/Atomics International:** Increasing rates of death due to all blood and lymph cancers with increasing doses of external and internal radiation were found in a study of workers who were employed between 1950 and 1993, and then followed through 1995. [*+] The largest effect was seen with a latent period of 15 to 20 years. The researchers who performed the study were "somewhat surprised" because the levels of internal radiation were low. [25] A possible increase in leukemia deaths was observed in workers monitored for external and internal radiation. [27]

- **Rocky Flats:** An increase in deaths due to all blood and lymph cancers was found in a study of 5,412 males who were employed for at least two years between 1952 and 1979 who had plutonium body burdens of at least 2 nanocuries (a measure of radiation exposure). The analysis assumed a latency period of five years following exposure for the disease to develop. [*] Possible increasing rates of death due to blood and lymph cancers were observed with increasing body burdens of plutonium or external radiation dose, assuming a latent period of two years. [+] The authors considered this "suggestive" of dose-response trends. [28]

- **Savannah River Site**: An increase in deaths to leukemia (and all blood and lymph cancers) was found in hourly workers hired before 1955, and employed for 5 to 15 years. [*]

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* *Findings were statistically significant (strong evidence)*

+ *Evidence of a dose-response relationship (strongest evidence)*

All blood and lymph cancers were also increased in white males employed before 1955. * Possible increases were observed in other groups. [44, 60]

- **West Chicago (Kerr-McGee) Thorium Plant:** Possible increase in deaths due to leukemia and aleukemia were observed in a study of 1,352 men who were employed between 1940 and 1954, and then followed through 1975. [45]

- **Women at 10 DOE Sites**: An increase in deaths due to leukemia (excluding CLL) was found in a study of 65,984 women employed between start-up and 1980 at 10 DOE facilities. [37 *]

Studies of Other Nuclear Workers World-Wide

Below are studies of nuclear workers outside of the United States that looked at leukemia in connection with radiation exposures.

- **Canadian Radiation Workers:** A 5.9% increase in the incidence of leukemia was found per 100 rem (a measure of radiation dose) in a study of 191,300 workers employed between 1951 and 1988. [47 *+]

- **Nuclear Workers in 3 Countries:** An increase in rates of death due to all leukemias (except CLL) was found in a study of 95,673 workers employed for at least six months and monitored for radiation. [40 *+]

- **3 Nuclear Workforces in the U.K.:** Increasing rates of death due to all blood and lymph cancers was found with increasing time since first monitored for plutonium in a study of 12,498 workers.[*+] Increasing rates of leukemia deaths was found with increasing whole body dose in a study of 75,211 workers who were employed between 1946 and 1986, and then followed through 1988. An increase in leukemia deaths (except CLL) was found in workers monitored for any radionuclide (This study assumed a latency period of 0 or 10 years). [29 *+]

- **Registry of Nuclear Workers in the U.K.:** Increasing rates of leukemia deaths (except CLL) were found with increasing doses of external radiation in a study of 95,217 workers, who were followed through 1988. [5]

- **Sellafield, England:** Increasing rates of leukemia deaths were found with increasing doses of external radiation in a study of 10,382 workers who were employed between 1947 and 1975, and then followed through 1992, assuming a latent period (time following exposure for disease to develop) of 2 years.[*+] Increasing incidence of leukemia was found with increasing combined dose of plutonium and external radiation in a study of 5,203 workers. [3 *+]

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* *Findings were statistically significant (strong evidence)*

+ *Evidence of a dose-response relationship (strongest evidence)*

Studies of Other Ionizing Radiation Exposures

Studies among other groups of people who were not nuclear workers can also be significant as evidence of possible increases in leukemia among those who have been exposed to ionizing radiation. Most other research has been conducted of people exposed to atomic bombs.

- **Atomic Bomb Survivors:** Increasing leukemia deaths were observed with increasing doses of radiation in a study of 86,572 A-bomb survivors.*+ Most of the deaths occurred within the first 15 years following exposure.[8] Children under age 15 are more susceptible.[38]

Is Leukemia Radiation-Sensitive?

- **Yes.** The National Research Council's BEIR V committee performed a detailed analysis of the risks of leukemia from radiation exposures. Among their conclusions are that radiation causes acute leukemia and chronic myeloid leukemia.[9]

The National Research Council advises the U.S. government on scientific matters. Their Committee on Biological Effects of Exposure to Ionizing Radiations (BEIR) V reviewed sensitivity of parts of the body to radiation. Their findings are based mostly on studies of cancer among atomic bomb survivors, as well as on some of the available information on the biology of the body, animal studies, and other evidence. The greatest risk is at high exposure levels.

Is Leukemia a "Specified" Cancer Under the Energy Employees Occupational Illness Compensation Program Act (EEOICPA)?

- **Yes.** Leukemia is a "specified" cancer under the EEOIC Act consideration of Special Exposure Cohorts, except for CLL.

Policy makers have identified certain types of cancer among energy employees at nuclear facilities, including those employed at Los Alamos National Laboratory, as being potentially related to occupational exposures under the EEOICPA.

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* *Findings were statistically significant (strong evidence)*

\+ *Evidence of a dose-response relationship (strongest evidence)*

What Are Other Risk Factors Associated with Leukemia?

In considering the cancer risk from exposure to ionizing radiation at work, it is important to understand other risk factors. Below is a list of other possible risk factors for leukemia.

- **Electromagnetic fields.** Some research suggests that exposure to electromagnetic fields is a possible risk factor for leukemia. (Electromagnetic fields are a type of low-energy radiation that comes from power lines and electric appliances.)
- **Genetics.** Certain genetic conditions can increase the risk for leukemia. One such condition is Down's syndrome; children born with this syndrome are more likely to get leukemia than other children.
- **Certain Chemical exposure.** Workers exposed to certain chemicals over a long period of time are at higher risk for leukemia. Benzene is one of these chemicals.
- **Certain cancer drugs.** Some of the drugs used to treat other types of cancer may increase a person's risk of getting leukemia. However, this risk is very small when compared with the benefits of chemotherapy.
- **Viruses.** Scientists have identified a virus that seems to increase the risk for one very uncommon type of leukemia. However, this virus has no known connection with common forms of leukemia. (National Cancer Institute)
- A "weak relationship" has been observed between myeloid leukemia and smoking in men. But not for women or for other types of leukemia. [41]

These factors may add to any risk due to workplace exposure to ionizing radiation. Leukemia occurs in males more often than in females and in white people more often than in black people.

Rates of Leukemia in Exposed Counties

Los Alamos County

There have been very high rates of leukemia incidence reported in Los Alamos County; yet relatively low rates of cancer mortality. In the 1950's and 1960's, all blood and lymph cancers may have been increased in males in the county, due to occupational exposures during the early years of the nuclear complex. [61] In recent years, about two to three case have occurred annually. [13, 14] Los Alamos County ranked:

- Ranked second highest in incidence of leukemia and
- 21st in mortality among the 33 counties in New Mexico from 1970 to 1996. [33]

Rio Arriba County

There have been moderate rates of leukemia reported in Rio Arriba County for both cancer incidence and mortality. Rio Arriba County:

- Ranked 16th in incidence and
- 12th in mortality among the 33 counties in New Mexico from 1970 to 1996. [33]

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* *Findings were statistically significant (strong evidence)*

\+ *Evidence of a dose-response relationship (strongest evidence)*

Liver Cancer and
(including intra-hepatic bile duct)
Exposure to Ionizing Radiation

Summary: Moderately strong evidence has been recorded of a possible connection between liver cancer deaths and exposure to ionizing radiation. This evidence is based upon studies conducted at Los Alamos National Laboratory, studies of nuclear workers at other sites, and others exposed to ionizing radiation. These findings are consistent with the National Research Council's determination that the liver is sensitive to ionizing radiation. Liver cancer is designated as a "specified" cancer under the Energy Employees Occupational Illness Compensation Program Act. Historically, incidence of liver cancer has been among the lowest in the state for Los Alamos County. Incidence of liver cancer in Rio Arriba County has been higher than average New Mexico county rates. Mortality in Rio Arriba County has been among the highest reported in the state. Incidence means new cases of cancer, while mortality means deaths due to cancer.

What is Liver Cancer?

The liver is the largest organ in the body. The liver removes harmful material from the blood and has other important functions that keep a person healthy. It makes enzymes and bile (a fluid) that help digest food. The bile duct is a tube that connects the liver and the gallbladder to the small intestine. The part of the bile duct that is inside the liver is called the intrahepatic bile duct. Cancer of this part of the bile duct is often reported together with liver cancer. (National Cancer Institute)

Cancer that begins in the liver is called *primary* liver cancer. In the United States, this type of cancer is uncommon. However, it is common for cancer that began in other parts of the body to spread to the liver (metastasize). When this happens, the disease is not liver cancer. Instead it is a secondary cancer that would be named for the organ or the tissue in which it began (such as breast cancer if the cancer first began in the breast).

Findings of Human Health Research Studies

Human health research studies compare the patterns of disease among groups of people with different amounts of exposure to a suspected risk factor. Below are results reported from such studies of liver cancer among people exposed to ionizing radiation.

All of these studies found increases and possible increases in liver cancer among certain groups of exposed workers. Statistically significant is a term used to mean that the connection between the health outcome and the exposure was strong enough that it was unlikely to be due to chance. An asterisk (*) was placed by statistically significant findings. Several of these studies directly measured personal exposure to radiation.

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* *Findings were statistically significant (strong evidence)*

\+ *Evidence of a dose-response relationship (strongest evidence)*

Studies of Los Alamos National Laboratory (LANL) Workers

Research conducted of LANL workers provides the most direct evidence about possible relationships between a health problem and workplace exposures at LANL.

- **Zia Study (unpublished):** A possible increase in deaths due to cancer of the liver and the gall bladder was observed in 4,942 men who were employed by Zia between 1946 and 1978, and then followed through 1984.[15]

Studies of Other Nuclear Workers in the United States

The next most relevant evidence comes from studies of workers in similar occupations with the same types of exposures. Listed below are studies that looked at liver cancer and workplace exposures among nuclear workers in other parts of the United States.

- **Fernald:** A possible increase in liver cancer deaths was observed in uranium processing workers employed from 1951 to 1989, followed to 1990.[1]

- **Hanford:** A possible dose-response trend was observed between external radiation exposure and the risk of death due to liver cancer in workers employed from 1944-1978 and followed to 1987.[49 +]

Studies of Other Nuclear Workers World-Wide

Below are studies of nuclear workers outside of the United States that looked at liver cancer in connection with radiation exposures.

- **Canadian Radiation Workers:** There was a possible increase in the rate of liver cancer in female workers who were monitored for external radiation.[47]

- **Mayak, Russia:** An increased rate of liver cancer was seen in plutonium oxide workers. This was most strongly observed among those with large body burdens (average = 230 nanocuries ? a measure of radiation exposure), who also had lifetime exposures to external radiation over 100 rem (a measure of radiation dose).[62]

Studies of Other Ionizing Radiation Exposures

Studies among other groups of people who were not nuclear workers can also be significant as evidence of possible increases in liver cancer among those who have been exposed to ionizing radiation. Most other research has been conducted of people exposed to atomic bombs.

- **Atomic Bomb Survivors:** Increasing liver cancer deaths were observed with increasing doses of radiation in a study of 86,572 A-bomb survivors.[*+] Possible increasing deaths were observed due to cancer of the gall bladder with increasing doses of radiation.[8 +]

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* *Findings were statistically significant (strong evidence)*

+ *Evidence of a dose-response relationship (strongest evidence)*

Other Research and Policy Findings

Is the Liver Sensitive to Radiation?

- **Yes.** According to the National Research Council's BEIR V Committee, there is "conclusive" evidence that chronic exposure to alpha emitters can cause liver cancer in humans. Beta emitters have caused liver cancer in animals. (Alpha and beta emitters are different categories of radioactive substances).[12]

The National Research Council advises the U.S. government on scientific matters. Their Committee on Biological Effects of Exposure to Ionizing Radiations (BEIR) V reviewed sensitivity of parts of the body to radiation. Their findings are based mostly on studies of cancer among atomic bomb survivors, as well as on some of the available information on the biology of the body, animal studies, and other evidence. The greatest risk is at high exposure levels.

Is Liver Cancer a "Specified" Cancer Under the Energy Employees Occupational Illness Compensation Program Act (EEOICPA)?

- **Yes.** Liver cancer is a "specified" cancer under the EEOICPA consideration of Special Exposure Cohorts (except if cirrhosis or hepatitis B is indicated). Cancer of the bile ducts is also a specified cancer as well.

Policy makers have identified certain types of cancer among energy employees at nuclear facilities, including those employed at Los Alamos National Laboratory, as being potentially related to occupational exposures under the EEOICPA.

What Are Other Risk Factors for Liver Cancer?

In considering the risks of occupational exposure to ionizing radiation leading to liver cancer, it is important to understand other risk factors. Below is a list of other possible risk factors for liver cancer.

- Liver diseases including hepatitis B, cirrhosis, and hepatitis C.
- Hazardous chemicals, including vinyl chloride and thorium oxide.
- Aflatoxins, a hazardous substance made from mold that is sometimes a contaminant of poorly stored grain and nuts.

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* *Findings were statistically significant (strong evidence)*

\+ *Evidence of a dose-response relationship (strongest evidence)*

These factors may add to any risk due to workplace exposure to ionizing radiation. Hispanics are known to have a higher rate of cancer of the gallbladder; however the reasons are not yet known. Note that the risk of liver cancer is not higher in Hispanics.[1]

What Makes Liver Cancer and Radiation Exposure Difficult to Study?

There are difficulties in all human studies because one cannot precisely determine all exposures and track all individual outcomes. In cancer this is especially the case as the cancer may take many years to develop to the point of diagnosis and possible death (disease latency). Liver cancer research is made particularly difficult due to errors in diagnosing liver cancer. Primary cancers of many other sites in the body can spread (metastasize) to the liver. This may lead to some other cancers to be improperly diagnosed as liver cancer. It is important to make sure that primary liver cancer is the accurate diagnoses.

Rates of Liver Cancer In Exposed Counties

Los Alamos County

There have been very low rates of liver cancer reported in Los Alamos County for liver cancer incidence.

- Los Alamos County had the lowest rate of liver cancer incidence from 1970 to 1996 of the 33 counties in New Mexico.[33]
- In recent years, there have been fewer than one case diagnosed each year in Los Alamos County.[14]

Rio Arriba County

Rates of liver cancer incidence reported in Rio Arriba County have been somewhat higher than average county rates and quite high for liver cancer mortality. These higher rates may be due to chance differences in area rates.

- Rio Arriba County ranked 11th highest in liver cancer incidence from 1970 to 1996 and
- 4th highest in liver cancer mortality from 1970 to 1996 of the 33 counties in New Mexico.[33]

Rio Arriba County's ranking for liver cancer mortality is worse than its ranking for liver cancer incidence. This means that the rates of diagnosis and treatment may be low relative to the number who actually have the disease. More work needs to be done to detect and treat liver cancer early.

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[1] New Mexico Department of Health. Steering Committee Meeting Minutes, Third Meeting. Los Alamos Cancer Rate Study: Phase I. Santa Fe, NM, 1992;21.

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* *Findings were statistically significant (strong evidence)*

+ *Evidence of a dose-response relationship (strongest evidence)*

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Lung Cancer and Exposure to Ionizing Radiation

Summary: Studies conducted at the Los Alamos National Laboratory and other nuclear facilities suggest an increased likelihood of developing lung cancer for workers who have been exposed to ionizing radiation. These findings are consistent with the determination of the National Research Council's BEIR V committee that lung tissue if sensitive to ionizing radiation. Lung cancer is a "specified" cancer under the Energy Employees Occupational Illness Compensation Program Act. Historically, lung cancer incidence and mortality ranked among the lowest in the state for both Los Alamos and Rio Arriba Counties. Incidence means new cases of cancer, while mortality means deaths due to cancer.

What is Lung Cancer?

The lungs are part of the respiratory system. Cancers that begin in the lungs are divided into two major types, non-small cell lung cancer and small cell lung cancer, depending on how the cells look under a microscope. Each type of lung cancer grows and spreads in different ways and is treated differently. Within these types, lung cancer may be named for the type of cells in which the cancer develops. (National Cancer Institute)

Findings of Human Health Research Studies

Human health research studies compare the patterns of disease among groups of people with different amounts of exposure to a suspected risk factor. Below are results reported from such studies of lung cancer among people exposed to ionizing radiation.

All of these studies found increased risk and possible increases in lung cancer risk among exposed groups. Statistically significant is a term used to mean that the connection between the health outcome and the exposure was strong enough that it was unlikely to be due to chance. Several of these studies directly measured personal exposure to radiation. The research included incidence studies, which look at new cases of cancer. These can track health more quickly and accurately than mortality studies of deaths due to cancer. Adding to the strength of the findings is that increasing rates of lung cancer were observed with higher doses in some studies.

Studies of Los Alamos National Laboratory (LANL) Workers

Research conducted of LANL workers provides the most direct evidence about possible relationships between a health problem and workplace exposures at LANL.

- **Mortality Study up to 1991:** Possible increase in lung cancer deaths were observed in a study of plutonium workers with body burdens of at least 2 nanocuries (a measure of radiation exposure) who were first employed at LANL between 1943 and 1977. [21]

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* *Findings were statistically significant (strong evidence)*

\+ *Evidence of a dose-response relationship (strongest evidence)*

- **Manhattan Project Workers:** Three cases of lung cancer have occurred in the 26 Manhattan project workers enrolled in a long-term study. All three had histories of cigarette smoking. [17]

- **Zia Study (unpublished):** Possible increase in lung cancer deaths were found among Hispanic males who were employed between 1946 and 1978 and exposed to external radiation and/or plutonium. [15]

Studies of Other Nuclear Workers in the United States

The next most relevant evidence comes from studies of workers in similar occupations with the same types of exposures. Listed below are studies that looked at lung cancer and workplace exposures among nuclear workers in other parts of the United States.

- **Atomic Weapons Establishment of the U.K.:** A possible increase in lung cancer was found in an analysis of the 3,044 workers who were monitored for plutonium who were employed between 1951 and 1982, and then followed through 1982, when compared to other (non-plutonium) radiation workers. [53]

- **Fernald, Ohio:** A possible increase in lung cancer deaths was seen in a study of 4,014 uranium processing workers who were employed between 1951 and 1989, and then followed through 1989. A strong effect was observed in cases of internal doses of at least 20 rem (a measure of radiation dose) in combination with an external radiation dose of at least 5 rem. [1]

- **Hanford, Washington:** A possible increase in lung cancer deaths (and all respiratory cancers combined) was found in a study of women who were employed between 1944 and 1978, and then followed through 1981. [52] A possible increase in lung cancer deaths was also found in 24,900 males who were employed between 1944 and 1972, and followed through 1972. [51]

- **Mayak, Russia:** Risk of lung cancer correlated with high body burdens of plutonium in a case-control study of 162 cases of lung cancer that were diagnosed in Mayak workers between 1962 and 1991. [63] Adenocarcinoma was the kind of lung cancer most frequently associated with plutonium.

- **Mound, Ohio:** A possible increase in lung cancer deaths was found in a study of white males ever employed at Mound or monitored for polonium-210, between 1944 and 1972. The highest risk was among workers hired during World War II. Also, a possible increase in lung cancer deaths was found in 3,229 males monitored for external radiation between 1943 and 1979. [43]

- **Oak Ridge:** Increasing rates of lung cancer deaths (and all respiratory system cancers combined) was found with increasing doses of external radiation in a study of 28,008 white males who were employed at least 30 days between 1943 and 1947, and then followed

through 1979.[64 *+] A "notable" increase in the rate of lung cancer was found in a study of 106,000 workers employed between 1943 and 1985.[65]

- **Oak Ridge K-25 Gaseous Diffusion Plant:** Increase in deaths due to lung cancer (and all respiratory system cancers combined) were observed in a study of males employed from 1945 to 1984.[18 *]

- **Oak Ridge, Tennessee Eastman:** Increase in lung cancer deaths was found in 18,869 males employed between 1943 and 1947 in a uranium conversion and enrichment plant.[66 *]

- **Oak Ridge X-10:** About a 5% increased risk of death due to lung cancer was found for each 1 rem (a measure of radiation dose) of external radiation dose in a study of 8,318 males who were employed between 1943 and 1972, and then followed through 1984.[57 *] For doses received after age 45, the increased risk was sometimes greater than 5% per 1 rem.[67]

- **Oak Ridge Y-12:** Increase in deaths due to lung cancer were seen in a study of 6,781 males who were employed at least 30 days between 1947 and 1974.[*] Risk was greatest for workers who had both gamma and alpha radiation doses of at least 5 rem (a measure of radiation dose) each.[23] When followed through 1990, the rates of death due to lung cancer were highest for those with 5 to 19 years of exposure, and 10 to 29 years since first exposure.[24]

- **Oak Ridge Welders:** A possible increase in deaths due to lung cancer (and all respiratory cancers combined) were found in a study of 1,059 white male welders who were hired between 1943 and 1973, and then followed through 1973. The biggest risk may have been for those who worked at least a year welding at K-25 (a lot of nickel alloy).[68]

- **Rocketdyne/Atomics International, Santa Susana, California**: A possible increase in rates of death due to lung cancer was observed with increasing doses of external radiation in a study of 4,563 workers who were monitored between 1950 and 1993, and then followed through 1994.[27 +]

- **Rocky Flats, Colorado:** A small increase in lung cancer was seen in a study of 5,413 white males with a plutonium body burden of at least 2 nanocuries (a measure of radiation exposure) employed for at least two years between 1952 and 1979, when a 10-year latent period (time following exposure for the disease to develop) is assumed.[28]

- **Savannah River Site:** A possible increase in risk of lung cancer deaths was found in hourly and salaried white males, especially those who worked at least 90 days before 1974 or were first hired before 1955.[44]

- **Uranium Operations at Several Plants (Y-12, Mallinckrodt & Fernald):** A possible increase in lung cancer deaths was found in workers with internal doses of at least 25 rem (a

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* *Findings were statistically significant (strong evidence)*

\+ *Evidence of a dose-response relationship (strongest evidence)*

measure of radiation dose). Risk of lung cancer from external radiation may be higher for workers hired at age 45+.[69]

- **West Chicago (Kerr-McGee) Thorium Plant:** A possible increase in lung cancer deaths was observed in 1,352 men who were first employed between 1940 and 1954, and then followed through 1976. A similar effect was found among 1,446 men who were first employed between 1955 and 1969.[45]

Studies of Other Nuclear Workers World-Wide

Below are studies of nuclear workers outside of the United States that looked at lung cancer in connection with radiation exposures.

- **Sellafield, England:** A possible increase in lung cancer incidence (tumors) was found in a study of 5,203 plutonium workers who were employed between 1947 and 1976, and then followed through 1992, when compared to other radiation workers.[3]

- **3 Nuclear Workforces in the U.K.:** An increase in lung cancer deaths was found in a study of 10,185 workers who were "ever monitored" for radionuclides like Zn-65, Fe-59, Co-60 and Cr-51.* A possible increase in rate of death due to lung cancer was seen with increasing time since first being monitored for plutonium (in 12,498 plutonium workers)[29].+

- **Atomic Energy Establishment of U.K:** Increasing rates of lung cancer deaths were found with increasing doses of external radiation in females who were employed between 1946 and 1979, and then followed through 1986.[6 *+]

- **Canadian Radiation Workers:** An increase in lung cancer incidence was found in a study of 191,300+ male and female workers who were first exposed to radiation between 1951 and 1988.[47 *]

- **Mayak, Russia:** An increase in lung cancer deaths was seen in a study of workers with plutonium body burdens who were first employed between 1948 and 1958, and then followed through 1993.* The biggest risks were in workers 50+ years old. Increasing rates of lung cancer deaths were found with increasing alpha dose to the lung.[70 +]

Studies of Other Ionizing Radiation Exposures

Studies among other groups of people who were not nuclear workers can also be significant as evidence of possible increases in lung cancer among those who have been exposed to ionizing radiation. Most other research has been conducted of people exposed to atomic bombs.

- **Atomic bomb Survivors:** In studies performed to date, there is reported evidence of increased rates of lung cancer deaths (and all respiratory cancers combined)[54] with increasing doses of radiation in a study of 86,572 survivors.[8 *+]

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* *Findings were statistically significant (strong evidence)*

\+ *Evidence of a dose-response relationship (strongest evidence)*

Other Research and Policy Findings

- **Yes.** The National Research Council's BEIR V committee concluded that lung tissue is sensitive to ionizing radiation. The committee conducted an intensive analysis of radiation-induced lung cancer. Among the issues they addressed are the bases for apparent gender differences; interaction with smoking; and dose rate effects in animal studies. [9]

The National Research Council advises the U.S. government on scientific matters. Their Committee on Biological Effects of Exposure to Ionizing Radiations (BEIR) V reviewed sensitivity of parts of the body to radiation. Their findings are based mostly on studies of cancer among atomic bomb survivors, as well as on some of the available information on the biology of the body, animal studies, and other evidence. The greatest risk is at high exposure levels.

Is Lung cancer a "Specified" Cancer Under the Energy Employees Occupational Illness Compensation Program Act (EEOICPA)?

- **Yes.** Lung Cancer is a "specified" cancer under the EEOICPA consideration of Special Exposure Cohorts

Policy makers have identified certain types of cancer among energy employees at nuclear facilities, including those employed at Los Alamos National Laboratory, as being potentially related to occupational exposures under the EEOICPA.

What Are Other Risk Factors for Lung Cancer?

In considering the risks of occupational exposure to ionizing radiation leading to lung cancer, it is important to understand other risk factors. The following is a list of other possible risk factors for lung cancer.

- **Smoking.** Smoking is an important risk factor for lung cancer. [12]
- **Air pollutants.** Exposure to radon, asbestos, and second hand tobacco smoke may lead to lung cancer. Researchers have also found a link between lung cancer and exposure to certain other air pollutants, such as by-products of the combustion of diesel and other fossil fuels.
- **Certain lung diseases.** Lung diseases such as tuberculosis (TB), increase a person's chance of developing lung cancer.
- A person who has had lung cancer once is more likely to develop a second lung cancer compared with a person who has never had lung cancer. Quitting smoking after lung cancer is diagnosed may prevent the development of a second lung cancer.

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* *Findings were statistically significant (strong evidence)*

+ *Evidence of a dose-response relationship (strongest evidence)*

These factors may add to any risk due to workplace exposure to ionizing radiation.

Rates of Lung Cancer in Exposed Counties

Los Alamos County

There have been low rates of lung cancer reported in Los Alamos County for both cancer incidence and mortality. Los Alamos County:

- Ranked 28th in lung cancer incidence and
- Ranked 30th in mortality among the 33 counties in New Mexico from 1970 to 1996. [33]
- In recent years there have been about five to six cases annually in the county. [13, 14]

Rio Arriba County

There have been low rates of lung cancer reported in Rio Arriba County for both cancer incidence and mortality. Rio Arriba County:

- Ranked 30th in lung cancer incidence and
- 29th in mortality among the 33 counties in New Mexico from 1970 to 1996. [33]

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* *Findings were statistically significant (strong evidence)*

+ *Evidence of a dose-response relationship (strongest evidence)*

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Multiple Myeloma (MM) and Exposure to Ionizing Radiation

Summary: Studies conducted at the Los Alamos National Laboratory and other nuclear facilities, as well as those exposed to radiation from the atomic bomb suggest an increased likelihood of developing multiple myeloma for those who have been exposed to ionizing radiation. These findings are consistent with the determination of the National Research Council's BEIR V committee that multiple myeloma has been associated with exposure to ionizing radiation. Multiple myeloma is a "specified" cancer under the EEOICPA. Historically, multiple myeloma incidence and mortality in Los Alamos County fall in the middle of New Mexico counties while Rio Arriba County is among counties with the highest rates in the state. Incidence means new cases of cancer, while mortality means deaths due to cancer.

What is Multiple Myeloma?

Multiple myeloma is a type of cancer that affects certain white blood cells called plasma cells. Plasma cells and other white blood cells are part of the immune system, which helps protect the body from infection and disease. When cancer involves plasma cells, the body keeps producing more and more of these cells. The unneeded plasma cells -- all abnormal and all exactly alike -- are called myeloma cells. Myeloma cancer cells tend to collect in the bone marrow and in the hard, outer part of bones. Sometimes they collect in only one bone and form a single mass, or tumor. In most cases, however, the myeloma cells collect in many bones, often forming many tumors. When this happens, the disease is called multiple myeloma. Although multiple myeloma affects the bones, they begin in cells of the immune system. These cancers are different from bone cancer, which actually begins in cells that form the hard, outer part of the bone. (National Cancer Institute)

Findings of Human Health Research Studies

Human health research studies compare the patterns of disease among groups of people with different amounts of exposure to a suspected risk factor. Below are results reported from such studies of multiple myeloma among people exposed to ionizing radiation.

All of these studies found increases and possible increases in multiple myeloma (MM) among certain groups of exposed workers. Statistically significant is a term used to mean that the connection between the health outcome and the exposure was strong enough that it was unlikely to be due to chance. The research included incidence studies, which look at new cases of cancer. These can track health more quickly and accurately than mortality studies of deaths due to cancer. Adding to the strength of the findings is that increasing rates of MM were observed with higher doses in some studies.

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* *Findings were statistically significant (strong evidence)*

\+ *Evidence of a dose-response relationship (strongest evidence)*

Studies of Los Alamos National Laboratory (LANL) Workers

Research conducted of LANL workers provides the most direct evidence about possible relationships between a health problem and workplace exposures at LANL.

- **Study of Four DOE Sites:** LANL contributed 37 cases of multiple myeloma to a case-control study at four DOE sites. All together, the rate of death due to MM increased with increasing whole body dose of radiation received between age 40 and 50.[71]

Studies of Other Nuclear Workers in the United States

The next most relevant evidence comes from studies of workers in similar occupations with the same types of exposures. Listed below are studies that looked at multiple myeloma and workplace exposures among nuclear workers in other parts of the United States.

- **Hanford:** A possible increase in MM deaths was observed in 35,000 males employed between 1943 and 1972, and then followed through 1972.(51) In later studies, this finding has depended upon the assumptions used in the analysis.(18, 48, 52) Under certain assumptions, there are increasing rates of death due to MM with increasing doses of external radiation. [49, 52, 72, 73 *+]

- **Mallinckrodt, St. Louis:** A possible increase in deaths from MM was observed in a study of 2,514 males who were employed between 1942 and 1966, and then followed through 1993. [2]

- **Oak Ridge Y-12:** The disease category of "other lymphatic cancer," which includes MM (ICD 203), showed a possible increase in deaths in a study of 8,116 workers who were employed between 1947 and 1974, and then followed through 1990. [24]

Studies of Other Nuclear Workers World-Wide

Below are studies of nuclear workers outside of the United States that looked at multiple myeloma in connection with radiation exposures.

- **Sellafield, England:** A possible increase in deaths was observed due to MM in a study of 5,203 plutonium workers who were employed between 1947 and 1975, and then followed through 1992. A possible increase was seen in incidence between 1971 and 1986 in plutonium workers. [3] In a study of 14,327 workers who were monitored for external radiation during this time period, there were increasing rates of death due to MM with increasing doses of external radiation. [4 *+] The researchers who conducted the study wrote: "This may represent a true radiation effect."

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* *Findings were statistically significant (strong evidence)*

\+ *Evidence of a dose-response relationship (strongest evidence)*

- **3 Nuclear Workforces in England:** Increasing rates of death due to MM were found with increasing time since first being monitored for plutonium in a study of 12,498 workers. [29 *+]

- **Registry of Nuclear Workers in the U.K.:** Increasing rates of death due to MM were found with increasing doses of external radiation in a study of 95,000 workers. [5 *+]

Studies of Other Ionizing Radiation Exposures

Studies among other groups of people who were not nuclear workers can also be significant as evidence of possible increases in multiple myeloma among those who have been exposed to ionizing radiation. Most other research has been conducted of people exposed to atomic bombs.

- **Atomic Bomb Survivors:** Increasing deaths due to multiple myeloma with increasing doses of radiation in a study of 86,572 A-bomb survivors. [8, 74 *+]

Other Research and Policy Findings

The National Research Council advises the U.S. government on scientific matters. Their Committee on Biological Effects of Exposure to Ionizing Radiations (BEIR) V reviewed sensitivity of parts of the body to radiation. Their findings are based mostly on studies of cancer among atomic bomb survivors, as well as on some of the available information on the biology of the body, animal studies, and other evidence. The greatest risk is at high exposure levels.

- According to the National Research Council's BEIR V committee, "[t]he incidence of multiple myeloma has been observed to be elevated after widespread irradiation of the bone marrow in the majority of populations studied to date."[9]

Is Multiple Myeloma a "Specified" Cancer Under the Energy Employees Occupational Illness Compensation Program Act (EEOICPA)?

- **Yes.** Multiple myeloma is a "specified" cancer under the EEOICPA consideration of Special Exposure Cohorts

Policy makers have identified certain types of cancer among energy employees at nuclear facilities, including those employed at Los Alamos National Laboratory, as being potentially related to occupational exposures under the EEOICPA.

What Are Other Risk Factors for Multiple Myeloma?

In considering the risks of occupational exposure to ionizing radiation leading to multiple myeloma, it is important to understand other risk factors. Below is a list of other suspected risk

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* *Findings were statistically significant (strong evidence)*

\+ *Evidence of a dose-response relationship (strongest evidence)*

factors for multiple myeloma. Children and brothers and sisters of patients who have this disease have a slightly increased risk.

- **Hazardous chemicals.** Farmers and petroleum workers exposed to certain chemicals also seem to have a higher-than-average chance of getting multiple myeloma.

These factors may add to any risk due to workplace exposure to ionizing radiation. Most multiple myeloma patients are between 50 and 70 years old. This disease affects blacks more often than whites and men more often than women. Smoking has not been found to be related to multiple myeloma.

Rates of Multiple Myeloma in Exposed Counties

Los Alamos County

There have been moderate rates of multiple myeloma reported in Los Alamos County for both cancer incidence and mortality. Los Alamos County:

- Ranked 19th in incidence of multiple myeloma and
- 19th in mortality among the 33 counties in New Mexico from 1970 to 1996. [33]
- In recent years there has been about one case per year in the county. [13, 14]

Rio Arriba County

There have been very high rates of multiple myeloma reported in Rio Arriba County for both cancer incidence and mortality. Rio Arriba County:

- Ranked 5th highest in incidence of multiple myeloma and
- Highest in mortality among the 33 counties in New Mexico from 1970 to 1996. [33]

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* *Findings were statistically significant (strong evidence)*

+ *Evidence of a dose-response relationship (strongest evidence)*

Non-Hodgkin's Lymphoma (NHL) and
(Lymphosarcoma and reticulum cell sarcoma)
Exposure to Ionizing Radiation

Summary: Some evidence has been recorded of a possible connection between non-Hodgkin's lymphoma and exposure to ionizing radiation. There is possible evidence from studies conducted at Los Alamos National Laboratory. Studies of nuclear workers at other sites who have been exposed to ionizing radiation and persons exposed to the atomic bomb show an increase risk of developing non-Hodgkin's lymphoma. The National Research Council's BEIR V committee did not address the issue of radiation-induced non-Hodgkin's lymphoma. Non-Hodgkin's lymphoma is designated as a "specified" cancer under the Energy Employees Occupational Illness Compensation Program Act. Historically, non-Hodgkin's lymphoma incidence and mortality have been among the highest in the state for Los Alamos County. Non-Hodgkin's lymphoma incidence and mortality in Rio Arriba County is less than most counties in New Mexico. Incidence means new cases of cancer, while mortality means deaths due to cancer.

What is Non-Hodgkin's Lymphoma?

Lymphoma is a general term for cancers that develop in the lymphatic system. The lymphatic system is part of the body's immune system. It helps the body fight disease and infection. Hodgkin's disease is one type of lymphoma, all others may be grouped together and referred to as Non-Hodgkin's Lymphoma. Lymphosarcoma or reticulum cell sarcoma can be other names for Non-Hodgkins Lymphoma. Lymphomas account for about 5 percent of all cases of cancer in this country. Because lymphatic tissue is present in many parts of the body, non-Hodgkin's lymphoma can start almost anywhere in the body. This type of cancer can spread to almost any part of the body, including the liver, bone marrow, and spleen. (National Cancer Institute)

Findings of Human Health Research Studies

Human health research studies compare the patterns of disease among groups of people with different amounts of exposure to a suspected risk factor. Below are results reported from such studies of non-Hodgkin's lymphoma among people exposed to ionizing radiation.

All of these studies found possible increases of non-Hodgkin's lymphoma among certain groups of exposed workers. Statistically significant is a term used to mean that the connection between the health outcome and the exposure was strong enough that it was unlikely to be due to chance. Note that some of the findings were based on only a few cases. The research included incidence studies, which look at new cases of cancer. These can track health more quickly and accurately than mortality studies of deaths due to cancer.

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* *Findings were statistically significant (strong evidence)*

\+ *Evidence of a dose-response relationship (strongest evidence)*

Studies of Los Alamos National Laboratory (LANL) Workers

Research conducted of LANL workers provides the most direct evidence about possible relationships between a health problem and workplace exposures at LANL.

- **UC & Zia Employees**: A possible increased incidence of lymphosarcoma and reticulosarcoma was found in a study of Anglo males who were employed for at least one year between 1969 and 1978. The finding was based on just four cases. [16]

- **Mortality Study up to 1991:** Possible increased deaths were found to be due to lymphosarcoma in an analysis of 3,775 males who were monitored for plutonium while employed between 1943 and 1977. Based on just one case, which occurred in a worker with body burden greater than 2 nanocuries (a measure of radiation exposure). [21]

- **Zia Study (unpublished):** Possible increased deaths were found in an analysis of 564 females employed by Zia Company between 1946 and 1978 who were monitored for either plutonium or external radiation. Findings were based on just one case. [15]

Studies of Other Nuclear Workers in the United States

The next most relevant evidence comes from studies of workers in similar occupations with the same types of exposures. Listed below are studies that looked at non-Hodgkin's lymphoma and workplace exposures among nuclear workers in other parts of the United States.

- **Hanford, Washington:** A possible increase in deaths to "lymphomas"was found in a study of 35,000 males who were employed between 1943 and 1972, and then followed through 1972. [51]

- **Savannah River Site**: A possible increase in deaths in the category of lymphomas that includes NHL was found among white male hourly employees who were hired before 1955.[44]

- **UC & Zia Employees:** A possible increased incidence of lymphosarcoma and reticulosarcoma was found in a study of Anglo males who were employed for at least one year between 1969 and 1978. The finding was based on just four cases. [16]

- **Mortality Study up to 1991:** Possible increased deaths were found to be due to lymphosarcoma in an analysis of 3,775 males who were monitored for plutonium while employed between 1943 and 1977. Based on just one case, which occurred in a worker with body burden greater than 2 nanocuries (a measure of radiation exposure). [21]

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* *Findings were statistically significant (strong evidence)*

\+ *Evidence of a dose-response relationship (strongest evidence)*

Studies of Other Nuclear Workers World-Wide

Below are studies of nuclear workers outside of the United States that looked at non-Hodgkin's lymphoma in connection with radiation exposures.

- **Sellafield, England:** A possible increase in non-Hodgkin's lymphoma deaths was observed in a study of 5,203 plutonium workers who were employed between 1947 and 1975, and then followed through 1992, when compared to non-radiation workers and to other radiation (non-Pu) workers. [3]

- **Atomic Energy Establishment of U.K.:** A possible increase was found in non-Hodgkin's lymphoma deaths in a study of radiation workers who were employed between 1946 and 1979, and then followed through 1986. [6]

- **Rocky Flats, Colorado:** A possible increased deaths due to lymphosarcoma and reticulum cell sarcoma was observed in a study of 5,413 men employed for at least two years between 1952 and 1979 (This study assumed a latent period of 2 or 5 years). Findings were based on just one case. [28]

- **Portsmouth, Ohio:** Possible increased deaths were seen due to lymphoreticulosarcoma in a study of 8,887 workers employed for at least one day between 1954 and 1991, followed through 1992. [18]

Studies of Other Ionizing Radiation Exposures

Studies among other groups of people who were not nuclear workers can also be significant as evidence of possible increases in non-Hodgkin's lymphoma among those who have been exposed to ionizing radiation. Most other research has been conducted of people exposed to atomic bombs.

- **Atomic Bomb Survivors:** A possible increase has been observed in non-Hodgkin's lymphoma deaths in A-bomb survivors who were followed through 1978. [71 *]

Other Research and Policy Findings

Is Non-Hodgkins Lymphoma Considered Radiation-Sensitive?

The National Research Council advises the U.S. government on scientific matters. Their Committee on Biological Effects of Exposure to Ionizing Radiations (BEIR) V reviewed sensitivity of parts of the body to radiation. Their findings are based mostly on studies of cancer

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* *Findings were statistically significant (strong evidence)*

\+ *Evidence of a dose-response relationship (strongest evidence)*

among atomic bomb survivors, as well as on some of the available information on the biology of the body, animal studies, and other evidence. The greatest risk is at high exposure levels.

- The National Research Council's BEIR V committee did not comment on the radiation-relatedness of non-Hodgkin's lymphoma.

Is Non-Hodgkins Lymphoma a "Specified" Cancer Under the Energy Employees Occupational Illness Compensation Program Act (EEOICPA)?

- **Yes.** Non-Hodgkin's lymphoma, Lymphosarcoma and reticulum cell sarcoma are is a "specified" cancer under the EEOICPA consideration of Special Exposure Cohorts.

Policy makers have identified certain types of cancer among energy employees at nuclear facilities, including those employed at Los Alamos National Laboratory, as being potentially related to occupational exposures under the EEOICPA.

What Are Other Risk Factors for Non-Hodgkin's Lymphoma?

In considering the cancer risk from exposure to ionizing radiation at work, it is important to understand other risk factors. Below is a list of other possible risk factors for Non-Hodgkins Lymphoma.

- **Drinking water contamination.** Contamination of drinking water with nitrate, a chemical found in fertilizers, may be associated with an increased risk of non-Hodgkin's lymphoma (NHL), particularly in agricultural areas, a National Cancer Institute (NCI) study suggests.
- **Chemical exposures.** People who work extensively with or are otherwise exposed to certain chemicals, such as pesticides, solvents, or fertilizers, have a greater chance of developing non-Hodgkin's lymphoma.
- **Poor Immune System.** Non-Hodgkin's lymphoma is more common among people with inherited immune deficiencies, autoimmune diseases, or HIV/AIDS, and among people taking immunosuppressant drugs following organ transplants.
- **Viruses.** Human T-lymphotropic virus type I (HTLV-1) and Epstein-Barr virus are two infectious agents that increase the chance of developing non-Hodgkin's lymphoma.

These factors may add to any risk due to workplace exposure to ionizing radiation. The likelihood of getting non-Hodgkin's lymphoma increases with age and is more common in men than in women. Smoking is not a risk factor.

Rates of Non-Hodgkin's Lymphoma Cancer in Exposed Counties

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* *Findings were statistically significant (strong evidence)*

+ *Evidence of a dose-response relationship (strongest evidence)*

Los Alamos County

Rates of non-Hodgkin's lymphoma incidence and mortality were very high in Los Alamos County. Los Alamos County:

- Ranked first highest in incidence of non-Hodgkin's lymphoma and
- Ranked third highest in mortality among the 33 counties in New Mexico from 1970 to 1996.
- In the early 1970's the rate in Los Alamos County was considerably higher than New Mexico or the U.S..[32]
- From 1970 to 1990, it was up to twice the expected rate. [35]
- In recent years, about three to four cases have occurred annually.

Rio Arriba County

Rates of non-Hodgkin's lymphoma incidence and mortality in Rio Arriba County were among the lowest third of counties. Rio Arriba County:

- Ranked 25th in incidence of non-Hodgkin's lymphoma and
- Ranked 23 in mortality for NHL among the 33 counties in New Mexico from 1970 to 1996.

The findings suggest that more needs to be done to prevent, diagnose and treat non-Hodgkin's lymphoma in Los Alamos County.

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* *Findings were statistically significant (strong evidence)*

+ *Evidence of a dose-response relationship (strongest evidence)*

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Cancer of the Oral Cavity and Pharynx and Exposure to Ionizing Radiation

Summary: Little evidence has been recorded of a possible connection between cancers of the oral cavity and pharynx and exposure to ionizing radiation. There is no evidence from studies conducted at Los Alamos National Laboratory or studies of nuclear workers at other sites who have been exposed to ionizing radiation. The National Research Council's determination that the pharynx and hypopharynx have "low" sensitivity to ionizing radiation. Salivary glands, another site among head and neck cancers, are considered more sensitive to radiation. Oral cancer and pharyngeal cancer (cancer of the pharynx) are designated as "specified" cancers under the Energy Employees Occupational Illness Compensation Program Act. Historically, oral and pharyngeal cancer incidence and mortality have been among the lowest in the state for Los Alamos County. Incidence and mortality in Rio Arriba County are approximately among the top third of New Mexico County rates.

What are cancers of the oral cavity and pharynx?

These cancers that begin in the oral cavity or pharynx are among the cancers of the head and neck. The oral cavity includes the lips and parts of the mouth and tongue. The pharynx is a hollow tube about 5 inches long that starts behind the nose and leads to the esophagus (the tube that goes to the stomach) and the trachea (the tube that goes to the lungs).

Most head and neck cancers begin in the squamous cells that line the structures found in the head and neck. Because of this, head and neck cancers are often referred to as squamous cell carcinomas. Some head and neck cancers begin in other types of cells. (National Cancer Institute)

Findings of Human Health Research Studies

Human health research studies compare the patterns of disease among groups of people with different amounts of exposure to a suspected risk factor. Below are results reported from the few such studies that have been conducted of cancers of the oral cavity and pharynx among people exposed to ionizing radiation.

Studies of Los Alamos National Laboratory (LANL) Workers

Research conducted of LANL workers provides the most direct evidence about possible relationships between a health problem and workplace exposures at LANL.

– In studies performed to date, there is no reported evidence from health studies of LANL workers of increased rates of oral or pharyngeal cancer.

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* *Findings were statistically significant (strong evidence)*

\+ *Evidence of a dose-response relationship (strongest evidence)*

Studies of Other Nuclear Workers in the United States

The next most relevant evidence comes from studies of workers in similar occupations with the same types of exposures. Listed below are studies that looked at oral or pharyngeal cancer and workplace exposures among nuclear workers in other parts of the United States.

- Lawrence Livermore, California: Increased incidence of salivary gland tumors was seen in females who were employed between 1969 and 1980.* Findings were based on just two cases. [22]

Studies of Other Nuclear Workers World-Wide

Below are studies of nuclear workers outside of the United States that looked at oral or pharyngeal cancer in connection with radiation exposures.

- No evidence is available from health studies of nuclear workers in other countries of increased rates of oral or pharyngeal cancer.

Other Research and Policy Findings

Do the Oral Cavity and Pharynx Contain Radiation-Sensitive Organs?

- According to the National Research Council's BEIR V Committee, the tissues of the pharynx and hypopharynx have low sensitivity to the cancer-causing effects of ionizing radiation. Salivary glands, also located in the head and neck under the tongue, in front of the ears, and under the jawbone, as well as in other parts of the upper digestive tract, are more radiation-sensitive. [12]

The National Research Council advises the U.S. government on scientific matters. Their Committee on Biological Effects of Exposure to Ionizing Radiations (BEIR) V reviewed sensitivity of parts of the body to radiation. Their findings are based mostly on studies of cancer among atomic bomb survivors, as well as on some of the available information on the biology of the body, animal studies, and other evidence. The greatest risk is at high exposure levels.

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* *Findings were statistically significant (strong evidence)*

\+ *Evidence of a dose-response relationship (strongest evidence)*

Is Cancer of the Oral Cavity and Pharynx a "Specified" Cancer Under the Energy Employees Occupational Illness Compensation Program Act (EEOICPA)?

- **Yes.** Cancer of the oral cavity and pharynx is a "specified" cancer under the EEOICPA consideration of Special Exposure Cohorts.

Policy makers have identified certain types of cancer among energy employees at nuclear facilities, including those employed at Los Alamos National Laboratory, as being potentially related to occupational exposures under the EEOICPA.

What Are Other Risk Factors for Cancer of the Oral Cavity and Pharynx Cancer?

In considering the risks of occupational exposure to ionizing radiation, it is important to understand other risk factors. Below is a list of other possible risk factors for oral and pharyngeal cancer.

- **Tobacco**. Tobacco (including smokeless tobacco) is an important risk factor for cancers of the oral cavity, oropharynx, hypopharynx, and larynx. Eighty-five percent of head and neck cancers are linked to tobacco use.[2]
- **Alcohol.** Alcohol is another important risk factor for these cancers. People who use both tobacco and alcohol are at greater risk for developing these cancers than people who use either tobacco or alcohol alone.
- Other risk factors for cancers of the oral cavity include: sun exposure (lip) and human papillomavirus (HPV) infection.
- Other risk factors for cancers of the pharynx include:
  Nasopharynx—Epstein-Barr virus infection; occupational exposure to wood dust; and consumption of certain preservatives or salted foods.
  Oropharynx—Poor oral hygiene, mechanical irritation such as from poorly fitting dentures, and use of mouthwash that has a high alcohol content.
  Hypopharynx—Plummer-Vinson (also called Paterson-Kelly) syndrome, a rare disorder that results from nutritional deficiencies.

  These factors may add to any risk due to workplace exposure to ionizing radiation.

What Makes Cancer of the Oral Cavity and Pharynx and Radiation Exposure Difficult to Study?

There are difficulties in all human studies because one cannot precisely determine all exposures and track all individual outcomes. In cancer this is especially the case as the cancer may take many years to develop to the point of diagnosis and possible death (disease latency).

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[2] Harras A, Edwards K, Blot WJ, Gloeckler Ries LA. Cancer Rates and Risks. 4th ed. Washington, D.C.: National Cancer Institute, 1996.

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* *Findings were statistically significant (strong evidence)*

+ *Evidence of a dose-response relationship (strongest evidence)*

Rates of Cancer of the Oral Cavity and Pharynx In Exposed Counties

Los Alamos County

There have been low rates of cancer of the oral cavity and pharynx reported in Los Alamos County for both cancer incidence and mortality. This is probably due to lower rates of smoking in residents of the county. Los Alamos County

- Ranked 28th in incidence of cancer of the oral cavity and pharynx and
- also ranked very low in cancer mortality due to cancer of the oral cavity and pharynx from 1970 to 1996 of the 33 counties in New Mexico.[13]
- In recent years, there has been about one new case diagnosed every couple of years in Los Alamos County. [14]

Rio Arriba County

Rates of cancer of the oral cavity and pharynx reported in Rio Arriba County have been somewhat higher than average county rates for both cancer incidence and mortality. These higher rates may be due to chance differences in area rates. Rio Arriba County:

- Ranked 11th in incidence of cancer of the oral cavity and pharynx and
- Ranked 12th in cancer mortality due to cancer of the oral cavity and pharynx from 1970 to 1996 of the 33 counties in New Mexico. [33]

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* *Findings were statistically significant (strong evidence)*

+ *Evidence of a dose-response relationship (strongest evidence)*

Ovarian Cancer and Exposure to Ionizing Radiation

Summary: There has been moderately strong evidence recorded of a possible connection between ovarian cancer and exposure to ionizing radiation. This possible connection is supported by evidence from studies conducted at Los Alamos National Laboratory and other studies of nuclear workers at other sites who have been exposed to ionizing radiation. The National Research Council's has determined that there is evidence among atomic bomb survivors of ovarian cancer in connection with exposure to ionizing radiation. Ovarian cancers are designated as "specified" cancers under the Energy Employees Occupational Illness Compensation Program Act. Historically, pancreatic cancer incidence and mortality have been very high for Los Alamos County. Incidence and mortality in Rio Arriba County is in the middle of New Mexico county rates.

What is Ovarian Cancer?

A cancerous tumor that begins in a woman's ovaries is called ovarian cancer. There are several types of ovarian cancer. Ovarian cancer that begins on the surface of the ovary (epithelial carcinoma) is the most common type. Ovarian cysts and tumors that are not cancerous can also commonly form on the ovaries. (National Cancer Institute)

Findings of Human Health Research Studies

Human health research studies compare the patterns of disease among groups of people with different amounts of exposure to a suspected risk factor. Below are results reported from such studies of ovarian cancer among people exposed to ionizing radiation.

These studies found increases and possible increases in ovarian cancer among certain groups of exposed individuals, in some cases followed over time. Statistically significant is a term used to mean that the connection between the health outcome and the exposure was strong enough that it was unlikely to be due to chance. An asterisk (*) was placed by statistically significant findings. The research did not include incidence studies, which look at new cases of cancer. These can track health more quickly and accurately than mortality studies of deaths due to cancer. Adding to the strength of the findings is that increasing rates of ovarian cancer were observed with higher doses in some studies.

Studies of Los Alamos National Laboratory (LANL) Workers

Research conducted of LANL workers provides the most direct evidence about possible relationships between a health problem and workplace exposures at LANL.

- **Female Lab Employees Study:** An increase in ovarian cancer deaths was found in women who were monitored for external radiation while employed at the Lab from 1943

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* *Findings were statistically significant (strong evidence)*

+ *Evidence of a dose-response relationship (strongest evidence)*

to 1981. Based on four cases, three of which had cumulative radiation doses less than 1 rem (a measure of radiation dose).[36]

Studies of Other Nuclear Workers in the United States

The next most relevant evidence comes from studies of workers in similar occupations with the same types of exposures. Listed below are studies that looked at pancreatic cancer and workplace exposures among nuclear workers in other parts of the United States.

- **Hanford, Washington:** Increasing rates of deaths due to ovarian cancer were found with increasing doses of external radiation in 12,600 women who were employed from 1944 through 1978, and then followed through 1981 (This study assumed a 10 year latent period between time of exposure and diagnosis of the disease). [52 +]

Studies of Other Nuclear Workers in the United States

The next most relevant evidence comes from studies of workers in similar occupations with the same types of exposures. Listed below are studies that looked at ovarian cancer and workplace exposures among nuclear workers in other parts of the United States.

- **3 Nuclear Workers in the U.K.:** Increasing rates of ovarian cancer deaths were found with increasing length of time since 3,366 women were first monitored for radiation (including plutonium),[*] and then followed through 1988. But findings were based on only two cases. [29]

Studies of Other Nuclear Workers in the United States

The next most relevant evidence comes from studies done on workers in similar occupations facing the same types of exposures. Below are studies that observed ovarian cancer in possible connection with certain exposures among nuclear workers in the United States.

- **Atomic Bomb Survivors:** Increasing ovarian cancer deaths were found with increasing doses of radiation in a study of 86,572 A-bomb survivors. [8 *+]

Other Research and Policy Findings

Is the Ovary Sensitive to Radiation?

The National Research Council advises the U.S. government on scientific matters. Their Committee on Biological Effects of Exposure to Ionizing Radiations (BEIR) V reviewed sensitivity of parts of the body to radiation. Their findings are based mostly on studies of cancer

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* *Findings were statistically significant (strong evidence)*

+ *Evidence of a dose-response relationship (strongest evidence)*

among atomic bomb survivors, as well as on some of the available information on the biology of the body, animal studies, and other evidence. The greatest risk is at high exposure levels.

According to the National Research Council's BEIR V committee, the Atomic bomb studies provide the strongest evidence that radiation exposure causes ovarian cancer. [9]

Is Ovarian Cancer a "Specified" Cancer Under the Energy Employees Occupational Illness Compensation Program Act (EEOICPA)?

- **Yes.** Ovarian cancer is a "specified" cancer under the EEOICPA consideration of Special Exposure Cohorts (except if cirrhosis or hepatitis B is indicated).

Policy makers have identified certain types of cancer among energy employees at nuclear facilities, including those employed at Los Alamos National Laboratory, as being potentially related to occupational exposures under the EEOICPA.

What Are Other Risk Factors for Ovarian Cancer?

In considering the risks of occupational exposure to ionizing radiation leading to ovarian cancer, it is important to understand other risk factors. Below is a list of other possible risk factors for ovarian cancer.

- **Relatives** (mother, daughter, sister) of a woman who has had ovarian cancer are at increased risk of developing this type of cancer themselves. A family or personal history of breast or colon cancer is also associated with an increased risk of developing ovarian cancer.
- **Childbearing.** Women who have never had children are more likely to develop ovarian cancer than women who have had children.
- **Fertility drugs.** Drugs that cause a woman to ovulate may slightly increase a woman's chance of developing ovarian cancer. Researchers are studying this possible connection.
- **Talc.** Some studies suggest that women who have used talc in the genital area for many years may be at increased risk of developing ovarian cancer.
- **Hormone replacement therapy (HRT).** Some evidence suggests that women who use HRT after menopause may have a slightly increased risk of developing ovarian cancer.

These factors may add to any risk due to workplace exposure to ionizing radiation. The likelihood of developing ovarian cancer increases as a woman gets older. Ovarian cancer has not been found to be related to smoking.

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* *Findings were statistically significant (strong evidence)*

+ *Evidence of a dose-response relationship (strongest evidence)*

Rates of Ovarian Cancer In Exposed Counties

Los Alamos County

Rates of ovarian cancer incidence and mortality were very high in Los Alamos County. Los Alamos County:

- Ranked second highest among the 33 counties in New Mexico in ovarian cancer incidence and mortality from 1970 to 1996. [33]
- In recent years, one to two cases have occurred annually. [13, 14]
- In the mid-1980's the rate in the county was elevated, [35] particularly in Census Tract #1 (North and Barranca Mesas). [75] Factors discussed by the Steering Committee for the state's epidemiology study were: the low birth rate and pregnancies later in life (childbearing protects against ovarian cancer); random variability; and the introduction of improved diagnostic technology (ultrasound) in 1985. [32]

Rio Arriba County

Rates of ovarian cancer were moderate in Rio Arriba County. Rio Arriba County:

- Ranked 22nd in incidence and
- Ranked 18th in mortality among the 33 counties in New Mexico from 1970 to 1996. [33]

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* *Findings were statistically significant (strong evidence)*

+ *Evidence of a dose-response relationship (strongest evidence)*

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Pancreatic Cancer and Exposure to Ionizing Radiation

Summary*:* Some evidence has been recorded of a possible connection between cancers of the pancreas and exposure to ionizing radiation. This possible connection is supported by evidence from studies conducted at Los Alamos National Laboratory and other studies of nuclear workers at other sites who have been exposed to ionizing radiation. The National Research Council's, on the other hand, has determined that the pancreas is relatively insensitive to ionizing radiation. Pancreatic cancers are designated as "specified" cancers under the Energy Employees Occupational Illness Compensation Program Act. Historically, incidence of pancreatic cancer in Los Alamos County is in the middle of New Mexico county rates. Incidence in Rio Arriba County is among the ten highest county rates. Incidence means new cases of cancer, while mortality means deaths due to cancer.

What is Pancreatic Cancer?

The pancreas is a gland located between the stomach and the spine (backbone). The pancreas makes certain hormones and pancreatic juices. These juices contain enzymes that help digest food. The pancreas releases the juices into a system of ducts leading to the common bile duct. Most pancreatic cancers begin in the ducts that carry pancreatic juices. Cancer of the pancreas may be called pancreatic cancer or carcinoma of the pancreas. (National Cancer Institute)

Findings of Human Health Research Studies

Human health research studies compare the patterns of disease among groups of people with different amounts of exposure to a suspected risk factor. Below are results reported from such studies of pancreatic cancer among people exposed to ionizing radiation.

These studies found increases and possible increases in pancreatic cancer among certain groups of exposed individuals, in some cases followed over time. Statistically significant is a term used to mean that the connection between the health outcome and the exposure was strong enough that it was unlikely to be due to chance. An asterisk (*) was placed by statistically significant findings. All were mortality studies of pancreatic cancer death as a health outcome. Incidence studies that look at new cases of cancer can track health more quickly and accurately

Studies of Los Alamos National Laboratory (LANL) Workers

Research conducted of LANL workers provides the most direct evidence about possible relationships between a health problem and workplace exposures at LANL.

- **Female Lab Employees Study**: An increase in pancreatic cancer deaths was found in women who were employed at the Lab from 1943 to 1981, assuming a 25-year latent period.* But this was based on only one case, who had a cumulative dose of 690 mrem (a measure of

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* *Findings were statistically significant (strong evidence)*

+ *Evidence of a dose-response relationship (strongest evidence)*

radiation dose). The researcher who conducted the study felt it was "highly unlikely that her radiation exposure contributed to the development of pancreatic cancer."[36]

- **Zia Study (unpublished):** Possible increasing rates of pancreatic cancer deaths were observed with increasing doses of external radiation in males employed between 1946 and 1978. [15]

Studies of Other Nuclear Workers in the United States

The next most relevant evidence comes from studies done on workers in similar occupations facing the same types of exposures. Below are studies that observed pancreatic cancer in possible connection with certain exposures among nuclear workers in the United States.

- **Hanford:** Dr. Thomas Mancuso (University of Pittsburgh) discovered an increased rate of death due to pancreatic cancer in a study of 35,000 white males employed between 1943 and 1972. [51] In a follow-up study through 1989, there were increasing rates of death due to pancreatic cancer with increasing doses of external radiation in workers who were employed for at least six months from 1945 to 1986.[+] But the researchers who conducted the study did not interpret it as evidence of an effect. [49]

- **Mallinckrodt, St. Louis, Missouri:** Possible increased rates of pancreatic cancer deaths were found in a study of 2,514 men who were employed in uranium processing between 1942 and 1966, and then followed through 1993. [2]

- **Oak Ridge Y-12:** A possible increase in pancreatic cancer deaths was found in a study of 8,116 men and women who were employed between 1947 and 1972, and then followed through 1990. [24]

- **Savannah River Site**: A possible increase in pancreatic cancer deaths was observed in white male hourly and long-term (15+ years) workers who were employed before 1955. [44]

- **West Chicago (Kerr-McGee) Thorium Plant**: An increase in pancreatic cancer deaths was found in a study of 1,446 men who were first employed between 1955 and 1969, and then followed through 1976.[*] Rates were highest in workers with at least one year in a dusty job. [45]

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[*] *Findings were statistically significant (strong evidence)*

[+] *Evidence of a dose-response relationship (strongest evidence)*

Studies of Other Nuclear Workers World-Wide

Below are studies of nuclear workers outside of the United States that looked at pancreatic cancer in connection with radiation exposures.

- **Sellafield, England:** Compared to non-radiation workers, a possible increase in pancreatic cancer deaths was seen in a study of 5,203 plutonium workers who were employed between 1947 and 1975, and then followed through 1992. A possible increase in the incidence of pancreatic cancer was found in plutonium workers who were employed between 1971 and 1986, and then followed through 1992. [3]

Studies of Other Ionizing Radiation Exposures

Studies among other groups of people who were not nuclear workers can also be significant as evidence of possible increases in pancreatic cancer among those who have been exposed to ionizing radiation. Most other research has been conducted of people exposed to atomic bombs.

Atomic Bomb Survivors: In studies performed to date there is no reported evidence of increased rates of pancreatic cancer in A-bomb survivors.

Other Research and Policy Findings

Is the Pancreas Sensitive to Radiation?

- According to the National Research Council's BEIR V committee, the pancreas is "relatively insensitive" to radiation. [9] This was published before some of the nuclear worker studies cited above.

The National Research Council advises the U.S. government on scientific matters. Their Committee on Biological Effects of Exposure to Ionizing Radiations (BEIR) V reviewed sensitivity of parts of the body to radiation. Their findings are based mostly on studies of cancer among atomic bomb survivors, as well as on some of the available information on the biology of the body, animal studies, and other evidence. The greatest risk is at high exposure levels.

Is Pancreatic Cancer a "Specified" Cancer Under the Energy Employees Occupational Illness Compensation Program Act (EEOICPA)?

Yes. Pancreatic cancer is a "specified" cancer under the EEOICPA consideration of Special Exposure Cohorts (except if cirrhosis or hepatitis B is indicated).

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* *Findings were statistically significant (strong evidence)*

\+ *Evidence of a dose-response relationship (strongest evidence)*

Policy makers have identified certain types of cancer among energy employees at nuclear facilities, including those employed at Los Alamos National Laboratory, as being potentially related to occupational exposures under the EEOICPA.

What Are Other Risk Factors for Pancreatic Cancer?

In considering the risks of occupational exposure to ionizing radiation, it is important to understand other risk factors. Below is a list of other possible risk factors for pancreatic cancer.

- **Tobacco.** Smoking is related to pancreatic cancer. [10, 12]
- **Diabetes.** Pancreatic cancer occurs more often in people who have diabetes
- **Family history.** The risk for developing pancreatic cancer triples if a person's mother, father, sister, or brother had the disease. Also, a family history of colon or ovarian cancer increases the risk of pancreatic cancer
- **Disease of the pancreas.** Chronic pancreatitis is a painful condition of the pancreas. Some evidence suggests that chronic pancreatitis may increase the risk of pancreatic cancer.

These factors may add to any risk due to workplace exposure to ionizing radiation. The likelihood of developing pancreatic cancer increases with age. African Americans are more likely than Asians, Hispanics, or whites to get pancreatic cancer. More men than women are diagnosed with pancreatic cancer

Rates of Pancreatic Cancer In Exposed Counties

Los Alamos County

Rates of cancer of the pancreas incidence was moderate in Los Alamos County.

- Incidence of pancreatic cancer ranked in the middle (17th) of the 33 counties in New Mexico, from 1970 to 1996. [33]
- In recent years there have been about two cases per year in the county. [13, 14]

Rio Arriba County

Rates of cancer of the pancreas incidence was high in Rio Arriba County. Rio Arriba County:

- Ranked 6th among the 33 counties in New Mexico for the incidence of pancreatic cancer, from 1970 to 1996. [33]
- In recent years there have been about four cases per year in the county.

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* *Findings were statistically significant (strong evidence)*

+ *Evidence of a dose-response relationship (strongest evidence)*

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Prostate Cancer and Exposure to Ionizing Radiation

Summary: Evidence has been recorded of an connection between cancers of the prostate and exposure to ionizing radiation. This connection is supported by evidence from studies of nuclear workers in England who have been exposed to ionizing radiation. The National Research Council's, on the other hand, has determined that the prostate is relatively insensitive to ionizing radiation. Prostate cancer is not designated as a "specified" cancer under the Energy Employees Occupational Illness Compensation Program Act. Historically, prostate cancer incidence has been high for Los Alamos County while prostate cancer mortality has been low compared to other counties in the state. Prostate cancer incidence and mortality rates in Rio Arriba County were among the top third of New Mexico counties. Incidence means new cases of cancer, while mortality means deaths due to cancer.

What is Prostate Cancer?

The prostate is a gland in a man's reproductive system. The prostate is about the size of a walnut. It is located below the bladder. Cancer of the prostate occurs when cells of the prostate become abnormal and reproduce without control. Tumors of the prostate that are not cancer are common. (National Cancer Institute)

Findings of Human Health Research Studies

Human health research studies compare the patterns of disease among groups of people with different amounts of exposure to a suspected risk factor. Below are results reported from such studies of prostate cancer among people exposed to ionizing radiation.

All of these studies found increases and possible increases in prostate cancer among certain groups of exposed workers. Statistically significant is a term used to mean that the connection between the health outcome and the exposure was strong enough that it was unlikely to be due to chance. An asterisk (*) was placed by statistically significant findings. The research included incidence studies, which look at new cases of cancer. These can track health more quickly and accurately than mortality studies of deaths due to cancer.

Studies of Los Alamos National Laboratory (LANL) Workers

Research conducted of LANL workers provides the most direct evidence about possible relationships between a health problem and workplace exposures at LANL.

– In studies performed to date, no reported evidence of increased rates of prostate cancer in LANL employees.

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* *Findings were statistically significant (strong evidence)*

\+ *Evidence of a dose-response relationship (strongest evidence)*

Studies of Other Nuclear Workers in the United States

The next most relevant evidence comes from studies of workers in similar occupations with the same types of exposures. Listed below are studies that looked at prostate cancer and workplace exposures among nuclear workers in other parts of the United States.

- **Fernald, Ohio:** A possible increase in prostate cancer deaths was found in a study of 4,014 males who were employed between 1951 and 1989, and then followed through 1989. [1]

- **Lawrence Livermore, California:** A possible increased incidence of prostate cancer was seen in men employed between 1969 and 1980. [22]

- **Mallinckrodt, St. Louis, Missouri:** A possible increase in prostate cancer deaths was found in a study of 2,514 males employed in uranium processing between 1942 and 1966, followed-up through 1993. [2]

- **Oak Ridge:** A possible increase in prostate cancer deaths was found in a study of 8,375 males who were employed for at least 30 days between 1943 and 1972, and then followed through 1977. [50] Similar findings in 3,763 workers who were monitored for internal contamination, followed through 1984. [57]

- **Oak Ridge Y-12:** A possible increase in prostate cancer deaths was seen in a study of 7,043 males employed between 1947 and 1990, and then followed through 1990. [24]

- **Rocky Flats, Colorado:** A possible increase in prostate cancer deaths was found in a study of 5,413 males who were employed for at least two years between 1952 and 1979, and then followed through 1979. [28]

- **Savannah River Site**: A possible increase in prostate cancer deaths was seen among salaried employees and in white males employed before 1955. [44]

Studies of Other Nuclear Workers World-Wide

Below are studies of nuclear workers outside of the United States that looked at prostate cancer in connection with radiation exposures.

- **Atomic Energy of Canada:** A possible increase in prostate cancer deaths was found in a study of 8,977 men who were employed between 1956 and 1985. [46]

- **Atomic Weapons Establishment of the U.K.:** An increase in prostate cancer deaths was found in a study of 9,389 workers who were monitored for radiation while employed between 1951 and 1982, and then followed through 1982.* A possible increase in prostate cancer deaths was found in an analysis of the 3,742 workers who were monitored for internal radionuclides (This study assumed a 10 year latent period). [53]

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* *Findings were statistically significant (strong evidence)*

+ *Evidence of a dose-response relationship (strongest evidence)*

- **Sellafield, England:** An increase in prostate cancer deaths was found in a study of radiation workers who were employed between 1947 and 1975, and then followed to 1992, when compared to non-radiation workers.* Also, an increase in deaths due to benign prostatic hyperplasia (BPH) was found in plutonium workers employed between 1947 and 1975, when compared to other radiation workers.[3] *

- **Atomic Energy Authority of the U.K.:** Risk of prostate cancer increased in men who were internally contaminated by tritium, chromium-51, iron-59, cobalt-60 or zinc-65.* Risk increased with length of time working in contaminated areas and increasing levels of contamination.[76] *+ A scientist commenting on this study pointed out that zinc-65 localizes in the prostate gland.[letters to BMJ re: Rooney #37, #44]

Studies of Other Ionizing Radiation Exposures

Studies among other groups of people who were not nuclear workers can also be significant as evidence of possible increases in prostate cancer among those who have been exposed to ionizing radiation. Most other research has been conducted of people exposed to atomic bombs.

- **Atomic Bomb Survivors:** In studies performed to date there is no reported evidence of increased rates of prostate cancer in A-bomb survivors.

Other Research and Policy Findings

Is the Prostate Sensitive to Radiation?

- According to the National Research Council's BEIR V committee, "the sensitivity of the prostate to the induction of cancer by irradiation appears to be comparatively low."(9) However, this was written before the British nuclear worker studies (above) were published.

The National Research Council advises the U.S. government on scientific matters. Their Committee on Biological Effects of Exposure to Ionizing Radiations (BEIR) V reviewed sensitivity of parts of the body to radiation. Their findings are based mostly on studies of cancer among atomic bomb survivors, as well as on some of the available information on the biology of the body, animal studies, and other evidence. The greatest risk is at high exposure levels.

Is Prostate Cancer a "Specified" Cancer Under the Energy Employees Occupational Illness Compensation Program Act (EEOICPA)?

- **No.** Prostate cancer is not a "specified" cancer under the EEOICPA consideration of Special Exposure Cohorts.

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* *Findings were statistically significant (strong evidence)*

+ *Evidence of a dose-response relationship (strongest evidence)*

Policy makers have identified certain types of cancer among energy employees at nuclear facilities, including those employed at Los Alamos National Laboratory, as being potentially related to occupational exposures under the EEOICPA.

What Are Other Risk Factors for Prostate Cancer?

In considering the risks of occupational exposure to ionizing radiation, it is important to understand other risk factors. Below is a list of other possible risk factors for prostate cancer.

- **Family History.** A man's risk for developing prostate cancer is higher if his family has a history of developing prostate cancer
- **Diet.** Some evidence suggests that a diet high in animal fat may increase the risk of prostate cancer and a diet high in fruits and vegetables may decrease the risk

These factors may add to any risk due to workplace exposure to ionizing radiation. Risk increases with age. This disease is much more common in African American men than in white men, but less common in Asian and American Indian men. Smoking is not related to prostate cancer.

Rates of Prostate Cancer In Exposed Counties

Los Alamos County

Rates of prostate cancer incidence was very high in Los Alamos County, while mortality was very low. Los Alamos County:

- Ranked highest in incidence of prostate cancer and
- Ranked 23rd in mortality among 33 counties in New Mexico from 1970 to 1996.

This is evidence of earlier detection and successful treatment of prostate cancer in Los Alamos County, compared to other counties. In recent years, about 20 cases have occurred annually.[13]

Rio Arriba County

Rates of prostate cancer incidence and mortality for Rio Arriba County were in the top third of counties. The county:

- Ranked 10th in incidence and
- Ranked 8th in mortality for prostate cancer among the 33 counties in New Mexico from 1970 to 1996. [33]

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* *Findings were statistically significant (strong evidence)*

+ *Evidence of a dose-response relationship (strongest evidence)*

Stomach Cancer and Exposure to Ionizing Radiation

Summary: Moderately strong evidence has been recorded of a possible connection between stomach cancer and exposure to ionizing radiation. This evidence is based upon studies of nuclear workers exposed to ionizing radiation. These findings are consistent with the National Research Council's determination that the stomach is sensitive to ionizing radiation. Stomach cancer is designated as a "specified" cancer under the Energy Employees Occupational Illness Compensation Program Act. Historically, stomach cancer incidence and mortality have been very low for Los Alamos County. Incidence and mortality in Rio Arriba County have been very high among New Mexico counties. Incidence means new cases of cancer, while mortality means deaths due to cancer.

What is Stomach Cancer?

Stomach cancer can develop in any part of the stomach and may spread throughout the stomach. It may extend along the stomach wall and grow into the esophagus or small intestine that are attached to the stomach. It also may spread to other parts of the body. Stomach cancer is also called gastric cancer. Stomach cancer is the second leading cause of cancer death in the world. (National Cancer Institute)

Findings of Human Health Research Studies

Human health research studies compare the patterns of disease among groups of people with different amounts of exposure to a suspected risk factor. Below are results reported from such studies of stomach cancer among people exposed to ionizing radiation.

All of these studies found possible increases in stomach cancer among certain groups of exposed workers. Statistically significant is a term used to mean that the connection between the health outcome and the exposure was strong enough that it was unlikely to be due to chance. An asterisk (*) was placed by statistically significant findings. All were mortality studies of stomach cancer death as a health outcome. Incidence studies, which look at new cases, can track health more quickly and accurately.

Studies of Los Alamos National Laboratory (LANL) Workers

Research conducted of LANL workers provides the most direct evidence about possible relationships between a health problem and workplace exposures at LANL.

- **Zia Study (unpublished):** An increase in deaths due to stomach cancer was found in a study of 4,942 men employed by Zia Company between 1946 and 1978. * Hispanics had higher rates than Anglos. [15]

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* *Findings were statistically significant (strong evidence)*

+ *Evidence of a dose-response relationship (strongest evidence)*

Studies of Other Nuclear Workers in the United States

The next most relevant evidence comes from studies of workers in similar occupations with the same types of exposures. Listed below are studies that looked at stomach cancer and workplace exposures among nuclear workers in other parts of the United States.

– **Fernald:** A possible increase in stomach cancer deaths was observed among white male uranium processing workers employed from 1951 to 1989, followed to 1990.[1]

- **Oak Ridge Y-12:** Studies observed a possible increase in stomach cancer deaths among white male workers employed from 1943 to 1972, who were followed until 1978. This increase was seen in comparison to rates in Tennessee.[50] However this increase was not seen when the comparison was made to U.S. rates or in later years of follow-up.[23, 24, 57, 67, 77]

– **Portsmouth:** There was a possible increase in stomach cancer deaths in workers from 1954 to 1991.[18]

Studies of Other Nuclear Workers World-Wide

Below are studies of nuclear workers outside of the United States that looked at stomach cancer in connection with radiation exposures.

- **Sellafield, England:** There was a possible increase in stomach cancer deaths seen in non-plutonium radiation workers who were employed between 1947 and 1975, and then followed until 1993.[3]

Other Research and Policy Findings

Is the Stomach Sensitive to Radiation?

– **Yes.** According to the National Research Council's BEIR V Committee, the stomach is sensitive to the cancer-causing effects of ionizing radiation.[8]

The National Research Council advises the U.S. government on scientific matters. Their Committee on Biological Effects of Exposure to Ionizing Radiations (BEIR) V reviewed sensitivity of parts of the body to radiation. Their findings are based mostly on studies of cancer among atomic bomb survivors, as well as on some of the available information on the biology of the body, animal studies, and other evidence. The greatest risk is at high exposure levels.

Is Stomach Cancer a "Specified" Cancer Under the Energy Employees Occupational Illness Compensation Program Act (EEOICPA)?

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* *Findings were statistically significant (strong evidence)*

\+ *Evidence of a dose-response relationship (strongest evidence)*

– **Yes.** Stomach cancer is a "specified" cancer under the EEOICPA consideration of Special Exposure Cohorts.

Policy makers have identified certain types of cancer among energy employees at nuclear facilities, including those employed at Los Alamos National Laboratory, as being potentially related to occupational exposures under the EEOICPA.

What Are Other Risk Factors for Stomach Cancer?

In considering the risks of occupational exposure to ionizing radiation, it is important to understand other risk factors. Below is a list of other possible risk factors for stomach cancer.

– **Tobacco.** Smoking is believed to be a "minor" cause of stomach cancer; [41] "to a limited degree."[42]
– **Diet.** Salted, pickled and smoked foods are among additional risk factors.
– **Other Work Exposures.** Asbestos and certain other dusts and fumes in the workplace have been linked to a higher than average risk of stomach cancer

These factors may add to any risk due to workplace exposure to ionizing radiation. Stomach cancer affects men twice as often as women, and is more common in black people than in white people. Also, stomach cancer is more common in some parts of the world -- such as Japan, Korea, parts of Eastern Europe, and Latin America -- than in the United States.

Nine counties in New Mexico have big deposits of uranium. These include Rio Arriba, Taos, Santa Fe, Sandoval, and Mora counties. Some scientists think that this may contribute to higher rates of stomach cancer in these counties.[3]

[3] Wilkinson GS. Gastric cancer in New Mexico counties with significant deposits of uranium. Archives of Environmental Health 1985;40(6):307-.

What Makes Stomach Cancer and Radiation Exposure Difficult to Study?

There are difficulties in all human studies because one cannot precisely determine all exposures and track all individual outcomes. In cancer this is especially the case as the cancer may take many years to develop to the point of diagnosis and possible death (disease latency). It is particularly difficult to diagnose stomach cancer until late stages.

Rates of Stomach Cancer In Exposed Counties

Los Alamos County

There have been very low rates of stomach cancer reported in Los Alamos County for both stomach cancer incidence and mortality.

- Los Alamos County ranked 27th in stomach cancer incidence and very low in mortality from 1970 to 1996 of the 33 counties in New Mexico.[13]
- In recent years, about one new case of stomach cancer has been diagnosed each year in Los Alamos County.[13, 33] Most of the cases are in men. [14]

Rio Arriba County

Rates of stomach cancer reported in Rio Arriba County have been very high for both stomach cancer incidence and mortality. These higher rates may be due to chance differences in area rates.

- Rio Arriba County ranked 4th highest in stomach cancer incidence from 1970 to 1996 of the 33 counties in New Mexico.[33]
- Rio Arriba County ranked highest in stomach cancer mortality from 1970 to 1996 of the 33 counties in New Mexico. [33]

Rio Arriba County's ranking for stomach cancer mortality is worse than its ranking for stomach cancer incidence. This means that the rates of diagnosis and treatment may be low relative to the number who actually have the disease. More work needs to be done to detect and treat stomach cancer early.

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* *Findings were statistically significant (strong evidence)*

+ *Evidence of a dose-response relationship (strongest evidence)*

Testicular Cancer and Exposure to Ionizing Radiation

Summary: Evidence varies on whether there may be an connection between testicular cancer and exposure to ionizing radiation. This connection is supported by some evidence from studies of nuclear workers in England who have been exposed to ionizing radiation. The National Research Council's, on the other hand, has determined that the testis are relatively insensitive to ionizing radiation. Testicular cancer is not designated as a "specified" cancer under the Energy Employees Occupational Illness Compensation Program Act. Historically, testicular cancer incidence has been very high for Los Alamos County while mortality was very low compared to other counties. Incidence in Rio Arriba County was in the top third of New Mexico county rates.

What is Testicular Cancer?

Testicular cancer is a disease in which cells become cancerous in one or both testicles. The testicles (also called testes or gonads) are a pair of male sex glands. They produce and store sperm, and are also the body's main source of male hormones. (National Cancer Institute)

Findings of Human Health Research Studies

Human health research studies compare the patterns of disease among groups of people with different amounts of exposure to a suspected risk factor. Below are results reported from such studies of testicular cancer among people exposed to ionizing radiation.

These studies found increases and possible increases in testicular cancer among certain groups of exposed individuals, in some cases followed over time. Statistically significant is a term used to mean that the connection between the health outcome and the exposure was strong enough that it was unlikely to be due to chance. An asterisk (*) was placed by statistically significant findings. The research included incidence studies, which look at new cases of cancer. These can track health more quickly and accurately than mortality studies of deaths due to cancer. Adding to the strength of the findings is that increasing rates of testicular cancer were observed with higher doses in some studies.

Studies of Los Alamos National Laboratory (LANL) Workers

Research conducted of LANL workers provides the most direct evidence about possible relationships between a health problem and workplace exposures at LANL.

– **UC & Zia Employees:** A possible increased incidence of testicular cancer was found in Anglo males employed for at least one year between 1969 and 1978. This finding was just based on three cases.[16]

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* *Findings were statistically significant (strong evidence)*

+ *Evidence of a dose-response relationship (strongest evidence)*

Studies of Other Nuclear Workers in the United States

The next most relevant evidence comes from studies of workers in similar occupations with the same types of exposures. Listed below are studies that looked at testicular cancer and workplace exposures among nuclear workers in other parts of the United States.

- **Lawrence Livermore, California:** A possible increased incidence of testicular cancer was found in men employed between 1969 and 1980. [22]

- **U.S. Transuranics Registry:** Plutonium is retained in the testis longer than in other soft tissues. [78]

Studies of Other Nuclear Workers World-Wide

Below are studies of nuclear workers outside of the United States that looked at testicular cancer in connection with radiation exposures.

- **Nuclear Workers in England:** Increase in deaths due to cancer of the testis was found in a study of 40,761 men who were ever monitored for tritium.[29] *

- **Atomic Energy Authority of the U.K.:** A possible increase in deaths from cancer of the testis was found in a study of men who were employed between 1946 and 1979, and then followed through 1986. Most of the cases accounting for the excess occurred at the Harwell facility. [6]

- **Canadian Radiation Workers:** Increasing incidence of cancer of the testis was seen with increasing doses of radiation in a study of 95,643 men exposed between 1951 and 1988.[*+] The researchers who conducted the study wrote "the result needs to be interpreted with caution."[47]

Studies of Other Ionizing Radiation Exposures

Studies among other groups of people who were not nuclear workers can also be significant as evidence of possible increases in testicular cancer among those who have been exposed to ionizing radiation. Most other research has been conducted of people exposed to atomic bombs.

- **Atomic Bomb Survivors:** In studies performed to date, there is no reported evidence of increased rates of testicular cancer in A-bomb survivors.

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* *Findings were statistically significant (strong evidence)*

\+ *Evidence of a dose-response relationship (strongest evidence)*

Other Research and Policy Findings

Is the Testis Sensitive to Radiation?

- According to the National Research Council's BEIR V committee, "the human testis is relatively insensitive to the carcinogenic effects of radiation."[9]

The National Research Council advises the U.S. government on scientific matters. Their Committee on Biological Effects of Exposure to Ionizing Radiations (BEIR) V reviewed sensitivity of parts of the body to radiation. Their findings are based mostly on studies of cancer among atomic bomb survivors, as well as on some of the available information on the biology of the body, animal studies, and other evidence. The greatest risk is at high exposure levels.

Is Testicular Cancer a "Specified" Cancer Under the Energy Employees Occupational Illness Compensation Program Act (EEOICPA)?

- **No.** Testicular cancer is not a "specified" cancer under the EEOICPA consideration of Special Exposure Cohorts.

Policy makers have identified certain types of cancer among energy employees at nuclear facilities, including those employed at Los Alamos National Laboratory, as being potentially related to occupational exposures under the EEOICPA.

What Are Other Risk Factors for Testicular Cancer?

In considering the risks of occupational exposure to ionizing radiation, it is important to understand other risk factors. Below is a list of other possible risk factors for testicular cancer.

- **Development of the testis.** Men who have had a testicle that did not move down into the scrotum are at greater risk for developing the disease. This is true even if surgery is performed place the testicle in the scrotum
- **Genetics.** Men with Klinefelter's syndrome (a sex chromosome disorder that may be characterized by low levels of male hormones, sterility, breast enlargement, and small testes) are at greater risk of developing testicular cancer.
- **Cancer history.** Men who have a history of testicular cancer are at increased risk of redeveloping the cancer

These factors may add to any risk due to workplace exposure to ionizing radiation. Smoking is not related to testicular cancer.

Rates of Testicular Cancer in Exposed Counties

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* *Findings were statistically significant (strong evidence)*

+ *Evidence of a dose-response relationship (strongest evidence)*

Los Alamos County

Rates of testicular cancer incidence was very high in Los Alamos County, while mortality was very low. Los Alamos County:

- Ranked highest in the incidence of testicular cancer among the 33 counties in New Mexico from 1970 to 1996.
- There were no deaths due to testicular cancer, however. This is evidence of earlier detection and successful treatment of testicular cancer in Los Alamos County, compared to other counties in New Mexico.
- In recent years, about one to two cases have occurred annually in the county.[14, 78] There was a consistent increase in incidence between 1984 and 1997.[79]

Rio Arriba County

Rates of testicular cancer incidence for Rio Arriba County were in the top third of counties. The county:

- Ranked 10th highest in incidence among the 33 counties in New Mexico from 1970 to 1996.
- During this time, there were three deaths due to testicular cancer.[33]

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Thyroid Cancer and other Thyroid Diseases and Exposure to Ionizing Radiation

Summary: Strong evidence has been recorded of a possible connection between thyroid cancer and exposure to ionizing radiation. This evidence is based upon studies conducted at Los Alamos National Laboratory, studies of nuclear workers at other sites, and others exposed to ionizing radiation. These findings are consistent with the National Research Council's determination that the thyroid is sensitive to ionizing radiation. Thyroid cancer is designated as a "specified" cancer under the Energy Employees Occupational Illness Compensation Program Act. Historically, thyroid cancer incidence for both Los Alamos County and Rio Arriba County are very high in comparison to other counties in New Mexico. Mortality rates for both counties were very low. Incidence means new cases of cancer, while mortality means deaths due to cancer.

What is Thyroid Cancer?

The thyroid is a gland in the neck. The thyroid lies at the front of the neck, beneath the voice box (larynx). It has two parts, or lobes. A healthy thyroid is a little larger than a quarter and usually cannot be felt through the skin. A swollen lobe might look or feel like a lump, or nodule, in the front of the neck. Most thyroid nodules are benign, which means they are not cancerous. (National Cancer Institute)

Findings of Human Health Research Studies

Human health research studies compare the patterns of disease among groups of people with different amounts of exposure to a suspected risk factor. Below are results reported from such studies of thyroid cancer among people exposed to ionizing radiation.

All of these studies found increases and possible increases in thyroid cancer among certain groups of exposed workers. Statistically significant is a term used to mean that the connection between the health outcome and the exposure was strong enough that it was unlikely to be due to chance. An asterisk (*) was placed by statistically significant findings. Most studies of nuclear workers in the U.S. were mortality studies of cancer deaths. Incidence studies, which look at new cases of cancer, can track health more quickly and accurately. Thyroid cancer seldom results in death. It spreads slowly, if at all. And it is easily detected, especially in nuclear workers who are medically screened on a regular basis. So it is not surprising that the few positive studies are those in which the incidence of the disease was studied.

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* *Findings were statistically significant (strong evidence)*

\+ *Evidence of a dose-response relationship (strongest evidence)*

Studies of Los Alamos National Laboratory (LANL) Workers

Research conducted of LANL workers provides the most direct evidence about possible relationships between a health problem and workplace exposures at LANL.

- **UC & Zia Employees:** A possible increased incidence of thyroid cancer was found in Anglo females employed between 1969 and 1978. But this finding was based on just two cases.[16]

- **State of New Mexico Study:** From 1998 to 1995 the incidence of thyroid cancer in Los Alamos County as a whole was four times higher than state or national rates.* About 30 cases of thyroid cancer accounted for the increase. Only 12 had ever worked at LANL.[79] This raised the possibility of a community-wide exposure. Centers for Disease Control's Historical Documents Discovery Project may shed light on past emissions of radioactive materials from LANL that could have caused the increase.

Studies of Other Nuclear Workers in the United States

The next most relevant evidence comes from studies of workers in similar occupations with the same types of exposures. Listed below are studies that looked at thyroid cancer and workplace exposures among nuclear workers in other parts of the United States.

- **Lawrence Livermore, California:** Possible increased incidence of thyroid cancer in males employed between 1969 and 1980. But based on just three cases.[22]

- **Atomic Weapons Establishment of the U.K.:** A possible increase in thyroid cancer deaths was observed in a study of 9,389 workers with a radiation record who were employed between 1951 and 1982.[53]

- **Canadian Radiation Workers:** Increased incidence of thyroid cancer was found in a study of 191,333 workers employed between 1951 and 1988.[47*]

- **Sellafield, England:** Increased thyroid cancer deaths were observed in non-plutonium radiation workers who were employed between 1947 and 1975, and then followed through 1992.* Also observed was increased incidence of thyroid cancer in non-plutonium radiation workers.[3*]

- **Registry of Nuclear Workers in the U.K.:** Increased thyroid cancer deaths were found in a study of more than 95,000 radiation workers.[5*]

- **Three Nuclear Workforces in the U.K.:** Possible increased thyroid cancer deaths were seen in a study of 75,006 workers who were exposed to external radiation while employed between 1946 and 1983, and then were followed through 1988,when compared to unexposed workers.[80]

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* *Findings were statistically significant (strong evidence)*

+ *Evidence of a dose-response relationship (strongest evidence)*

Studies of Other Ionizing Radiation Exposures

Studies among other groups of people who were not nuclear workers can also be significant as evidence of possible increases in thyroid cancer among those who have been exposed to ionizing radiation. Most other research has been conducted of people exposed to atomic bombs.

- **Atomic Bomb Survivors:** With increasing doses of radiation the rates of thyroid cancer[81, 82] and benign nodules[83] increase in incidence in A-bomb survivors.[*+] Also, increased rates of autoimmune thyroid disease. [84 *]

Is the Thyroid Sensitive to Radiation?

- According to the National Research Council's BEIR V committee, "[t]hyroid cancer is well established as a late consequence of exposure to ionizing radiation from both external and internal sources..."[9]

The National Research Council advises the U.S. government on scientific matters. Their Committee on Biological Effects of Exposure to Ionizing Radiations (BEIR) V reviewed sensitivity of parts of the body to radiation. Their findings are based mostly on studies of cancer among atomic bomb survivors, as well as on some of the available information on the biology of the body, animal studies, and other evidence. The greatest risk is at high exposure levels.

Is Thyroid Cancer a "Specified" Cancer Under the Energy Employees Occupational Illness Compensation Program Act (EEOICPA)?

- **Yes.** Thyroid cancer is a "specified" cancer under the EEOICPA consideration of Special Exposure Cohorts.

Policy makers have identified certain types of cancer among energy employees at nuclear facilities, including those employed at Los Alamos National Laboratory, as being potentially related to occupational exposures under the EEOICPA.

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* *Findings were statistically significant (strong evidence)*

\+ *Evidence of a dose-response relationship (strongest evidence)*

Rates of Thyroid Cancer in Exposed Counties

Los Alamos County

Rates of thyroid cancer incidence was very high in Los Alamos County, while mortality was very low. Los Alamos County:

- Ranked highest in incidence from 1970 to 1996 in the 33 counties in New Mexico.
- Mortality due to thyroid cancer was very low in the county. [33]

Rio Arriba County

Rates of thyroid cancer incidence for Rio Arriba County was very high, while mortality was very low. The county:

- Ranked 5th highest in incidence from 1970 to 1996 among the 33 counties in New Mexico.
- Mortality due to thyroid cancer was very low in the county. [33]

The low mortality rates are evidence of earlier detection and successful treatment of thyroid cancer in these counties.

Information Resources:

For more information on these types of cancer and risk factors, telephone the Cancer Hotline: Telephone: 1-800-4 CANCER, by Internet: (www.cancer.gov/cancerinfo).

The U.S. Environmental Protection Agency has useful information on Understanding Radiation. (www.epa.gov/radiation/understand/protection_basics.htm)

The Los Alamos National Laboratory Community Relations contact can be reached at 1-888-841-8256 or by Internet (LANL.gov)

You can reach the Department of Energy's Office of Environment, Safety and Health Through their Helpline at 800-473-4375 or on the Internet at: (tis.eh.doe.gov/portal/home.htm)

Information from the Department of Labor on the ENERGY EMPLOYEES OCCUPATIONAL ILLNESS COMPENSATION PROGRAM ACT OF 2000
Toll free phone: 1-866-4-USA-DOL
Internet: (www.dol.gov/esa/regs/compliance/owcp/eeoicp/law/EEOICPA%20ALLamends.htm)

The following contact information is for a local advocacy organization engaged in this project: El Rio Arriba Environmental Health Association, PO Box 1699, Santa Cruz, NM 87567, 505-412-0746

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