JSI **Center for Environmental Health Studies** (617) 482-9485
44 Farnsworth Street, Boston, MA 02210 http://www.jsi.com

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)

---

* *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]

---

* *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. [*]

---

* *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 *+]

---

* *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.

---

* *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]

---

* *Findings were statistically significant (strong evidence)*

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