No Excess Mortality Risk Found in Counties with Nuclear Facilities

A National Cancer Institute (NCI) survey published in the *Journal of the American Medical Association*, March 20, 1991, showed no general increased risk of death from cancer for people living in 107 U.S. counties containing or closely adjacent to 62 nuclear facilities. The facilities in the survey had all begun operation before 1982. Included were 52 commercial nuclear power plants, nine Department of Energy research and weapons plants, and one commercial fuel reprocessing plant. The survey examined deaths from 16 types of cancer, including leukemia. In the counties with nuclear facilities, cancer death rates before and after the startup of the facilities were compared with cancer rates in 292 similar counties without nuclear facilities (control counties).

The NCI survey showed that, in comparison with the control counties, some of the study counties had higher rates of certain cancers and some had lower rates, either before or after the facilities came into service. None of the differences that were observed could be linked with the presence of nuclear facilities. "From the data at hand, there was no convincing evidence of any increased risk of death from any of the cancers we surveyed due to living near nuclear facilities," said John Boice, Sc.D., who was chief of NCI's Radiation Epidemiology Branch at the time of the survey.

He cautioned, however, that the counties may be too large to detect risks present only in limited areas around the plants. "No study can prove the absence of an effect," said Dr. Boice, "but if any excess cancer risk due to radiation pollution is present in counties with nuclear facilities, the risk is too small to be detected by the methods used."

The survey, conducted by Seymour Jabon, Zdenek Hrubec, Sc.D., B.J. Stone, Ph.D., and Dr. Boice, was begun in 1987 for scientific purposes in response to American public health concerns, and after a British survey of cancer mortality in areas around nuclear installations in the United Kingdom showed an excess of childhood leukemia deaths near some facilities.[1] No increases in total cancer mortality were found in the British study, and other smaller surveys of cancer deaths around nuclear facilities in the United States and the United Kingdom have yielded conflicting results.

The NCI scientists studied more than 900,000 cancer deaths in the study counties using county mortality records collected from 1950 to 1984. The researchers evaluated changes in mortality rates for 16 types of cancer in these counties from 1950 until each facility began operation and from the start of operation until 1984. For four facilities in two states (Iowa and Connecticut), cancer incidence data were also available. Data on cancer incidence in these counties resembled the county's mortality data patterns.

For each of the 107 study counties, three counties that had populations similar in income, education, and other socioeconomic factors, but did not have or were not near nuclear facilities, were chosen for comparison. The study and control counties were within the same geographic region and usually within the same state. Over 1.8 million cancer deaths were studied in the control counties.

[1] "Cancer Near Nuclear Installations," David Forman, Paula Cook-Mozaffari, Sarah Darby, et al. *Nature*, October 8, 1987.

The numbers of cancer deaths in the study counties and in the control counties were analyzed and compared to determine the relative risk (RR) of dying of cancer for persons living near a nuclear facility. A relative risk of 1.00 means that the risk of dying of cancer was the same in the study and control counties; any number below 1.00 indicates that the overall risk was lower in the study county than in the control county; and any number greater than 1.00 indicates a higher risk in the study county. For example, an RR of 1.04 would indicate that there was a 4 percent higher risk of cancer death in the study county. Conversely, an RR of 0.93 would indicate a 7 percent lower risk in the study county.

For childhood leukemia in children from birth through age 9 years, the overall RR comparing study and control counties before the startup of the nuclear facilities was 1.08; after startup the RR was 1.03. These data indicate that the risk of childhood leukemia in the study counties was slightly greater before startup of the nuclear facilities than after. The risk of dying of childhood cancers other than leukemia increased slightly from an RR of 0.94 before the plants began operation to an RR of 0.99 after the plants began operating.

For leukemia at all ages, the RRs were 1.02 before startup and 0.98 after startup. For other cancer at all ages, the RRs were essentially the same: 1.00 before startup and 1.01 after startup. These results provide no evidence that the presence of nuclear facilities influenced cancer death rates in the study counties.

Questions and Answers

National Cancer Institute (NCI) Survey
Cancer Mortality in Populations Living Near Nuclear Facilities

1. Which nuclear facilities were included in the survey?

Only major nuclear facilities that are or once were in operation and went into service before 1982 were included in the survey. All 52 commercial nuclear power facilities in the United States that started before 1982 were included. A facility may include more than one reactor.

In addition to the commercial nuclear power facilities, nine U.S. Department of Energy (DOE) nuclear installations and one commercial fuel reprocessing plant were included. These facilities do not generate electrical power for commercial use.

Facilities such as small research reactors at universities were not included. See the Appendix for a complete list of facilities.

2. Why were the DOE facilities included?

In the British study that helped to prompt this survey, an excess of childhood leukemias was found mainly around nuclear installations that were involved in the enrichment, fabrication, and reprocessing of nuclear fuel or research and development of nuclear weapons. The DOE facilities included in the study are similar to these British facilities.

Also, some DOE installations have been operating since 1943, which is longer than any commercial nuclear power plant in the United States. The first commercial nuclear power plant began operation in 1957.

The DOE facilities were evaluated both as part of the total group of nuclear facilities and separately.

3. Which counties were included in the survey?

All counties with a major nuclear facility that is or once was in operation and went into service before 1982 were included in the survey as study counties. Other adjacent counties that contain one-fifth of the land that lies within a 10-mile radius of these facilities were also included as study counties. In total, 107 counties were identified as study counties. See the Appendix for a complete list.

For each study county, three control counties within the same geographic region that do not have or are not near nuclear facilities were identified for comparison. Control counties

were chosen that were the most similar to study counties based on population size and socioeconomic characteristics such as race and income.

4. What were the 16 types of cancer surveyed?

The following 16 types of cancer were surveyed: leukemia; all cancers other than leukemia (as a group); Hodgkin lymphoma; lymphomas other than Hodgkin lymphoma; multiple myeloma; cancers of the digestive organs (as a group and separately), including cancer of the stomach, colon and rectum, and liver; cancer of the trachea, bronchus, and lung; female breast cancer; thyroid cancer; cancer of the bone and joints; bladder cancer; brain and other central nervous system cancer; and other benign or unspecified tumors.

5. Why was childhood leukemia a special focus of the analysis?

The excess risk identified in the British study pertained to leukemia deaths among persons under the age of 25. Leukemia is one of the major cancers induced by high doses of radiation and may occur as soon as 2 years after exposure. Other cancers associated with high-dose radiation may not develop until 10 years after exposure.

Studies have also suggested that children are more sensitive to the cancer-producing effects of radiation than adults. Children may spend more time in and around the home than parents, whose jobs may take them to other areas. They are also more likely to come in close contact with the soil, upon which radioactive releases may have been deposited following discharges from the facilities.

6. Why were cancer deaths (mortality) compared instead of the number of cancer cases that occurred (incidence)?

Although data on cancer incidence (the number of newly diagnosed cases in a given period of time) could provide a more complete evaluation of the possible impact of living near nuclear facilities, cancer incidence data for the entire Nation do not exist. The reporting of county mortality data by state provides nationwide data that can show important geographic and time-related patterns of cancer. In past NCI studies, mortality data have proven useful in developing clues about the causes of cancer and in targeting areas for future research.

Cancer incidence data were available in two states (Iowa and Connecticut) for four facilities. The cancer registries that provided this information were among those that participate in the NCI Surveillance, Epidemiology, and End Results Program and are of high quality. Survey results using cancer incidence data resembled results using cancer mortality data.

7. Did any individual county or plant have an excess risk of cancer death?

Overall, the risks for childhood leukemia, adult leukemia, and all cancers were about the same in the counties with nuclear installations as in the control counties. The areas around some facilities appeared to have higher risks of leukemia while others had lower risks.

Generally, however, the differences are not large and are consistent with the random variations seen when making many comparisons based on geographic data.

The county surrounding the Millstone Power Plant located in New London, Connecticut, had a significant excess of cases of leukemia in children under 10 years of age (shown in incidence statistics) in comparison to its control counties. The RR was 3.04 after startup of the facility. Upon review, the excess risk shown using incidence data arose partly from comparison with significantly low cancer rates in the control counties rather than from a high rate in the study county.

No other excesses of childhood leukemia were found that could be linked to any of the nuclear facilities. Further, three facilities—San Onofre in Orange County and San Diego County, California; Quad Cities in Rock Island County and Whiteside County, Illinois; and Vermont Yankee in Windham County, Vermont—were marked by significant deficits in the RR for leukemia death at ages 10 to 19 years. The RRs were 0.75, 0.24, and 0.09, respectively.

8. Is it possible that "chance" could explain some of the high or low relative risks observed in the survey?

Due to the large scope of the study and the many comparisons made, it could be expected that a number of "statistically significant" increased or decreased RRs would be observed due to chance alone. Further, significant variations in rates might also result from underlying differences in other cancer risk factors that have nothing to do with the presence of nuclear facilities. The prevalence of important risk factors, such as cigarette smoking and diet, might be the cause of many of the observed differences in cancer rates between study and control counties. As expected, comparisons of cancer rates in study and control counties showed substantial variation, but there was no general tendency for cancer rates to be higher after nuclear facilities began operating than before operation began.

9. Did the counties with DOE facilities, individually or as a group, have an increased risk of cancer for the surrounding counties?

The findings for the DOE facilities were similar to those for the electricity-generating plants. There was no overall suggestion of cancer excesses that could be attributed to the presence of the DOE nuclear facilities. The lone commercial fuel reprocessing plant was included in the overall evaluation of DOE facilities.

For these counties, the RRs for childhood leukemia (ages birth to 9 years) were 1.45 before the facilities began operation and 1.06 after opening. For all other childhood cancers, the RRs were 1.06 and 0.95 before and after operation began, respectively. For leukemia at all ages, the RRs were 1.07 before startup and 0.96 after startup. For other cancer at all ages, the RRs were essentially the same, 1.06 before startup and 1.04 after startup.

10. Why was the study based on the county as the geographic unit?

The data for a study based on counties were readily available for the entire United States. The NCI and the U.S. Environmental Protection Agency have prepared detailed data on cancer mortality by county since 1950. Population data, which are needed to calculate cancer rates, are also available by county. Thus, the county was the smallest geographic unit for which nationwide data could be quickly evaluated.

11. Have similar county-based studies been valuable in the past?

Yes, surveys using methods that analyze county mortality patterns have been used effectively several times by NCI. Based on findings from NCI "cancer maps" constructed from county mortality statistics, a clustering of lung cancer deaths was seen among residents of counties along the southern Atlantic coast. Across the United States, counties with shipyard industries were found to have elevated rates of lung cancer deaths, particularly in men. Subsequent indepth studies of the high-risk areas linked the excess lung cancer deaths to asbestos and cigarette smoke exposure in shipyards, especially during World War II.

In another study, mortality rates from lung cancer were found to be elevated among men and women living in counties with smelters and refineries that emitted arsenic. A previous NCI study had shown arsenic to cause lung cancer in smelter workers who were heavily exposed to the substance. Further analytical study of counties with smelters showed an elevated risk of lung cancer associated with residential exposure to arsenic released by smelters into the local environment.

The county mortality surveys are often considered a first step toward directing future research efforts. These surveys also have their limitations. The county may be too large to detect risks present only in limited areas, death certificates are sometimes not accurate regarding the actual cause of death, and exposures to individuals are unknown.

12. Would a study based on smaller geographic units be feasible?

Mortality and population data are not available on a national basis for areas smaller than counties. The data required for studies of small areas, such as cities or neighborhoods, are collected at the state or local level when they are available.

Using the existing county mortality data, the survey took 3 years to complete. A national survey using data for areas smaller than counties would take much longer.

13. Were the study design and results reviewed?

In addition to internal review, the design of the study was evaluated by an expert team of scientists from outside the U.S. Government who also reviewed the entire intramural research program of the Radiation Epidemiology Branch in the Division of Cancer Etiology (DCE), NCI.

Because of the importance of clarifying any potential health hazards associated with living near nuclear facilities, a special advisory group was also established to help evaluate the study results. The advisory group consisted of selected members of DCE's Board of Scientific Counselors as well as other scientists from outside the U.S. Government with expertise in radiation epidemiology.

14. What levels of radiation might be expected from the normal operation of most of the nuclear facilities studied?

Reported radioactive releases from monitored emissions of nuclear facilities in the United States show very low radiation exposure to the surrounding populations. Maximum individual radiation doses from these plants are reported to be less than 5 millirem annually, or less than 5 percent of what is received annually from natural background sources of radiation, such as cosmic rays and radon. Levels this low are believed to be too small to result in detectable harm. However, there have been high releases of radioactive emissions from some facilities, such as the Hanford facility (Benton, Franklin, and Grant Counties, Washington).

It is important to distinguish between a major release of radioactivity from a reactor accident, such as the accident at Chernobyl in the former Soviet Union, and the small amounts of radiation that are likely to be emitted by nuclear facilities under normal operation.

15. Will there be more research on the possible hazards of living near nuclear facilities?

The NCI county mortality survey is only the initial step in evaluating the possible hazards of living near nuclear facilities. The study provides background information that will complement that from other studies being conducted or planned by the Centers for Disease Control and Prevention, various state health departments, and other groups. Information gained from this survey and other ongoing projects will guide future research efforts.

In its consensus statement, the ad hoc advisory committee that reviewed and evaluated this study has also recommended areas for further research.

The complete three-volume report titled *Cancer in Populations Living Near Nuclear Facilities* can be ordered from the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402-9325. The GPO stock number is 017-042-00276-1.

Appendix
Facilities and Counties Included in the Study

State	County	Study Facility	Year of Startup
Alabama	Houston	Farley	1977
	Lawrence	Browns Ferry	1973
	Limestone	Browns Ferry	1973
Arkansas	Pope	Arkansas	1974
California	Amador	Rancho Seco	1974
	Humboldt	Humboldt Bay	1963
	Orange	San Onofre	1967
	Sacramento	Rancho Seco	1974
	San Diego	San Onofre	1967
	San Joaquin	Rancho Seco	1974
Colorado	Boulder	Fort St. Vrain	1976
		*Rocky Flats	1953
	Jefferson	*Rocky Flats	1953
	Larimer	Fort St. Vrain	1976
	Weld	Fort St. Vrain	1976
Connecticut	Middlesex	Haddam Neck	1967
	New London	Millstone	1970
Delaware	New Castle	Salem	1976
Florida	Citrus	Crystal River	1977
	Dade	Turkey Point	1972
	St. Lucie	St. Lucie	1976
Georgia	Appling	Hatch	1974
	Burke	*Savannah River	1950
	Early	Farley	1977
	Toombs	Hatch	1974
Idaho	Bingham	*Idaho National Engineering Lab.	1949
	Butte	*Idaho National Engineering Lab.	1949
	Jefferson	*Idaho National Engineering Lab.	1949

Illinois	Grundy Lake Rock Island Whiteside Will	Dresden Zion Quad Cities Quad Cities Dresden	1960 1972 1972 1972 1960
Iowa	Benton Harrison Linn	Duane Arnold Fort Calhoun Duan Arnold	1974 1973 1974
Kentucky	Ballard McCracken	*Paducah Gas. Diff. *Paducah Gas. Diff.	1950 1950
Maine	Lincoln Sagadahoc	Maine Yankee Maine Yankee	1972 1972
Maryland	Calvert	Calvert Cliffs	1974
Massachusetts	Berkshire Franklin Plymouth	Yankee Rowe Vermont Yankee Yankee Rowe Pilgrim	1960 1972 1960 1972
Michigan	Berrien Charlevoix Emmet Monroe Vanburen	Cook Big Rock Point Big Rock Point Fermi Palisades	1975 1962 1962 1963 1971
Minnesota	Goodhue Sherburne Wright	Prairie Island Monticello Monticello	1973 1971 1971
Missouri	Atchinson	Cooper Station	1974
Nebraska	Gage Lancaster Nemaha Richardson Washington	Hallam Hallam Cooper Station Cooper Station Fort Calhoun	1962 1962 1974 1974 1973
New Hampshire	Chesire	Vermont Yankee	1972
New Jersey	Ocean Salem	Oyster Creek Salem	1969 1976

New York	Cattaraugus	**Nuclear Fuel Services	1966
	Oswego	Nine Mile Point/ Fitzpatrick	1969
	Rockland	Indian Point	1962
	Wayne	Ginna	1969
	Westchester	Indian Point	1962
North Carolina	Brunswick	Brunswick	1975
	Gaston	McGuire	1981
	Lincoln	McGuire	1981
	Mecklenburg	McGuire	1981
Ohio	Butler	*Fernald	1951
		*Mound	1947
	Hamilton	*Fernald	1951
	Montgomery	*Mound	1947
	Ottawa	Davis Besse	1977
	Pike	*Portsmouth Gaseous Diffusion	1952
	Warren	*Mound	1947
Oregon	Columbia	Trojan	1975
Pennsylvania	Beaver	Shippingport/Beaver Valley	1957
	Dauphin	Three Mile Island	1974
	Lancaster	Peach Bottom	1974
		Three Mile Island	1974
	York	Peach Bottom	1974
		Three Mile Island	1974
South Carolina	Aiken	*Savannah River	1950
	Barnwell	*Savannah River	1950
	Chesterfield	Robinson	1970
	Darlington	Robinson	1970
	Oconee	Oconee	1973
	Pickens	Oconee	1973
South Dakota	Lincoln	Pathfinder	1964
	Minnehaha	Pathfinder	1964
Tennessee	Anderson	*Oak Ridge	1943
	Hamilton	Sequoyah	1980
	Roane	*Oak Ridge	1943

Virginia	Caroline Hanover Isle of Wight Louisa Surry	North Anna North Anna Surry North Anna Surry	1978 1978 1972 1978 1972
Vermont	Windham	Vermont Yankee	1972
Washington	Benton Cowlitz Franklin Grant	*Hanford Trojan *Hanford *Hanford	1943 1975 1943 1943
Wisconsin	Kenosha Kewaunee Manitowoc Pierce Vernon	Zion Kewaunee Point Beach Kewaunee Point Beach Prairie Island La Crosse (Genoa)	1972 1973 1970 1973 1970 1973 1967
West Virginia	Hancock	Shippingport/Beaver Valley	1957

*Department of Energy facility
**Commercial fuel reprocessing plant

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Related NCI materials and Web pages:

- National Cancer Institute Fact Sheet, *I–131 and Radioactive Fallout: Questions and Answers* (http://www.cancer.gov/cancertopics/factsheet/I131qa)
- Radioactive I–131 from Fallout Web Page (http://www.cancer.gov/i131)

For more help, contact:

NCI's Cancer Information Service
Telephone (toll-free): 1–800–4–CANCER (1–800–422–6237)
TTY (toll-free): 1–800–332–8615
LiveHelp® online chat: https://cissecure.nci.nih.gov/livehelp/welcome.asp

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