UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

Title: BRIEFING ON STUDIES OF CANCER IN POPULATIONS NEAR NUCLEAR FACILITIES, INCLUDING THREE MILE ISLAND

Location: ROCKVILLE, MARYLAND

Date: SEPTEMBER 28, 1990

Pages: 53 PAGES

NEAL R. GROSS AND CO., INC.

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BRIEFING ON STUDIES OF CANCER IN POPULATIONS NEAR NUCLEAR FACILITIES, INCLUDING THREE MILE ISLAND

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PUBLIC MEETING

Nuclear Regulatory Commission
One White Flint North
Rockville, Maryland

Friday, September 28, 1990

The Commission met in open session, pursuant to notice, at 2:00 p.m., James R. Curtiss, Commissioner, presiding.

COMMISSIONERS PRESENT:

KENNETH C. ROGERS, Commissioner
JAMES R. CURTISS, Commissioner
FORREST J. REMICK, Commissioner

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STAFF AND PRESENTERS SEATED AT THE COMMISSION TABLE:

SAMUEL J. CHILK, Secretary

JOE SCINTO, Office of the General Counsel

JOHN BOICE, JR., National Cancer Institute/NIH

SEYMOUR JABLON, National Cancer Institute/NIH

P-R-O-C-E-E-D-I-N-G-S

2:05 p.m.

COMMISSIONER CURTISS: Welcome.

Chairman Carr will not be with us this afternoon.

The Commission meets today to hear the results of the National Cancer Institute's recently completed study of cancer rates in the vicinity of nuclear facilities in the United States. This study, which represents an important contribution to an area that has generated a great deal of interest over the years, covers all commercial nuclear power plant sites that were operating before 1982, as well as nine Department of Energy sites and the West Valley site in New York. In view of the Commission's responsibility for the licensing and regulation of commercial nuclear power plants, we will be especially interested in your conclusions about these facilities.

Doctor Hatch of the Columbia University School of Public Health, who was to present the work undertaken on behalf of the TMI Public Health Fund, has had an unavoidable conflict this afternoon and accordingly will not be present today. In view of that, the results of her work, which is entitled "Cancer Near the Three Mile Island Nuclear Plant

Radiation Emissions," and which appeared in the September issue of *The American Journal of Epidemiology*, will be placed in the record of today's meeting.

Before we begin, do either of my fellow Commissioners have any comments?

If not, Doctors Boice and Jablon, we welcome you to the Commission and you may proceed.

DOCTOR BOICE: (Slide) May I have the first slide, please?

My name is John Boice and I'm Chief of the Radiation Epidemiology Branch at the National Cancer Institute, and Mr. Jablon is an expert within the Program, an expert in epidemiology and biostatistics, and he is the principal investigator for the study. And, as mentioned, we will be discussing this recently conducted study of cancer in populations living near nuclear facilities.

I'll start with a brief overview of the study and then Mr. Jablon will present the study design, methods and results, then I'll conclude briefly with the comments made from our oversight committee which monitor the progress of the investigation.

(Slide) The next slide.

The study was initiated in 1987 after reports from -- could I have the next slide, please?

COMMISSIONER CURTISS: Takes them a while there sometimes.

DOCTOR BOICE: Takes them a while, okay.

There we go. The study was started in 1987, after reports from the United Kingdom suggested elevated rates of childhood leukemia around certain nuclear installations. A protocol was developed and reviewed in 1988 and an advisory committee was established. The committee met three times and the report was published this month by the Government Printing Office.

(Slide) Next slide.

The advisory committee consisted of seven scientists outside the United States government and their charge was to provide overall guidance, to assist in the interpretation, and to suggest areas for further study. The members included Doctor Roswell Boutwell from the University of Wisconsin; Doctor Pelayo Correa from Louisiana State University; Doctor Clark Heath, Vice President for Epidemiology and Biostatistics at the American Cancer Society; Doctor Colin Muirhead, a member of the National Radiation Protection Board in England; Doctor Donald Pierce from

Oregon State University; Doctor Moyses Szklo, Johns Hopkins University; and Doctor Arthur Upton, New York University. Doctor Upton was also the Chairman of the recent National Academy of Sciences committee, the BEIR V Report, which published their findings on low level radiation effects earlier this year.

(Slide) Now, the next slide.

In 1987, the Office of Population Census' and Surveys in the United Kingdom published a comprehensive volume of cancer risk in the vicinity of their nuclear installations. They reported a significant excess of childhood leukemia around certain facilities, specifically defense and fuel reprocessing plants. In large part, this investigation prompted us to initiate a similar survey based on routinely collected vital statistics data in the United States. Our study of county death rates used similar methodology as that used in the United Kingdom.

(Slide) Could I have the next slide?

In the United Kingdom, the excess of childhood leukemia was particularly noted around the Sellafield Nuclear Fuel Reprocessing Plant shown here. There was little evidence of excess risk around the nuclear power plants that generated electricity. Most

recently, the Sellafield excess was suggested to be possibly related to occupational exposure of the fathers prior to conception.

(Slide) Could I have the next slide?

As Mr. Jablon will discuss in detail, our study includes nine Department of Energy facilities, one commercial reprocessing plant that was active in New York but eventually closed, and 52 commercial nuclear power plants that began operating prior to 1982.

(Slide) Could I have the next slide?

This map shows the distribution of study counties in blue and the control counties in yellow, which were selected for the analysis. There were 107 counties with or adjacent to nuclear installations, and 292 control counties. I think it is important to note that the methods used to study cancer deaths at the county level have been used effectively by the National Cancer Institute in the past.

(Slide) Next slide.

For example, this map is taken from our published cancer maps and displays levels of lung cancer deaths for each of the more than 3,000 counties in the United States. Red represents counties at highest risk. Although risk is seen to

vary across the United States, most remarkable are the high rates of lung cancer in counties along the South Atlantic and the Gulf Coasts. Subsequent studies link the excess rates to asbestos exposure in shipyards, particularly during World War II.

(Slide) The next slide.

In another survey, counties with non-ferrous smelters and refineries showed elevated rates of lung cancer deaths. Subsequent analytic studies linked the excess risk to residential exposure to arsenic released by smelters into the general environment. These examples are just to indicate that studies of cancer deaths at the county level, despite their limitations which we will discuss, they have been valuable in the past in identifying environmental factors responsible for some geographic patterns of cancer.

(Slide) Could I have the next slide?

Returning now to our survey around nuclear installations, the study once again includes the Department of Energy facilities such as this one at Hanford.

(Slide) And, the next slide, and 52 nuclear power stations, such as this one at Calvert Cliffs in Maryland.

(Slide) The next slide.

Now, just to give you a feeling for the numbers involved, there were 62 nuclear facilities in 107 of the counties in the United States. Approximately 19 million people live in or near to counties with nuclear facilities.

The number of cancer deaths from 1950 through 1984 was approximately 900,000. The cancer rates for 16 causes of death due to cancer were contrasted for the control counties, which were 292 control counties, which had a population of 33 million people based on the 1980 census, and 1.8 million cancer deaths occurred during this 35 year period. The average population --

COMMISSIONER REMICK: Excuse me, would you mind if I ask a question at this point or would you prefer --

DOCTOR BOICE: If it's for clarification. We do have a presentation.

COMMISSIONER REMICK: I was just wondering how you decided upon the control counties and the number, how that was decided.

DOCTOR BOICE: Mr. Jablon will present that in detail, so that you'll see that.

COMMISSIONER REMICK: Fine.

DOCTOR BOICE: Another interesting fact, I think, would be that the median population size for these counties was approximately 60,000 individuals.

(Slide) Could I have the next slide?

As mentioned, the results were published this month in three volumes, approximately 1,700 pages. We are also preparing an article for submission to a peer review journal at this time.

And now, Mr. Jablon will discuss the study design and the methods and the results in some detail.

DOCTOR JABLON: Thank you, John.

I may say that if you would like to interrupt me for a question at any time, please feel free to do so.

(Slide) May I have the first slide, please?

My presentation is divided into several sections.

First, why do a study?

What are the data that are available?

Which facilities and counties were studied?

How were control counties selected?

What's the form of analysis and the process of interpretation?

What was found for childhood leukemia or for other cancers?

What are the limitations and strengths of the study?

And what are the conclusions?

(Slide) May I have the next slide, please?

In 1983, Yorkshire TV broadcast a documentary indicating excessive mortality from leukemia among young persons who lived near the Sellafield Nuclear Fuel Reprocessing Plant in Cumberland. This aroused considerable interest and the Ministry of Health asked a committee chaired by Sir Douglas Black to investigate the situation. This shows the essence of what the Black Committee reported in the next year, 1984. There were only a few cases of leukemia in young persons, but the number was clearly excessive. There were eight cases, while only 2.3 would have been expected at national mortality rates, so there were 3.5 times as many deaths from leukemia as would have occurred had the leukemia rate been the same as in England and Wales. Other forms of cancer, however, were not increased.

In 1985, the government established a committee on the medical aspects of radiation in the

environment called COMARE to investigate further, and in 1986 the scope of the investigation was broadened when the Scottish authorities reported on the incidence of leukemia in the neighborhood of the Dounreay Reprocessing Plant, a facility that had much lower radiation emissions than Sellafield.

(Slide) May I have the next slide, please?

Near Dounreay there were only four cases of childhood leukemia, but the population is not large and at national rates less than half a case would be expected. The number of cases was nearly 12 times the number expected. These reports have stimulated a large number of studies of individual nuclear plants in Britain and the U.S.

(Slide) Next slide, please.

In particular, COMARE investigated the situation near the Aldermaston and Burghfield military weapons plants and found some increases in childhood cancer, not only leukemia but other forms of cancer also, unlike the situation around Sellafield where childhood leukemia mortality was increased but not deaths from other forms of cancer. The leukemia increase was, however, much smaller than at the two reprocessing plants.

The British Office of Population Census' and Surveys then published a massive study of populations near every nuclear facility in the United Kingdom and this stimulated the National Cancer Institute to mount a parallel study in the United States making use of the county data that were available, as Doctor Boice has told you.

(Slide) Next slide, please. What data are available? Next slide, please.

The data available included counts of the numbers of deaths each year in each county. Population data, which are needed to calculate rates, were also available.

(Slide) Next slide.

Although incidence data -- that is, the number of cases of disease diagnosed -- are very desirable for research purposes, they existed only for a few states and cities, while the mortality data were available for every county in the U.S. for each year from 1950 forward, classified by cause of death, age, sex, and race. Also, the findings in the U.K. had largely been based on mortality data.

(Slide) Next slide, please.

COMMISSIONER CURTISS: Just out of curiosity, is the incidence data collected at the

discretion of the states or why do we have it just for some limited states here?

DOCTOR JABLON: Well, it's largely at the discretion of the states. Some years ago, the National Cancer Institute organized a program called "Surveillance, Epidemiology, and End Results," or SEER for short, and there are now ten SEER registries in ten different states. Other states have started tumor registries also that are not part of the SEER program. Most of the registries now existent have started relatively recently, so it's not easy to do a long-term longitudinal study for those states. We could for two states, as we shall see.

COMMISSIONER CURTISS: If you could, just slide over in front of that mike so the people in the back can hear you. Just speak in the box there.

DOCTOR JABLON: Is this better?

COMMISSIONER CURTISS: They're hard to pick up.

DOCTOR JABLON: Okay.

COMMISSIONER CURTISS: Can you hear back there?

DOCTOR JABLON: I don't know which slide we're on now. Okay. Well, which facilities.

(Slide) May I have the next, please? No.

Back two. Well, all right.

Though incidence data -- that is, the number of cases of disease diagnosed -- are very desireable for research purposes, they existed only for a few states and cities while the mortality data were available for every county. Well, I guess we had gone through that.

Every nuclear generating plant in the United States that went into service before 1982 was included in the survey, in addition to nine facilities operated for the Department of Energy and one former commercial reprocessing plant. The DOE plants include reprocessing plants such as Hanford, and nuclear weapons manufacturing plants analogous to Aldermaston and Burghfield such as Rocky Flats, Fernald, and others. Sellafield and Dounreay are both reprocessing plants, so there was much interest in similar facilities in this country.

Besides the reprocessing plants and other Department of Energy facilities, 52 commercial nuclear electric plants are included in the survey. So, there's a total of 62 facilities. The nuclear electric plants have been treated in three groups.

(Slide) Next slide, please.

The early plants, those that went into

service before 1970, generally had much lower power levels than the later plants, but they have been active long enough that if their emissions or other characteristics were responsible for the induction of leukemia or other cancer, the increase might be detected in mortality data through 1984.

(Slide) Next slide, please.

Many more electric generating plants came into service in the years 1970 to 1974. The minimum time for the development of a radiation induced leukemia is thought to be about two years. So, if these plants are associated with excess deaths from leukemia, that fact might possibly be detected from mortality data through 1984. The elapsed time is rather short, however, for detection of other forms of radiation-induced cancer which generally take ten or more years to develop.

(Slide) Next slide, please.

The last group of facilities, those that started service in 1975 or later, conceivably could be associated with detectable deaths from leukemia, but other forms of cancer, if induced after plant start-up, would not be reflected in mortality data through 1984, since less than ten years would have elapsed since the earliest possible radiation exposure to the

neighboring population.

(Slide) Next slide, please.

There are 107 counties -- that is, counties that either contain or are adjacent to one of the facilities -- which account for 20 percent or more of the area within ten miles of the facility.

(Slide) Next slide, please.

Three control or comparison counties were chosen for each study county, attempting to match on several characteristics that are important for mortality rates. For purposes of analysis, data for all of the study counties for a particular facility were added together as were the data for the comparison counties to create study areas and corresponding comparison areas for that facility.

(Slide) Next slide.

Doctor Boice has shown you the totality of study and comparison areas as shown here, and it's plain that the counties in the West are often much larger than are the Eastern counties.

(Slide) Next slide.

How are the data presented and analyzed?

(Slide) Next slide, please.

The data are presented as the number of deaths, the expected number at concurrent rates for

the United States, and the ratio of the observed number to the expected number.

(Slide) Next slide, please.

Expected numbers of deaths were calculated taking account of age, sex, race, and year. Although age was considered in five year groups when expected values were calculated, for presentation the data have been combined into five age classes.

(Slide) Next slide, please.

One to 10, 10 to 19, and so forth, plus the all ages group.

(Slide) Next slide, please.

Standardized mortality ratios, or SMRs, are simply the ratios of the observed number of deaths to the number expected at U.S. death rates; while standardized registration ratios, called SRRs, refer to the numbers of cases of disease diagnosed rather than deaths caused. They measure by what percent the disease in question is increased or decreased over national or other standard rates.

(Slide) Next slide, please.

The relative risk or, briefly, the RR, measures the excess or deficit of a disease in one group compared with another. An RR of 1.0 shows that the amount of disease in the two groups is the same,

while an RR of 1.1, for example, would imply ten percent more disease in one group than in the other, while an RR of 0.9 would show ten percent less disease.

In this survey, we compare the frequency of disease in counties with nuclear facilities with the frequency in control counties and compare the amount of disease before a facility went into service with the amount afterwards. All relative risks, when the numbers were large enough to sustain the calculation, were tested for what's called "statistical significance" to determine whether or not the difference could be the result of chance.

(Slide) Next slide, please.

Sixteen kinds of cancer have been examined including leukemia, all other cancers combined, and particular forms of cancer including breast cancer, lung cancer, and other types known to be sensitive to induction by radiation.

(Slide) Next slide, please.

Here's an extract from the data in the report. These data are for mortality in children below age ten for all facilities combined.

The first column shows the numbers of deaths in the study area before plant start-up, and

the second column the corresponding SMR or standardized mortality ratio. There were 2,020 leukemia deaths before start-up and the SMR was 1.07. That is, the number of deaths was seven percent more than the number expected at U.S. national death rates.

The next two columns show corresponding data for the control areas also for the period before plant start-up.

The next four columns show parallel data for the period after start-up. And they show that leukemia was one percent high compared with the U.S. in the study areas, while other forms of cancer mortality were three percent high, and so forth.

COMMISSIONER CURTISS: That chart is for both DOE and NRC facilities?

DOCTOR JABLON: That's everything.

COMMISSIONER CURTISS: Okay.

DOCTOR JABLON: The last two columns show the same data for the control areas. In the report itself, data are shown in the same format for all 16 kinds of cancer for each of the six age groups for each individual facility and for various groupings of facilities such as all plants other than electric utilities, and so forth.

(Slide) Next slide, please.

Each table, like the preceding one, is paired with a table showing relative risks which compare the study areas with the corresponding control areas before start-up and after start-up. The relative risks also compare the study and control areas after start-up with themselves before. One can, therefore, not only compare the study and control areas after start-up, but see if the comparison changed after the plants went into operation and see what the time trends were in each group separately.

For leukemia, the relative risk was 1.08 for the study counties before start-up and only 1.03 afterwards. The relative risk 1.08 is marked by two asterisks, signifying that the relative risk was unlikely to arise by chance. That is, it's significantly elevated.

Also, before start-up, the relative risk for all cancer other than leukemia was significantly low, only 0.94. For leukemia, the relative risks comparing after start-up with before are 0.93 in the study areas and 0.95 in the control, so that in both the study and comparison areas the risk of death from childhood leukemia went down after plant start-up.

(Slide) Next slide, please.

A very large number of significance tests

have been made, more than shown here. Computers make such wholesale testing possible, and I'm not sure that it's necessarily a good thing. It must be remembered that one test in 20 will turn out to be significant purely as a consequence of random variation. So more than 1,000 of these 25,000 tests will turn out to be "significant." Further, a statistical test of significance speaks only to the mathematical meaning of a comparison and not about the biological significance or relevance.

(Slide) Next slide, please.

The report is quite voluminous, as you know. The tabulated data for all facilities combined as well as certain groups of facilities such as DOE plants, all electric generating plants, early and late plants are included in the first volume. The second and third volumes contain the detailed data concerning individual facilities, and each has more than 700 pages. The data in volume III are shown in five year periods, which permits an assessment of whether cancer rates are increasing relative to the U.S., decreasing, or not changing.

(Slide) Next slide.

What was found for childhood leukemia or for other cancers?

(Slide) Next slide, please.

The table shown here concerns childhood leukemia, which some consider almost as a bell weather indicator of radiation carcinogenesis. Shown are the numbers of deaths in the study and control areas for the groups of facilities before plant start-up and after, and the relative risks both before and after start-up.

All of the relative risks before start-up are larger than 1.0, and three of them are statistically significant. The relative risks for after start-up are sometimes more than 1.0 and sometimes less, but are never significantly different from 1.0. It is presumably mere coincidence that the relative risks before start-up are in every case larger than those after start-up.

(Slide) Next slide, please.

These are the data for all cancer except leukemia for all the facilities for all of the age groups. The overall relative risks are 1.0 before start-up and 1.01 after. The largest relative risk after start-up is for the Department of Energy facilities, but the value is only 1.04 and is actually less than the value, 1.06, before start-up. The number of deaths included here is more than two

million, so that even trivial and probably meaningless relative risks such as 1.02 for the later electric plants, but before start-up, are statistically significant.

(Slide) Next slide, please.

These are the summary relative risks combining all facilities for leukemia and for other cancers. For childhood leukemia, the relative risks are larger than 1.0 both before and after start-up, but actually a little larger before start-up than after. Similarly, for all ages combined, the leukemia relative risk went down after start-up to a value of less than 1.0. For other cancers, the relative risks for children were both less than 1.0, and for all ages only 1.01 after start-up, a one percent increase.

(Slide) Next slide, please.

We also examined data on childhood leukemia for every individual plant. This shows the distribution of the ratios of the relative risks after start-up to before. If there were increases in childhood leukemia after start-up, the ratios for more of the facilities would be larger than 1.0 and shifted to the right. In fact, as can be seen, the distribution is approximately symmetrical. And, in fact, 17 of the ratios are less than 1.0 and only 15

larger.

(Slide) Next slide, please.

We have searched for every significant statistical test of a relative risk of leukemia that differed from 1.0 after start-up for any facility for any age group. We found 18. Since there were 390 such tests in total. Nineteen and a half could have been anticipated to be statistically significant as a result of chance, so the actual number was very close to the number that chance alone would have produced.

It's noteworthy that 14 of the significant comparisons were for low relative risks, while only four were high. Further, although the excesses in the U.K. concerned childhood leukemia, only a single one of the significant comparisons was for children under age 10, and there were three significantly low comparisons for children 10 to 19. The significantly high value was found in the data on incidence for the Millstone Nuclear Electric Plant in New London County, Connecticut.

(Slide) Next slide, please.

Data on cancer incidence were available from two states, Iowa and Connecticut, for the study and comparison counties for four commercial nuclear electric generating stations. In view of the British

reports, we were especially interested in leukemia in young children.

These are leukemia incidence data for children under age 10 in the study areas in Connecticut and Iowa. Adding together the observations for the four facilities, the standardized registration ratios are: 1.36, which is significantly high, after start-up; and 1.13, not significantly high, before start-up.

For individual plants, the numbers for Fort Calhoun are too small to be meaningful. For neither Duane Arnold nor Haddam Neck was the relative risk after start-up significantly elevated.

For Millstone in New London County, however, the SRR after start-up was significantly high, 1.55, compared with only 1.19 before start-up. The ratio for mortality was a little smaller than the incidence ratio, 1.45 compared with 1.55. The mortality ratio was not significantly high. There were only 17 deaths, however, in contrast with 44 incident cases.

The raised SRR near Millstone may simply be a chance finding, or some other characteristic of New London County may be responsible. The SRR was somewhat high even before start-up. In any case, the

doses to persons in the area from radioactive emissions from Millstone have been reported to be less than three percent of the doses from natural background, at a maximum, to any person.

The Connecticut Department of Health Services in 1987 reported on a study of cancer rates in relation to the Haddam Neck and Millstone power plants and reported no association between leukemia rates or rates for other cancers in proximity to those plants.

I should interject at this point that less than a week ago we learned that in 1972 a report on a "leukemia cluster" in the town of Waterford was investigated by CDC. Waterford is, as you know, the town in which Millstone is located. In 1972 there were, I think it was, 11 cases of leukemia and lymphoma compared with an expected number of something like a quarter of that. That was a significant elevation.

One of the hypotheses was that it was somehow related to Millstone, but there was no -- on looking at the exact geographic location of these persons, no relationship could be found. In any case, Millstone only went into service in 1972, if I'm not mistaken, so there certainly would not have been time

for Millstone to have caused excess cases of leukemia before it went on-line.

It's interesting that the excesses of childhood leukemia in the county -- I don't have data for Waterford, but in the county of New London -- have continued to be high. So presumably something is causing childhood leukemia in New London County. What it is we don't know, but it seems unlikely that it's related to the operation of Millstone.

In summary, there's little indication of an increase in risk in the study counties after the facilities went into service. Our advisory committee, in fact, concluded that "even the highest relative risks for individual facilities were compatible with the general level of variation seen."

(Slide) Next slide, please.

What are the limitations and strengths of the survey? There are both.

(Slide) Next slide.

First, the limitations. So many comparisons have been made that some significant differences would result from chance. For leukemia after start-up, there were 390 comparisons in the different study areas and age groups. Just over 19 of the 366 of the 390 comparisons could be expected to

have probabilities below 0.05, and the number actually was 18.

The study is based upon counties, some of which are very large and contain large cities far distant from the facility. For example, San Onofre, in San Diego County, California, and Turkey Point in Dade County, Florida.

(Slide) Next slide, please.

Many of the facilities began operations only in recent years and not enough time may have passed to permit the detection of any cancers that may have been associated with their operations.

For most of the facilities studied, only mortality data were available. Incidence data, which are needed for the study of thyroid cancer and which are highly desirable for childhood leukemia and female breast cancer, were available for only four facilities.

There are, however, also some considerable strengths.

(Slide) Next slide.

It was possible to examine data for each study area over a span of 35 years, which in most instances allowed for comparison between cancer risks before and after nuclear facilities began operation.

(Slide) Next slide, please.

The very large number of facilities in the United States provided ample opportunity for the expression of risk. There were more than 35,000 deaths from leukemia and half a million deaths from other cancers in the study areas after plant start-up.

(Slide) Next slide, please.

And, as Doctor Boice has mentioned, the study of county data has in previous studies successfully identified lung cancer risks associated with asbestos exposures in shipyards and with arsenical air pollution from the smelting of non-ferrous ores.

(Slide) Next slide, please.

What are the final conclusions, the bottom line?

(Slide) Next slide, please.

No evidence was found that operations at any of the nuclear facilities studied caused excess deaths from childhood leukemia or from other cancers in the counties in which they are located. The increases in childhood leukemia seen in the United Kingdom occurred near reprocessing and weapons plants. No parallel increases near such plants are apparent in the United States.

The study does provide general background information that can help to guide any future studies around nuclear facilities.

Doctor Boice will close the session.

DOCTOR BOICE: Yes. I thought it might be informative to the Commission to hear what our advisory committee concluded with regard to the study and also what their recommendations were.

(Slide) Could I have the first slide, next slide?

Once again, there were seven eminent scientists who served on our committee. They were expert in radiation carcinogenesis and other relevant areas. They met three times to provide advice and guidance. They were extremely helpful and their consensus statement was also published in the volumes available from GPO.

(Slide) Go to the next slide, please.

"The Committee concludes that the survey has produced no evidence that an excess occurrence of cancer has resulted from living near nuclear facilities. Further, measurements of radioactive releases from nuclear facilities indicate that the dose from routine operations is generally much below natural background radiation, and hence may be

unlikely to produce observable effects on the health of surrounding populations."

(Slide) Could I have the next slide?

They go on to state, "however, there have been releases from some facilities, such as at Hanford, that were high, and there continues to be widespread public and scientific concern, in part raised by the unexpected findings in the United Kingdom that have not yet been fully explained. Consideration should be given, therefore, to further investigations and monitoring, including attention to the following points."

(Slide) Could I have the next slide?

These are the Committee's considerations for further study.

Consider surveys of smaller population groups, such as census tracts. The Department of Energy with investigators at the University of California at Berkeley have initiated such a study around the DOE facilities and also nuclear power plants. Departments of public health in Connecticut and other states have also conducted surveys at the town rather than the county level.

Continue monitoring of mortality rates. This is something that we can do relatively easily and

which we will do periodically, perhaps every five years.

Explore the use of cancer incidence data. We were able to use several registries in the current investigation, but in only two states. There are other cancer registries in the United States and it might be possible to expand the investigation accordingly.

The Committee stated that case-control studies in small areas around nuclear facilities are potentially informative, but should be undertaken only after careful consideration. Specific studies were not recommended because of the overall lack of excess cancer deaths around nuclear facilities and the lack of consistency with the U.K. studies.

Once again, recall that in the United Kingdom small clusters of childhood leukemia were noted around nuclear fuel reprocessing plants and weapons installations. The DOE facilities in the U.S. were most similar to these installations, but elevations in childhood leukemia were not observed.

Some additional types of studies, however, perhaps based on linking rosters of records together, might be feasible.

Consider replicating the United Kingdom

worker study of preconception effects that was conducted around the Sellafield fuel reprocessing plant In this regard, scientists at the Pacific Northwest Laboratories in Washington State have initiated a study around the Hanford site to learn whether childhood leukemia could possibly be linked to any occupational exposures of the parents. Also, the National Cancer Institute is currently conducting a large collaborative study of 2,000 children who developed leukemia, which will evaluate the risk of preconception radiation from diagnostic x-rays, environmental exposures, and parental occupation.

And finally, cooperate with others conducting similar research. We certainly believe that this is important and we have attempted to keep in contact with the Department of Energy investigations, those being conducted by the Centers for Disease control, and others.

Also, I should add that we have been interested for several years in studying the workers at nuclear power stations, and with the Nuclear Regulatory Commission we have recommended changing the requirements for reporting occupational doses so that a registry of radiation workers might be created. I understand that the proposed changes will be published

in the near future, but perhaps this volume in front of me indicates that it has been published in the *Federal Registry.*

(Slide) The next slide.

In conclusion, while the overall findings are reassuring, it should be kept in mind that the size of some of the counties may be too large to detect risks that are present only in limited areas around plants and that no study can in fact prove the absence of an effect.

However, if any excess cancer risks due to radiation pollution is present in counties with nuclear facilities, the risk may just be too small to be detected by the methods used. This study should thus not be considered the definitive one, but rather a first step in providing background information to help guide further studies.

Thanks very much for your attention. Seymour Jablon and I will be glad to address any questions that you might have.

COMMISSIONER REMICK: Several questions.

You mentioned that around Sellafield they found that occupational exposures might be the cause of the cancer. What type of occupational exposure? Did they find those? I assume that's industrial,

rather than radiological.

DOCTOR BOICE: What they did --

COMMISSIONER REMICK: It is radiological?

DOCTOR BOICE: It is radiological, yes.

COMMISSIONER REMICK: I see.

DOCTOR JABLON: They did a case controlled study on the leukemias and found there were five childhood leukemia deaths in the town of Seascale, which is only about three kilometers from the Sellafield plant. Four of the fathers were definitely identified in the Sellafield work force, and the fifth one probably was a Sellafield worker also although notes could not be obtained for him.

The fathers of these cases, the four fathers, had occupational doses exceeding ten rem, if you'll allow me to use an antiquated term.

COMMISSIONER ROGERS: I feel very comfortable with it.

DOCTOR JABLON: Ten rem over their lifetime work, and one rem presumably in the six months prior to conception. Doctor Gardner, who did the study, had a number of controls selected for each case and in those four instances in every case the dose to the father exceeded the dose to any of the controls. Now, this created a lot of excitement in

the United Kingdom, of course, but there are problems. There are problems.

The first problem, the first thing that was mentioned was that no such excess related to preconception irradiation had been seen in the Japanese survivors. But that really is not a pertinent observation, because, if you're talking about only six months prior to conception, there were very few children born in Hiroshima or Nagasaki that had been conceived during that time whose fathers had had any dose.

Studies are, as you can imagine, continuing. A study will probably appear this fall, a parallel around Dounreay where there's also an excess. It's regarded as a hypothesis which has not been proved, but which is kind of suggestive.

One of the problems is that one must presume that not every worker at Sellafield does exactly the same thing, that workers whose work imply collecting large doses are doing different kinds of work from other workers. There are a lot of chemical processes that go on at Sellafield. It's conceivable that these people are bringing something home on their clothing. I don't know what it is, but we can be sure that the British are going to investigate every

possible aspect of that problem.

COMMISSIONER REMICK: Thank you.

In several cases, you've indicated that one of the limitations of the study and ways of improving the study would be to have access to cancer incidence information. To the best of my knowledge, our health protection standards are based on cancer mortality. Is there anything based on the study, to your knowledge, which would indicate that we're not being conservative enough by using cancer mortality in contrast to cancer incidence or using both? Is there anything to suggest that?

DOCTOR BOICE: Well, I think on the basis of, you know, radiation effects, you would get a fuller expression of any adverse effects if you had cancer incidence, date of the occurrence of cases. Unfortunately, this is just not readily available and it's very difficult to obtain data on cancer incidence in the United States or in any other country.

For some cancer sites such as thyroid cancer, incidence data definitely would be preferred. I'm not sure how much further you could express that. If you were able to set recommendations based on cancer incidence, that might be a more complete picture.

COMMISSIONER CURTISS: Let me follow-up on that.

COMMISSIONER REMICK: Sure.

COMMISSIONER CURTISS: For the four sites where you had cancer incidence data, did the analysis of that information pretty much confirm what you would have concluded just based upon cancer mortality data?

DOCTOR BOICE: I think that's true, that the patterns were the same. You just get more cases. The occurrence of cancer, there is more cases, so that could lead to more significant findings or a clearer picture of what the patterns might be. But in large part, the mortality does pattern after the incidence for most cancers.

Noted exceptions are thyroid cancer, which has a great cure rate -- perhaps 90 to 95 percent of all thyroid cancers are cured -- and now childhood leukemia, in which great advances have been made now. So there's an increased survival in those areas. And there are a number of other cancers where incidence would be preferred.

DOCTOR JABLON: I think the New London situation shows what happens. Actually, the ratios were very close for mortality or for cancer incidence, but if one looked only at the mortality data, one

would shrug one's shoulders and say, "Well, it looks like a chance blip." It was not "statistically significant."

But we had 44 incident cases, as opposed to only 17 cancer deaths, and those 44 cases were significantly high, so that for those cancers which have cure rates which are significant, like childhood cancer now, like female breast cancer, like thyroid cancer, all of which are radiosensitive cancers, incidence data is very much to be desired, much more sensitive.

COMMISSIONER REMICK: The TMI study, if I recall, was based on cancer incidence. Is this the type of study that you have in mind?

DOCTOR BOICE: No. That was -- as other states and local communities have conducted some surveys based on the hospitals and the towns and closer geographic regions, they've -- they had to collect the data themselves retrospectively for years.

In terms of looking at the United States comprehensively for all nuclear sites, cancer incidence data is not available. What is available, what's reported and is available at the national level are mortality data at the counties.

Even the Department of Energy, through the

University of California at Berkeley, they're going to try to replicate our study but use census tracts, a smaller geographical area. They're going to do it from mortality. It's just so difficult. It doesn't exist comprehensively for the entire United States.

And now, even in the United States today, there are more cancer registries, but comprehensive areas just aren't covered. The National Cancer Institute cancer registries only cover ten percent of the United States population and they began in 1973.

COMMISSIONER REMICK: Is there anything in this study which would indicate a -- that you can validate or refute the use of the linear hypothesis in setting radiation protection standards?

DOCTOR BOICE: I don't think so.

DOCTOR JABLON: No.

DOCTOR BOICE: This is not the type of study that would address the issue of low dose radiation effects.

COMMISSIONER REMICK: Does the study show us -- tell us anything more about the effects of low levels of radiation?

DOCTOR JABLON: No. If you assume that low levels cause harm proportional to the dose, one would predict from the risk estimates at high levels

that you wouldn't be able to see it, and we didn't see it. Now whether that validates it or not, I don't know.

DOCTOR BOICE: I think it's important to remember that one of the reasons why we started this survey was because of the findings coming out of the United Kingdom where they did a comprehensive mortality survey around their facilities. And they reported in a number of their instances that excess childhood leukemia was occurring. We tried to replicate that and did not find that in the United States.

COMMISSIONER REMICK: I was just trying to find if there were findings in the survey that weren't in your conclusions. And certainly, these are some of the ones we're interested in.

I have no further questions, but I want to thank you for a very succinct and clear presentation of quite an extensive survey. It's been very helpful.

COMMISSIONER ROGERS: I was thinking, I take it that childhood leukemia is quite radiation specific. It's a good way to look at radiation-induced cancers.

So, the question I had was would there be any point in trying to extend this study to areas

around coal-fired fossil fuel plants, which tend to emit about ten times the radiation of a typical nuclear power plant? And there are a lot more of them, so that you've got another point on that curve because you're ten times up from the typical emissions of a nuclear power plant. And of course, they've been around for a longer time, so you have probably a lot more data to go on and to look at childhood leukemia in the counties surrounding coal-fired power plants.

DOCTOR BOICE: I think that's a good point, and we have in fact been discussing that in the last several weeks.

The National Cancer Institute has, in fact, been using the mappings of cancer since the 1970s to try to get leads for cancer etiology and the environmental factors that cause cancer in our society. And we had county based mortality surveys trying to link rates with non-ferrous smelters, shipyards, and a lot of other chemical factories. And we have, in fact, been discussing the possibility that perhaps coal-burning plants or other fossil fuel facilities might be a useful area to study and perhaps provide leads to cancer elevations in various counties.

COMMISSIONER ROGERS: Well, I was just

thinking that you might be able to even more directly connect it with radiation, because it's another source of radiation that is about ten times higher than the power plants that you're studying now, nuclear power plants you're studying now. So if it's very radiation specific, in a sense, so that the other emissions that come out of the stack are not as important in inducing childhood leukemia, then it might be a very, very useful piece of additional data.

DOCTOR BOICE: Yes, thank you.

COMMISSIONER ROGERS: What do you see as a follow-up to the Gardner study here? I mean, is there-- here or elsewhere, is this going to be left as a big unanswered question, you think, or do you think there will be some way of --

DOCTOR BOICE: Well, I --

COMMISSIONER ROGERS: -- down this question of hereditary effects of radiation?

DOCTOR BOICE: Certainly. The one plant or facility in the United States that's most similar to Sellafield is the Hanford plant, which started in 1943. And at this time, the Pacific Northwest Laboratories, Batelle, has initiated a study to replicate the Gardner findings. They're doing a survey of childhood leukemia, lymphoma around the

plant area, and then they'll link that roster, identify the parents and link the rosters to the radiation workers at Hanford to see if they can, in fact, here in the United States, if we can replicate that finding.

It is a peculiar finding, you know, because there's not evidence in genetics that leukemia is a particular heritable disease. And the geneticists and molecular biologists that have reviewed the report, they question it based on what's known about biology, that it would perhaps be peculiar that leukemia itself would be passed on and not all the other types of known genetic diseases such as retinoblastoma and Wilm's Tumor or excesses of congenital malformation, which have not been noted in the Cumbria area. So I think people are looking at alternative explanations in addition to preconception.

One of the other explanations that have come from the United Kingdom was the response to a virus in a viral infection. When you have a rural community and populations are moving in because of a large industrial complex and the local community somehow does not have an immunity built up, they're susceptible to a common infection and childhood leukemia results. So there's activity in the United

Kingdom trying to evaluate that particular factor.

Also, chemical exposures is another possibility, as Seymour mentioned. A number of these people, although they did receive meaningful radiation doses, over ten rem -- that's prior to conception -- I think four of the five or five of the key nine were analytical chemists and also were exposed to -- or chemical engineers exposed to a lot of the chemical processing that goes around with plutonium works.

COMMISSIONER ROGERS: Is there any -- you have such -- you have a fair amount of data. It's, I guess, the largest study of its kind that's every been conducted on this type. Can you look at any other effects, such as the effect of, well, socioeconomic effects such as nutrition and things like that? Is that too low? Are there too few cases where you could differentiate that way? Is that more or less what you were saying in some of your recommendations, don't try to differentiate below where you've done so far?

DOCTOR BOICE: I guess there are several levels. If you're doing a comprehensive study, you have to -- you know, covering all plants and the entire United States -- you have to just work with the data that you have at hand. And real specific data, such as smoking characteristics, dietary factors,

these things that you would like to do in a more -- we use the term "analytic" study, where you go into an area and you ask the people, their spouses, what factors-- what are their lifestyle factors, what are their occupations, what are their other exposures --

COMMISSIONER ROGERS: You just don't have any of that?

DOCTOR BOICE: It's not available. It's just not available. There are, though, studies that are trying to get that type of information now in the United Kingdom and the United States.

The Centers for Disease Control is supporting another study around the Hanford site, because, as you're probably aware, during World War II there was a rather massive release of radioactive iodine. Radioactive iodine would have been concentrated in the thyroid and that would be the disease of interest, thyroid disorders. So, with the Fred Hutchinson Cancer Center, they're conducting a real detailed study trying to find these people over the last 50 years, 45 years, and then trying to get detailed information on disease histories, as well as other factors.

Several state governments are also conducting more detailed studies around their sites.

COMMISSIONER ROGERS: I'd just like to say that it seems to me that you've handled this whole thing in a very admirable way, because there was very, very little leakage along the way of what your results were going to come out to be, and I think that's really the way it ought to be. Until it's out, it shouldn't be out. And it seems as if it's a very excellent study, that while it will never settle all questions it's certainly a very important piece of research in guiding our thinking on such matters.

What do you think will be the impact of your study? It seems to me so far, other than a brief flurry of press attention when the report was released, it hasn't seemed to -- it doesn't seem to be getting very much discussion, probably because it's the wrong kind of result. We all like to discuss the doomsday scenarios, but the opposite predictions don't seem to excite people very much. What do you think the impact will be of your study?

DOCTOR BOICE: Gosh, that's hard for me to say. I think it's too early to tell. The study has only been out for less than two weeks, so I think it's hard to see how others will respond to it.

COMMISSIONER ROGERS: Yes, but you know if the results had been quite different it would have

been a bombshell. It would have been talked about on radio, television time and time again. The fact that the results are negative seems to totally dissipated at least the media's interest in it.

DOCTOR BOICE: I think that's true in general, of course. In most of the studies that we're involved in in terms of epidemiology, whether it's radiation or chemicals or occupation, there does seem to be a lot more media or public interest when you have a significant finding. I think that might just be characteristic of our society.

COMMISSIONER ROGERS: Oh, I think you had a significant finding. It just wasn't a negative one.

DOCTOR BOICE: Right, sure.

COMMISSIONER ROGERS: Well, I'd also like to add my commendations to the very fine work that's been done here.

DOCTOR BOICE: Thanks.

COMMISSIONER ROGERS: Thank you.

COMMISSIONER CURTISS: I just have a handful of questions here.

Doctor Jablon, I wasn't sure I understood your explanation of the significance of statistical significance. I take it, from your explanation, what could be statistically insignificant in one case might

be statistically significant in another. Let's say five percent in one case might be statistically significant in one place but not another. Why is that? Without getting into a detailed explanation of how you calculate that, what is the explanation for that?

DOCTOR JABLON: "Significance" is a bad word. Statisticians, you know, took it over and it has connotations. It's a purely mathematical term, as it's used. It asks this question. You have a certain number of deaths that you might have expected from leukemia or something else, and there were a certain number that you observed. And that, of course, is not exactly the same. There's a certain amount of random variation.

The question is, what is the probability that a difference that large might have arisen by chance? And if that probability is less than some nominal amount, like five in a hundred or one in a hundred, that's called "significant." But that's all it means, that this is a difference which is sufficiently large that random variation would have produced it only five times in a hundred. But if you've done 25 thousand tests, you know, you're going to get a fair number of them.

Now what determines whether it's significant? It's a product of two things. First, how big is the difference? If you've observed two cases and you expected one, that's a relative risk or an SMR of 2.0, but it's not significant because if you expect one you could easily get two. But if your expectation was 100 and you actually observe 200, boy, that would be very significant. So there are formulas for calculating what is the probability that this would have arisen by chance, and that's what it comes to.

COMMISSIONER CURTISS: All right. A couple of other quick questions. The Gardner study that you referred to, is that the only study that has reached conclusions of that nature on preconception effects? Are there any others that have reached similar conclusions?

DOCTOR JABLON: I'm not aware of any others. Well, there have been others. The Tristate Leukemia Study, which was done a considerable number of years ago, found some excesses of, I guess, preconception irradiation to the parents. I don't think it was taken very seriously. Again, part of the problem was that the data concerning parental irradiation were a little on the soft side. They were

obtained by interview and they did some checking of doctor's offices, but when you ask people about prior radiological examinations you're likely to get some very incomplete information. Sometimes people think that they're being x-rayed when actually the procedure was something else.

And I guess Alice Stewart's original study in the 1957 publication on *The Oxford Survey of Childhood Cancer.* She had a small excess. She had an excess in a small number of cases of preconception irradiation and she dismissed that as just one of these chance things. She may have changed her mind about that now. I don't know.

COMMISSIONER CURTISS: Okay.

DOCTOR JABLON: There are a few little indications.

COMMISSIONER CURTISS: One final question, I guess. Doctor Hatch, of course, isn't here, but I assume you've read the study that was done for the TMI Public Health Fund. Is there anything between the two studies that you detected constitute an inconsistency or have they reached pretty much the same conclusions?

DOCTOR JABLON: I was very pleased when I saw hers. You know, we couldn't find anything going on around TMI and I was somewhat relieved that she

hadn't found much either.

COMMISSIONER CURTISS: It did strike me that the different methodologies that were used to reach the same conclusion confirmed the results.

DOCTOR JABLON: Right.

COMMISSIONER CURTISS: Other questions?

Well, let me thank you for the presentation this afternoon. I must say I found the results quite interesting and the results of the study somewhat reassuring.

As Commissioner Rogers indicated, I suspect the debate on this subject will go on, but the contribution which you've made and in particular I guess the credibility that the National Cancer Institute brings to this subject constitutes a real service not just to the country as a whole but I think to those of us who are interested in the subject on a day to day basis and I'd like to thank you.

We stand adjourned.

(Whereupon, at 3:14 p.m., the hearing was adjourned.)

CERTIFICATE OF TRANSCRIBER

This is to certify that the attached events of a meeting of the United States Nuclear Regulatory Commission entitled:

TITLE OF MEETING: BRIEFING ON STUDIES OF CANCER IN POPULATIONS NEAR NUCLEAR FACILITIES, INCLUDING THREE MILE ISLAND
PLACE OF MEETING: ROCKVILLE, MARYLAND

DATE OF MEETING: SEPTEMBER 28, 1990

were transcribed by me. I further certify that said transcription is accurate and complete, to the best of my ability, and that the transcript is a true and accurate record of the foregoing events.

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CANCER IN POPULATIONS LIVING NEAR NUCLEAR FACILITIES

NATIONAL CANCER INSTITUTE

NIH PUBL No. 90-874

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DR. ARTHUR UPTON	NEW YORK UNIVERSITY

STUDY OVERVIEW

- INITIATED AFTER 1987 REPORTS FROM U.K.
- PROTOCOL REVIEWED AT 1988 SITE VISIT
- ADVISORY COMMITTEE MET 3 TIMES 1989-1990
- REPORT PUBLISHED 1990

NUCLEAR FACILITIES STUDIED

- 9 DOE INSTALLATIONS
- 1 COMMERCIAL FUEL REPROCESSING PLANT
- 52 COMMERCIAL NUCLEAR POWER PLANTS

AREA	NUMBER FACILITIES	NUMBER COUNTIES	NUMBER CA DEATHS (MILLIONS)	NUMBER RESIDENTS (MILLIONS)
STUDY	62	107	0.9	18.7
CONTROL	0	292	1.8	33.0

"THE COMMITTEE CONCLUDES THAT THE SURVEY HAS PRODUCED NO EVIDENCE THAT AN EXCESS OCCURRENCE OF CANCER HAS RESULTED FROM LIVING NEAR NUCLEAR FACILITIES. FURTHER, MEASUREMENTS OF RADIOACTIVE RELEASES FROM NUCLEAR FACILITIES INDICATE THAT THE DOSE FROM ROUTINE OPERATIONS IS GENERALLY MUCH BELOW NATURAL BACKGROUND RADIATION, AND HENCE MAY BE UNLIKELY TO PRODUCE OBSERVABLE EFFECTS ON THE HEALTH OF SURROUNDING POPULATIONS."

"HOWEVER, THERE HAVE BEEN RELEASES FROM SOME FACILITIES, SUCH AS AT HANFORD, THAT WERE HIGH, AND THERE CONTINUES TO BE WIDESPREAD PUBLIC AND SCIENTIFIC CONCERN, IN PART RAISED BY UNEXPECTED FINDINGS IN THE UNITED KINGDOM THAT HAVE NOT YET BEEN EXPLAINED FULLY. CONSIDERATION SHOULD BE GIVEN, THEREFORE, TO FURTHER INVESTIGATIONS AND MONITORING, INCLUDING ATTENTION TO THE FOLLOWING POINTS."

ADVISORY COMMITTEE
CONSIDERATIONS FOR FURTHER STUDIES

- SURVEYS OF SMALLER POPULATION GROUPS, e.g., CENSUS TRACTS
- CONTINUED MONITORING OF MORTALITY RATES
- EXPLORE USE OF CANCER INCIDENCE DATA
- USE CAUTION IN CONSIDERING CASE-CONTROL STUDIES
- CONSIDER REPLICATING U.K. WORKER STUDY OF PRECONCEPTION EFFECT
- COOPERATE WITH OTHERS CONDUCTING SIMILAR RESEARCH

CONCLUSIONS

- FINDINGS REASSURING, BUT

  -- COUNTY SIZE LARGE
  -- CAN NEVER PROVE ABSENCE OF EFFECT

- RISK MAY BE SMALL

- PROVIDES BASELINE DATA

1. WHY DO A STUDY?

2. WHAT DATA ARE AVAILABLE?

3. WHICH FACILITIES AND COUNTIES ARE STUDIED?
   HOW WERE CONTROL COUNTIES SELECTED?

4. WHAT IS THE FORM OF ANALYSIS AND
   PROCESS OF INTERPRETATION?

5. WHAT WAS FOUND FOR CHILDHOOD LEUKEMIA?
   WHAT WAS FOUND FOR OTHER CANCERS?

6. WHAT ARE THE LIMITATIONS AND STRENGTHS
   OF THE STUDY?

7. WHAT ARE THE CONCLUSIONS?

DEATHS FROM CANCER AROUND SELLAFIELD

AGE 0-24, MILLOM RURAL DISTRICT, 1963-80

	OBSERVED NUMBER	EXPECTED NUMBER	RATIO O/E
LEUKEMIA	8	2.31	3.5 **
OTHER CANCER	5	5.03	1.0

** $p < 0.01$

(BLACK, 1984)

LEUKEMIA INCIDENCE AROUND DOUNREAY

AGE 0-14 <12.5 KM FROM DOUNREAY

PERIOD	LEUKEMIA CASES	OBS/EXP	P
1979-84	4	11.73	<0.001

(COMARE II, 1988)

CANCER INCIDENCE AGE 0-14 NEAR ALDERMASTON & BURGHFIELD

ELECTORAL WARDS <10 KM FROM AN ESTABLISHMENT

	OBSERVED NUMBER	EXPECTED NUMBER	RATIO O/E
LEUKEMIA	41	28.6	1.4*
OTHER CANCER	61	47.5	1.3*

* $p < 0.05$

(COMARE III, 1989)

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DATA AVAILABLE FOR COUNTIES

DEATHS: ANNUAL BY CAUSE, SEX, RACE, AGE

POPULATIONS: ESTIMATES BY YEAR, SEX, RACE, AGE

INCIDENT CANCERS: BY KIND OF CANCER, SEX, RACE, AGE
FOR COUNTIES IN CONNECTICUT AND IOWA

WHY MORTALITY?

- NATIONAL DATA ALREADY AVAILABLE IN NCI DATABANK, 1950-84
- DATA FOR EVERY COUNTY BY
  - -- YEAR
  - -- AGE
  - -- SEX
  - -- RACE
- METHODOLOGY SUCCESSFUL IN PAST

1. WHY DO A STUDY?

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DEPARTMENT OF ENERGY FACILITIES

	YEAR OPERATIONS BEGUN
HANFORD	1943
OAK RIDGE NAT. LAB.	1943
MOUND	1947
IDAHO NAT. ENG. LAB.	1949
PADUCAH	1950
SAVANNAH RIVER	1950
FERNALD	1951
PORTSMOUTH	1952
ROCKY FLATS	1953
NUCLEAR FUEL SERVICES (COMMERCIAL REPROCESSING)	1966

ELECTRICITY-GENERATING PLANTS IN SERVICE BEFORE 1970

	YEAR COMMERCIAL POWER
SHIPPINGPORT/	1957
BEAVER VALLEY	1976
DRESDEN 1	1959
YANKEE ROWE	1960
BIG ROCK POINT	1962
HALLAM	1962
INDIAN POINT 1	1962
FERMI 1	1963
HUMBOLDT BAY	1963
PATHFINDER	1964
HADDAM NECK	1967
LA CROSSE	1967
SAN ONOFRE 1	1967
GINNA	1969
NINE MILE POINT	1969
OYSTER CREEK	1969

ELECTRICITY-GENERATING PLANTS IN SERVICE 1970-1974

	YEAR		YEAR
MILLSTONE	1970	BROWNS FERRY	1973
POINT BEACH/	1970	FORT CALHOUN	1973
KEWAUNEE	1974	OCONEE	1973
ROBINSON	1970	PRAIRIE ISLAND	1973
MONTICELLO	1971	ARKANSAS	1974
PALISADES	1971	CALVERT CLIFFS	1974
MAINE YANKEE	1972	COOPER STATION	1974
PILGRIM	1972	DUANE ARNOLD	1974
QUAD CITIES	1971	HATCH	1974
SURRY	1972	PEACH BOTTOM	1973
TURKEY POINT	1972	RANCHO SECO	1974
VERMONT YANKEE	1972	THREE MILE ISLAND	1974
ZION	1973		

ELECTRICITY-GENERATING PLANTS IN SERVICE 1975-1981

	YEAR COMMERCIAL POWER
BRUNSWICK	1975
COOK	1975
TROJAN	1975
FORT ST. VRAIN	1976
SALEM	1976
ST. LUCIE	1976
CRYSTAL RIVER	1977
DAVIS BESSE	1977
FARLEY	1977
NORTH ANNA	1978
SEQUOYAH	1980
MCGUIRE	1981

STUDY COUNTIES

107 COUNTIES THAT

(A) CONTAIN A NUCLEAR FACILITY (64), OR

(B) ARE ADJACENT TO A COUNTY WITH A FACILITY AND ACCOUNT FOR >20% OF THE AREA WITHIN 10 MILES (43)

292 CONTROL COUNTIES

THREE SELECTED FOR EACH STUDY COUNTY

(A) USUALLY SAME STATE
(B) ALWAYS SAME REGION

MATCHED ON (1979 DATA)

(A) MEAN FAMILY INCOME, NET MIGRATION RATE, INFANT DEATH RATE, POPULATION (1980)

(B) PERCENT OF POPULATION WHITE, BLACK, HISPANIC, URBAN, RURAL FARM, EMPLOYED IN MANUFACTURING, HIGH SCHOOL GRADUATE, OVER AGE 25

NUCLEAR INSTALLATIONS, COMMERCIAL AND DOE

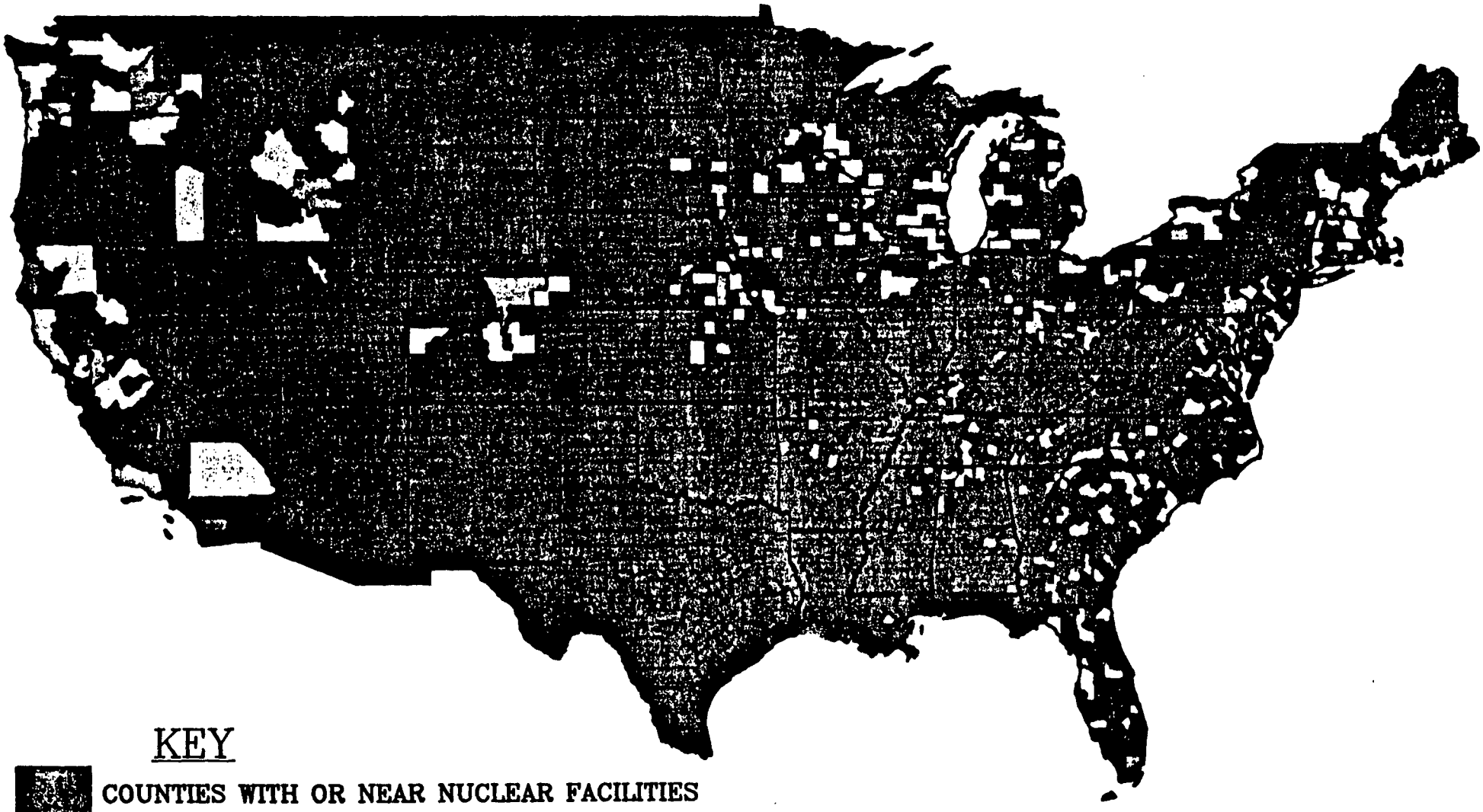

FIGURE 1

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FORM OF DATA PRESENTATION

OBSERVED DEATHS

NUMBER EXPECTED AT CONCURRENT NATIONAL RATES

STANDARDIZED MORTALITY RATIO (SMR): NUMBER OBSERVED/NUMBER EXPECTED

EXPECTED VALUES CALCULATED FOR STUDY AND CONTROL COUNTIES FROM U.S. RATES SPECIFIC FOR

AGE (5-YEAR GROUPS)

SEX

RACE (WHITE, NON-WHITE)

YEAR

DATA STANDARDIZED FOR SEX AND RACE
SHOWN FOR EACH CANCER FOR AGES:

UNDER 10

10-19

20-39

40-59

60 AND OVER

ALL AGES

$$\text{SMR:} \quad \frac{\text{OBSERVED DEATHS}}{\text{NO. EXPECTED AT U.S. RATES}}$$

$$\text{SRR:} \quad \frac{\text{OBSERVED CASES}}{\text{NO. EXPECTED AT STATE RATES}}$$

RELATIVE RISKS - RATIO OF SMRs

(A) STUDY VS. CONTROL - BEFORE STARTUP

STUDY VS. CONTROL - AFTER STARTUP

(B) STUDY COUNTY AFTER STARTUP VS. BEFORE STARTUP

CONTROL COUNTY AFTER STARTUP VS. BEFORE START

KINDS OF CANCER

16 CLASSES, INCLUDING LEUKEMIA, NON-LEUKEMIA CANCER, LYMPHOMA, MULTIPLE MYELOMA, CANCER OF THE BREAST, LUNG, STOMACH, COLON, BONE, THYROID, BLADDER, LIVER, BRAIN

AGE AT DEATH: UNDER 10

ALL FACILITIES COMBINED

	BEFORE STARTUP				AFTER STARTUP			
	STUDY		CONTROL		STUDY		CONTROL	
	OBS	SMR	OBS	SMR	OBS	SMR	OBS	SMR
LEUKEMIA & ALEUKEMIA	2020	1.07	4251	0.99	1390	1.01	2572	0.97
ALL CANCER, EXCL LEUK	1969	0.99	4623	1.03	1717	1.03	3243	1.02
HODGKIN'S DISEASE	42	1.33	69	0.95	13	0.75	26	0.78
OTHER LYMPHOMA	266	0.99	584	0.96	217	1.13	397	1.08
. . .	. . .		. . .		. . .		. . .	

AGE AT DEATH: UNDER 10

ALL FACILITIES COMBINED

RELATIVE RISKS

	STUDY VS. CONTROL		AFTER VS. BEFORE	
	BEFORE	AFTER	STUDY	CONTROL
LEUKEMIA & ALEUKEMIA	1.08**	1.03	0.93	0.95
ALL CANCER, EXCL LEUK	0.94*	0.99	1.05	0.96
HODGKIN'S DISEASE	1.41	0.90	0.94	0.99
OTHER LYMPHOMA	0.94	1.00	0.93	0.94

* : 0.01 < P <= 0.05

** : 0.001 < P <= 0.01

NUMBER OF SIGNIFICANCE TESTS ON RELATIVE RISKS

61 STUDY AREAS, TIMES

6 AGE GROUPS, TIMES

16 CANCER CLASSES, TIMES

4 COMPARISONS (STUDY VS. CONTROL, AFTER VS. BEFORE)

23,424

CONTENTS OF REPORT

VOL 1: DESCRIPTION, DATA FOR GROUPS OF FACILITIES, DISCUSSION AND CONCLUSIONS

VOL 2: DATA FOR EACH FACILITY, BEFORE AND AFTER STARTUP

VOL 3: DATA FOR EACH FACILITY, BY 5 YEAR TIME PERIODS

1. WHY DO A STUDY?

2. WHAT DATA ARE AVAILABLE?

3. WHICH FACILITIES AND COUNTIES ARE STUDIED?
   HOW WERE CONTROL COUNTIES SELECTED?

4. WHAT IS THE FORM OF ANALYSIS AND
   PROCESS OF INTERPRETATION?

5. WHAT WAS FOUND FOR CHILDHOOD LEUKEMIA?
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   OF THE STUDY?

7. WHAT ARE THE CONCLUSIONS?

MORTALITY FROM LEUKEMIA, UNDER AGE 10, BY TYPE OF FACILITY

TYPE OF FACILITY	BEFORE STARTUP NUMBER OF DEATHS			AFTER STARTUP NUMBER OF DEATHS		
	STUDY	CONTROL	RR	STUDY	CONTROL	RR
DEPT. OF ENERGY	39	48	1.45	601	1009	1.06
ELECTRIC UTILITIES						
BEFORE 1970	593	1035	1.03	534	993	1.00
1970-1974	996	2383	1.09*	227	482	1.06
1975-1981	392	785	1.11	28	88	0.82
TOTAL	1981	4203	1.08*	789	1563	1.01
ALL FACILITIES	2020	4251	1.08*	1390	2572	1.03

MORTALITY FROM ALL CANCER EXCEPT LEUKEMIA, ALL AGES, BY TYPE OF FACILITY

TYPE OF FACILITY	BEFORE STARTUP NUMBER OF DEATHS			AFTER STARTUP NUMBER OF DEATHS		
	STUDY	CONTROL	RR	STUDY	CONTROL	RR
DEPT. OF ENERGY	5780	8991	1.06	141635	247308	1.04
ELECTRIC UTILITIES						
BEFORE 1970	79902	157745	1.00	197158	364675	1.01
1970-1974	179208	471890	0.98*	139175	317206	0.98
1975-1981	69310	157884	1.02*	26325	68785	0.99
TOTAL	328420	787519	0.99	362658	750666	0.99
ALL FACILITIES	334200	796510	1.00	504293	997974	1.01

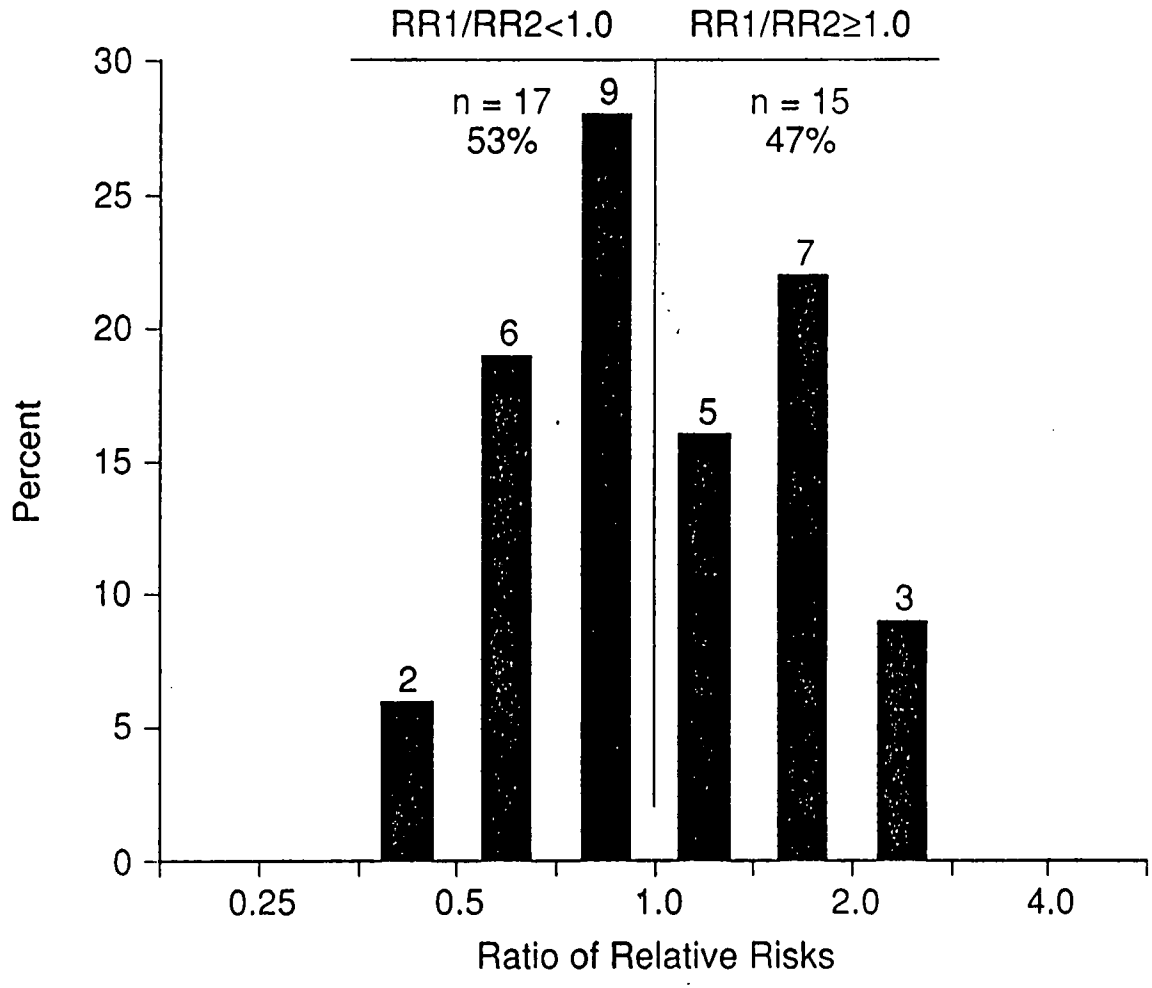
OVERALL FINDINGS

RELATIVE RISK

	BEFORE STARTUP	AFTER STARTUP
LEUKEMIA		
CHILDHOOD	1.08	1.03
ALL AGES	1.02	0.98
OTHER CANCER		
CHILDHOOD	0.94	0.99
ALL AGES	1.00	1.01

Distribution of RATIOS of Relative Risks (RR1 / RR2) of CHILDHOOD LEUKEMIA

$$\frac{RR1}{RR2} = \frac{\text{Study vs. Control County After Startup}}{\text{Study vs. Control County Before Startup}}$$



FACILITIES WITH RELATIVE RISKS SIGNIFICANTLY DIFFERENT FROM 1.00

ALL LEUKEMIA, STUDY VS. CONTROL AFTER STARTUP

FACILITY	AGE GROUP	RELATIVE RISK
		LARGER THAN 1.00
Millstone (Incidence)	<10	3.04
Savannah River	20-39	1.83
Prairie Island	40-59	2.41
Salem	40-59	1.45
		LESS THAN 1.00
San Onofre	10-19	0.75
Quad Cities	10-19	0.29
Vermont Yankee	10-19	0.09
Hanford	40-59	0.71
Mound	60+	0.92
Robinson	60+	0.64
Maine Yankee	60+	0.64
Turkey Point	60+	0.88
Brunswick	60+	0.15
Fernald	All	0.94
Humboldt Bay	All	0.47
Turkey Point	All	0.93
Pilgrim	All	0.87
Brunswick	All	0.51

INCIDENCE DATA

LEUKEMIA, UNDER 10 YR	BEFORE		AFTER	
	OBS	SRR	OBS	SRR
HADDAM NECK, CT (1967)	15	0.98	16	0.97
MILLSTONE, CT (1970)	49	1.19	44	1.55
FT. CALHOUN, NE (1973)	1	1.91	4	3.13
DUANE ARNOLD, IA (1974)	9	1.04	17	1.26
TOTAL	74	1.13	81	1.36

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LIMITATIONS OF THE STUDY

1. SO MANY COMPARISONS HAVE BEEN MADE THAT SOME 'SIGNIFICANT' DIFFERENCES WILL RESULT FROM CHANCE. FOR LEUKEMIA AFTER STARTUP THERE ARE 61 STUDY AREAS AND 6 AGE GROUPINGS. JUST OVER 18 OF THE 366 COMPARISONS COULD BE EXPECTED TO HAVE PROBABILITIES BELOW 0.05, AND THE NUMBER ACTUALLY WAS 18.

2. THE STUDY IS BASED UPON COUNTIES, SOME OF WHICH ARE VERY LARGE AND CONTAIN LARGE CITIES FAR DISTANT FROM THE FACILITY, e.g., SAN ONOFRE, IN SAN DIEGO COUNTY, CA AND TURKEY POINT IN DADE COUNTY, FL.

3. MANY OF THE FACILITIES BEGAN OPERATIONS IN RECENT YEARS AND NOT ENOUGH TIME MAY HAVE PASSED TO ALLOW FOR THE DETECTION OF CANCERS ASSOCIATED WITH THEIR OPERATION.

4. FOR MOST OF THE FACILITIES STUDIED ONLY MORTALITY DATA WERE AVAILABLE; INCIDENCE DATA, NEEDED FOR THE STUDY OF THYROID CANCER AND HIGHLY DESIRABLE FOR CANCERS SUCH AS THOSE OF THE FEMALE BREAST, WERE AVAILABLE FOR ONLY FOUR FACILITIES.

STRENGTHS

1. IT HAS BEEN POSSIBLE TO EXAMINE DATA FOR EACH STUDY AREA OVER A SPAN OF 35 YEARS WHICH, IN MOST INSTANCES, ALLOWED FOR COMPARISON BETWEEN CANCER RISKS BEFORE AND AFTER NUCLEAR FACILITIES BEGAN . OPERATION.

2. THE VERY LARGE NUMBER OF FACILITIES IN THE UNITED STATES PROVIDED AMPLE OPPORTUNITY FOR THE EXPRESSION OF RISK; THERE WERE MORE THAN 35,000 DEATHS FROM LEUKEMIA AND HALF A MILLION DEATHS FROM OTHER CANCERS IN THE STUDY AREAS AFTER PLANT. STARTUP.

3. THE STUDY OF COUNTY DATA HAS, IN PREVIOUS STUDIES, SUCCESSFULLY IDENTIFIED LUNG CANCER RISKS ASSOCIATED WITH ASBESTOS EXPOSURES IN SHIPYARDS AND WITH ARSENICAL AIR POLLUTION FROM THE SMELTING OF NON-FERROUS ORES.

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CONCLUSIONS

NO EVIDENCE WAS FOUND THAT OPERATIONS AT ANY OF THE NUCLEAR FACILITIES STUDIED CAUSED EXCESS DEATHS FROM CHILDHOOD LEUKEMIA OR FROM OTHER CANCERS IN THE COUNTIES IN WHICH THEY ARE LOCATED. THE INCREASES IN CHILDHOOD LEUKEMIA SEEN IN THE UNITED KINGDOM OCCURRED NEAR REPROCESSING AND WEAPONS PLANTS. NO PARALLEL INCREASES NEAR SUCH PLANTS ARE APPARENT IN THE UNITED STATES.

THIS STUDY PROVIDES GENERAL BACKGROUND INFORMATION THAT CAN HELP TO GUIDE ANY FUTURE STUDIES AROUND NUCLEAR FACILITIES.