Spotlight

Public Health Risks Of Extending Licenses Of The Indian Point 2 and 3 Nuclear Reactors

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November 12, 2007

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EXECUTIVE SUMMARY

The Indian Point nuclear plant, 35 miles north of midtown Manhattan, has three reactors, two of which remain in operation. Entergy Nuclear, which operates the plant, has requested that the federal government extend the operating licenses of the two reactors for 20 additional years beyond their 2013 and 2015 expiration dates.

To date, federal officials have not acknowledged any public health risks of license extension at Indian Point. This report explores risks from extending the Indian Point licenses.

Continued operation of Indian Point raises the risk of radioactivity exposure in two ways.

- First, the reactor cores would produce high-level waste to be added to the 1,500 tons already at the site, worsening the consequences of a large-scale release.
- Second, because reactors routinely release radioactivity, keeping Indian Point in service would mean greater releases and risks to local residents.

The principal findings of this report are:

1. A large-scale release of radioactivity in a meltdown, from mechanical failure or act of sabotage, would harm thousands through acute radiation poisoning or cancer.
2. Indian Point has released the 5th greatest amount of airborne radioactivity out of 72 U.S. nuclear plants. In some periods, releases are up to 100 times greater than normal.
3. Radioactivity levels in the Hudson River near Indian Point are over 10 times greater than those in Albany. Large variations exist in local radioactivity levels; for example, 2006 airborne radioactivity was three times as high in late fall, an in late spring.
4. Levels of Strontium-90 in local baby teeth are the highest of any area near seven U.S. nuclear plants. Local children born in the late 1990s have an average Sr-90 level 38% greater than

those born a decade earlier.

5. In the four counties closest to Indian Point, the incidence of cancer exceeds the state and national rates. In 2000-2004, excess cancer cases range from 2090 to 3631.
6. Local incidence rates of childhood cancer and thyroid cancer, both known to be sensitive to radiation exposure, are among the highest in New York State. Local thyroid cancer incidence is about 70% above the U.S. rate.
7. Cancer incidence in the towns within five miles of Indian Point is 20% greater than the rest of Rockland and Westchester Counties.
8. There is a statistical link between average levels of Strontium-90 in local baby teeth and local childhood cancer rates.
9. If closing Indian Point is associated with decreases in cancer mortality as it did near the Rancho Seco CA plant, 5000 fewer cancer deaths would occur in the next 20 years.

While many factors contribute to cancer risk, evidence suggests that more detailed study on Indian Point is warranted, and that the public be informed of any health risks.

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Spotlight

GEOGRAPHIC VARIANCE IN PENNSYLVANIA THYROID CANCER INCIDENCE AND THE LINK WITH NUCLEAR POWER REACTORS

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February 14, 2007

Summary. The rate of thyroid cancer, which is rising faster than any other cancer, is highest in Pennsylvania. Within the state, the highest rates are in the eastern counties closest to and east (downwind) of four nuclear power plants. Because radioactive iodine found only in nuclear weapons and reactors is known to cause thyroid cancer, it would be helpful to conduct closer examination of reactor emissions and the disease.

Background. Thyroid cancer is a relatively rare type of malignancy, accounting for about 1-2% of all new cancers in the U.S. It is one of the least deadly cancers, with a five year survival rate over 95%. Not much is known about the causes of thyroid cancer; the most recognized risk factor is exposure to ionizing radiation, specifically to radioactive iodine.

Established cancer registries in five states and four cities (9% of the U.S. population) show incidence of thyroid cancer changed little in from 1973-1980. From 1980-2003, incidence more than doubled from 4.3 to 9.4 cases/100,000 (adjusted to the 2000 U.S. population). Rates doubled for males, females, whites and blacks. Thyroid cancer is the fastest-rising cancer in the country, with no explanation for this trend.

A recent article in the journal JAMA suggested that better diagnosis accounts for the increase. This theory is questionable, as most thyroid cancers are found through routine physical examinations. No data exists that physicians are more proficient in examining patients for thyroid cancer, or provide more physical exams than a generation ago.

Geographic Patterns - by State. With cancer registries now operating in all states, the U.S. Centers for Disease Control and Prevention has assembled cancer incidence data for the years 1999-2002, for 38 states and the District of Columbia. Pennsylvania had the highest thyroid cancer incidence, at 10.61 cases per 100,000 persons, adjusted to the 2000 U.S. standard (5436 cases). The state with the lowest rate was North Carolina (4.89, 1207 cases). Table 1 shows rates for the states with the five highest and five lowest rates.

Table 1
Thyroid Cancer Incidence, By State, 1999-2002
In Age-Adjusted Cases Per 100,000 Persons
(U.S. Rate = 7.42, cases = 72269)

Highest			Lowest		
State	**Rate**	**Cases**	**State**	**Rate**	**Cases**
Pennsylvania	10.61	5436	North Carolina	4.89	1207
Montana	10.16	374	Arkansas	5.04	408

Rhode Island	9.82	425	Oklahoma	5.10	702
Delaware	9.69	313	Alabama	5.57	1003
Nevada	9.64	607	South Carolina	5.61	912
Excludes Connecticut, Hawaii, Iowa, Kansas, Maryland, Mississippi, New Mexico, South Dakota, Tennessee, Utah, Virginia, and Wyoming.					

The differences between the states with the highest and lowest rates are substantial, for no apparent reason. Pennsylvania is of particular interest, not just because it has the highest rate, but because it is the 6th most populated in the U.S (see Table 2). Its high rates are consistent among all years, genders, and races (for 38 states and District of Columbia).

Table 2
Ranks of Pennsylvania Thyroid Cancer Incidence Rates

Period	Category	Rank	Period	Category	Rank
1999-2002	All Races	1st	1999	All Races	6th
1999-2002	Whites	1st	2000	All Races	1st
1999-2002	Blacks	2nd	2001	All Races	1st
1999-2002	Males	2nd	2002	All Races	1st
1999-2002	Females	1st	1999-2002	Age 0-44	2nd
1999-2002	Age 45-64	2nd	1999-2002	Age 65+	1st

Geographic Patterns - by Pennsylvania County. The next step in a geographic analysis of thyroid cancer patterns is to examine rates by region or county. Such an analysis is feasible for Pennsylvania, as the state makes annual age-specific cancer cases for each county from 1990-2003 available on the internet. The 2000 U.S. census age-specific population allows age-adjusted incidence rates for each county to be calculated.

Average annual thyroid cancer rates for 1997-2003, adjusted to the 2000 standard U.S. population, were calculated for each of the 67 Pennsylvania counties. The state rate was 9.89 cases per 100,000 (8871 cases), with a wide range in rates by county (Table 3).

Table 3
Thyroid Cancer Incidence, By Pennsylvania County, 1997-2003
In Age-Adjusted Cases Per 100,000 Persons
(PA rate = 9.89, cases = 8871)

	County	Rate	Number
1.	Sullivan	17.87	8
2.	Lehigh	16.44	377
3.	Northampton	14.88	291
4.	Luzerne	13.51	333
5.	Lancaster	13.46	440
6.	Bucks	13.26	581
7.	Montgomery	12.76	703
8.	Clinton	12.00	34

9.	York	11.81	331
10.	Wyoming	11.65	23
11.	Chester	11.41	356
12.	Monroe	10.77	108
13.	Carbo	10.50	47
14.	Lackawann	10.28	162

A remarkable pattern emerges from the county-specific analysis of thyroid cancer rates in Pennsylvania. Of the 14 counties with the highest rates, 13 are located in the eastern third of the state (Clinton is the exception). There are no apparent socioeconomic factors distinct to this part of the state. Some counties are densely populated, while others are rural. The percentages of poverty and minorities vary as well. Even if there were a clear-cut pattern, none of these factors suggest a high risk for thyroid cancer.

Thyroid Cancer in Pennsylvania and Nuclear Reactors. The risk factor most commonly associated with thyroid cancer is exposure to radioactive iodine. There are various forms of iodine; I-129 decays slowly (half life of 16 million years) while I-131 decays quickly (half life of 8 days). When iodine enters the body, it seeks out the thyroid gland, where it kills and injures cells, leading to cancer and other disorders.

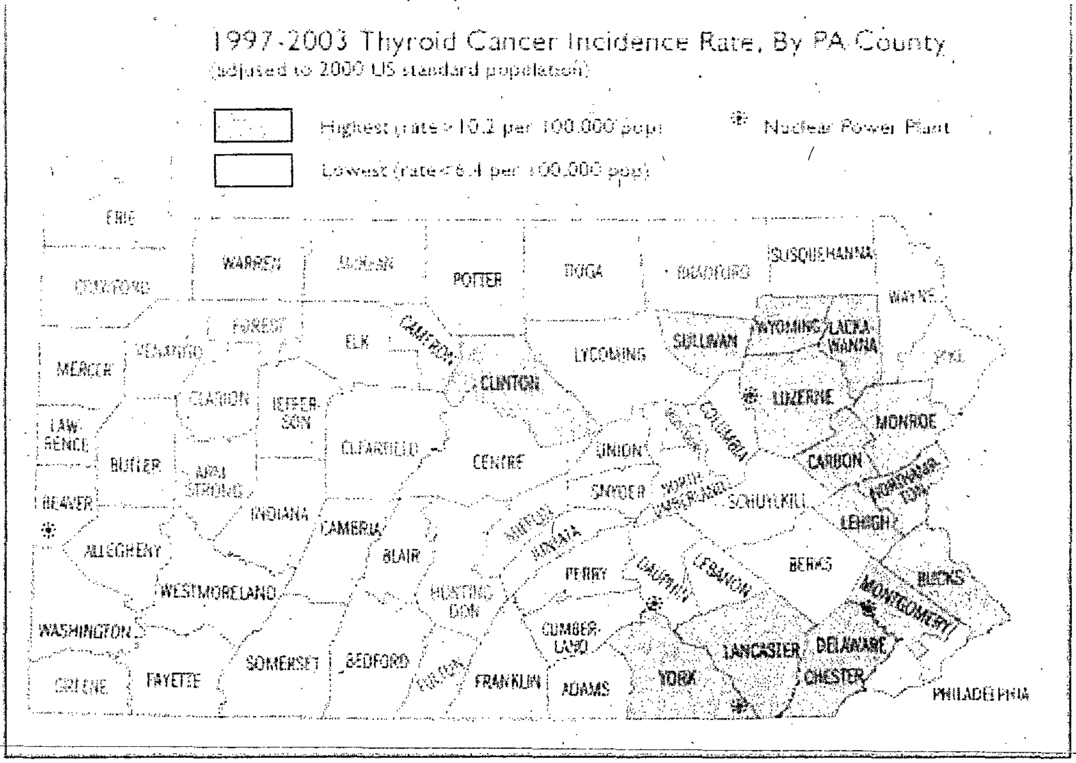
Radioactive iodine is only created when atomic bombs explode or when nuclear reactors operate. Above-ground atomic testing ended in 1963 and all testing ended in 1992. Nuclear reactors have operated in Pennsylvania since 1957. There are five plants with 12 reactors, 9 of which are still operating (Table 4). The state has more reactors than any except Illinois. All plants except Beaver Valley are in the eastern part of the state.

Table 4
Nuclear Power Reactors in Pennsylvania

Plant	No. of Reactors	Location	Year Startup
Beaver Valley	3	Southern Beaver County	1957, 1976, 1987
Peach Bottom	3	Southern York County	1966, 1973, 1974
Limerick	2	Northern Montgomery County	1984, 1989
Susquehanna	2	Western Luzerne County	1982, 1984
Three Mile Island	2	Southern Dauphin County	1974, 1978

Except for Clinton County, each of the 14 counties with the highest incidence rates from 1997-2003 are situated directly to the east, northeast, or southeast of a nuclear plant (see Map 1). This finding raises the theory that thyroid cancer risk has been raised by exposure to radioactive iodine, which is routinely released as airborne particles from each plant. Most iodine is propelled by prevailing winds, which blow from the northwest in colder months and the southwest in the warmer months.

Map 1



Iodine enters human bodies through breathing and the food chain. One means to transport iodine into the body is water; east of reactors, municipal drinking water is typically obtained from local sources. Another vector is milk, which is often not produced locally, but transferred from dairy farms. Much of the milk consumed in eastern Pennsylvania is produced on farms in Lancaster and York Counties, which lie in the midst of the Limerick, Peach Bottom, and Three Mile Island nuclear plants.

There is often a lag of a decade or more between radiation exposure and onset of cancer. Seven of the 12 reactors in the state were operating by 1978, and all reactors had started by 1989. Thus, several decades have elapsed since reactors began emitting radioactive iodine into the environment, making the reactor-thyroid cancer link plausible.

The one Pennsylvania nuclear plant not in the eastern part of the state is Beaver Valley. The Beaver county thyroid cancer rate is not one of the highest in the state, but exceeds all but one of the 16 most western counties in the state (Table 5). The only western county with a higher rate is Lawrence, which adjoins Beaver. Typically, thyroid cancer incidence is low in the area; Armstrong, Crawford, Forest, Greene, and Venango counties are among the lowest seven in the state.

Table 5
Thyroid Cancer Incidence, By Western Pennsylvania County, 1997-2003
In Age-Adjusted Cases Per 100,000 Persons
(PA rate = 9.89, cases = 8871)

	County	Rate	Cases
1.	Lawrence	10.06	69
2.	Beaver	9.84	134
3.	Mercer	9.20	81
4.	Allegheny	8.97	866
5.	Washington	7.98	125
6.	Butler	7.74	95

7.	Westmoreland	7.43	212
8.	Erie	7.20	142
9.	Warren	7.13	25
10.	Fayette	6.49	73
11.	Clarion	5.52	16
12.	Forest	5.24	2
13.	Armstrong	4.64	25
14.	Greene	4.30	13
15.	Crawford	4.27	28
16.	Venango	3.79	16

Implications. There is considerable state-by-state variation in the incidence of thyroid cancer, fastest-rising cancer in the U.S. The rate in some states is more than double that of others. In Pennsylvania, the state with the highest rate, there is considerable variation by county. Rates are highest in the counties in the eastern part of the state, each of which lies east of a nuclear power plant. The release of radioactive iodine into the atmosphere from these plants raises the possibility that these emissions are driving up thyroid cancer rates. More detailed study should be undertaken to better understand this relationship.

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INTERNATIONAL JOURNAL OF
HEALTH SERVICES
health and social policy
political economy and sociology
history and philosophy
ethics and law

editor-in-chief: vicente navarro

Volume 36, Number 1—2006

A Short Latency between Radiation Exposure from Nuclear Plants and Cancer in Young Children

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A SHORT LATENCY BETWEEN RADIATION EXPOSURE FROM NUCLEAR PLANTS AND CANCER IN YOUNG CHILDREN

Joseph J. Mangano

Previous reports document a short latency of cancer onset in young children exposed to low doses of radioactivity. The standard mortality ratio (SMR) for cancer in children dying before age ten rose in the period 6–10 years after the Three Mile Island and Chernobyl accidents in populations most exposed to fallout. SMRs near most nuclear power plants were elevated 6–10 years after startup, particularly for leukemia. Cancer incidence in children under age ten living near New York and New Jersey nuclear plants increased 4–5 years after increases in average strontium-90 in baby teeth, and declined 4–5 years after Sr-90 averages dropped. The assumption that Sr-90 and childhood cancer are correlated is best supported for a supralinear dose-response, meaning the greatest per-dose risks are at the lowest doses. Findings document that the very young are especially susceptible to adverse effects of radiation exposure, even at relatively low doses.

The latency period between radiation exposure and the onset of cancer has been documented to be as long as several decades. However, some radiation-induced cancer occurs after a much shorter period. Perhaps the first evidence of a short latency was documented in the 1950s, with high rates of thyroid and other cancers typically within 10 years of X-ray irradiation to infants and young children (1–3). Leukemia rates among Hiroshima and Nagasaki survivors were elevated beginning 5 years after the 1945 bombings, reaching a peak 10 years after (4–6). Adults treated with therapeutic radiation for ankylosing spondylitis demonstrated increases in mortality from leukemia within 2 years, and prostate cancer, pancreatic cancer, and extracranial tumors, each after 5 years (7). Lung cancer after the same treatment became elevated beginning 9 years after exposure (8). Irradiation treatment for cervical cancer resulted in elevated pancreatic cancer and

International Journal of Health Services, Volume 36, Number 1, Pages 113–135, 2006

leukemia 1–4 years after exposure (9–11). Peak levels of bone cancer after injection of radium-224 occurred 8 years after treatment (12).

Even at relatively low doses, irradiated adults are at greater risk for cancer just several years after exposure. A peak of chronic myeloid leukemia incidence was observed 6–10 years after X-rays to the back, gastrointestinal tract, and kidneys (13). Mormon families in Utah living directly downwind of atmospheric nuclear weapons tests in Nevada were found to have significantly higher incidence of all cancers combined and certain radiosensitive tumors 7–15 years after the tests began (14). Four to 5 years after the Chernobyl accident, thyroid cancer among adults in the Czech Republic and Poland increased (15, 16).

The developing fetus and infant have a predisposition to cancer from various types of low-dose radiation exposure within a decade. Pelvic X-rays to pregnant women in the 1950s initially was linked to a near doubling of the risk of cancer death before 10 years of age (17, 18). Subsequent reports on larger populations confirmed this excess, for both leukemia and other childhood cancers (19–21).

Elevated levels of radiosensitive cancers in the young shortly after exposure to fallout from atmospheric nuclear weapons tests have also been documented. Peaks in acute myeloid leukemia deaths in U.S. children age 5–9 years occurred in 1962 and 1968, about 5 years after the peak testing periods of the late 1950s and early 1960s (22). From 1948–52 to 1958–62, the number of Utah residents under age 30 who had their cancerous thyroid gland removed surgically rose from 6 to 30, much faster than the national increase (23). In five Nordic countries, leukemia incidence in children under age 5 peaked during the highest periods of fallout from bomb tests (24).

More recently, an elevation in leukemia diagnosed in the first year of life was seen in children born in 1986 and 1987, just after the accident at Chernobyl, representing a latency period of less than 2 years between in utero exposure and diagnosis. These elevations were documented in multiple nations, including Belarus (25), Greece (26), Scotland (27), the United States (28), Wales (29), and West Germany (30), plus a grouping of European countries (31). A latency beginning just 4 years between the accident at Chernobyl and elevated thyroid cancer rates in children has been reported in Belarus and the Ukraine (32–34). Rising thyroid cancer incidence in children has also been reported within 10 years of the accident in the moderately exposed areas of Belgium (35), East Hungary (36), and northern England (37). While some reports have found no excess in non-thyroid cancers in children irradiated by Chernobyl fallout, elevated rates with 10 years of exposure have been documented in the Ukraine (38) and Turkey (39).

Other reports have found unexpectedly high rates of childhood cancer, often leukemia and typically diagnosed before age 10, near nuclear installations. Early childhood cancer near nuclear plants likely represents effects of exposures in utero and in infancy. In the United Kingdom alone, at least eleven such reports representing different nuclear plants exist (40–50). Similar results were observed in Canada (51), France (52), Germany (53), and the former Soviet Union (54). Reports on this topic from the United States have been limited to several examining populations near a single facility at least two decades ago (55–59). Data from a 1990 National Cancer Institute report show that cancer incidence for age 0–9 years near each of four U.S. reactors exceeds the state rate (60). A recent analysis shows that cancer incidence for age 0–9 within 30 miles of each of 14 U.S. plants exceeds the national average for 1988–97, based on 3,669 cases (61).

The many reports documenting a 5–10 year lag between radiation exposure and childhood cancer onset, plus elevated childhood cancer near nuclear power plants, illustrate the heightened sensitivity of the fetus and infant to toxins. In this report I further examine this susceptibility by analyzing temporal trends in childhood cancer in populations exposed to low-dose nuclear power plant emissions 5–10 years after initial exposure.

METHODOLOGY

The first part of this report analyzes changes in childhood cancer mortality in four U.S. populations (described below) exposed to radioactivity from nuclear reactor emissions. Mortality is used since it is easily available for each U.S. county for each year from 1979 to 2002. Deaths of children before age 10 years are used, due to the heightened sensitivity to the fetus and infant and the expected latency of 5–10 years.

Because of the expected brief latency between exposure and disease onset, cancer deaths at age 0–9 in the periods 1–5 and 6–10 years after startup (used in the 1990 National Cancer Institute study of 52 U.S. nuclear power plants) can serve as controls and cases, respectively. Temporal changes in the standard mortality ratio (SMR), representing the ratio of observed to expected (local vs. national) rates, are examined. Significance of differences in observed and expected changes is tested using a standard z-score test.

Three Mile Island. On March 28, 1979, reactor unit 2 at the Three Mile Island nuclear installation in Pennsylvania experienced a partial core meltdown resulting from loss of cooling water. The damaged reactor emitted elevated (but still relatively low) levels of radioactivity; the total of 14.2 curies of airborne iodine-131 and effluents (all radioisotopes with a half-life of more than eight days) was about 400 times the average annual emissions from the plant to that time (62). The majority of fallout from the accident traveled with prevailing winds, in a north-northeasterly direction, being detected in elevated levels in the environment in distant locations such as Albany, NY (63), and Portland, ME (64).

This study considers cancer mortality for children age 0–9 years residing in the 34 contiguous counties north and northeast of Three Mile Island (see Appendix I).

Of these, 28 counties are in Pennsylvania and six in New Jersey, and all lie within 130 miles of the plant. SMRs in the period 1979–83 (1–5 years after the accident) and 1984–88 (6–10 years after) are compared. ICD-9 diagnosis codes 140.0–239.9 are used to identify all cancers combined, in all four study groups in this report. SMR changes for leukemia (ICD-9 204.0–208.9) and all other cancers combined are also reviewed.

Chernobyl. On April 26, 1986, reactor unit 4 at the Chernobyl plant in the Ukraine experienced a total core meltdown. Fallout from the disaster was propelled well into the stratosphere and across the globe. In the United States, elevated but relatively low levels of environmental radioactivity were observed beginning May 5, as precipitation returned fallout to earth. Short-lived radioisotopes remained elevated during the remainder of May and June; and long-lived isotopes did not return to pre-accident levels for another three years (65).

U.S. government measurements during May and June identified areas of the country that received the greatest levels of Chernobyl fallout. The upper Midwest and Pacific northwest, along with New York City, Washington, DC, and Maine, had the highest concentrations of iodine-131 (half-life of 8.05 days) in pasteurized milk from May 6 to June 30, 1986 (Table 1).

The change in SMR for cancer at age 0–9 years from the period 1986–90 to 1991–95 (1–5 and 6–10 years after the accident) for 17 states and the District of Columbia is compared with that of the remaining U.S. states. In New York, only the New York City area is included, since the average I-131 concentration in Buffalo and Syracuse was 8.0 picocuries per liter of pasteurized milk, well below the New York City average (14.0). In California, only the 29 northern counties are included, as I-131 averages for Sacramento and San Francisco (19.6 and 17.2) were well above that for Los Angeles (6.7). See Appendix II for a list of states and counties studied.

Counties near New Nuclear Plants—Startup before 1982. The 1990 study by the National Cancer Institute examined cancer mortality before and after startup of 52 nuclear power plants. The 1990 report calculated SMRs for 5-year intervals (1–5 years before and after startup, 6–10 years before and after startup, etc.) for various age groups. This report examines the change in SMR from 1–5 years after startup to 6–10 years after startup for children age 0–9 years living near plants. Included [illegible] of the 20 areas near nuclear plants (defined by the 1990 study) with the largest populations, which account for 89 percent of annual cancer deaths at age 0–9 near the 52 plants. More than 18.3 million persons lived in these counties in 2000 (Table 2).

Counties near New Nuclear Plants—Startup since 1982. Beginning in 1982, a total of 23 U.S. nuclear plants began operations at installations with no existing nuclear reactors. These were not included in the 1990 study, because of the late

Table 1

U.S. sites with highest average concentrations of iodine-131 in pasteurized milk after the Chernobyl accident

Site	No. of samples	Average I-131[a]
Boise, ID	8	71.0
Spokane, WA	12	42.0
Helena, MT	12	30.8
Rapid City, SD	12	27.8
Salt Lake City, UT	12	25.6
Seattle, WA	11	24.8
Wichita, KS	10	19.7
Sacramento, CA	13	19.6
Portland, OR	10	18.8
Minneapolis, MN	10	18.1
San Francisco, CA	13	17.2
Des Moines, IA	9	16.8
Grand Rapids, MI	10	16.5
Las Vegas, NV	13	15.5
Omaha, NE	10	15.4
New York, NY	12	14.0
Oklahoma City, OK	11	13.6
Minot, ND	12	12.9
Portland, ME	11	12.6
Washington, DC	11	11.6
Detroit, MI	10	11.1
Other U.S. sites		8.0

Source: Office of Radiation Programs (65).
[a]Average picocuries of iodine-131/liter of pasteurized milk, May 6–June 30, 1986.

startup date. For purposes of this report, proximate areas were defined as those counties situated completely or mostly within 30 miles of the plant. Of the areas proximate to these 23 plants, the most populated 14 (with 88% of the childhood cancer deaths a decade after startup) were selected for study. One of these, near the Catawba plant in South Carolina, was excluded from the analysis, since it lies close to the McGuire plant, which began operations four years before Catawba startup, and is included in the previous analysis. More than 17.5 million Americans lived in counties proximate to these plants in 2000 (Table 3). The SMRs for childhood cancer at age 0–9 for the periods 1–5 years and 6–10 years after startup are compared near each plant. If a plant began operations in 1982, the periods 1983–87 and 1988–92 are used.

Table 2

U.S. nuclear plants started before 1982 and proximate counties, as defined by the National Cancer Institute, with largest populations in 2000

Plant	Startup	Counties	Population
Shippingport	1957	Beaver, PA; Hancock, WV	214,079
Dresden	1960	Grundy, Will, IL	539,801
Yankee Rowe	1960	Berkshire, Franklin, MA	206,488
Indian Point	1962	Rockland, Westchester, NY	1,210,212
San Onofre	1962	Orange, San Diego, CA	5,660,122
Fermi	1963	Monroe, MI	145,945
Oyster Creek	1969	Ocean, NJ	510,916
Millstone	1970	New London, CT	259,088
Pilgrim	1972	Plymouth, MA	472,822
Quad Cities	1972	Rock Island, Whiteside, IL	210,027
Turkey Point	1972	Dade, FL	2,253,362
Zion	1974	Kenosha, WI; Lake, IL	793,933
Duane Arnold	1974	Benton, Linn, IA	217,009
Rancho Seco	1974	Amador, Sacramento, San Joaquin, CA	1,822,197
Three Mile Island	1974	Dauphin, Lancaster, York, PA	1,104,207
Cook	1975	Berrien, MI	162,453
Fort St. Vrain	1976	Boulder, Larimer, Weld, CO	723,718
Salem	1976	New Castle, DE; Salem, NJ	564,550
Sequoyah	1980	Hamilton, TN	307,896
McGuire	1981	Gaston, Lincoln, Mecklenberg, NC	949,599
Total 20 areas			18,328,424

Source: Bureau of the Census, 2000 Census of the United States, State/County quick facts, www.census.gov.

The second part of this study examines the effects of radioactive emissions, as detected in the bodies of children. The average strontium-90 concentration in baby teeth was measured for more than 4,000 American children, most residing near nuclear power plants. The amount of Sr-90 per gram of calcium at birth in each baby tooth was measured in a radiochemistry laboratory, using a scintillation counting technique.

Average Sr-90 concentrations were analyzed by birth year of the tooth donor, since much of the Sr-90 uptake in deciduous teeth occurs during pregnancy and early infancy. Temporal trends in Sr-90 averages were compared with trends in cancer incidence for children under age 10 in the counties near nuclear plants for which the largest numbers of teeth were available. These plants include Suffolk County (NY; near the Brookhaven National Laboratories); Monmouth and Ocean

Table 3

U.S. Nuclear plants started since 1982 and proximate counties with largest populations in 2000 at sites with no previously existing reactors

Plant	Startup	Counties	Population
Summer	1982	Chester, Fairfield, Lexington, Newberry, Richland, Union, SC	660,202
Susquehanna	1982	Carbon, Columbia, Luzerne, Montour, Schuylkill, Sullivan, Wyoming, PA	645,411
Diablo Canyon	1984	San Luis Obispo, Santa Barbara, CA	586,028
Limerick	1984	Berks, Bucks, Chester, Montgomery, Lehigh, PA	2,466,961
Byron	1985	Boone, De Kalb, Ogle, Stephenson, Winnebago, IL; Rock, Walworth, WI	755,250
Fermi 2	1985	Lenawee, Monroe, Washtenaw, Wayne, MI	2,628,892
Palo Verde	1985	Maricopa, AZ	3,072,149
River Bend	1985	E./W. Baton Rouge, E./W. Feliciana, Pointe Coupee, LA; Wilkinson, MS	503,999
Waterford	1985	Ascension, Jefferson, Lafourche, Orleans, St. Charles, St. James, St. John the Baptist, LA	1,219,073
Perry	1986	Ashtabula, Cuyahoga, Geauga, Lake, OH	1,815,112
Braidwood	1987	Grundy, Kankakee, Kendall, Will, IL	698,178
Harris 1	1987	Chatham, Durham, Harnett, Lee, Orange, Wake, NC	1,168,781
Seabrook	1990	Rockingham, Strafford, NH; Essex, MA; York, ME	1,299,753
Total 13 areas			17,529,789

Source: Bureau of the Census, 2000 Census of the United States, State/County quick facts, www.census.gov.

Counties (NJ; near the Oyster Creek plant); and Putnam, Rockland, and Westchester Counties (near the Indian Point plant). The correlation between these two trends is assessed using a Poisson regression analysis testing the hypothesis that they are related. Linear and quadratic correlations are tested using the actual value, square root, and fourth root of Sr-90 averages.

The specific methodology to calculate Sr-90 concentration for each tooth is described elsewhere (66, 67). Teeth from Suffolk County were analyzed using a Wallac WDY 1220X Quantulus low-level scintillation spectrometer; a Perkin-Elmer 1220-005 Quantulus Ultra Low-Level Liquid Scintillation Spectrometer was used for other teeth. In addition, the method used to clean teeth before testing differed between Suffolk County and other teeth; a more sophisticated preparation for non-Suffolk teeth, plus use of a different counter, allowed more Sr-90 to be detected. However, results for each area are internally consistent, allowing Sr-90 patterns and trends to be analyzed.

Strontium-90 results are compared with cancer incidence diagnosed in children age 0–9 years who resided in counties near nuclear plants at the time of diagnosis. Cancer registries from the states of New Jersey and New York provided counts of incident cases, while U.S. Census Bureau counts and inter-censal estimates are used for resident population. Three-year moving averages, rather than individual years, are used for both Sr-90 and cancer rates, to increase the statistical power of the comparison.

RESULTS

Three Mile Island

In the 34 downwind (north and northeast) counties closest to Three Mile Island, the SMR for cancer in children age 0–9 years rose 23.8 percent (0.87 to 1.08) from 1979–83 to 1984–88, the periods 1–5 years and 6–10 years after the accident. The crude cancer mortality rate at age 0–9 in the 34 counties increased 3.6 percent, compared with a national decline of 16.4 percent. Because the number of local deaths in each 5-year period (127 and 135) was relatively small, the rise in SMR is of borderline significance at $P < .09$ (Table 4). While the SMR for leukemia fell from 0.95 to 0.88, the ratio for all other cancers combined rose from 0.83 to 1.17, statistically significant at $P < .03$.

Chernobyl

From 1986–90 to 1991–95 (1–5 years and 6–10 years after the accident) the SMR for cancers at age 0–9 years in the 18 states with the most fallout from the

Table 4

Three Mile Island: change in standard mortality ratio, children age 0–9, after the March 28, 1979, accident, 1979–83 vs. 1984–88, 34 counties north/northeast and closest to Three Mile Island

	SMR (deaths)		
Type of cancer	1979–83	1984–88	% Change SMR
All cancers combined	0.87 (127)	1.08 (135)	+23.8 ($P < .09$)
Leukemia	0.95 (48)	0.88 (35)	–6.8 ($P < .90$)
All other cancers	0.83 (79)	1.17 (100)	+41.0 ($P < .03$)

Source: U.S. Centers for Disease Control and Prevention, http://wonder.cdc.gov; underlying cause of death; uses ICD-9 codes 140.0–239.9.

Chernobyl accident rose from 0.97 to 1.06, a significant increase ($P < .02$). The crude cancer death rate at age 0–9 declined 6.6 percent in the 18 states, compared with a reduction of 14.0 percent elsewhere in the United States. The SMR rise for leukemia (0.90 to 1.01) exceeded that for all other cancers (1.00 to 1.07). Neither increase achieved statistical significance ($P < .10$ and $P < .13$, respectively) (Table 5).

Counties near Nuclear Plants—Startup before 1982

The SMR for all cancers in children dying before their tenth birthday in the 20 most populated areas near nuclear power plants cited in the 1990 National Cancer Institute report (startup before 1982) increased for 17 of the 20 areas from 1–5 to 6–10 years after plant startup. Table 6 shows the total SMR rose from 0.99 to 1.18. Because of the large number of deaths in each period (587 and 590), the change was statistically significant at $P < .003$. Only one of the 20 changes near individual plants (Shippingport) was statistically significant. The increase in SMR for leukemia (1.00 to 1.22) exceeded that for all other cancers (0.98 to 1.15). Both increases achieved statistical significance ($P < .03$ and $P < .05$, respectively).

Counties near Nuclear Plants—Startup since 1982

Table 7 shows that the cancer SMR for age 0–9 in the 13 most populated areas near nuclear plants started since 1982 rose from 0.92 to 1.05, which is of borderline significance ($P < .08$). The ratio rose in nine of the 13 areas near nuclear plants, declined near three, and was essentially unchanged in another. The crude rate near the 13 plants fell just 1.6 percent, compared with larger declines nationwide. The SMR increase for leukemia (0.85 to 1.04) was roughly double that of all other cancers (0.96 to 1.06). Neither of these changes achieved statistical significance ($P < .12$ and $P < .28$, respectively).

Table 5

Chernobyl: change in standard mortality ratio, children age 0–9, after the April 26, 1986, accident, 1986–90 vs. 1991–95, 18 states with sites with highest average I-131 measurements

	SMR (deaths)		
Type of cancer	1986–90	1991–95	% Change SMR
All cancers combined	0.97 (1,501)	1.06 (1,466)	+8.7 ($P < .02$)
Leukemia	0.90 (434)	1.01 (422)	+11.5 ($P < .10$)
All other cancers	1.00 (1,067)	1.07 (1,040)	+7.0 ($P < .13$)

Source: U.S. Centers for Disease Control and Prevention, http://wonder.cdc.gov; underlying cause of death; uses ICD-9 codes 140.0–239.9.

Table 6

Counties near nuclear power plants that began operations before 1982: change in cancer mortality, children age 0–9, 1–5 years vs. 6–10 years after startup, 20 most populated areas

Type of cancer	SMR (deaths) 1–5 yrs after	SMR (deaths) 6–10 yrs after	% Change SMR
All cancers combined	0.99 (587)	1.18 (590)	+19.3 (*P* < .003)
Leukemia	1.00 (276)	1.22 (264)	+22.9 (*P* < .03)
All other cancers	0.98 (311)	1.15 (326)	+16.6 (*P* < .05)
All cancers by plant			
Shippingport	0.84 (20)	1.47 (29)	+73.7 (*P* < .05)
Dresden	1.00 (22)	1.26 (26)	+26.6
Yankee Rowe	0.65 (11)	1.23 (17)	+89.9
Indian Point	0.98 (75)	1.22 (79)	+23.9
San Onofre	1.07 (186)	1.11 (153)	+3.4
Fermi 1	0.68 (7)	1.18 (10)	+73.2
Oyster Creek	1.12 (15)	0.69 (8)	–38.6
Millstone	1.34 (17)	0.60 (5)	–55.6
Pilgrim	1.02 (19)	1.10 (16)	+8.3
Quad Cities	1.03 (11)	1.48 (12)	+43.3
Turkey Point	0.94 (48)	1.12 (49)	+18.3
Zion	0.74 (18)	1.01 (20)	+36.2
Duane Arnold	1.06 (8)	1.29 (8)	+22.3
Rancho Seco	1.14 (44)	1.43 (55)	+25.1
Three Mile Island	0.87 (28)	1.29 (36)	+47.4
Cook	1.35 (9)	1.54 (8)	+14.1
Fort St. Vrain	0.67 (10)	1.11 (16)	+67.0
Salem	0.79 (12)	1.01 (13)	+27.5
Sequoyah	1.60 (13)	1.51 (10)	–5.6
McGuire	0.78 (14)	1.16 (20)	+49.2
Total	0.99 (587)	1.18 (590)	+19.3

Source: National Cancer Institute, *Cancer in Populations Near Nuclear Facilities*, U.S. Government Printing Office, Washington, DC, 1990.

Strontium-90 Trends and Childhood Cancer Incidence

Figures 1, 2, and 3 illustrate the comparisons of average Sr-90 in baby teeth and cancer incidence in children under age 10 years (Ca 0–9) near three nuclear plants. Each represents between 10 and 14 three-year periods (moving average) covering persons born in the 1980s and the early 1990s. The analyses include a large

Table 7

Counties near nuclear power plants that began operations since 1982: change in cancer mortality, children age 0–9, 1–5 years vs. 6–10 years after startup, 13 most populated areas

Type of cancer	SMR (deaths) 1–5 yrs after	SMR (deaths) 6–10 yrs after	% Change SMR
All cancers combined	0.92 (353)	1.05 (368)	+14.7 ($P < .08$)
Leukemia	0.85 (115)	1.04 (124)	+21.6 ($P < .12$)
All other cancers	0.96 (238)	1.06 (244)	+10.6 ($P < .28$)
All cancers by plant			
Summer	0.95 (14)	0.76 (10)	–19.8
Susquehanna	0.41 (6)	0.87 (11)	+113.0
Diablo Canyon	0.54 (7)	0.77 (10)	+42.9
Limerick	0.76 (39)	0.99 (48)	+30.8
Byron	0.59 (10)	1.26 (19)	+112.6
Fermi 2	0.94 (64)	1.20 (73)	+28.2
Palo Verde	1.01 (55)	0.89 (49)	–11.6
River Bend	0.83 (11)	1.18 (13)	+41.7
Waterford	0.69 (24)	0.94 (26)	+35.6
Perry	1.10 (47)	1.31 (48)	+18.6
Braidwood	0.57 (8)	0.71 (10)	+25.3
Harris 1	1.67 (31)	1.06 (19)	–36.7
Seabrook	1.37 (37)	1.37 (32)	–0.3
Total	0.92 (353)	1.05 (368)	+14.7

Source: U.S. Centers for Disease Control and Prevention, http://wonder.cdc.gov; underlying cause of death; uses ICD-9 codes 140.0–239.9.

number of teeth and cancer cases (453 and 390 for Suffolk County, 167 and 434 for Monmouth and Ocean Counties, and 239 and 371 for Putnam, Rockland, and Westchester Counties). The three areas indicate a similarity of trends in Sr-90 and childhood cancer, with a four-year latency between the two in New York and a five-year latency in New Jersey. For example, the average Sr-90 level in Suffolk County teeth steadily rose from 0.97 to 1.68 picocuries of Sr-90 per gram of calcium from 1981–83 to 1984–86. The rate of Suffolk children age 0–9 diagnosed with cancer steadily rose from 1.518 to 2.075 cases per 10,000 persons from 1985–87 to 1988–90.

The correlation was statistically significant ($P < .05$) for Monmouth/Ocean and Suffolk Counties, but fell short of significance for Putnam/Rockland/Westchester. It was also significant for all three areas combined, after taking into account that

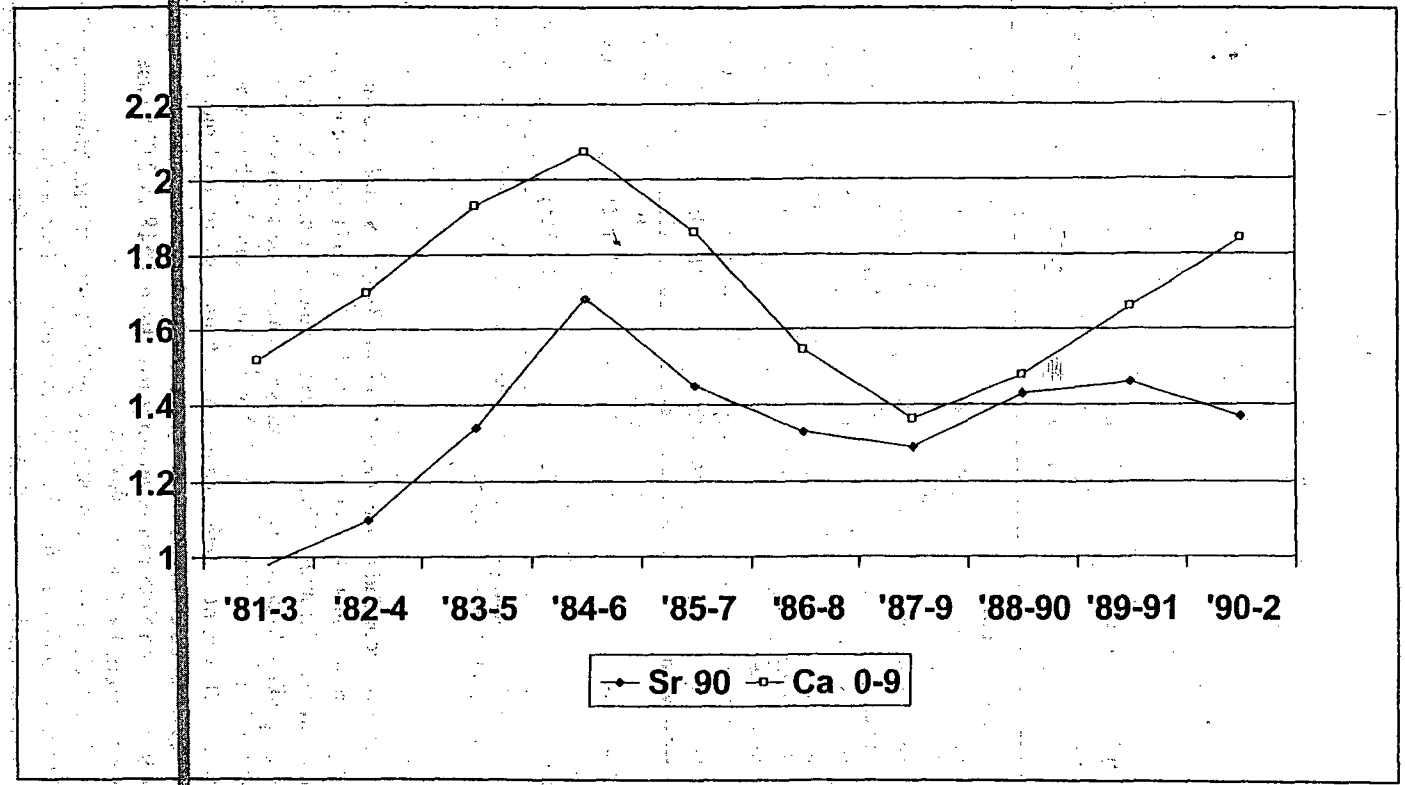

Figure 1. Strontium-90 in baby teeth vs. cancer incidence at age 0–9 years, Suffolk County, NY. Picocuries of Sr-90 per gram of calcium; cancer cases (Ca) per 10,000 population; four-year lag (Sr-90 begins 1981–83; Ca begins 1985–87).

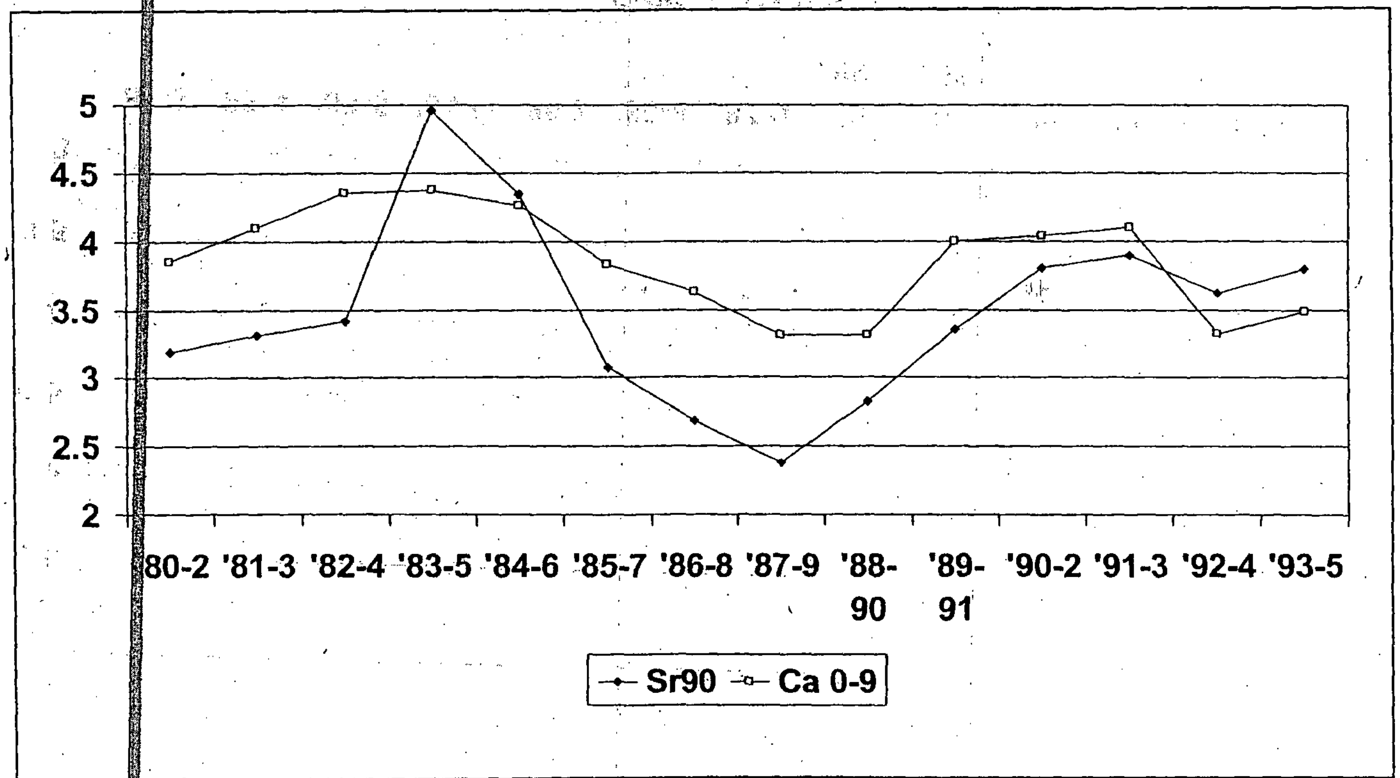

Figure 2. Strontium-90 in baby teeth vs. cancer incidence at age 0–9 years, Monmouth and Ocean Counties, NJ. Picocuries of Sr-90 per gram of calcium; cancer cases (Ca) per 2,000 population; five-year lag (Sr-90 begins 1980–82; Ca begins 1985–87).

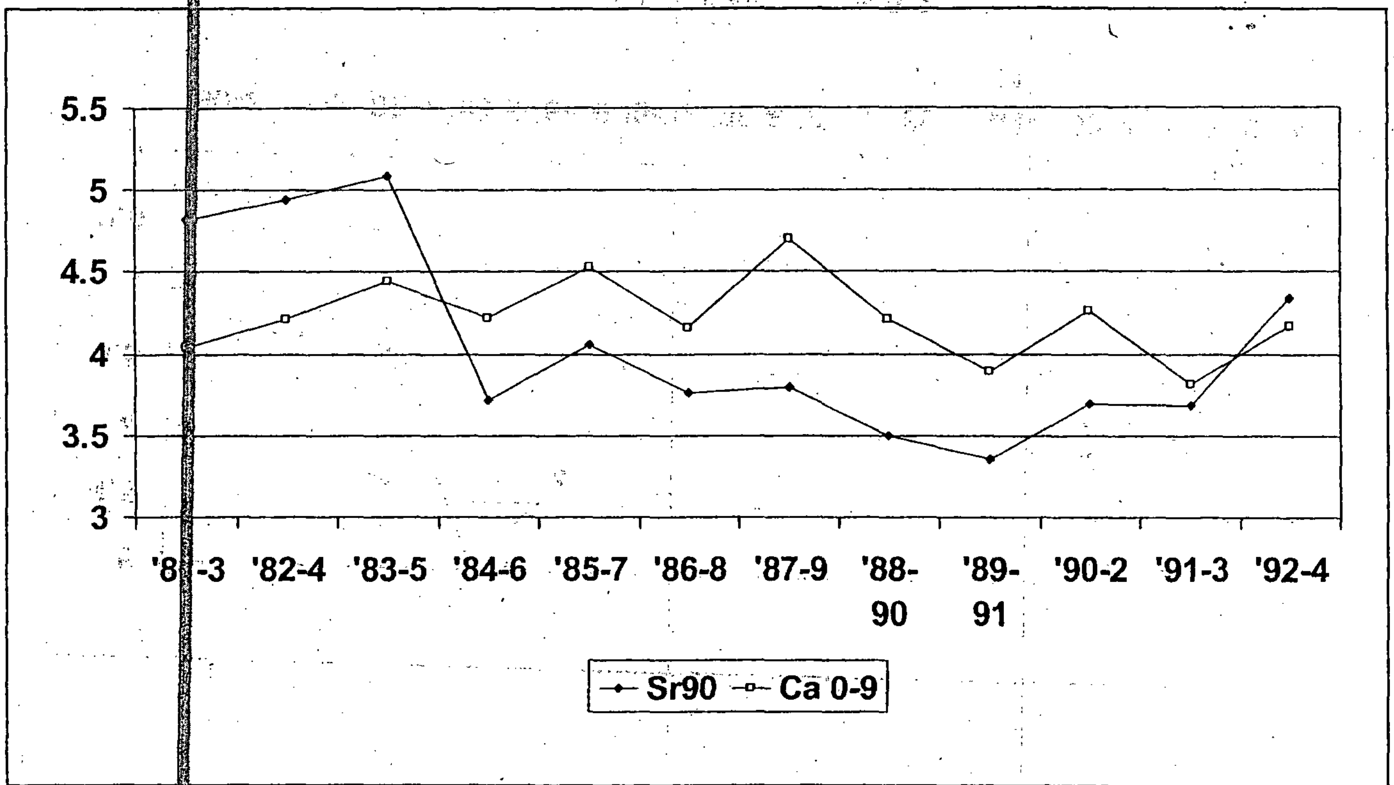

Figure 3. Strontium-90 in baby teeth vs. cancer incidence at age 0–9 years, Putnam, Rockland, and Westchester Counties, NY. Picocuries of Sr-90 per gram of calcium; cancer cases (Ca) per 2,000 population; four-year lag (Sr-90 begins 1981–83; Ca begins 1985–87).

Table 8

Poisson regression results, average Sr-90 concentration and cancer incidence, age 0–9, areas near New York and New Jersey nuclear power plants

Counties	*P* value	95% CI	IRR
Monmouth/Ocean, NJ			
Actual Sr-90 value	.039	1.005–1.201	1.099
Square root of Sr-90	.038	1.020–2.003	1.430
Fourth root of Sr-90	.038	1.058–6.716	2.665
Suffolk, NY			
Actual Sr-90 value	.043	1.011–2.029	1.432
Square root of Sr-90	.049	1.002–4.908	2.218
Fourth root of Sr-90	.053	0.978–28.886	5.314
Putnam/Rockland/Westchester, NY			
Actual Sr-90 value	.704	0.912–1.146	1.022
Square root of Sr-90	.693	0.688–1.755	1.099
Fourth root of Sr-90	.688	0.346–5.029	1.316
All areas combined			
Actual Sr-90 value	.020	1.005–1.064	1.035
Square root of Sr-90	.021	1.017–1.223	1.115
Fourth root of Sr-90	.021	1.041–1.650	1.311

Note: CI, confidence interval; IRR, incidence rate ratio.

there may be confounding factors. *P* values were similar whether the actual value, square root, or fourth root of the Sr-90 measurements was used. However, the quadratic (fourth root) of Sr-90 best fits the assumption that the two variables are related; the incidence rate ratio (IRR) is highest for each area when the fourth root is used for Sr-90 (Table 8).

DISCUSSION

The minimum latency period between radiation exposure of the fetus and infant and onset of cancer has often been documented as about 5–10 years. This latency includes various types of radiation exposure (from X-rays, nuclear weapons test fallout, the Chernobyl accident) and various types of cancer (leukemia, thyroid cancer, and other malignancies). In the United States, the issue of whether nuclear reactor operations have affected childhood cancer risk is largely unexamined. Reactor operations is a pertinent area of study, since atmospheric and subterranean weapons tests ceased in 1963 and 1992, respectively. The 103 U.S. nuclear power reactors now in operation represent nearly one-fourth of the world's total, and include some of the oldest reactors.

This report analyzes cancer mortality in children exposed to radioactivity from nuclear power reactors who died before their tenth birthday. Because the lag between exposure and diagnosis can often be 5–10 years, the periods 1–5 years and 6–10 years after initial exposure were compared. Excess cancer deaths among children during the first 5 years after exposure would not be expected, and thus represent a control group, while an elevated level of cancer deaths 6–10 years after exposure would be expected.

In areas of the United States exposed to the greatest levels of fallout from accidents at Three Mile Island and Chernobyl, and areas proximate to newly started nuclear reactors, increases in the standard mortality ratio 6–10 years after initial exposure in children under age 10 were observed. Increases in SMR ranged from 8.7 to 23.8; each of these temporal changes achieved or approached statistical significance. For each of the four areas studied other than the area near Three Mile Island, the SMR increase for leukemia exceeded that for all other cancers. All SMRs were less than 1.00 in the period 1–5 years after initial exposure, and were greater than 1.00 in the period 6–10 years after; this indicates that populations with cancer rates below the national average changed to those with rates above the national average in just a few years.

In addition, the report examines the relationship between temporal trends of in-body radioactivity (i.e., Sr-90 in baby teeth at birth) and childhood cancer incidence near three U.S. nuclear installations. For each area, the pattern of childhood cancer increasing 4–5 years after a rise in Sr-90 (and decreasing 4–5 years after a Sr-90 decline) was consistent. While the relationship achieved statistical significance in just two of the three areas, plus all three areas combined, the results suggest a link between fetal/infant exposures from nuclear plant emissions and cancer in childhood. Much of the Sr-90 in deciduous teeth of children living near nuclear plants probably represents emissions from the plant that are ingested in air and food (67).

An important finding in the comparison of Sr-90 and childhood cancer trends is that the quadratic (fourth root) value of Sr-90 in baby teeth provides the highest incidence rate ratio, and thus supports the theory that a quadratic of Sr-90 fits the assumption of a link better than does linearity. Thus, the upward supralinear dose-response best describes the relationship between in-body Sr-90 and childhood cancer risk. This relationship indicates that the greatest per-dose risk occurs at the lowest dose levels, which is critical to understanding the health risks of radioactive environmental emissions routinely released from nuclear facilities.

The findings of this in-depth examination of temporal childhood cancer patterns near U.S. nuclear plants are important in several ways. They support the pattern of a relatively short lag period between exposures early in life and disease onset. The pattern of children exposed to radiation being especially susceptible to leukemia as opposed to other types of cancer is consistent with many earlier findings. Perhaps the most important aspect of the report is documentation of an apparent childhood cancer risk at relatively low levels of exposure. Many previous studies involved considerably larger doses, including fallout from atomic bomb tests and radiation from the Chernobyl accident. Radioactivity levels in the United States from the Three Mile Island and Chernobyl accidents were considerably lower than that in Belarus/Ukraine after Chernobyl. While environmental emissions of fission products from nuclear plants vary, they are typically lower than those released in major accidents or in bomb test fallout. Results indicate that ongoing exposure to radioactivity may present an increased health risk to infants and children not previously understood. Exposures such as Hiroshima and medical use of X-rays represent a single dose, while nuclear plant emissions are continuous, and long-lived isotopes from Three Mile Island/Chernobyl remained in the U.S. food chain for years.

The study has limitations that should be addressed in subsequent research efforts. Perhaps the most important of these is the need to continue to improve dose estimates for exposures from nuclear plant emissions and to further explore epidemiological comparisons of health risks. A case-control comparison of in-body doses of radioactivity in children with and without a disease such as cancer who live proximate to nuclear facilities would be useful to fill this need. This report isolates only one specific type of cancer (leukemia). It examines potential effects only on young children, not adolescents or adults. It examines patterns of cancer mortality only in the first decade after initial exposure, and not thereafter. Not all increases in SMR, or all correlations between Sr-90 in baby teeth and childhood cancer incidence, are statistically significant.

Despite these shortcomings, the epidemiological findings documented here represent a novel contribution to the understanding of radiation risks to the very young. With tens of millions of Americans living close to nuclear reactors, more detailed studies should be pursued forthwith.

Acknowledgments — The author thanks Araceli Busby, Ph.D., for her assistance with statistical significance testing for this report.

APPENDIX I

Counties Included in Table 4

Pennsylvania and New Jersey counties located north/northeast of Three Mile Island and within 130 miles of the plant that are included in analysis in Table 4:

Pennsylvania Counties

Berks	Monroe
Bradford	Montour
Bucks	Northampton

Pennsylvania Counties (cont'd.)

Carbon	Northumberland
Columbia	Perry
Cumberland	Pike
Dauphin	Schuylkill
Juniata	Snyder
Lackawanna	Sullivan
Lebanon	Susquehanna
Lehigh	Tioga
Luzerne	Union
Lycoming	Wayne
Mifflin	Wyoming

New Jersey Counties

Hunterdon
Mercer
Morris
Somerset
Sussex
Warren

Populations Age 0–9

	PA/NJ Counties	*U.S.*
1979–83	2,981,889	165,992,436
1984–88	3,058,676	175,532,642

APPENDIX II
States and Counties Included in Table 5

States and counties with highest iodine-131 averages in milk, measured during May and June 1986, after the Chernobyl accident, that are included in analysis in Table 5:

States

California (29 counties)	Nebraska
District of Columbia	Nevada
Idaho	New York (7 counties)
Iowa	North Dakota
Kansas	Oklahoma
Maine	Oregon

Michigan	South Dakota
Minnesota	Utah
Montana	Washington

California Counties

Amador	Placer
Butte	Plumas
Colusa	Sacramento
Contra Costa	San Francisco
Del Norte	Shasta
El Dorado	Sierra
Glenn	Siskiyou
Humboldt	Solano
Lake	Sonoma
Lassen	Sutter
Marin	Tehama
Mendocino	Trinity
Modoc	Yolo
Napa	Yuba
Nevada	

New York Counties

Bronx
Kings
New York
Queens
Richmond
Rockland
Westchester

Populations Age 0–9

	States with High I-131	*Other U.S.*
1986–90	39,082,847	141,343,373
1991–95	40,863,580	151,355,461

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The Health Effects of Low Level Radiation

Proceedings of a Symposium held at the House of Commons, London, April 24th, 1996

edited by
Richard Bramhall

Green Audit Books
Green Audit Wales Ltd
Aberystwyth 1997

Cynog Dafis: "Thank-you. Now our last listed speaker is Professor Ernest Sternglass, Professor of Radiological Physics at the University of Pittsburgh School of Medicine, author of *Low Level Radiation*, *Secret Fallout* and other publications."

Professor Sternglass: "As you can imagine from what you've heard just now, there's a wide range of views on how to evaluate radiation exposures that take place in the actual environment of the world. The A-bomb study was the first of the major studies that gave one kind of result. There were studies of medically exposed people and of course Dr. Stewart's famous study[12] that showed a very high risk for the developing infant in utero - typically anywhere from ten to a hundred times that of the adult - in direct relation to the dose, so that there was no evidence for a safe threshold. Dr. Stewart was clearly a pioneer in showing extremely small doses to be harmful, especially since for the better part of a hundred years there had been no significant evidence of serious side effects in adults given ordinary diagnostic x-rays. So the question is: "Can we explain the surprising effects of small doses, and how can we detect effects in the environment at exposures that are so small that most people had expected not to be able to find any?"

Well, Chernobyl gave us a terrible example of what can happen to a society that has greatly underestimated the risks, and this is how we began to find out about it. All of you know how enormous the effects have been on the children of Belarus - that there has now been an increase of the order of something like a hundred-fold in the incidence of thyroid cancer, which amazingly appeared in a period of only a few years. Just to give you an idea of what this looks like, Figure 37 shows the incidence of thyroid cancer in children in Belarus. It is taken from an article in *Nature* in 1992[13]. Incidence of the disease went from only two to fifty-five by 1991, and by today, within the latest data, it is more than double this. So there can be no question about two very important things that we did not expect. From studies of children whose thymuses were irradiated by x-rays in the 1950s and '60s to shrink the thymus (in the mistaken belief that the thymus was not an important organ) it was found that the children did not develop cancer until - typically - ten, fifteen, twenty years afterward. Many did not for twenty or forty years. So it was totally unexpected to see thyroid cancers in only four to five years. Furthermore the incidence was vastly greater than expected: something like a hundred or more cases were found than had been expected. In fact the World Health Organisation and the International Atomic Energy Agency had predicted that no detectable increase in cancers would be found after Chernobyl.

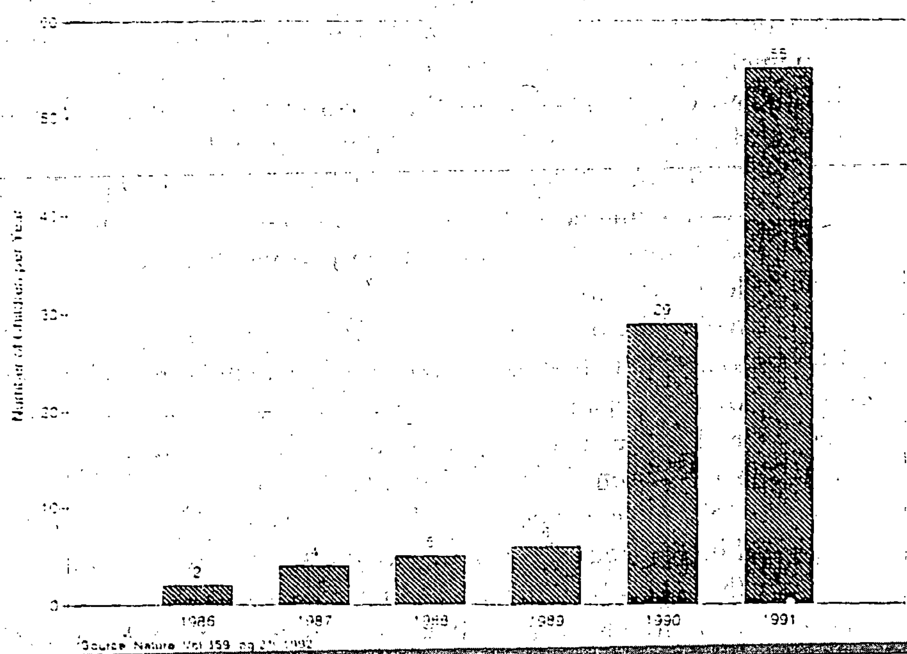


FIG. 37. Incidence of thyroid cancer in Belarus 1986 - 91

In the United States we did see very serious effects of the Chernobyl fallout reaching the U.S. more than five or six thousand miles away. This is what happened. In 1986 the fallout reached the US and beginning on May 10th, as you can see very clearly in Figure 38[14] there was an excess of radioactive iodine-131 in milk above what is normally registered - just a few picoCuries per litre. A picoCurie is 1/27th of a Becquerel, so that these levels result in extremely small doses. In fact the levels observed were not very much larger than those typically observed as a result of normal operations of nuclear reactors anywhere, when from two to ten picoCuries per litre (pCi/lt) are usually recorded in the milk. Every U.S. state measured the radioactivity in milk after Chernobyl.

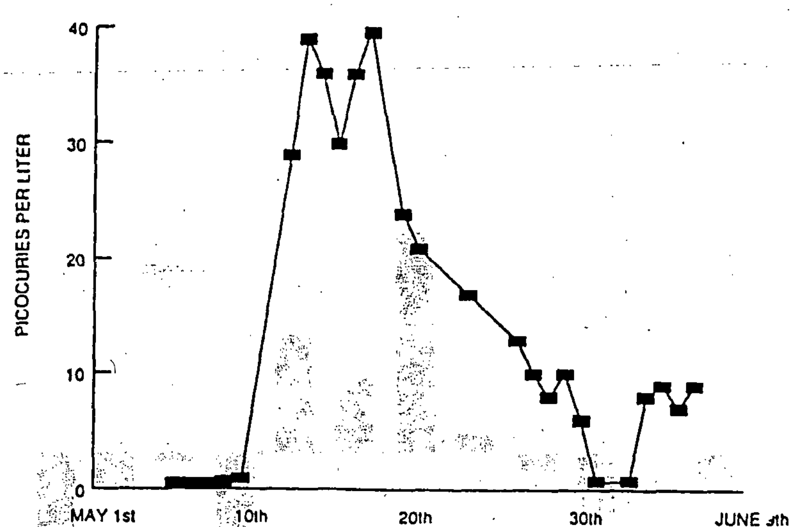


FIG. 38. Iodine-131 in fresh farm milk in New York/ New Jersey Metropolitan area after Chernobyl, May - June 1986

Professor Sternglass

Here are some of the monthly statistics on infant mortality that are available in the U.S. In Figure 39 we see that in the case of the Pacific states after the arrival of the Chernobyl fallout in early May, by June there was an increase of 50% or so in the infant mortality rate over the previous year's rate, with lesser rises in July and August, and then a decline. This was found all over the U.S. as you can see in Figure 40. There was a very clear peak in the total infant mortality for the U.S. as a whole - in this case 12% to 13% in June, and declining in July and August. This is extremely unexpected in the sense that the doses were calculated to be extremely small - of the order of tens of millirads for infants - well below permissible levels. You have to understand, the slide you saw earlier showed 40 pCi/lt, but the permissible activity in the U.S. at the time was 15,000 of these units.

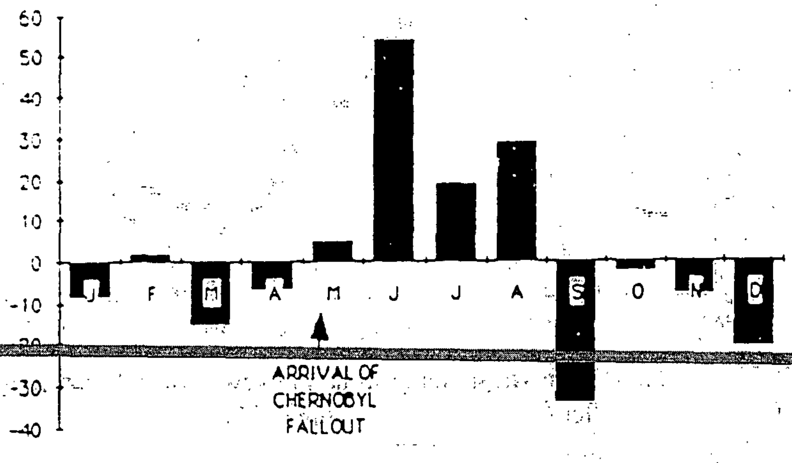


FIG. 39. Percent change in monthly infant mortality in the Pacific states of the U.S. 1986 vs. 1985

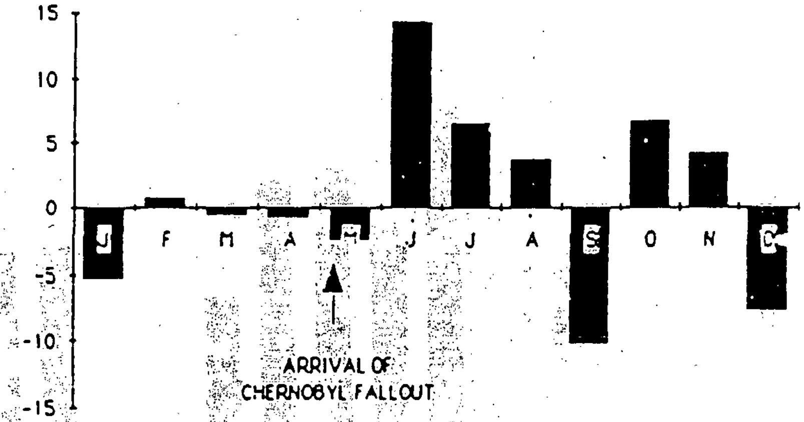


FIG. 40. Percent change in monthly infant mortality in the U.S. 1986 vs. 1985

But there was more than that. In the case of the state of Massachusetts, suddenly - as in the case of Poland and other areas hard hit by Chernobyl - there was a terrible decline in the number of live births. Let me just show you this here in Figure 41. Monthly live births in Massachusetts, which are very accurately recorded, declined extremely sharply, from something close to 8,500 in January to 1352 in the month of June. In July the Health Department did not report any data, and that means there must have been an enormous number of spontaneous miscarriages and other causes of infant death, which, by the way, paralleled what was seen in many parts of Europe and Russia.

Now we also have something else. It so happened that in California in a bird sanctuary just north of San Francisco, Dr David deSante had been banding birds every year to check the number of newly born birds and he found suddenly, without knowing that there was any fallout from Chernobyl a 60% decline in the number of newly hatched birds (Figure 42). It was only later that he realised that there had been rain-out from the Chernobyl radioactive cloud, and that large amounts of

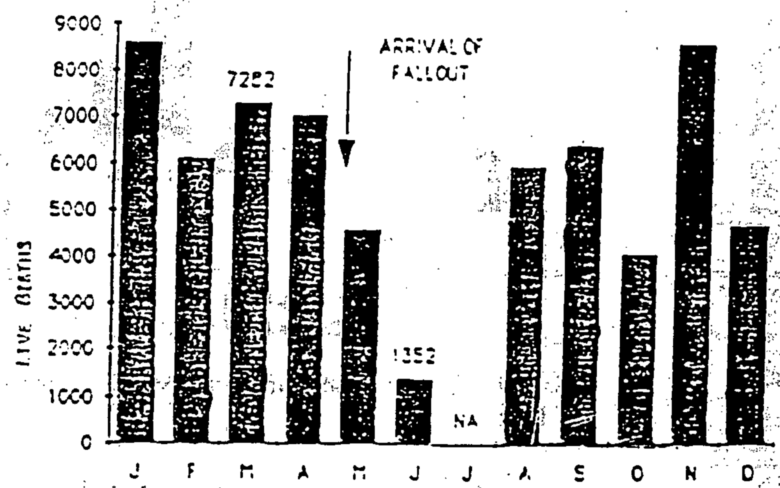


FIG.41. Monthly live births in Massachussetts 1986

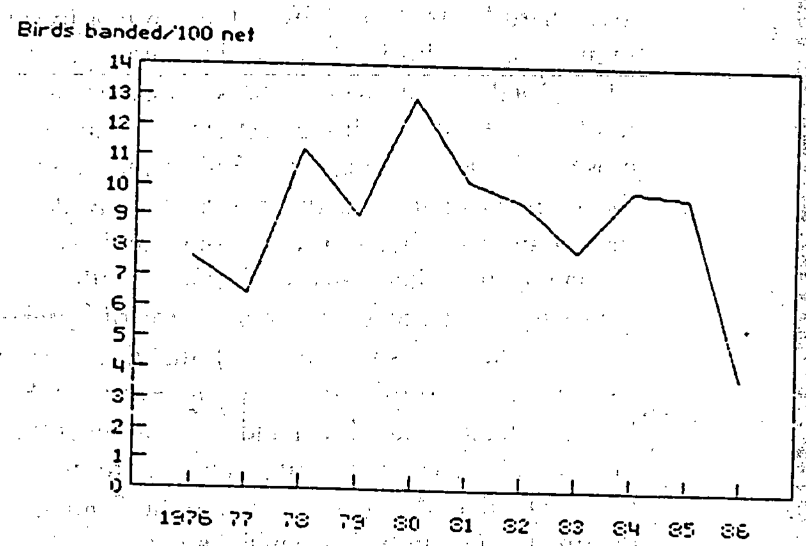


FIG. 42. Number of newly hatched land birds in the period May 10 - Aug 17 1976 - 1986

radioactive iodine had come down. But again, as you can see from the milk data, half-way round the world we are dealing with extremely small doses. This was published in the *Condor* magazine in 1987 (15), and it's also discussed in the book *Deadly Deceit*, by J. M. Gould and Ben Goldman(16). Incidentally, no such effects were seen in an area of the west coast of the U.S. which was spared by the rain that contained the Iodine 131; bird fertility was normal in that same part of the world where there was very little rainfall.

Intrigued by these observations we gathered the statistics which are available in the U.S. for the effects on total mortality by census region in the summer of '86(14). We again looked at the measured data reported by the EPA for Iodine 131 in pasteurised milk in each region- again measured in picoCuries per litre. As you can see in Figure 38 for the case of the New York area, typical for the U.S, the highest doses were of the order of 40pCi/lt. This is roughly 1.5 Becquerels, so we're talking about extremely small doses. In Figure 43 we are talking about nine regions: Middle Atlantic, West South Central, South Atlantic, East South Central, East North Central, West South Central, Mountain and Pacific states - (all these are census regions). You can see that the curve relating the percent change in mortality to the Iodine-131 in pasteurised milk across the U.S. for the months of May through August 1986 relative to the same period in 1985 is slightly better fitted by a supralinear or concave downward relationship than by a linear dose-response relationship. But that there should be a dose-response relationship down to the very lowest doses is extremely significant because, as you heard from the previous speaker, there was no way of measuring doses is this range among the Hiroshima survivors, and therefore all the estimates we have seen in the past have been based, essentially, on an assumed linear extrapolation from vastly greater doses.

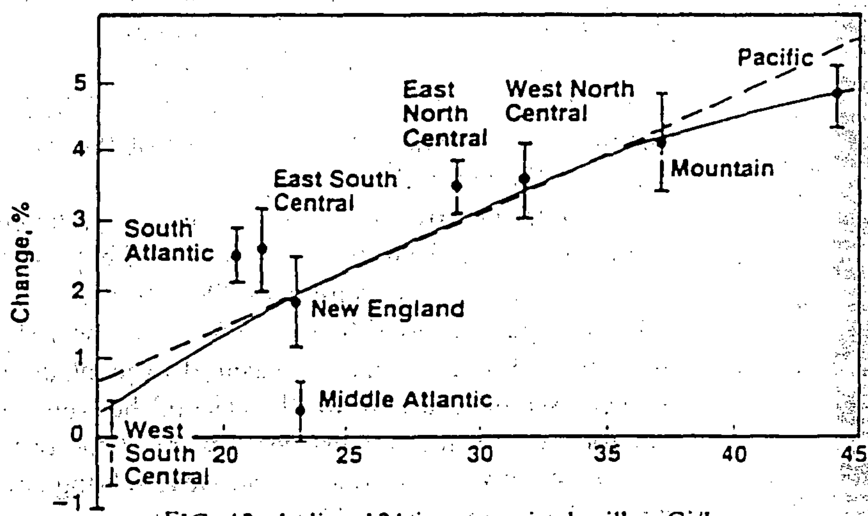


FIG. 43. Iodine-131 in pasteurised milk, pCi/L

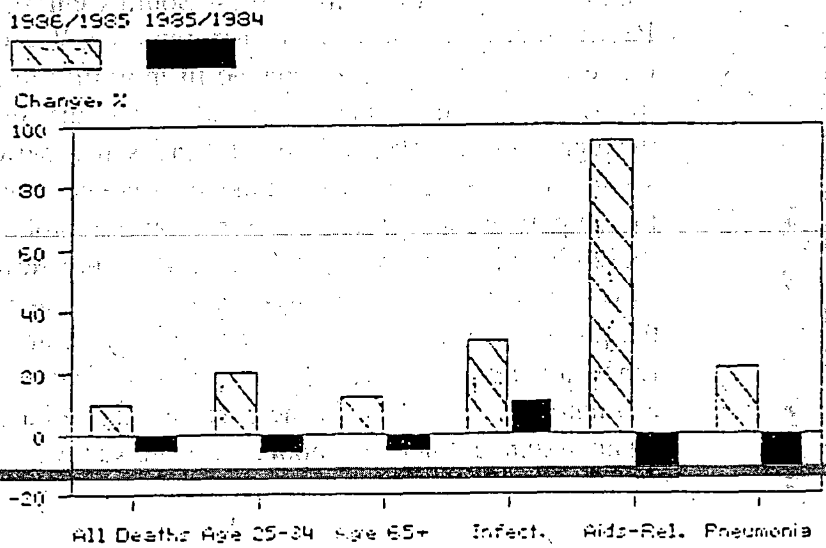


FIG. 44. Changes in mortality rates, 5/'86 vs. 5/'85 compared with 5/'85 vs. 5/'84

We also investigated what individuals died of, as shown in Figure 44 [14] [16] and this is very revealing. The greatest increase in the month of May over the same month in the previous year, was in AIDS-related deaths, which had actually declined the previous year. This means that individuals whose immune systems were already compromised were kicked over the brink.

That is exactly what also happened with all types of infectious diseases combined, which were very high compared with May 1985, such as pneumonia, as well as with total mortality in young people - 20 to 34 years old - who are normally very resistant. These people were born during the period of massive nuclear testing. So we now believe that this data is further support for the idea that the principal effects of nuclear fission products are on the immune system, which fits with the idea of strontium-90 because Sr-90 concentrates in the bone, and unlike natural radium, which emits a short-range alpha particle, emits a powerful million-volt beta ray which penetrates to the bone marrow. The Sr-90 accumulated in bone keeps irradiating and damaging the development of the cells of the immune system at an extremely slow and gentle rate over a period of decades (since the half-life is 28 years). An article which Gould and I published in the International Journal of Health Services in 1994[17] is extremely supportive of this idea, because we find, as you can see in Figure 45, a very close correlation between Sr-90 measured in bone and low birth weight for New York State. Now we've already heard from Dr. Busby that the paper by R. K. Whyte [4] supported our earlier findings by rises in first day neonatal death, 28 day neonatal deaths and new-born deaths both in the US and the UK, and that Whyte concluded that there was no alternative explanation other than the fallout from the testing of nuclear weapons. I might add that a recent study by Araceli Busby, the daughter of Dr Busby, who independently investigated

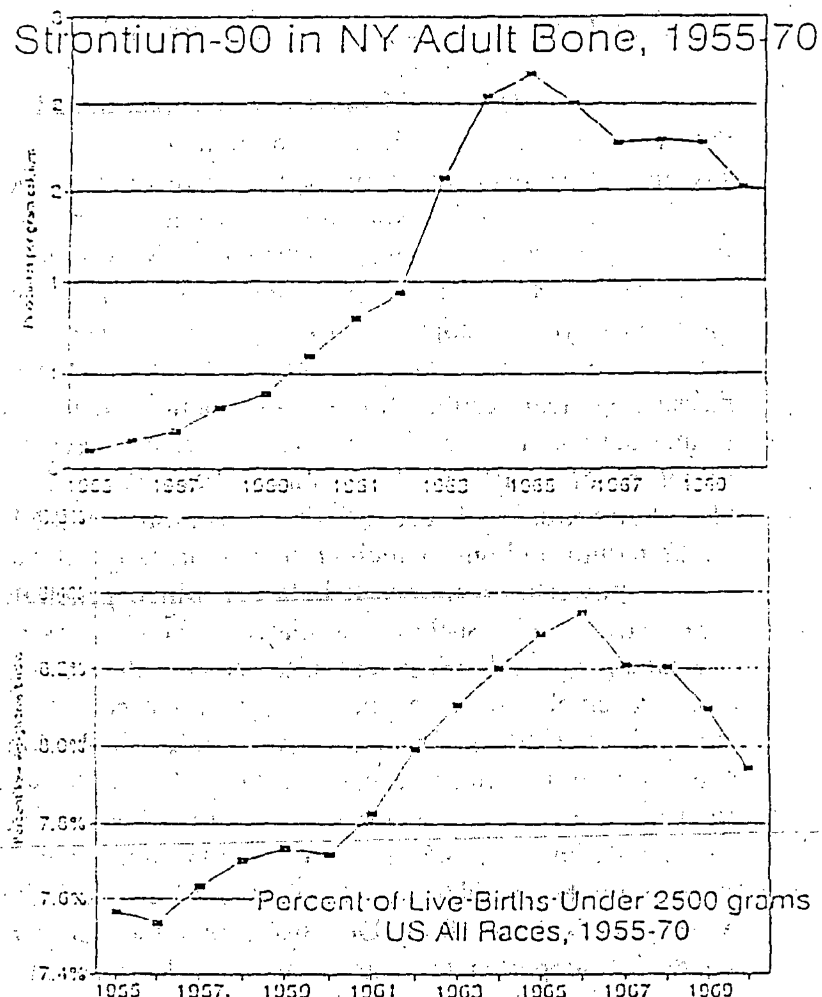


FIG. 15: Sr-90 and low birthweight 1955 - 1970

the changes in infant mortality for her thesis at Imperial College, also concluded there is no other known explanation for the effect on infant deaths.

Now, we have the evidence, as seen in Figure 37, that thyroid cancer in children rose very strongly in Belarus after Chernobyl. We also have data on what we've seen in the U.S. at much lower doses. I want to show you how the data looks in terms of changes of thyroid cancer rates in Connecticut in successive five-year periods during this time. First let me show you the annual data for 1935 to 1992. Connecticut has the oldest cancer registry in the U.S. and the only one to have continuous data of a very high quality since 1935. You can see in Figure 46 that between 1935 and 1944 there was actually a slight decline(18). Beginning within four or five years of the first fallout the number of cases goes up. This is happening very much more quickly than we know for x-rays in connection with treatment to shrink the thymus, where thyroid cancer typically does not evolve until decades after exposure. But here, in the case of fission products, we find the number of cases of thyroid cancer going up only five years after exposure. This is a solid tumour that is clearly related to radioactivity, since 95% or more of iodine concentrates in the thyroid gland. Thyroid cancer has been found in the Marshall Islands after fallout from a nuclear test so that there is no question that thyroid cancer is related to radiation. As you can see in Figure 46 there was an enormous rise four to seven years after the first bomb-tests, very much like the thyroid cancer in Belarus after Chernobyl; there were peaks after large releases from the Millstone reactor and again a very large rise at the end of the 1980s, four to seven years after Chernobyl. You can see that the increase after Chernobyl was comparable to that after the bomb fallout in the early 1950s, and that the recent rise represents a 26% and therefore highly statistically significant increase in cancer incidence in Connecticut, as you see in Figure 47.

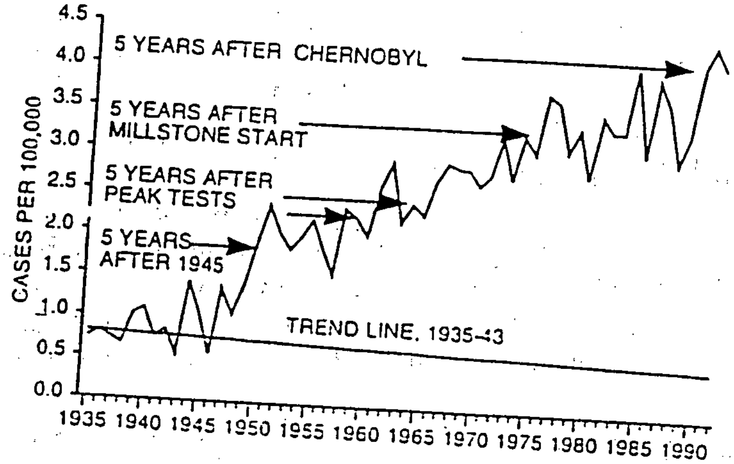
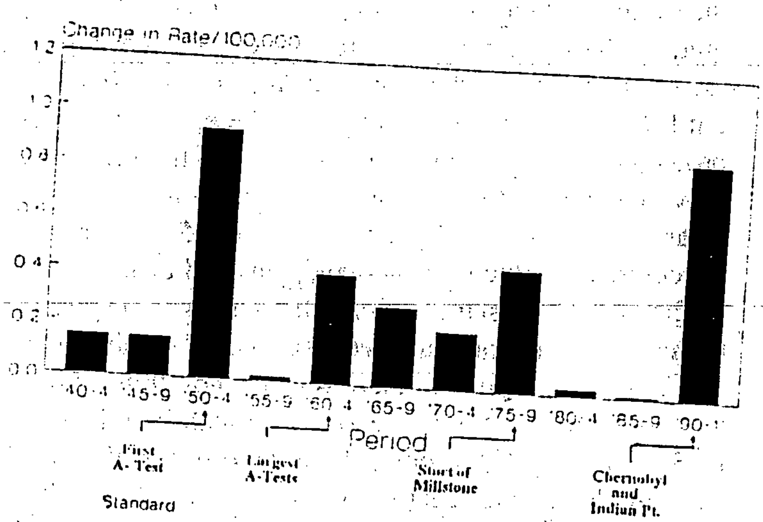


FIG. 46. Thyroid cancer incidence rates 1935-'92. Connecticut, age adjusted.



hanges in thyroid cancer incidence rates: Connecticut.

Now the question is: "Is there any way we can hope to explain it?". We are not sure about all the possible biological mechanisms that take place when two hundred different chemical isotopes at a time enter the human body, concentrating in different organs, but there is a theory based on the work of Dr. Abram Petkau, working for the Canadian Atomic Energy Establishment, who made the following discovery in 1972[19].

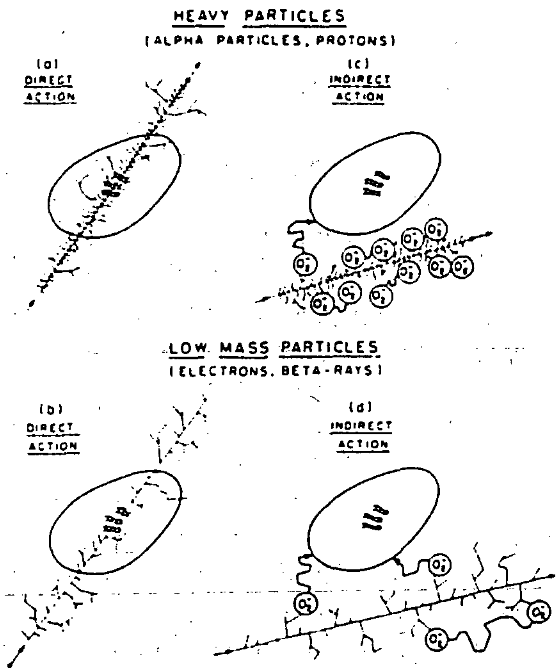


Figure 1. Basic modes of biological action of ionizing particles on living cells. (a) and (b) represent the direct action of massive and light-weight particles, primarily on the genes. (c) and (d) represent the indirect chemical action via the production of free radicals such as O_2^-. Note that the higher ionization density leads to a greater concentration of free radicals in (c) than for the lower ionization density in (d), resulting in a larger fraction of O_2^- molecules able to reach the cell membrane in (d) than in (c).

FIG. 48. "Petkau" effect of oxygen free radicals on cell membranes

Professor Sternglass

Petkau found that when he took a cell membrane and immersed it in water and put an x-ray beam on it, if he protracted the radiation over longer and longer times it took less and less of a dose to damage the membrane. He finally concluded after many studies that a different mechanism than direct damage is involved. It involved the creation of negatively charged free radical oxygen molecules. These molecules are attracted to the membrane and initiate a chain reaction in the membrane which then ruptures in a matter of less than an hour.

This means that there is an enormous target for this effect. Let me illustrate this here in Figure 48. We can see on the left you have the typical case of direct damage to the DNA. You have to hit the DNA in the nucleus of a cell - a very small target. But with the indirect effect of oxygen you don't have to hit the nucleus. The target is the whole cell, and since only one free radical oxygen molecule reaching the membrane can lead to its rupture, it is like asking how many needles does it take to puncture a balloon? Obviously only one, and throwing a thousand at it is a waste of energy or a waste of needles, so there is very little further damage per unit dose. And that's exactly what seems to be going on here. Thus, the free radical effect is very efficient at the very low doses, where you are producing only one free radical oxygen at a time. This is why Strontium-90 is so deadly - it spreads its action over a long time, compared to a single exposure to a diagnostic x-ray which occurs in a short time and produces a very high local concentration of oxygen molecules which, by collisions with each other, immediately de-energise each other, you could say detoxify each other, so that they become ordinary oxygen.

This allows one to explain how there can be a very rapid rise of the dose-response relationship at low doses and a levelling off at high doses. At very high doses the free radical damage is inefficient and the DNA mechanism takes over. But the DNA represents a very small target, in addition to which it is very easily repaired, because over millions of years fantastically effective means of repairing DNA damage evolved to protect the reproductive genes. The only one who cannot repair DNA damage very well is the embryo and the foetus - it's not yet fully developed. This is why Dr. Stewart found serious effects on childhood leukaemia and other cancers from diagnostic x-rays, because they were given to women during pregnancy, mainly just before birth. Not only are the repair mechanisms not adequately developed in early foetal life, but the cells are very rapidly multiplying, and so the embryo and foetus are very radiation sensitive.

Petkau's findings can be put into context with other work - he is not the only one who has observed a much higher sensitivity at low dose rates than at high ones. It is also found in human beings.

In Figure 49 the results of Petkau and others are plotted for various dose rates from 10^{-8} to 10^{8} rads per minute.(20) There were many experiments done of the effects of radiation at high dose rates on cell function and cell membrane permeability, and they showed that it took an enormous dose of ten thousand rads or so to break a membrane. But Petkau found that doses as low as one rad could break a cell membrane at low dose rates, and he measured the dose needed to break a membrane down to background radiation levels, where the dose required was only some ten to twenty millirads. Now we get about a hundred millirad per year from the normal background in our environment, and you could ask, rightly, why haven't we all dissolved? Why are we still here? The answer is that over millions of years our cells evolved the means of detoxifying the oxygen free radical. Under most normal conditions the means of deactivation works to a very high degree, otherwise we wouldn't be here to talk about it.

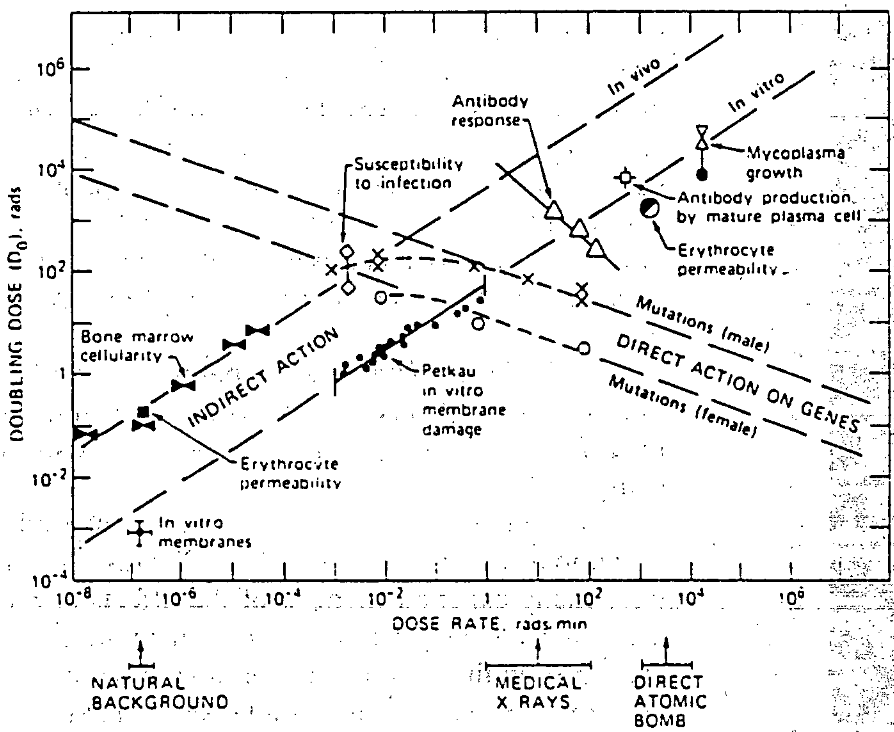


FIG. 49. Plot of doubling dose D_0 vs. dose rate for direct and indirect radiation effects

One of the protective mechanisms is the production of dismutase enzyme, which is extremely effective. In fact this is seen in the difference between the data for the in vivo and in vitro studies, which show that cells are ten to a hundred times more protected when the dismutase enzyme is present, as can be seen in Figure 49. The line marked "in vitro" shows the results of Stokke in the Oslo Cancer Hospital, who found extremely small doses in the millirad range damaging the cells of the bone marrow in rats(21). Also on this line is the data of Scott who studied x-ray technicians who were exposed to low doses at very low rates but he nevertheless found the permeability of their blood cells to be significantly increased. So the effect of free radicals on cells has been seen in the laboratory over an enormously wide dose range, as seen in Figure 49. Furthermore you can see that at the relatively high dose rates used in diagnostic x-rays and x-ray therapy we are not finding these terribly low doses needed to damage cells that is seen for the very low dose rates encountered in the case of environmental exposures.

Now let us see what the implications are for the form of the dose-response relation. If Petkau is right, and there's every reason to believe that it occurs in every kind of environment, then instead of being a straight line, having a safe threshold, or having quadratic form that curves upward, one gets a supralinear curve, which is concave downwards, rising most rapidly at low dose.

Therefore, what we need to do is to test the shape of the dose response at low doses and see what form it has. This can be done for the case of large human populations exposed to distant fallout from Chernobyl across the U.S. and we have done it for the case of hypothyroidism - which is the under functioning of the thyroid, comparing the change for two years before Chernobyl and the two years afterwards. As shown in Figure 50, taken from a paper(18) we have just given at a conference in Vienna, we found a curvilinear relationship between new-born hypothyroidism and the actual, measured picoCuries per litre of Iodine-131 in the milk. As you can see, there were never much more than 45 or 50 picoCuries pre litre anywhere in the U.S, and so we find here the kind of data that the study of Hiroshima and Nagasaki survivors could not give us, namely data at the extremely small doses that are associated with levels of contamination or emissions far below presently permissible levels.

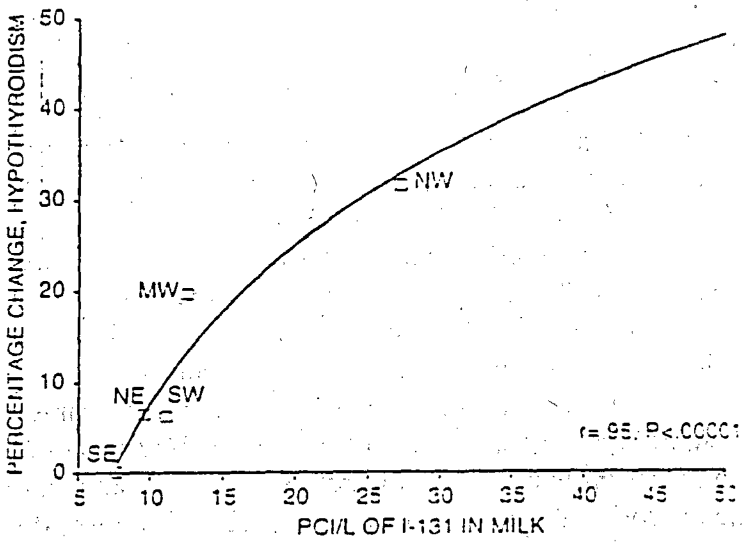


FIG. 50. Hypothyroidism and Iodine-131 in milk: correlations before and after Chernobyl

With a correlation coefficient of 0.95 the chances of this being purely an accident is less than 1 in 10,000. So we are dealing with a high statistical certainty; we are dealing with a thousand cases in each period. It is therefore an enormously powerful study, in terms of statistical power.

But, in addition, we also discovered a very disturbing phenomenon. The incidence of new-born hypothyroidism should have disappeared within a year or two after Chernobyl, but instead it kept climbing, and that puzzled us for a long time. This is what we found, as shown in Figure 51 for the thirty states for which data is available. Until 1985 - 86 there were just a few bumps, but then a continuous rise that lasted until about 1993 - 94 when it seemed to level off, and we'll have to wait for the next few years' data to see whether it will come down again.

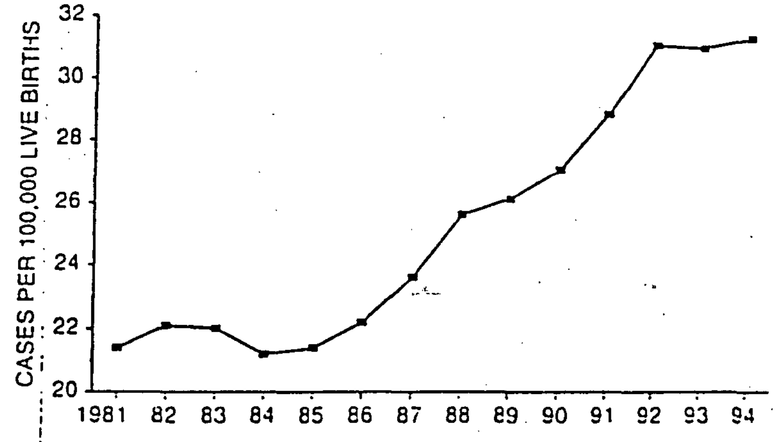


FIG. 51. Newborn hypothyroidism in the U.S. 1981 - '94
30 states with 66% of all live births

This is so disturbing because it involves a significant increase from about twenty-one to thirty-two cases per hundred thousand new-borns - an increase of almost 50%. Now, children that are born with under-functioning thyroids can become permanently damaged in terms of mental ability; if not detected and treated early they often have extremely low IQs. So this is a very serious finding that affects an enormous number of people, because small amounts of thyroid dysfunction can have an effect on prematurity and low birthweight.

In Figure 52 we see a similar finding for premature birth, almost exactly the same shape as for hypothyroidism, and more disturbingly yet, an even larger number of children who are born under 2.5 kilos or 5.5lb, shown in Figure 53. We are now dealing with about 7% of four million children born each year in the U.S.

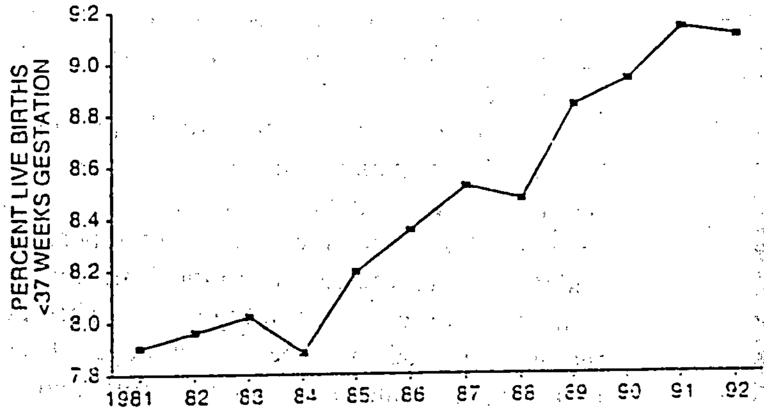


FIG. 52. Percentage of premature live births (under 37 weeks gestation) U.S. 1981 - '92

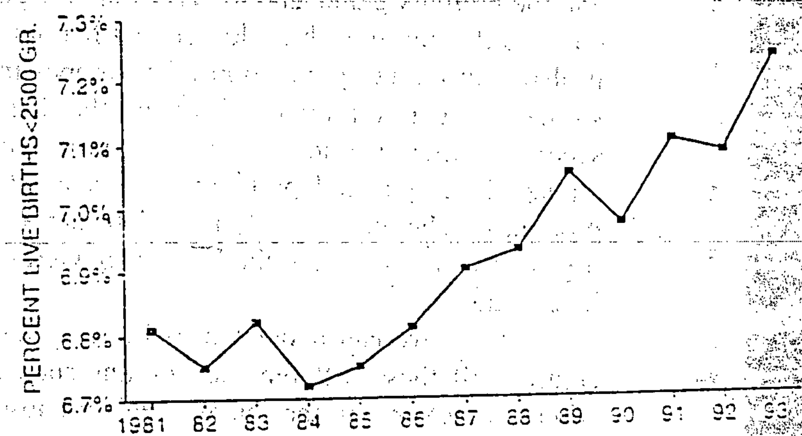


FIG. 53. Low birthweight (live births under 2.5 kg) U. S. 1981 - '93

We're talking here about tens of thousands of children who were born prematurely and with low birthweight. Premature birth is very serious, because it leads to an increased risk of brain damage, epilepsy, and a much higher incidence of learning disabilities.

This data on low birthweight provided an important clue because in a paper in the International Journal of Health Services(17) we found a very high correlation between Strontium-90 in adult bone in New York and the percentage of infants born under 2.5 kg as you can see in the almost perfectly similar shapes of the two curves shown in Figure 45. This means that it is really the Sr-90 that seems to be the main agent because it concentrates in the bone, irradiates the bone marrow, and affects the growth of the child by an indirect mechanism - as Dr Busby feels.

Two things happen; when the immune system of the mother is slightly damaged it tends to reject the foetus early as a foreign object; this leads to premature and low weight birth. The other thing is that the Sr-90 creates Yttrium-90, which has a different valence, and concentrates in all the glandular organs, and the pituitary gland, and the reproductive glands. The pituitary controls the entire birth cycle - sexual maturation and so on, and it also controls the production of hormones in the thyroid gland so that you get both direct effects on the thyroid and indirect or secondary hypothyroidism. This in turn leads to physical and mental developmental problems which are traced to hormonal problems. The concentration of Yttrium-90 in the glandular organs was discovered in the late 50s in Germany by a number of investigators.

Now we can understand what is going on. The pituitary controls all these different key organs such as the thyroid and adrenal functions. In the female adult it causes decreased libido and abnormal menstruation. In the male adult it produces decreased libido, reduced sperm count, and loss of facial and body hair. All this is done through tiny damage to the pituitary which controls all these hormone producing organs.

In order to test this hypothesis we can now ask: "Did Strontium-90 increase in the United States after Chernobyl?" Here, in Figure 54, is the answer.

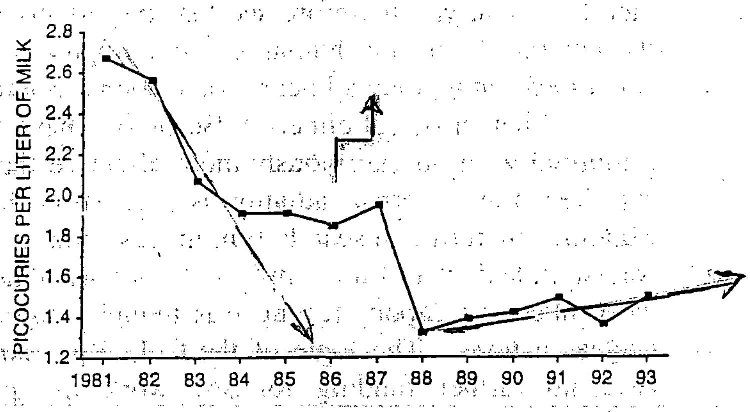


FIG. 54. Sr-90 in milk in the U.S. 1981 - '93 Oct-Dec average for 10 EPA districts

This is EPA data for all areas of the U.S. in the last quarter of every year from 1981 to 1993 You can see that in 1986 it stopped declining and in 1987 there was in fact a peak. The levels in the milk declined again in 1988 but then they refused to go down any further and actually rose again [18] We believe this has to do with the fact that many nuclear reactors have begun to corrode and leak particularly in the heat exchanger or steam generator systems, as has recently been discussed in a report by Ralph Nader's *Public Citizen* group in Washington which found that there were fourteen lawsuits brought against Westinghouse for leaks in the system that divides the primary from the secondary coolant in all Pressurised Water Reactors [22].

These findings therefore support what Stokke found for tiny doses of fifty to a hundred millirads produced by Sr-90 in the crucial cells of the bone marrow in rodents. This is in the same order as the yearly exposure allowed to the public around nuclear facilities. You can therefore see that the effects indeed fit both the laboratory and the human epidemiological data, showing a supralinear rather than a linear dose-response relation.

Whether or not either Dr Busby or I have found just why Strontium-90 is so enormously more effective than anything we expected from external radiation is a question that needs to be examined by further research. But this research is something that was squashed, that was simply not supported during the time when nuclear weapons testing was thought essential by all the nuclear nations. The logic of the Cold War explains why we have no further funding for any work in epidemiology at extremely low doses of the kind we are talking about here, except for the recent U.S. National Cancer Institute study, which is the sad story of a cover-up discussed in a new book, *The Enemy Within*[23].

What this all means is that if you have data at high doses and high dose rates, the risk per unit dose goes up only slowly. If you make the mistake of assuming linearity all the way down to zero dose, then your underestimation of the risk at low doses can be anywhere from a hundred to a thousand fold.

You may now ask: "Can we be more specific; does this happen around nuclear reactors as a result of normal operations, which produce even smaller doses than we'd expect from Chernobyl fallout in the United States?"

Professor Sternglass

Here, then, is a most important finding related to a reactor near New York City. The Black population in Harlem and the Bronx uses the drinking water from reservoirs located near the reactors at Indian Point. As shown in Figure 55, we found that there were three successive peaks of emissions from the plant and three successive increases in babies born grossly underweight - 1.5 kilos or 3.3 lbs. (The emissions peaks were shifted by one year to take care of the delay in the effect on the new-born.)

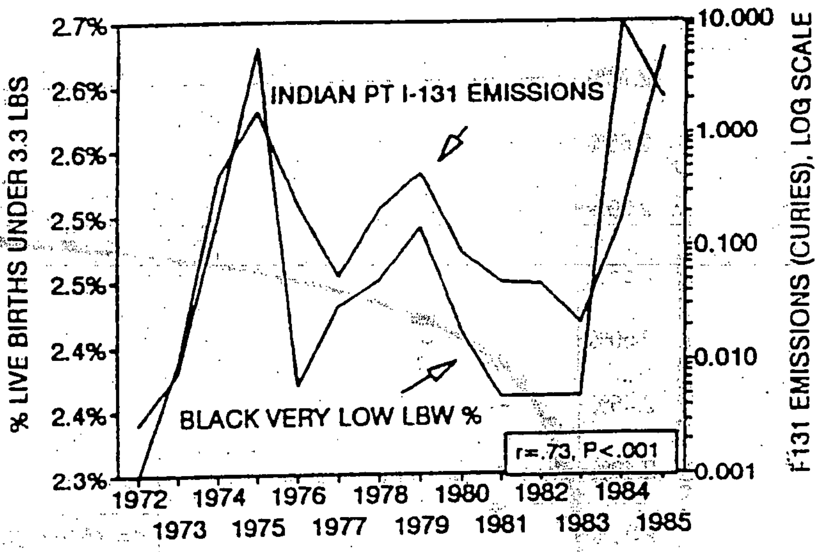


FIG. 55. Low birthweight in Black population and Iodine-131 emissions from Indian Point reactor 1972 - '86.

This is an enormously significant result because there are a lot of infants born in this way, and the effect does obey the supralinear relationship associated with free radicals. This is shown in Figure 56, which is a plot of the percentage of very low birthweight infants in Figure 55 versus the annual airborne releases of Iodine-131 from Indian Point. Clearly, the best fit is again not a straight line, but a concave downward curve that rises rapidly at low doses. As you can see, a straight line extrapolation from the highest doses would vastly underestimate the effect at low doses. If you simply took the slope at high dose and assumed it would give the risk per unit dose at low doses it would grossly underestimate the risk. This was done with the Hiroshima data, because there was no very low dose data in the '50s.

As shown in Figure 57, when you plot it on a logarithmic scale for the dose, the points fall on a straight line.

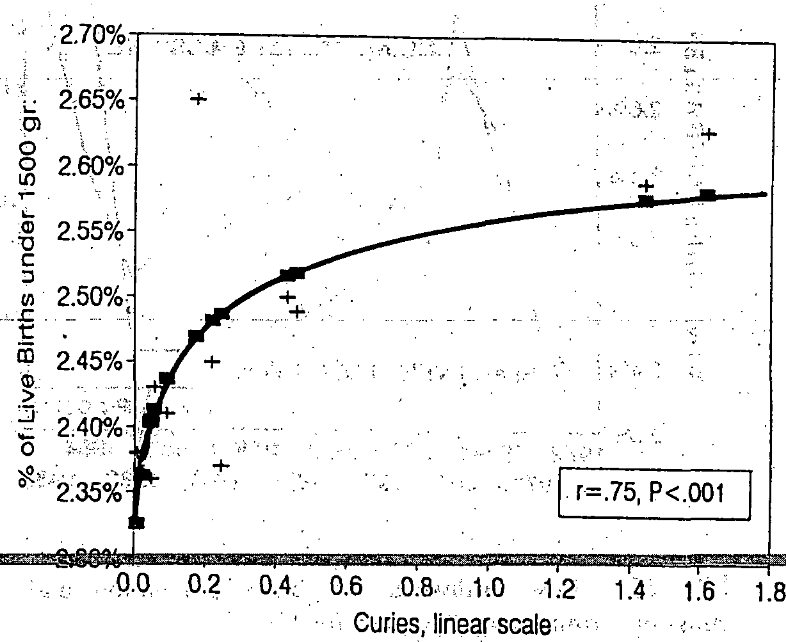


FIG. 56. New York Black births <1500 gr 1974 - '86 *vs* ^{131}I 1973 - '85

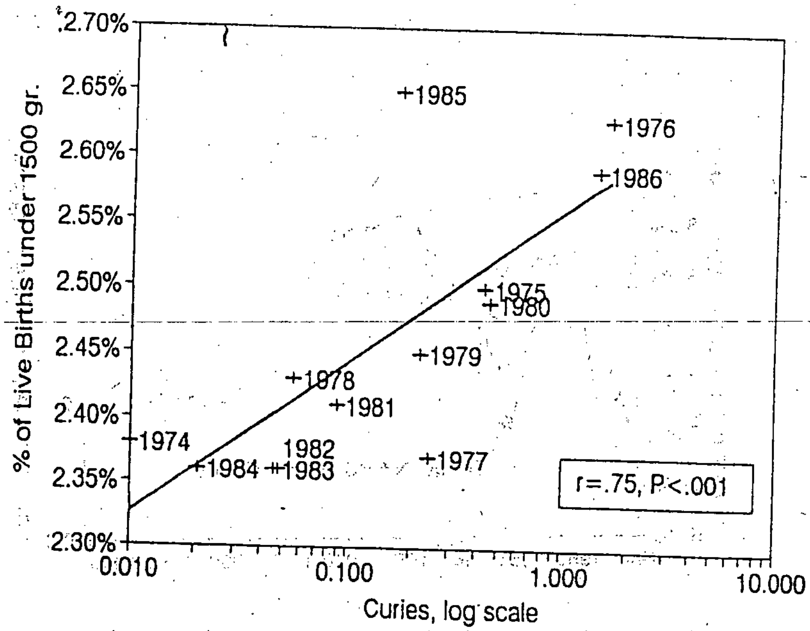


FIG. 57. NY Black births < 1500gr. 1974-86
vs. I-131 emissions 1973-85

This is very serious because in the U.S. today there is a recurrence of an epidemic of low birth weight that started in the U.S. in 1950 (Figure 58). In fact the rate of low birthweight was even lower between 1945 and 1950 when we have data only for New York, but since the U.S. and New York state data moved in parallel, the U.S. rate must also have been lower than in 1950, and then peaked in about 1966 - 67, which is the time when Strontium-90 peaked, as we know from Figure 45. Then we see a decline after the end of bomb testing and a renewed rise when nuclear reactor operations began on a large scale in the early '70s.

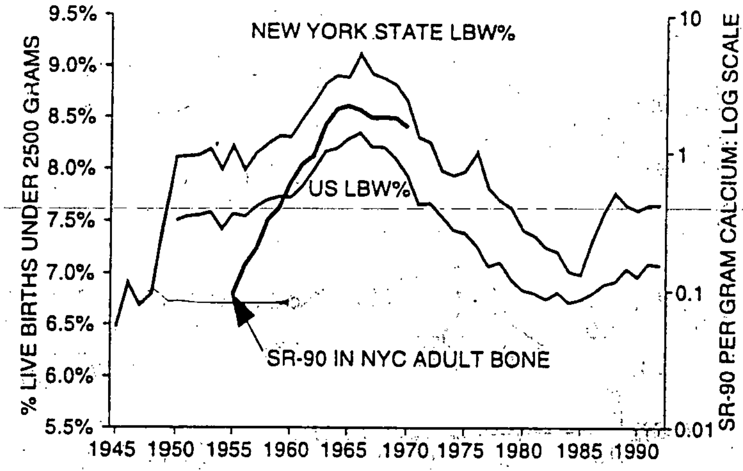


FIG. 58. New York low birthweight percent, 1945 - '92, and Sr-90

You can see that especially in New York there has been an enormous resurgence in very low birthweight, which is now greater in terms of percentage of the babies under 1.5 kilos than had been found at the height of nuclear bomb-testing.

This is all very serious, because, as shown in Figure 59, the children who are born underweight, according to studies published by Buka (24), have a much greater chance of not having normal intelligence test scores and adequate academic achievements by age seven; and those with birthweight less than 1.5 kilos were found to have twice as great a risk of having less than normal ability than those with normal birthweight.

Professor Sternglass

Thus, the real problem that we are confronting now is that if we refuse to look at the data because it would prevent us from building more reactors or threatening to use nuclear bombs then our societies risk going the way of Rome, where lead piping for drinking water eventually destroyed the brains of the children, as we now know from many recent studies into the effects of lead on learning and behavioural problems. In this connection it is important to point out that lead in bone contains a significant ~~amount of radioactivity, comparable with that of Strontium-90.~~ Thus, the future for us and or children is bleak unless we have the courage to face the fact that with the end of the Cold War, the protection of human health and life must come first."

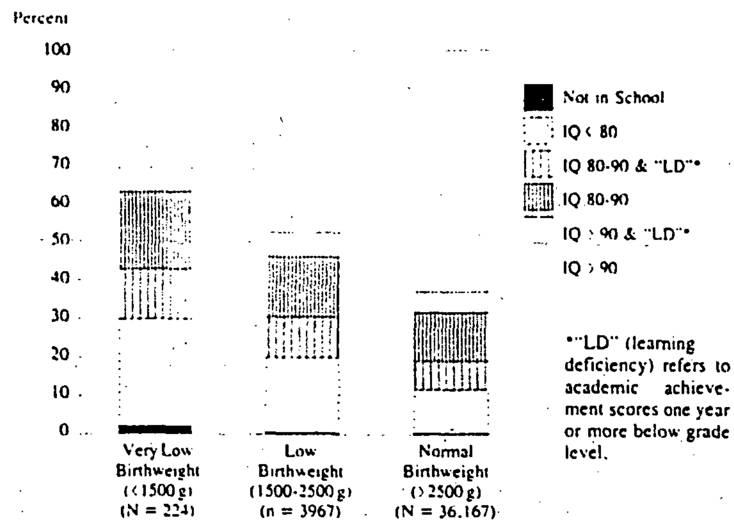


FIG. 59. Relation of birthweight to intelligence and achievement scores at age 7.
(Source: Buka *et al.* 1990. Based on 40,000 children followed from birth (1960-66) to age 7 in the National Collaborative Perinatal Project)

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FROM SECRET FALLOUT 1972

15

Fallout at Shippingport

THE STUDIES of Lave and DeGroot provided independent evidence that infant mortality was correlated with low-level radioactivity from nuclear-weapons fallout and reactor releases, but a number of puzzling questions remained unanswered. It was understandable in the light of Dr. Stewart's latest findings, published in 1970, that infant mortality might go up significantly as a result of early intrauterine exposure due to the hundredfold greater sensitivity of the fetus in the first three months of development as compared to the adult. It was difficult to understand, however, how total mortality rates, dominated by the older age groups rather than by the small number of newborn infants, could possibly be affected as strongly as Lave's study had shown.

Still another puzzle was the finding by DeGroot that although infant mortality rates in Beaver County, where the Shippingport reactor was located, did not decline as rapidly as for the state of Pennsylvania as a whole, there was no correlation between the abnormally high infant mortality rates and the officially announced small releases from the plant.

Both of these puzzles were destined to find their solution in a most unexpected manner within a year after DeGroot's and Lave's studies had been completed. Late in 1972, a notice in the Pittsburgh newspapers announced that hearings would shortly be held by the Atomic Energy Commission to grant an operating license for the Beaver Valley Unit I reactor, which was then nearing completion. This power station was being built right next to the original Shippingport reactor on the Ohio River, some 25 miles downstream and to the west of Pittsburgh. According to the newspaper story, it would be of the same pressurized-water type that had been pioneered in Pittsburgh by Westinghouse, under Admiral Rickover's direction, except that it would be some ten times larger.

Knowing that it was a naval type of reactor with a double cooling loop to minimize the amount of gas that would have to be discharged into the atmosphere caused me to feel little concern, especially in view of the fact that the AEC had only recently announced that it was proposing to tighten up the standards for permissible emissions. (These new standards had been issued following hearings in Washington at which I had been asked to testify in behalf of various environmental groups on the need to lower permissible doses.) Also, Westinghouse had just announced that it had been possible to operate Shippingport with "zero" gaseous releases in 1971, so that I felt certain that this much more advanced new power station only a short distance upwind from Westinghouse headquarters and the Bettis Nuclear Laboratories, where the first submarine reactors had been built, would surely be provided with the very latest in the available equipment for containing all radioactive gases.

Thus, when some of my students asked me whether I planned to attend the hearings I expressed no great concern, saying only that I might take a look at the Safety Analysis Report being kept in the public library of the nearby town of Beaver, a few miles from Shippingport, to make sure that the planned emissions were indeed as low as I expected them to be.

A few weeks later, an opportunity presented itself to check on the proposed releases. I had to go to the nearby Pittsburgh airport to pick up my mother, and since the Beaver County Library was only a few miles from the airport, I left a few hours early to check the figures.

Since I had examined similar reports for the Davis-Besse and other plants within the past year, it did not take me long to find the information I was looking for. But what I found shocked me profoundly. Instead of gaseous releases of only a small fraction of a curie, such as had been reported for Shippingport in recent years, the more advanced commercial plant about to go into operation was apparently designed to release some 60,000 curies of fission gases per year into the already heavily polluted air of the Ohio River valley. This was millions of times more than was claimed to have been discharged annually from the old Shippingport plant in recent years, even though the power output would be only ten times greater.

In fact the summary of past releases from nuclear facilities published by the Bureau of Radiological Health had listed only 0.35 curies of fission gases at the time of the highest reported discharges back in 1963, for which the calculated dose was 0.87 percent of the maximum permissible of 500 millirems to someone living near the plant. This meant that the estimated radiation dose produced by 0.35 curies was only about 4 millirems. Yet even at these relatively low calculated external doses (due to gas releases), there seemed to be a disturbing rise in infant mortality in surrounding Beaver County and especially the nearby town of Aliquippa, some 10 miles to the east in the Ohio valley.

There were thus only two possibilities. If the reported figures on the likely magnitude of gaseous releases from the new large reactor were correct, there would very likely be a major increase in infant mortality and other detrimental health effects unless vastly more efficient means of trapping the gases were installed to bring them down to the levels reported for the existing reactor.

The other possibility was that the actual releases from the Shippingport plant had somehow been much larger than the amounts officially reported. And this would of course explain why DeGroot did not find a relationship between the tabulated releases and the yearly changes in infant mortality for the Shippingport plant.

Deeply troubled by these findings, I decided to contact the utility lawyer for the City of Pittsburgh, Albert Brandon, who had long been battling the Duquesne Light Company's growing requests for rate increases needed to finance the escalating cost of the Beaver Valley nuclear plant. My hope was to persuade the city to intervene in the upcoming license hearings in order to get to the bottom of the disturbing discrepancy between the annual claim for "zero-release" nuclear plants and the actually planned emissions. Even though it was too late to stop the plant from going into operation, perhaps it would still be possible to force the utility to install the latest equipment for trapping the radioactive gases so as to reduce to a minimum the health risk to the people living in the area.

Concerned by these facts, Brandon promised to discuss the matter with the mayor, Pete Flaherty. A few days later, a meeting was arranged, and after a brief discussion, Flaherty agreed to have the City of Pittsburgh become an intervenor in the upcoming license hearings, together with a group of local environmentalists to whom I had previously outlined my findings.

Shortly after the public announcement that the City of Pittsburgh would intervene in the hearings for the new plant, I received a telephone call from a man who identified himself as the manager of the new power station being built at the Shippingport site. He said that great efforts were being made to assure the safety of the people in the area, and that he would be glad to send me the detailed plans for the environmental monitoring that would be done to assure that no harmful amounts of radioactivity could reach the public.

Within a day, a large manila envelope was delivered to my office at the university from the Duquesne Light Company. As I leafed through its contents, I noticed a series of documents entitled "Pre-Operational Environmental Radioactivity Monitoring Program at the Beaver Valley Power Station" in the form of quarterly reports for the years 1971 and 1972. The documents had been prepared by the N.U.S. Corporation of Rockville, Maryland. These were apparently part of the Environmental Report for the Beaver Valley Power Station Unit II Construction Permit Application, submitted to the AEC in November 1972 as required by the new National Environmental Protection Act, which had just come into effect. Thus, the data were gathered to establish the radiation levels existing at the site prior to the operation of the new plant, providing a baseline for comparison with later measurements that would be gathered once the plant had gone into operation.

As I began to look through the tables with their long lists of numbers, I noticed that there were some very high measurements for the external gamma doses in early 1971, measured in microrems per hour. When I worked it out in the more familiar units of millirems per year, I could hardly believe the result: In March the rate was 370 millirems per year for Station No. 10, located in the town of Shippingport, compared to the normal values for the area of 70 to 90 millirems per year. There were a few more readings at this location in the range of 300 to 350 millirems per year by June, and not until January of 1972 did the numbers return to the normal rate of 86 millirems per year.

Other locations showed comparable peaks of gamma radiation, but the highest were in the town of Shippingport closest to the site or on the site itself. Could it be that these extremely high radiation dose rates were produced by the old Shippingport plant, for which the official reports had shown almost no gaseous releases at all?

Turning to the tabulations of strontium 90 in the milk, I saw immediately that the levels measured in the farms around Shippingport were much higher than in Pittsburgh, Harrisburg, Cincinnati, and Buffalo as reported in *Radiation Health Data and Reports* for the early part of 1971. The fact that the extremely high readings were confined to the Shippingport area made it unlikely that they were due to worldwide fallout from high-altitude atmospheric bomb testing.

To check this further, I plotted the concentrations of strontium 90 in the soil and found that it dropped off sharply with distance away from the plant both east to west and north to south. In April of 1971, the levels within three-quarters of a mile were fifty times greater than the typical levels produced by worldwide fallout, and by early in 1972, the rains had apparently washed most of the activity into the Ohio River, the measured levels having gone down from their peak of 6000 picocuries per kilogram to less than 100.

Clearly, such a highly localized concentration of strontium 90 in the soil centered on the Shippingport plant could not be explained by worldwide fallout, which is more or less uniformly distributed around the globe as the rains bring down the fine particles circulating in the upper atmosphere.

Still further confirmation of the localized nature of the radioactive contamination came from the measurements of short-lived iodine 131 in the milk. Beginning in December of 1971 and peaking in February 1972, the levels of iodine for the six dairies within a 10-mile radius started to rise above 10 picocuries per liter, the Range I reporting level set by the Federal Radiation Council for continuous consumption, reaching as high as 120 picocuries per liter. This was well above the 100 picocurie-per-liter limit of Range II, and it equaled the kind of values reached in the eastern United States during the height of nuclear-bomb testing.

Yet when I looked up the monthly iodine 131 levels for other locations in Pennsylvania (such as Erie, Harrisburg, and Philadelphia) in *Radiation Health Data and Reports*, they were all listed with "zero" values, or below the limit of detection. Clearly, it was extremely unlikely that any Chinese fallout would somehow concentrate radioactive iodine 131 over the Shippingport site, leaving the nearby areas of Ohio and Pennsylvania without any detectable increases of radiation in the milk.

As a final check, I compared the monthly values of strontium 90 in the milk within a 10-mile radius of Shippingport with the monthly electrical power output in kilowatt-hours published in *Nucleonics Week*. Both strontium 90 and power output peaked in January 1971 and again in April, moving up and down together until the plant was closed for repairs later in the summer. After the plant was shut down, both the local and the Pittsburgh milk showed a sharp reduction in strontium 90 levels, from a peak of 27 picocuries per liter nearest the plant in early 1971 down to 7 picocuries per liter measured in Harrisburg that summer. As I learned later from an analysis of the milk-marketing reports, the city of Pittsburgh obtained about a third of its milk from an area within 25 miles of the Shippingport plant. This finding was consistent with the fact that the Pittsburgh milk showed strontium 90 concentrations some 30 percent higher than the Cincinnati and Philadelphia milk in early 1971.

Yet during the time of the sharp peaks in radiation levels in the air, the soil, and the milk that occurred between January and June of 1971 near Shippingport, there were no nuclear-weapons tests carried out in the atmosphere by any nation as reported in the monthly issues of *Radiation Health Data and Reports*.

After weeks of graphing and analyzing the data with the help of colleagues, volunteers from local environmental organizations, and students at the university, there could be no doubt about the result: The data collected by the Duquesne Light Company's own hired team of experienced health physicists clearly indicated that the Shippingport plant must have been the source of radioactivity in the environment many thousands of times as great as had been claimed in the official reports to state and federal agencies. Instead of annual radiation doses of less than 0.5 millirems claimed by the utility, the combination of external radiation (measured by the dosimeters) and internal radiation (from the gases that were inhaled or ingested with the milk, the water, and the local meat and vegetables) was many hundreds of millirems per year. Indeed, this dosage exceeded the level of radiation that was received by the people of this area during the height of nuclear-weapons testing. Moreover, the scientists who had carried out these measurements had clearly failed to warn either the utility officials who had hired them, the public-health officials at the state or federal level, or the public, whose health and safety were being endangered by the secret fallout from the plant.

Faced with these disturbing discoveries, the leaders of the local environmental groups in Beaver County decided to hold a public meeting at which both the Duquesne Light Company and spokesmen for a Pittsburgh environmental group would be able to present their views to the people of the area. The meeting took place early in January of 1973 at a shopping mall in the town of Monaca, just a few miles from the Shippingport plant. After the superintendent of the Shippingport plant explained that the new power station would be "the Cadillac of the industry" -- with a waste-disposal system that would permit only "minimal" amounts of radioactivity to escape -- the head of Environment Pittsburgh, David Marshall, and I presented the data gathered by the Duquesne Light Company's own consultants. Slide after slide showed the localized concentrations of radioactivity in the milk, the soil, and the river sediments rising to many times their normal value, together with the peaks during the months when there was no nuclear-weapons testing. Obviously, the findings in our presentation were completely at variance with what the utility had told the local people over the years.

The Duquesne Light officials were unprepared for this damaging evidence and could only lamely repeat their assurances that the new plant would have negligible impact on the health of the public. It took them a few days to prepare an advertisement for the *Pittsburgh Post-Gazette* in which they claimed that they had operated their Shippingport facility safely -- without releasing more than a small percentage of the releases allowed by the Atomic Energy Commission and the Commonwealth of Pennsylvania, and therefore without injuring any member of the public. But the people who had attended the meeting were no longer so certain that this was the case, and there was a demand for an independent investigation of these disturbing findings by the various environmental groups in Pittsburgh and Beaver County before a new and still larger reactor would be given a license. This demand was supported by the mayor of Pittsburgh, Pete Flaherty, and his utility lawyer, Albert Brandon.

Confronted with the evidence of very high levels of strontium 90, cesium 137, and iodine 131 in the area in 1971, while "zero" release had been officially reported, I began to wonder about earlier releases. The plant had been in operation since 1958, so in light of the unreliable claims by the company, I wondered if there might indeed have been long-term exposure to the people of Beaver County and nearby Allegheny County, in which the city of Pittsburgh was located. In particular, enough time had elapsed for leukemia and cancer to develop, so that one might for the first time be able to determine whether the operation of commercial nuclear plants did or did not lead to the same kind of cancer increases that I had begun to see following the start of nuclear-weapons tests in Nevada, the Pacific, and Siberia.

My students and I started to examine the annual vital statistics reports for Beaver County, Allegheny County, and the major towns at different distances from Shippingport up and down the Ohio River. Within a few days the first results were tabulated, and the figures were startling. In the town of Midland, just a mile downstream from Shippingport, the people drank the Ohio River water. The cancer death rate in this town had risen from a low of 149.6 per hundred thousand population in 1958, when the plant started to operate, to a peak of 426.3 by 1970. This was an increase of 184 percent in only twelve years.

For Beaver County as a whole, surrounding the plant, the rate had risen from 147.7 to 204.7 in the ten years from the time the plant had gone on line with so much hope for a cleaner and healthier environment. This was a rise of close to 40 percent during a time when the state of Pennsylvania as a whole showed an increase of only 10 percent and the U.S. cancer mortality rose by only 8 percent. From a low of 293 cancer deaths in Beaver County in 1958, the number had risen to 418 by 1968, an increase of 115 cancer deaths per year, when there should have been no more than an additional 30 if the county had continued to follow the average pattern for the state.

Likewise, the Pittsburgh cancer death rate had climbed by 31 percent between 1958 and 1968, despite the steady cleanup of ordinary air and water pollution that had begun right after World War II, when the burning of soft coal in the city was ended and a major effort was begun to clean up the air and water.

Similarly, in the towns along the Ohio River downstream from Shippingport and Midland, cancer rates had climbed sharply, the more so the closer they were to the plant. For East Liverpool, just across the border in Ohio and some 10 miles downstream, the cancer death rate had risen 40 percent by 1968 and 67 percent by 1971. In Steubenville, some 30 miles downstream, the cancer mortality rate was up 25 percent by 1968, and even as far away as Cincinnati, some 300 miles down the Ohio River, the cancer deaths had climbed 24 percent, while they increased only 6 percent for Ohio as a whole.

Further evidence suggested that the releases from Shippingport had added heavily to all the other sources of carcinogens, from bomb tests to chemical plants. The city of Columbus, Ohio, which did not use the Ohio River for its drinking-water supply, actually experienced a 10 percent decline in its cancer rate during the same period, even though it suffered from all the other likely sources of carcinogens, including automobile exhaust, cigarettes, food additives, hair dyes, artificial sweeteners, and so on.

But if Shippingport was responsible for these striking cancer rises in the towns using the Ohio River for their water supply, then the discharges into the river would have had to be vastly greater than the amounts for which the plant had been licensed. Was there any evidence that the activity in the water had been much greater downstream than upstream of the plant? After all, it was clear that it could not be the milk that was responsible for transmitting the radioactivity all the way to Steubenville and Cincinnati.

Fortunately, there was a way to check this. For many years, the Pennsylvania State Department of Environmental Resources in Harrisburg had been making quarterly measurements of the radioactivity in all the major streams of the state at various points along each river. When the students had collected the data for the Ohio and other streams in western Pennsylvania, the answer began to emerge. There was a large peak in the Ohio River radioactivity in late 1970 and early 1971, exactly the time when the N.U.S. data had shown a large peak of radioactivity in soil, milk, river sediment, and fish. At Midland, just a little over a mile below the Shippingport plant, the gross beta activity had climbed from a low of only 3 picocuries per liter to a high of 18. But for the two rivers that joined in Pittsburgh to form the Ohio, the Allegheny and the Monongahela, measured at locations more than 30 miles away, upstream to the east the rise was no greater than 5 of these units.

Thus, the rise in river radioactivity could not have been due to fallout, which would have affected the more distant upstream areas just as strongly. But it was consistent with high, unreported gaseous releases that would settle on the land and then be washed into the Ohio River with the rain and melting snow. In fact, the rapid disappearance of the high values of long-lived strontium 90 in the soil around the Shippingport plant between early 1971 and 1972 could be explained only by the action of rain carrying the radioactivity from gaseous releases into the local streams and rivers. This possibility was further supported by the fact that the two nearest small rivers that joined the Ohio just a few miles *upstream* from Shippingport, the Beaver River and Raccoon Creek, both showed even larger rises in activity, reaching peaks of 20 picocuries per liter during the same quarter.

It was apparently not any direct liquid discharges that were involved, which by the terms of the original license were to be held to less than 0.56 curies. Rather, the radioactivity must have originated from airborne releases that settled on the surrounding land as far upstream as 20 to 30 miles. Only releases into the air could also explain the large increases in milk activity all around the farms surrounding the Ohio River in Beaver County.

This would make it possible to understand the paradoxical finding that even "upstream" locations and tributaries of the Ohio within 20 to 30 miles, showed peaks in radioactivity when the local milk rose in strontium 90, cesium 137, and iodine 131. And it would explain why cancer rates in cities as far away as Pittsburgh, upstream by 25 miles, could have their water supplies contaminated. The wind was blowing the radioactive gases up the Ohio Valley to the streams that filled the reservoirs serving Pittsburgh, just as the fallout from the "Simon" shot in Nevada had contaminated the reservoirs of Albany and Troy back in the spring of 1953.

Clearly, if such releases were taking place but were somehow not reported, even cities using tributaries of the Ohio entering the river 10 to 30 miles upstream from Shippingport, as well as communities far downstream, could have their drinking water affected and their cancer rates increased by the invisible, tasteless, and odorless radioactive fallout secretly discharged into the ambient air.

By looking up the amount of water carried by the Ohio per second at Midland for each month of the year, it was possible to calculate how many curies had been carried downstream from the airborne releases in late 1970 above and beyond the amounts in the Allegheny and Monongahela Rivers that joined to form the Ohio some 25 miles upstream from the plant. The total worked out to 183 more curies in the Ohio below the plant in a year than were carried by the Allegheny and Monongahela Rivers, which combined to form the Ohio. This was 300 times more than the original permit had allowed for direct discharges into the Ohio River from the

Shippingport plant, and 2500 times more than the 0.07 curies that the Duquesne Light Company had officially reported for liquid discharges in 1970 to the state and federal health agencies.

There were apparently hundreds to thousands of times as many curies of highly toxic radioactivity in the Ohio River than were allowed by state and federal limits, designed to protect the health of the people using the Ohio for their drinking water. The radioactivity did not come from the direct liquid discharges, however, but through the run-off of unreported gaseous releases that had settled on the land.

Here, then, was at least one piece in the puzzle as to why not only infant mortality but mortality at all ages had been affected so strongly, despite the relatively small external radiation doses from gamma rays on the ground that irradiate the whole body uniformly. It was the airborne gaseous activity and the run-off into the rivers serving as drinking-water supplies that had apparently carried the more damaging short-lived beta-ray-emitting chemicals rapidly into the critical organs of the people, in addition to the other pathways via the milk, the vegetables, the fruits, the fish, and the meat that were most important for the long-lived strontium 90 and cesium 137. And although adults were more resistant to the biological damage than the developing fetus, they received the doses steadily over many years rather than just for a few months, by continuously drinking the water, inhaling the gases, and eating the food that was contaminated first by the fallout from the bomb tests, and then by the secret gaseous releases from the peaceful nuclear reactors along the rivers of the nation.

Of equal significance were the implications for one of the most important questions DeGroot was unable to answer: Why had he not found a correlation between the changes in infant mortality in Beaver County and the published radioactive releases in the case of the Shippingport reactor, while he had discovered such a correlation for the other three nuclear reactors he had studied? Clearly, if there existed such large unreported releases as the data gathered by the N.U.S. Corporation, the Environmental Protection Agency, and the State of Pennsylvania seemed to indicate, then one could not possibly expect to find a direct relationship between the *announced* annual releases and the changes in mortality rates.

Now a new and most disturbing question had arisen: How was it possible for large quantities of radioactive gases to escape from the Shippingport plant without being officially reported as required by the existing regulations? Not until many months later was this riddle destined to be solved in a most unexpected manner.

In the meantime, there was a growing public debate over the abnormally high levels of radioactivity around the Shippingport plant and the sharp rise in infant mortality in such nearby towns as Aliquippa. I documented my findings in a report and sent it to the governor of Pennsylvania, Milton Shapp, in January of 1973. Early in the spring, Governor Shapp announced his intention to appoint a special fact-finding commission of independent scientists and public health experts who would hold hearings on the question and issue their own report within a few months.

The latest numbers for infant mortality in Aliquippa, some 10 miles downwind and to the east of the plant, were indeed alarming. For the years 1970 and 1971, the years of high levels of radioactivity, Aliquippa's infant mortality rate climbed to a twenty-year high of 44.2 and 39.7 per 1000 live births. These were more than double the overall state rates of 19.9 and 18.2. Yet back in 1949 and 1952, when ordinary air pollution from the steel mills was much greater, but before Shippingport had started, Aliquippa's infant mortality rates had been as low as 16.0 per 1000 births.

This could not be simply explained by a change in the composition of the population, which had remained essentially constant, the nonwhite population representing 21 percent of the total in 1960 and 22 percent in 1970. And for the State of Pennsylvania and the United States as a whole, infant mortality had resumed its previous decline after the end of atmospheric bomb tests by the United States and the Soviet Union for both the white and nonwhite population.

News of the controversy had reached the cities along the Ohio below Shippingport, and in April I was asked to present my findings at a public lecture at the University of Cincinnati by a local environmental group and university professors concerned about the construction of the Zimmer nuclear power station upstream from the city's water intake. At the end of my presentation, members of the university's Department of Chemical and Nuclear Engineering attacked my findings, charging that numerous state and federal government health agencies, including those of the State of Pennsylvania, had found no substance to my allegations in the past and that I had been repudiated especially by such prestigious organizations as the Health Physics Society, the American Academy of Pediatrics, the National Academy of Science, the Atomic Energy Commission, and the Environmental Protection Agency.

As Dr. Bernd Kohn, director of the Radio Chemistry and Nuclear Engineering Research Center put it: "In each case, an epidemiologist has refuted his claim by the same data." But Dr. Kohn and the other engineers present were unable to point out how else to explain the startlingly high localized values of strontium 90, cesium 137, and iodine 131 in the environment around Shippingport, other than that it was likely to be Chinese fallout.

However, when I showed the data to the mayor of Cincinnati, Theodore M. Barry, he wrote a letter to Governor John J. Gilligan of Ohio, requesting an investigation by the Ohio Environmental Protection Agency. Also, the chairman of the energy conservation committee of the Cincinnati Environmental Task Force, after seeing the data on radioactivity and cancer mortality changes around Shippingport and the other reactors that had been studied by DeGroot and me, announced that he would recommend that the City of Cincinnati become an intervenor in the public hearings on an operating license for the Zimmer plant.

The next day, the *Cincinnati Inquirer* carried the following two headlined stories on its front page: "Mitchell Denies Knowledge of Plans to Bug Watergate" and, just below, "AEC Denies Radiation Damage to Ohio River."

In the light of the enormous discrepancy between the official claims of "zero releases" and the N.U.S. findings of much larger than normal amounts of strontium 90 in the soil, the milk, and the river sediment around Shippingport, the coincidental juxtaposition of these two stories took on an ominous ring. The facts that had emerged so far were hardly consonant with the AEC's claim in the *Inquirer* story that "the release of effluents from the Shippingport Atomic Power Station is carefully controlled and monitored so as not to endanger the public."

The story went on to say that "the radiation levels in these effluents are so extremely low that they pose no threat to the people in the cities mentioned by Dr. Sternglass." It all sounded exactly like the old reassurances that had been issued by the AEC at the time of the nuclear tests in Nevada, and the denial by former Attorney General John M. Mitchell before a federal grand jury that he had any prior knowledge of the Watergate case and always vetoed any bugging plans that were suggested while he was President Nixon's campaign manager.

There would soon be another kind of grand jury appointed to hear the differing claims of government officials and independent scientists who had stumbled upon information that was not meant to reach the ordinary citizen of our country.

Newspaper stories in the Pittsburgh area repeating the denial of large discharges from Shippingport and blaming the high readings either on fallout or on errors in the measurements were clearly indications of deep concern by the AEC, Duquesne Light, and N.U.S. All three organizations now knew that before long they would be facing hearings by an independent body of knowledgeable scientists. The bureaucrats and scientists in the AEC knew that this time the hearings would not be under their control, unlike the case of the usual licensing hearings, where both the hearing officers and the staff were appointed by the agency whose mandated task it was both to promote and regulate the safety of the nuclear industry.

But the full extent of the behind-the-scenes efforts to make the public believe that nothing had happened at Shippingport did not emerge until long after the hearings of the fact-finding commission had taken place at the end of July. The story was pieced together later in an article by a free-lance investigative writer, Joel Griffiths, and published in an article in the *Beaver County Times* on June 7, 1974, after the AEC had issued licenses for the operation and construction of the Beaver Valley Power Station Units I and II.

Quite unexpectedly, the story came to light as the result of a routine request submitted by the attorney for the City of Pittsburgh, Albert Brandon, in connection with the discovery procedures preceding the licensing hearings for the new reactors at Shippingport. (This was a few months after the Shapp Commission hearings in Aliquippa had taken place.) Brandon had asked for copies of all correspondence and internal memoranda connected with the Shippingport controversy in the files of the AEC. And then, one day in the fall of 1973, not long before the licensing hearings were scheduled to begin, a large envelope arrived at Brandon's office with a devastating series of internal memoranda, letters, and other documents revealing what had taken place behind the scenes.

As Griffiths described it in his article, early in 1973 the AEC's Earth Science Branch had conducted an in-depth investigation of the situation and concluded that "it is highly unlikely that the radioactivity was of Chinese origin. Most likely it was either of local origin, or the result of inadequate sampling procedures." Griffiths wrote that this was a crucial finding. "Local origin" was a euphemism for Shippingport, since there was nothing else in the vicinity that could have produced that amount of radioactivity. Thus, if the radioactivity had in fact been there, Shippingport was clearly implicated. The only other possibility was that maybe the radioactivity had really not been there in the first place.

As Griffiths put it:

> This was where "inadequate sampling procedures" came in. The idea was that N.U.S. might have bungled procedures it had used to measure the radioactivity in

the samples of soil, milk, and other items from Beaver Valley and somehow produced hundreds of erroneous readings, and all of them too high. This, however, was synonymous with the conclusion that N.U.S. was incompetent.

There was only one way this question could be settled in a conclusive manner. Some of the radioactivity in the samples that N.U.S. scientists had collected in 1970 and 1971 was long lasting. If N.U.S. could turn up some of the original samples that had shown the high levels, they could be reanalyzed to see if the radioactivity had really been there.

According to the records, N.U.S. conducted a search in February 1973 at its Rockville headquarters to see if any of the original high samples were still around. Unfortunately, it was the company's stated policy not to retain samples for more than a year after analysis, and none could be located.

Griffiths went on to relate an interesting development:

By this time, a sharp divergence of opinion had grown between N.U.S. on the one hand and the AEC and health agencies on the other. Faced with a choice between attributing the radioactivity to Shippingport or to N.U.S.'s incompetence, the AEC and others picked incompetence and began leveling various technical charges against the N.U.S. reports. This placed N.U.S. in a delicate position. If their reputation was to be salvaged without crucifying their employer, the Duquesne Light Company and the AEC, N.U.S. had somehow to prove that the radioactivity had been there but had not come from Shippingport. So despite all the evidence, N.U.S. picked fallout.

In March, 1973, N.U.S. completed a draft report on the Shippingport situation, defending the accuracy of its original high readings but attempting to prove that they were not particularly unusual and were probably due largely to Chinese bomb tests.

This draft report was sent to Dr. John Harley, director of the AEC's Health and Safety Laboratory. Dr. Harley had been playing a leading role in the AEC's investigation of the Shippingport affair, and he was well aware that the high radiation levels could not be explained by fallout.

In fact, I knew that he had worked in this field for years and had previously been involved with minimizing the health impact of the fallout from the "Simon" test that had rained over Albany and Troy back in 1953. He had also played a major role in trying to discredit the findings I had made that showed a connection between the upward changes in infant mortality from the atmospheric tests in the Pacific and Nevada and the levels of fallout in the milk and diet through the use of the misleading "gummed film" data, which falsely showed high strontium 90 levels in the dusty, dry areas where the milk levels were actually quite low.

As Griffiths's story indicated:

The memoranda in the AEC files showed very clearly that Dr. Harley was not happy with N.U.S.'s draft report.

In comments for the AEC's files, dated March 8, 1973, Harley fumed: "This draft proves to my satisfaction that the work of this organization is incompetent. ... It is obvious that their staff is not familiar with the field and is not competent to evaluate their data or those of others."

Harley went on to list several examples of N.U.S.'s incompetence in their attempt to prove the fallout theory and in other aspects of their report, remarking that "Investigation would certainly turn up gross calculation errors or even that some doctoring of the numbers had occurred."

He signed off: "I believe the situation is very serious."

Serious indeed. Could Dr. Harley have been referring to that team of "outstanding scientists" who, according to Duquesne's ads, were engaged in the vital work of making people aware that their large nuclear plant was to be "absolutely safe to the public health"?

Yes, he was.

More serious was that N.U.S. had already performed extensive safety studies for some thirty-four other nuclear power plants, many of which had already started operating.

If they were bunglers.

Dr. Harley's accusations of incompetence were more incongruous in view of the apparent excellent credentials of the N.U.S. staff, including the two members who prepared the draft report.

One, the vice-president in charge of all N.U.S. nuclear safety work, Dr. Morton Goldman, had spent ten years as a nuclear safety expert with the U.S. Public Health Service (now the Environmental Protection Agency) and was a consultant to state and federal health agencies.

The other, Joseph DiNunno, the scientist directly responsible for the Beaver Valley survey, had received all his training and experience in the AEC's own reactor safety branch.

Why, N.U.S. almost was the AEC and EPA. Incompetence? Doctoring of figures?

Nevertheless, a couple of months after Dr. Harley's outburst, the AEC issued a definitive report stating that the high radiation levels had been due to N.U.S. bungling. The report was hand carried to the Pittsburgh newspapers before N.U.S. even got a chance to look at it.

Shortly thereafter, on June 7, 1973, according to AEC documents, the president of N.U.S., Charles Jones, called the AEC. Jones maintained stoutly that the radioactivity really had been there and that there was nothing wrong with N.U.S.'s methodology.

The AEC representative to whom he spoke, Dr. Martin B. Biles, director of the Division of Operational Safety, disagreed. Jones then complained that the unfavorable publicity was damaging his company and something must be done. Dr. Biles suggested a meeting.

On June 20, 1973, a meeting was held between Dr. Goldman and DiNunno of N.U.S., Dr. Harley and Dr. Phil Krey of the AEC, and a Duquesne Light Co. attorney.

According to Dr. Harley's subsequent memo to the AEC's files [dated June 22] it was a fruitful meeting.

Goldman and DiNunno began by admitting [in a separate memorandum for the files] that someone in N.U.S. had indeed doctored up figures to support the company's position [in past work for the AEC's Health and Safety Laboratory] although there were unfortunately no laboratory records to verify the fact. This aside, however, they had a wonderful new development to report. In the time since President Jones had talked to the AEC, N.U.S. had found some of the original high samples from Beaver Valley.

Now it would be possible to see if that radioactivity had really been there.

This was indeed fortuitous, especially since these samples were by then nearly two years old and the company did not usually retain its samples for more than a year. Evidently they eluded the original search for samples in February.

According to Dr. Goldman, all the company's employees had been instructed to ransack the premises, and the samples had been turned up by two lab technicians in a storage basement where such samples were not usually kept.

Despite the AEC's earlier misgivings about N.U.S.'s credibility, the legitimacy of these newfound samples was accepted without question. Arrangements were immediately made to have them reanalyzed by the AEC, the EPA, an independent private lab, and N.U.S. It was also decided that N.U.S.'s performance in the reanalysis would serve as a test of whether the company had recovered its competence.

So what happened?

The samples were reanalyzed and no more radioactivity! Some of the samples turned out to be as much as twenty times lower than before, but N.U.S. had got it right this time. Their analytical methods were corrected at last. They were saved. Everybody was saved.

The press was notified.

There were a few loose ends.

N.U.S. had to explain why so many of its measurements had been twenty or more times too high in 1971. The company reviewed its laboratory records again and made a new discovery: all through 1971 there had been systematic errors in several of its analytical methods, all tending to produce only erroneously high readings.

That was it. The case was closed.

NUS's safety work for thirty-four other reactors, and even the low readings it somehow managed to obtain at various times and places in Beaver Valley, was allowed to stand unchallenged. Dr. Goldman and DiNunno fired several employees, including the lab chief, who never stopped defending his measurements, and N.U.S. has since continued in its work of making nuclear power plants "absolutely safe to public health."

None of this, of course, was known either to me or the members of the fact-finding commission when the hearings began on July 31, 1973 in the town of Aliquippa. The panel appointed by Governor Milton J. Shapp and chaired by Dr. Leonard Bachman, the Governor's Health Services Director, consisted of seven members in addition to the chairman, representing a broad range of disciplines and wide experience in matters related to public health. Only five of the panel members, however, were independent university-based scientists outside the state government, and only three of these had personal experience with studies of radiation effects in man.

Of the three, Dr. Karl Z. Morgan, Neely Professor of Health Physics at the School of Nuclear Engineering, Georgia Institute of Technology, editor-in-chief of the journal *Health Physics*, first President of the International Radiation Protection Association, and Director of the Health Physics Division of the AEC's Oak Ridge National Laboratory from 1944 to 1973, had the longest association with the problems of radiation, its control, and its measurement.

Next in the length of his professional involvement with radiation and its effects on man was Dr. Edward P. Radford, Professor of Environmental Medicine at the School of Hygiene and Public Health, Johns Hopkins University, who had recently served on the National Academy of Science's Committee on the Biological Effects of Radiation.

The third scientist with recent experience in the evaluation of the effects of radiation on human populations was Dr. Morris DeGroot, Professor of Mathematical Statistics and Chairman of the Department of Statistics at Carnegie-Mellon University.

Of the other two university scientists, one was Dr. Paul Kotin, Provost and Vice-President of the Health Science Center and Professor of Pathology at Temple University in Philadelphia, formerly Director of the National Institute of Environmental Health Science, with a special interest in the environmental causes of cancer, and a consultant to both the National Cancer Institute and the Environmental Protection Agency.

The other member of the scientific panel was Dr. Harry Smith, Jr., Dean of the School of Management at Rensselaer Polytechnic Institute at Troy, New York, who was a biostatistician active in the health field over many years, serving as consultant to the National Center for Health Statistics of the U.S. Department of Health, Education and Welfare.

Also serving on the Governor's Commission was the Secretary of Health for the State of Pennsylvania, J. Finton Speller, M.D., and the Secretary of the Pennsylvania Department of Environmental Resources, Maurice K. Goddard.

Although this was not known to me at the time, it would actually be the staffs of these two state officials who would prepare the final report, since there was no provision for any funding of an independent staff responsible only to the scientist members of the committee. In particular, the radiological portions of the report were to be drafted by Thomas M. Gerusky, Chief, Office of Radiological Health, and Margaret A. Reilly, Chief of Environmental Surveillance in Gerusky's office, both of whom reported to Secretary Goddard. The sections of the report dealing with health effects were to be prepared by Dr. George K. Tokuhata, an epidemiologist recently appointed as Director of Program Evaluation in the Department of Health. All three of these key individuals had in the past made public statements denying the validity of my findings on low-level radiation effects from fallout and releases from nuclear plants. As Griffiths later learned in a series of interviews with some of the commissioners also published in the *Beaver County Times*, the final report kept being delayed again and again because the staff kept creating drafts which reflected the view that there were no serious problems connected with Shippingport, and which the commissioners were unwilling to sign.

But on the day of the hearings, I was very hopeful that at long last an eminent group of concerned scientists and public health officials would provide the kind of scientific jury able to evaluate fairly the serious evidence for unreported releases and disturbing increases in mortality rates that had recently come to light.

After Dr. Bachman had opened the hearings and introduced the members of the panel, I summarized the data I had previously submitted in two reports to the governor in a series of slides. In addition, I presented further evidence on the changes in mortality rates involving other chronic diseases besides cancer in a number of towns along the Ohio. Thus, in East Liverpool, 5 miles downstream from Shippingport, heart-disease mortality had risen some 100 percent from its low point of 370 per 100,000 deaths in the period 1954-56 to 730 by 1971, while Ohio as a whole had remained constant at about 370 to 390 throughout this period. Yet back in the early 1950s, before Shippingport had started, there was more ordinary pollution from chemicals and coal burning in the Ohio River, from which the drinking water for East Liverpool originated. And in the ensuing two decades, there had been major efforts to clean up the air and water.

I then presented other recent data in support of the possibility that the action of radioactive fallout on all aspects of human health may have been seriously underestimated, thereby explaining the unexpectedly sharp rises in both infant mortality, cancer, and chronic diseases in Aliquippa and nearby river towns since the nuclear plant had gone on line.

Some of this data came from an extensive collection of heath statistics gathered by Dr. M. Segi at the School of Public Health, Tohoku University, Sendai, Japan, from work sponsored by the Japanese Cancer Society. It showed that many types of cancers known to be caused by radiation rose sharply all over Japan, and not just in Hiroshima and Nagasaki, beginning some five to seven years after the bombs were detonated. Thus, while pancreatic cancer had been level for a period of more than ten years prior to 1945 -- during a period of rapid industrialization, production of chemicals, and growth of electric-power generation by coal -- it shot up some 1200 percent by 1965, and only recently began to slow down its enormous rate of climb following the end of major atmospheric bomb testing. The pancreas is also the organ involved in diabetes, a disease that had also shown sharp rises not only in Japan but in the United States, and specifically in the Beaver County area.

Similar patterns emerged from plots of Dr. Segi's data for prostate cancer and lung cancer, the former rising to 900 percent of its pre-1945 incidence, and the latter to 750 percent. And again a similar pattern had taken place near Shippingport, where lung cancer for the nearest sizable town of Midland had risen 500 percent from its 1957-58 rate of 22 to a high of 132 per 100,000 population by 1970, while it had risen only some 70 percent, from 22 to 38 per 100,000 in Pennsylvania as a whole during the same period.

Again, these patterns could not simply be blamed on cigarette smoking alone, although it was known that uranium miners who smoked had some five to ten times the lung cancer mortality rate than those who did not, so that those who both worked in the mines and smoked showed a twenty-five- to hundredfold greater risk of dying of lung cancer as compared with those who neither smoked nor were exposed to the radioactive radon gas. Thus, in effect, the releases of radioactive gases into the already polluted air of Midland has produced the same kind of synergistic effect, as if the people in that town just a mile away from the Shippingport plant had suddenly started to work in the uranium mines.

Thus, the data for the changes in cancer rates in the area for which levels of radioactivity in the air, the water, the milk, and the total diet had been measured as comparable with the levels produced by fallout from bomb tests in Siberia and the Pacific drifting over Japan during the 1950s clearly supported the reality of the data gathered by the N.U.S. scientists recently, and also the reality of the existence of much-higher-than-reported releases from Shippingport in the past.

In further support of the argument that relatively low doses of radiation from nuclear reactor releases can have readily detectable results on human health, I summarized the evidence that infant mortality in Beaver County and other areas along the Ohio had increased in 1960 and 1961 following an accidental release of radioactive isotopes in the course of a fuel-element melt-down at the Waltz Mills nuclear reactor on the Youghiogheny River, some 20 miles upstream from the city of McKeesport in April of 1960.

Within a year after that little-known accident, infant mortality rates doubled in McKeesport and then slowly declined again to the level of the rest of Allegheny County, which gets its drinking water mainly from the Allegheny River. And the effects could be seen in a steadily declining pattern of infant mortality peaks along the Monongahela and Ohio River communities for 160 miles downstream.

In the course of the questioning period that followed my presentation, I was asked how it was possible that such relatively small doses comparable to normal background levels could lead to such large changes in mortality rates, when it apparently took ten to a hundred times these levels to double the risk for the survivors of Hiroshima and Nagasaki. In response I cited the startling results of a recent study published in the journal *Health Physics* in March of 1972 by a scientist working for the Canadian Atomic Energy Laboratories in Pinawa, Manitoba, Dr. Abram Petkau. Dr. Petkau had been examining the basic processes whereby chemicals diffuse through cell membranes. In the course of these studies, he had occasion to expose the membranes surrounded by water to a powerful X-ray machine, and observed that they would usually break after absorbing the relatively large dose of 3500 rads, the equivalent of some 35,000 years of normal background radiation.

This certainly seemed to be very reassuring with regard to any possible danger to vital portions of cells as a result of the much smaller doses in the environment from either natural or man-made sources. But then Dr. Petkau did something that no one else had tried before. He added a small amount of radioactive sodium salt to the water, such as occurs from fallout or reactor releases to a river, and measured the total absorbed dose before the membrane broke due to the low-level protracted radiation.

To his amazement, he found that instead of requiring a dose of 3500 rads, the membrane ruptured at an absorbed dose of three-quarters of one rad, or at a dose some 5000 times less than one rad, much less than was necessary to break it in a short, high-intensity burst of radiation such as had occurred at Hiroshima and Nagasaki.

Dr. Petkau repeated this experiment many times in order to be certain of this disturbing finding, and each time the result confirmed the initial discovery: the more protracted the radiation exposure was, the less total dose it took to break the membranes, completely contrary to the usual case of genetic damage, where it made no difference whether the radiation was given in one second, one day, one month, or one year.

By a further series of experiments, he finally began to understand what was taking place. Apparently a biological mechanism was involved in the case of membrane damage that was completely different from the usual direct hit of a particle on the DNA molecules in the center of the cell. It turned out that instead, a highly toxic, unstable form of ordinary oxygen normally found in cell fluids was created by the irradiation process, and that this so-called "free radical" was attracted to the cell membrane, where it initiated a chain reaction that gradually oxidized and thus weakened the molecules composing the membrane. And the lower the number of such "free radicals" present in the cell fluid at any given moment, the more efficient was the whole destructive process.

Thus, almost overnight, the entire foundation of all existing assumptions as to the likely action of very low, protracted exposures as compared to short exposures at Hiroshima or even from brief, low-level medical X-rays had been shaken. Instead of a protracted or more gentle exposure being less harmful than a short flash, it turned out that there were some conditions under which it could be the other way around: The low-level, low-rate exposure was more harmful to biological cells containing oxygen than the same exposure given at a high rate or in a very brief moment.

No longer was it the case that one could confidently calculate what would happen at very low, protracted environmental exposures from studies on cells or animals carried out at high doses given in a relatively short time. It was clear that the direct, linear relation between radiation dose and effect was no longer the most conservative assumption, for it was based on the implicit assumption that a given dose would always result in a given increase in risk, no matter whether the radiation was absorbed in one second or one year. Clearly, if Dr. Petkau's findings were to be confirmed by other experiments in the future, our whole present understanding of low-dose radiation effects would have to be revised, since small exposures might turn out to be far more harmful to living cells than we had ever realized.

Thus, I pleaded we should not reject evidence for much higher than expected infant and cancer mortality rates merely because that evidence did not seem to agree with our previous estimates based on high-level, high-rate exposures at Hiroshima and in various studies. I now believed that we had to be prepared to revise drastically our expectations as to what apparently innocuous low-level, chronic radiation exposures to critical cells and organs from environmental sources might do.

My own testimony was followed by that of Dr. Irving Bross, a well-known biostatistician from the Roswell Park Memorial Cancer Institute in Buffalo, New York, who had himself been studying the effect of low-level radiation on childhood leukemia for many years. In summarizing his findings Dr. Bross stated that there exists a wide range of individuals with very different degrees of sensitivity to radiation, depending upon their age and their past medical history.

This fact alone would invalidate any estimate of the likely effect of small radiation exposures to a large human population, since these had been based on the average adult, obtained at high doses, and on the assumption of a linear relationship between dose and effect. For a non-homogeneous group, the more resistant individuals such as healthy young adults would not show any significant effects, while either the very young or the very old and those with immune deficiencies, allergies, and other special conditions might show an unexpectedly large effect. As Bross had put it in a letter to *The New York Times* published just a few weeks before he testified: "It follows that procedures for calculating `safe levels' based on `average exposures' of `average individuals' are not going to protect the children or adults who need the protection most."

Next was the testimony of the Deputy Director of the Division of Biology and Medicine of the U.S. Atomic Energy Commission in charge of all biomedical and environmental research, Dr. W. W. Burr, Jr. This witness, as recorded by the reporter for the *Beaver County Times*, Bob Grotevant, "tabbed all allegations about a definite correlation between radioactive emissions from the Shippingport plant and increased infant deaths and cancer cases made by Dr. Sternglass as `unsupportable.'" Burr then announced that a number of follow-up tests after publication in 1971 of "erroneous" test data by the N.U.S. Corporation "proved that no such high levels of any radioactive products existed near the plant."

This, then, was the way that had been chosen by the AEC to deal with what had happened, as we were to learn later from the internal memoranda, and one witness after the other for N.U.S., for the utility, for the EPA, and for the Commonwealth of Pennsylvania followed the line agreed upon in the correspondence and secret meetings described in the memoranda. Each independent set of data was rejected as unreliable or meaningless when it showed the existence of high radiation levels or increases in mortality rates.

As Anna Mayo, who covered the proceedings for *The Village Voice*, put it in an article published a few months later, "it was all redolent of -- you guessed it -- Watergate. In the audience, environmentalists gnashed their teeth, wishing that the Shippingport horrors could have been exposed on national television. If Duquesne Light would cover up, would not Con Ed, LILCO, or Commonwealth Edison do the same if Indian Point, Shoreham, or Dresden were at stake?"

Indeed a great deal was at stake: In 1973 some thirty-eight new nuclear reactors were in the process of being ordered, the largest number ever in one year, each representing a potential business of about a billion dollars. And it was the stated aim of the Nixon administration and the nuclear industry to see a thousand of these reactors operating near the cities of our nation by the end of the century. It would indeed be difficult for any human beings not to have minimized the danger when a thousand billion dollars were at stake.

As expected, when the report of the Governor's Commission finally appeared a year later, after the licenses had been granted to Beaver Valley Unit I and II, it did not call for a moratorium on nuclear power plants, as Anna Mayo had suggested it should at the end of her article. In fact, she had predicted the outcome exactly. As she had put it bitterly: "About the most that can be expected is a modest plea for further studies: that is, more and more necrophiliac nitpicking."

The summary of the commission's report set the tone of the entire document. By carefully using certain qualifying words that are easily passed over by the hurried reader, such as "substantial," "systematic," or "significant," a draft had finally been prepared by Tokuhata, Gerusky, and Reilly that the members of the committee could no longer continue to refuse to sign after months of efforts to arrive at some sort of acceptable wording. It provided sentences which, when taken separately, could be widely used by the utility to claim that it had been completely cleared. For example, consider the very first sentence: "There is no substantial evidence that the quantities of radioactive materials released by Shippingport Atomic Power Station have been greater than reported by the plant operators." This sentence was followed, however, by one that would satisfy the consciences of some of the more concerned commissioners: "However, the absence of comprehensive off-site monitoring during plant operations precludes accurate verification of the data on plant releases," and so on throughout the long and inconclusive report.

Far more revealing than the report as to the true feelings of four of the five independent scientists on the commission willing to go on record were the answers to questions submitted to them by Griffiths in his article, which appeared just before Governor Shapp released the report in June of 1974.

For instance, to the question, "Did the data in the original N.U.S. report point to Shippingport as the source of the high radiation data," the scientists answered as follows:

> DR. DEGROOT: "If we accept those data, then the circumstantial evidence points to Shippingport largely because of the location of the radioactivity and the lack of plausible alternate sources."

> DR. MORGAN: "The original N.U.S. data very strongly suggested to me that the radioactivity came from the plant. If you take the data as fact, you'd be very hard-pressed to find any other source that could explain it."

DR. RADFORD: "Well, there was some indication in the original N.U.S. data that there was a release from some source. As to whether that source was Shippingport, I'd have to look up the data again."

DR. SMITH: "I can't find any direct connection between the radiation levels measured by N.U.S. and the Shippingport plant. All that mish-mash is so unscientific that one would never be able to draw any valid scientific inferences from it."

Another question referred to the discrepancy between the original N.U.S. analysis and the reanalysis: "After N.U.S. reanalyzed its data, the high radiation levels disappeared. Did this reanalysis prove to you that the radioactivity was never there?"

DR. DEGROOT: "No, it did not. It did convince me that the reanalysis was highly unreliable. However, I am equally convinced that the original N.U.S. data showing high levels cannot be considered reliable evidence. There are just so many inconsistencies in their work that I cannot accept any of it. . . . This comment does not mean that all their high readings were wrong. In fact, I find it highly unlikely that N.U.S. could have made systematic errors, all in one direction, in several different analytical techniques."

DR. MORGAN: "The explanations advanced by N.U.S. did not at all convince me. For example, if they had found something wrong in only one of their systems, it would not be too surprising. We all make mistakes. But to have systematic errors in several different analytical techniques, all tending to produce only high readings -- the chances of that are quite low. . . . There appears to be a strong suggestion of dishonesty, and that estimate is borne out by written comments from Dr. John Harley of the AEC, whose integrity I respect. Dr. Harley found that N.U.S. seems to have doctored some of their data to fit their arguments. If a person will do that with one set of scientific data, it is very possible he will do it with another. . . . So, as far as I can see, there is no proof that the radioactivity levels around Shippingport were not quite high in the past. For a long period now the radioactivity levels in milk in that general area have been high according to the public-health agency surveys, which are completely separate from the N.U.S. survey. This has never been explained."

DR. RADFORD: "Well, they had three separate laboratories reanalyze some of the original 1971 milk and soil samples, and each lab got similar low readings. If these samples were valid, then it is pretty clear there was not much radioactivity there to begin with. Now of course you could say they dug up soil from somewhere and analyzed it -- I cannot argue that."

DR. SMITH: "I think that the degree of scientific merit on one side really was better. I would accept the explanations advanced by N.U.S."

Another question: "Was there any evidence in the mortality statistics that Shippingport had caused health damage, or did the statistics tend to refute this?"

DR. DEGROOT: "We cannot really decide the issue because of the poor quality of the available health statistics and because the population is not large enough for a really meaningful statistical analysis. But there is certainly nothing in the available data to lower the probability that there may have been health damage. It is true that the Pennsylvania State Health Department went back and discovered errors of a certain type in its published infant mortality rate for Aliquippa in 1971, and that the ensuing corrections sharply lowered the rate. . . . However, I feel it is likely there were also errors of another type which could have raised the rate back up again. Unfortunately, the resources were not available to investigate this possibility. So, to my mind, the corrections are incomplete. The only type of error investigated was one that would reduce the number of deaths and lower the rate. . . In any case, I think there remain some anomalies that have not been fully explained. For example, I did an analysis of infant mortality in Aliquippa, and the rate definitely seems to have shifted upward recently. To my mind this upward shift is not fully explained by demographic or socioeconomic factors. I do not know if any of it is due to Shippingport, but I think it warrants further investigation."

DR. MORGAN: "I do not personally feel that the mortality statistics refute the possibility of some adverse effects on the population's health. Taking the original published data, it appears to me that there was an effect. However, after the Health Department got through making corrections and applying all the epidemiological and statistical techniques to the mortality rates for the population near the reactor, they seem to have come up with the belief that there were no significant health effects. . . . I cannot help but be a little skeptical. To me, if you are going to make all these corrections for the population that might have been exposed to radiation, you have to give equal consideration to the unexposed control population. It was very obvious to me that if they had, it would have made a difference in at least one instance."

DR. RADFORD: "The statistical evidence favors the hypothesis that the plant did not cause any health damage. For example, the mortality rates do not decline with distance in all directions away from the plant. The mortality rates for Beaver County as a whole are quite low, and on that basis one would be hard-pressed to say that Aliquippa was affected, since the rest of the county should also be high. . . . Then, when the mortality rates for Aliquippa are corrected for errors, you see that Aliquippa is no worse off than any other town with comparable population characteristics."

DR. SMITH: "In my opinion the mortality statistics indicate there was no effect from the reactor. The adjusted mortality rates are not abnormally high. One comes to the conclusion that the Shippingport area may not be the greatest place to live, since the mortality rates are higher there than in many other communities, but such high rates are normal, expected occurrences in places with the kind of demographic and socio-economic characteristics you find around Shippingport. . . . Also, I have to find a scientific link between radiation exposure and infant mortality, and this requires a great deal of what I call logical extrapolation or inferences step by step through a process which proceeds from the birth of a child to its ultimate death, and I cannot find sufficient evidence for that link in this case."

Although the majority clearly were deeply suspicious of the "reanalysis" of the radiation data and the "adjustment" of the vital statistics by Tokuhata, I was surprised by Radford's comment that the mortality rates do not decline with distance away from Shippingport, and that therefore the evidence favored the hypothesis that the plant did not cause any health damage.

Not until later, when I saw the final report, did I see what could have led Radford to this conclusion. In Table 13, Tokuhata had listed the cancer death rates according to distance from Shippingport for the years 1961 to 1971. There were columns for the rates within 5 miles, between 5 and 10 miles, beyond 10 miles, for Beaver County, and for Pennsylvania as a whole. And at the bottom of each column, there were listed the average mortality rates for each of these regions.

When I looked at them, I was startled to find that Radford seemed to be right. The lowest rate did in fact exist for the circle 5 miles in radius around Shippingport: 155.7 compared with 170.4 in the next, more distant region 5 to 10 miles away from the plant, and a still higher rate of 182.3 for Pennsylvania as a whole. This certainly seemed to suggest that radiation was good for one's health, and that the closer one lived to the reactor, the better off one would be.

What exactly had Tokuhata done to arrive at this conclusion that had obviously convinced Radford and Smith? It took me a while to work it out, but when I did I was furious. Looking down the entries for each year from 1961 to 1971, I saw that all areas showed lower cancer rates in 1961 than in 1971, but that the area nearest to Shippingport had happened to have by far the lowest rates to begin with, well before any major releases had occurred from Shippingport and well before any increases in cancer mortality due to Shippingport could have shown up in the statistics. It had been a largely rural area, relatively free from pollution and therefore with relatively good health, cancer mortality having reached a low point of only 102.6 per 100,000 population in 1964, lower than any other listed at any time for any area in the table. The average for the first four years, 1961-64 was only 133.4, compared with 155.3 for the 5-to-10 mile range and 176.8 for Pennsylvania as a whole.

But by the time that the 1963-64 Shippingport releases had had a chance to act, namely by 1969-70, the area nearest to Shippingport had increased the most, shooting up to a peak of more than double its lowest rate of 102.6, namely to 225.6 in 1969 and 218.9 in 1970, while the more distant areas increased much less. Thus, the 5-to-10-mile-distant zone had risen to 189.2 by 1969 and 191.2 by 1970, while the area of Beaver County beyond 10 miles from Shippingport was listed at only 164.9 and 164.3 for these years.

In fact, taking the last four years of 1968 to 1971 in the table when cancers had had a chance to manifest themselves, and comparing them with the first four years when the effect of any releases could not yet have appeared in the mortality statistics, it was clear that the data fully confirmed my earlier findings obtained from the Vital Statistics reports of Pennsylvania and Ohio by town and by county. The greatest increases had indeed taken place for the people nearest to the plant: a rise of 38 percent compared with only 22 percent for the next zone and 20 percent for the area beyond 10 miles, while Pennsylvania as a whole showed only a 6 percent increase in cancer mortality.

Thus, by averaging over all the eleven years listed in the table so as to include the years of lowest cancer rates for the rural area around Shippingport before the plant could have had any effect on cancer rates, Tokuhata had successfully managed to give the impression that the closer one lived to the plant, the less was the risk of cancer.

There was one question that had remained unanswered even by the internal documents from the AEC files: How and where in the plant did the radioactive gases escape without being officially reported, as required by both state and federal regulations?

As so often before in the Shippingport story, the answer came in the most unexpected manner, this time not through the mail but in a phone call late one evening a few weeks after the Aliquippa hearings had ended.

The caller said that what had been brought out at the hearings so far was in the right direction, but that the full story behind the high radioactivity in the area could be found by putting the plant operators on the stand in the forthcoming licensing hearings that were to be held by the AEC later in the year. What we needed to do was to have the men explain during cross-examination the details of the treatment system for the radioactive gases, and then force them under oath to say whether they had found any anomalous conditions in the hold-up tanks where the radioactive gases were supposed to be stored for many weeks to allow the shorter-lived radioactivity to decay before they would be discharged from the monitored stack.

This was of course the kind of break we had hoped for. Together with the internal memoranda of the AEC that had revealed the attempt to explain away the findings of high radioactivity in the air, the soil, the milk, the water, and the local diet, it would complete our case for arguing that the Duquesne Light Company should not be given a license to operate two even larger nuclear reactors, since their employees were either too incompetent or too corrupt to do so without endangering the health and safety of the public.

And so I obtained the detailed engineering drawings of the gas-treatment system for the Shippingport plant from articles published in the literature, and explained the complex system to the attorney for the city, Al Brandon, who would have to do the actual cross-examination.

The hearings by the Atomic Safety and Licensing Board on the operating permit for Beaver Valley Unit I and the construction permit for Unit II finally got under way in the fall of 1973 in the Federal Court House in Pittsburgh. Although we had few illusions as to what the ultimate decision would eventually turn out to be, we at least hoped to expose to the public what had actually been going on behind the scenes at the Shippingport plant, widely advertised all over the world by Westinghouse and Duquesne Light as the cleanest and safest nuclear reactor in the world.

For a while we did not know whether we would be allowed to put the operators of the plant on the stand. But then the ruling came down, and it all really happened.

The first few men, when shown the diagrams of the gas-treatment system, claimed that they were not aware of anything abnormal. But suddenly, one of the men, when pressed by Brandon as to whether he had ever noticed anything unusual in the operation of the system, and whether there might not have been some leakages from the gas-storage tanks in the yard, admitted that he had observed something that had caused him to become concerned.

Some time in late 1970 or early 1971 he had noticed an unusual drop in the amount of recorded radioactive gas releases in the plant log, and he had mentioned it to his supervisor, who told him not to worry about it. Questioned by Brandon he admitted that the situation persisted over a period of a few weeks, and that he then decided to investigate what might be going on for himself. He went out into the yard where the large gas-storage tanks were located and found that a lock on one of the rusty valves had been broken. The valve looked as if it might be leaking. Using a small brush to paint a soap solution over the suspected area, he saw bubbles being formed, indicating that radioactive gas was in fact leaking from the tank.

Again, he said that he reported the situation to his supervisor, who told him that he would take care of it, and that he should not concern himself with this problem any more since this was not part of his job.

As Brandon expected, none of the supervisors he put on the stand could recall this incident, and the local newspaper that evening reported that the plant personnel had testified that there were no problems in the plant.

Dr. Morton Goldman, the vice-president of N.U.S. and former public-health officer in the U.S. Department of Health, Education and Welfare, testified under oath that all their early high readings of radioactivity had been in error, substantiating the testimony of the plant supervisors that no unusual or unreported releases could have taken place, and a few months later the Atomic Safety and Licensing Board issued the permits for the new reactors.

Once again, the industry had managed to win the battle in the special courts set up by the AEC, which controlled the judges, the staff, and the rules of procedure for the benefit of the industry it was designed to promote and protect.

It was only the people that were the losers. Two years after the licenses were granted and five years after the high radiation levels had been measured by the N.U.S. Corporation, with the same time delay as in Hiroshima, the cancer rates in Beaver County and Pittsburgh climbed to a second peak. They rose a full 23 percent in Beaver County and an unprecedented 9 percent in Pittsburgh in the course of only three years. The rise to an all-time high of 304.8 per 100,000 population took place after a generation of costly efforts to reduce the ordinary pollution from fossil fuels in the air and chemicals in the water.

But the heaviest price of all was to be paid by the men who worked at Shippingport, as I was to learn at another kind of hearing at Aliquippa seven years later.

When preparing testimony for a hearing before a workmen's compensation referee in behalf of the family of a man who had died of bone-marrow-type leukemia while working at the Beaver Valley nuclear plant next to the old Shippingport reactor, I was shown the death certificates of twenty-one other operating engineers who had died between 1970 and 1979. All of them had been working with pumps and other heavy equipment to clean up the radioactive spills and move the radioactive wastes on the site. Out of these twenty-two men, ten had died of cancer, more than twice the number normally expected.

Even more significantly, four of these ten were of the bone-marrow-related type, namely multiple myeloma and myelogenous leukemia, known to be most readily induced by radiation, when less than one in twenty cancers of this type would have been expected.

The men who worked at Shippingport were only too well acquainted with these facts. There was a common saying among them: high pay and early death.

Yet there was also a sign of hope for the future. After Shippingport was shut down by an explosion of hydrogen gas in its electrical generator early in 1974, infant mortality in the town of Aliquippa declined to an all-time low of only 11.3 deaths per thousand babies born in 1976.

If the public could only learn these facts as the nation entered the third century of its revolution against the arbitrary authority of another distant government careless of the inalienable human rights to life and liberty, even the tragic tide of rising cancer and damage to the unborn could eventually be reversed.

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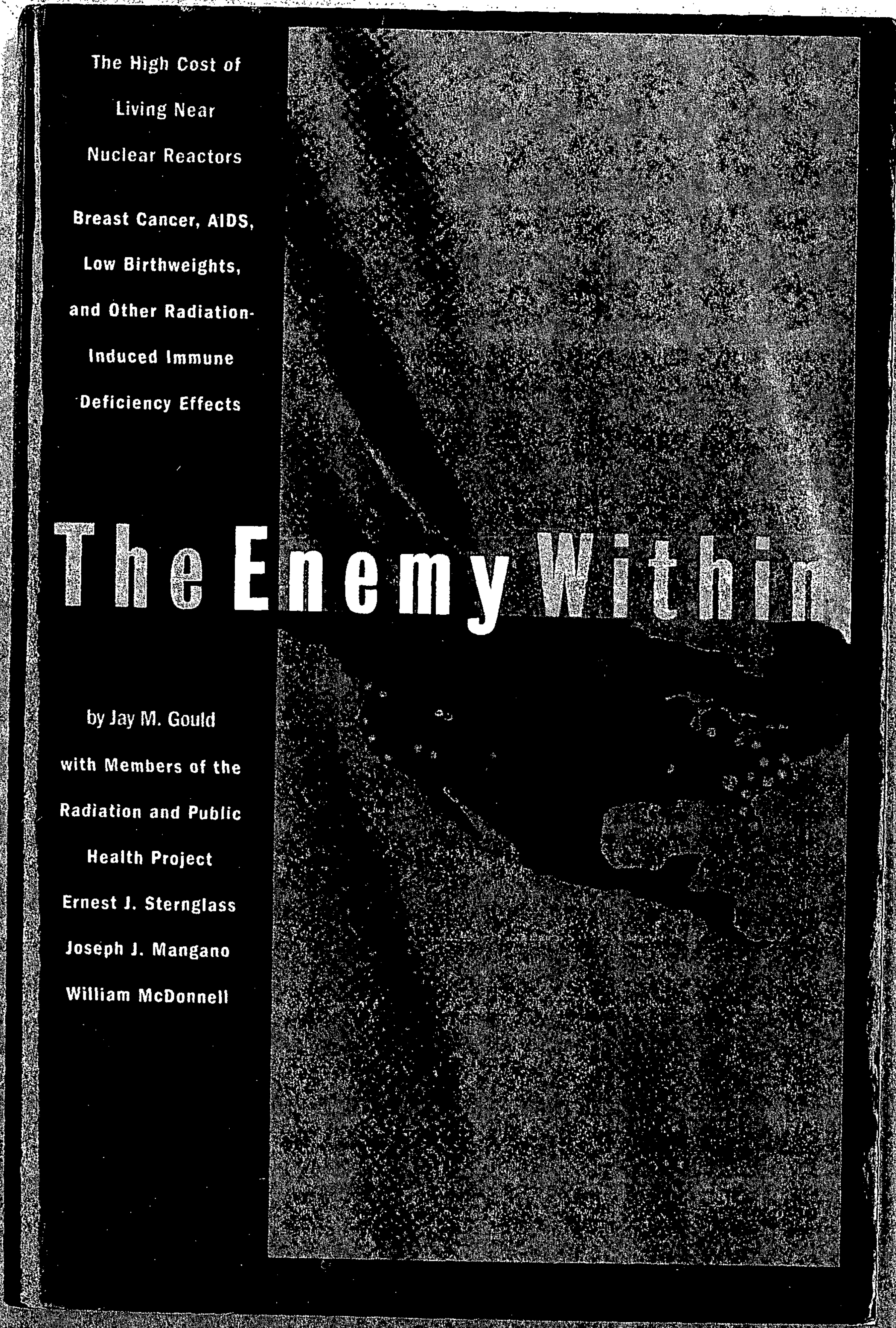
The High Cost of
Living Near
Nuclear Reactors
Breast Cancer, AIDS,
Low Birthweights,
and Other Radiation-
Induced Immune
Deficiency Effects
The Enemy Within
by Jay M. Gould
with Members of the
Radiation and Public
Health Project
Ernest J. Sternglass
Joseph J. Mangano
William McDonnell

$14.95/£10.99

The Enemy Within

exposes the startling correlation between deadly diseases and proximity to nuclear reactors. Using data from the National Cancer Institute, state health departments, and the Center for Disease Control, author Jay Gould offers official statistical evidence proving that residents of nuclear counties—the 1,321 counties within 100 miles of a reactor—suffer disproportionately from the interaction of nuclear fallout with industrial pollutants and other sources of urban stress.

Gould examines why women in nuclear counties have such a hugely inflated risk of breast cancer, why there are large numbers of premature and underweight births, and why AIDS and other immune deficiency syndromes seem to be related more to *where* you live than *how* you live. The answers lie in nuclear fallout patterns. . . . In the fifty years since the commencement of the Nuclear Age, over 1.5 million American women have died of breast cancer; prior to 1945 the breast cancer incidence rate had been declining. The anomaly is also true for low birthweights and immune deficiency syndromes.

The Enemy Within looks closely at the true cost of nuclear fallout—costs we can no longer afford to pay—and it presents our only reasonable solution: to ban the operation of nuclear power stations, nuclear weapon manufacturing, and nuclear bomb testing.

Jay M. Gould received his Ph.D. from Columbia University and is a former member of the EPA Science Advisory Board. He is the author of five books including *Deadly Deceit: Low-Level Radiation, High-Level Cover-Up* and *The Quality of Life in Residential Neighborhoods*.

"With a wealth of backup data, Gould raises critical and unanswered questions on the risks of breast cancer and other hazards of living near nuclear reactors. However controversial, we ignore Gould's warning at our own peril."

Dr. Samuel S. Epstein,
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Occupational Medicine,
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Four Walls Eight Windows
Distributed to the trade by
Publishers Group West
Cover design by Big Fish

ISBN 1-56858-066-5
51495
9 781568 580661

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WITH MEMBERS OF
THE RADIATION AND PUBLIC HEALTH PROJECT

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FOUR WALLS EIGHT WINDOWS
NEW YORK/LONDON

Published in the United States by
Four Walls Eight Windows
39 West 14th Street, Suite 503
New York, NY 10011

U.K. offices:
Four Walls Eight Windows/Turnaround
27 Horsell Road London, N51 XL, England

Library of Congress Cataloging-in-Publication Data:
The enemy within: the high cost of living near nuclear reactors:
breast cancer, AIDS, low birthweights, and other radiation-induced
immune deficiency effects / by Jay M. Gould, with members of the
Radiation and Public Health Project, Ernest J. Sternglass, Joseph J.
Mangano, William McDonnell.

p. cm.
Includes bibliographical references and index.
ISBN 1-56858-066-5
1. Nuclear reactors—Health aspects. 2. Radioactive fallout—
Health aspects. 3. Immunosupression—Risk factors.
4. Immunodeficiency—Complications. I. Gould, Jay M.
II. Radiation and Public Health Project.
RA569.E55 1996
616.9'897—dc20 96-789
CIP

10 9 8 7 6 5 4 3 2

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