FOR LES AMIS

ENVIRONMENTAL RADIATION AND HUMAN HEALTH

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1. Introduction

The present paper will address itself to the evidence that low level radiation from nuclear fission products in the environment such as are released by nuclear explosions and power reactors may already have produced serious effects on the health of the world's population far beyond those ever believed possible when our present radiation standards were originally formulated and adopted, especially for the case of the young infant.

Before discussing the latest evidence in some detail, I should like to review very briefly the nature of the early discovery that low level radiation can produce not only genetic but also serious somatic effects in man both at high and low dose rates.

2. Historical background

The earliest indication that low level radiation could produce serious effects in man came from the studies of Alice Stewart at Oxford University in 1958 showing that mothers who had received a series of three to five pelvic X-rays during pregnancy had children who were almost twice as likely to develop leukemia and other cancers before age ten than mothers who had had no pelvic X-ray examinations [1].

This work was independently confirmed in 1962 in a major epidemiological study involving close to 800,000 children born in New York and New England Hospitals by Brian MacMahon of the Harvard School of Public Health [2]. Using these two sets of data, it was possible to show that there appears to exist a direct, straight line relationship between the number of X-ray films given to a pregnant woman and the probability that the child will subsequently develop leukemia, and that there is therefore no evidence for the existence of a safe "threshold level" below which no additional cancers are produced, down to the relatively small dose from a single X-ray. Furthermore, the magnitude of the X-ray dose to the developing fetus *in utero* from one such X-ray was comparable with the dose normally received in the course of two to three years of natural background radiation, or from the fallout produced in the course of the 1961–1963 test series, namely 0.2–0.3 rad [3].

These early findings have since been confirmed by the most recent results of

FROM Proc 6TH BERKELEY SYMPOSIUM ON MATH. STATISTICS AND PROBABILITY, ED BY L.M. LECAM, J. NEYMAN and E SCOTT (Univ of Calif. Press). (1972)

A. Stewart, June, 1970 [4]. This extensive study, based on over 7,000 children born in England and Wales between 1943 and 1965 who developed leukemia or other cancers gave the result that for one rad to a population of one million children exposed shortly before birth, there were an extra 300 to 800 cancer deaths before age ten with a mean number of 572 ± 133 per rad. For a normal rate of incidence of about 700 cases per million children born, this means that only 1.2 rads (1200 mr) are required to double the spontaneous incidence. (See Figure 1.) Furthermore, Dr. Stewart's study showed that when the radiation

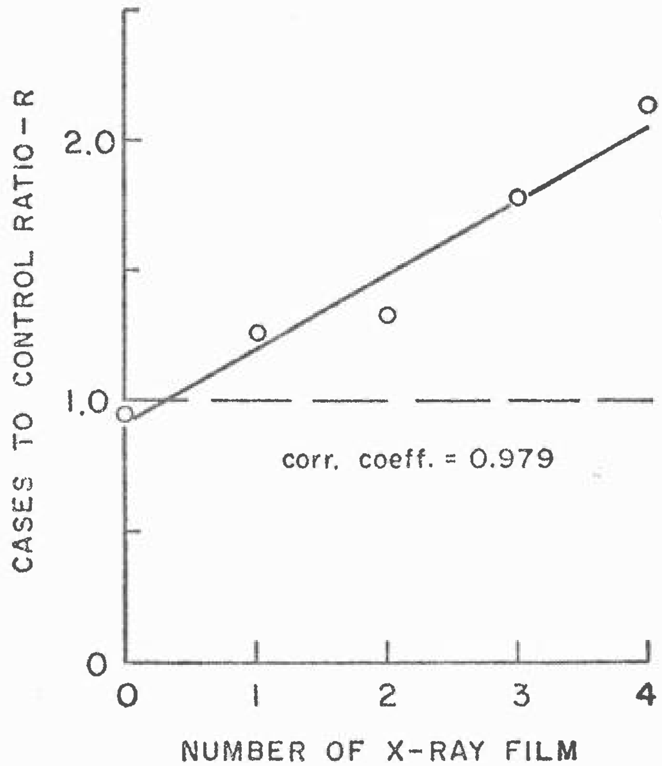

FIGURE 1

Ratio of cancer cases to controls as a function of the number of abdominal X-ray films as reported by Stewart and Kneale (*Lancet*, June 6, 1970).

exposure took place in the first trimester, the excess risk of cancer increased 15 times [4]. This means that a dose of only some 80 mr was found to double the normal cancer risk for the early embryo, much less than the presently permitted 500 mr annual dose to any member of the general population.

3. Fallout and childhood leukemia

It was therefore possible that studies of large populations of children exposed to known incidents where localized fallout occurred in a given area might show detectable increases in leukemia some years later. Such a localized "rain-out" was pointed out by Ralph Lapp [5] as having taken place in Albany-Troy, New York in April of 1953 following the detonation of a 40 kiloton bomb in Nevada. An examination of the data on leukemia incidence published by the New York State Department of Health showed that when plotted by year of death there was a clear increase in the number of cases per year among children under ten years of age at death from about two to three to as many as eight to nine per year some six to eight years after the arrival of the fallout, exactly the same delay in peak incidence as observed in Hiroshima and Nagasaki. Furthermore, the peak contained many children who were not even conceived until a year or more after the arrival of the fallout, suggesting for the first time the existence of an effect prior to conception, see Figure 2 [6].

Due to the relatively small number of cases in Albany-Troy, it was difficult to draw absolutely firm conclusions, and so the situation for New York State as a whole was examined. Again, peaks of leukemia incidence were clearly present some four to six years after known atmospheric tests in Nevada, greatly strengthening the initial observations for Albany-Troy alone [6].

4. Early indications relating fallout and infant mortality

Following the arrival of the fallout in Albany-Troy in 1953, there was also a drastic slowdown in the steady decline of fetal mortality or still births in that area see Figure 3 [6]. Following up this unexpected finding, the fetal and infant mortality statistics for New York State as a whole were examined, followed by those for California and other states. The same slowdown in the decline or even renewed rises in the mortality rates existed to varying degrees depending on the amount of fallout in the milk, beginning in the early 1950's, the declines resuming only two to four years after the end of atmospheric testing [7]. For the U.S. as a whole, the data is shown in Figure 4, where both the infant mortality rates for the total population and the nonwhite population has been plotted together with the data for Sweden. It was then drawn to our attention that I. M. Moriyama of the U.S. National Center for Health Statistics had previously pointed out the levelling trend in the U.S (beginning in about 1951) as early as 1960 [8], and that he had in fact suggested the possibility that similar upward changes of mortality for all age groups might be connected with the sharp rises in environmental radioactivity from nuclear testing [9].

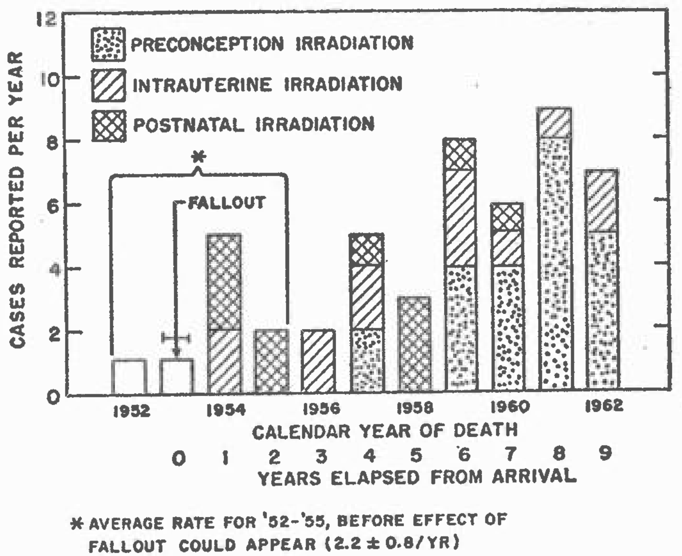

FIGURE 2

Number of leukemia cases per year of report for children under ten years of age in the Albany-Troy, N.Y. area, for which the data is complete, as reported by Lade (*Science*, Vol. 143 (1964), p. 994). Period from 1952 to 1955 before effect of fallout could appear (*) gives an average annual number of 2.2 ± 0.8 cases per year.

Since then, we have extended our studies to other countries in the world, and especially in northern Europe, which received the fallout from the Nevada tests in its northeasterly drift across the Atlantic, and the same patterns of slowdown followed by a renewed decline of infant mortality were found, as shown in Figure 5. At the same time the levelling trends were much less pronounced in countries like Canada and France, that were to the north or south of the path of the Nevada fallout on its northeasterly course, so that they did not receive as much short lived activity per unit strontium 90 in the milk (see Figure 6).

We have since established high degrees of correlation between the increases in infant mortality above the declining base lines, and the measured strontium 90 levels in the milk and therefore in the bone of fetuses, children and young

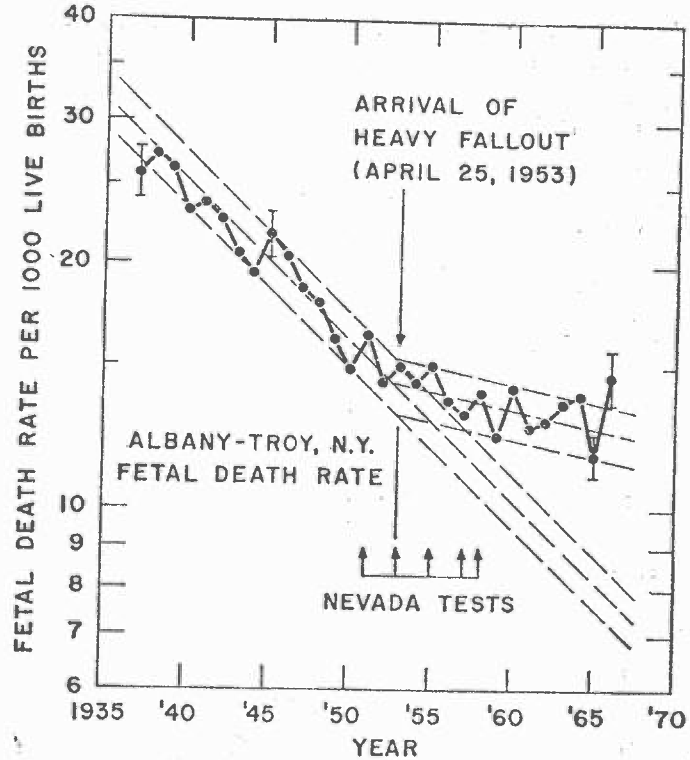

FIGURE 3

Fetal death rate reported per 1000 live births *versus* time before and after the arrival of fallout in the Albany-Troy area.

adults for all the nine regions of the Public Health Service's Raw Milk Network, for which data are available back to 1957–58. (Table I and Figure 7) [10]. These correlations suggest that as many as 400,000 infants up to one year old in the U.S. alone may have died as the result of nuclear testing by 1965.

These results are so startling and so unexpected, that they have naturally encountered considerable skepticism primarily because the technique of trend

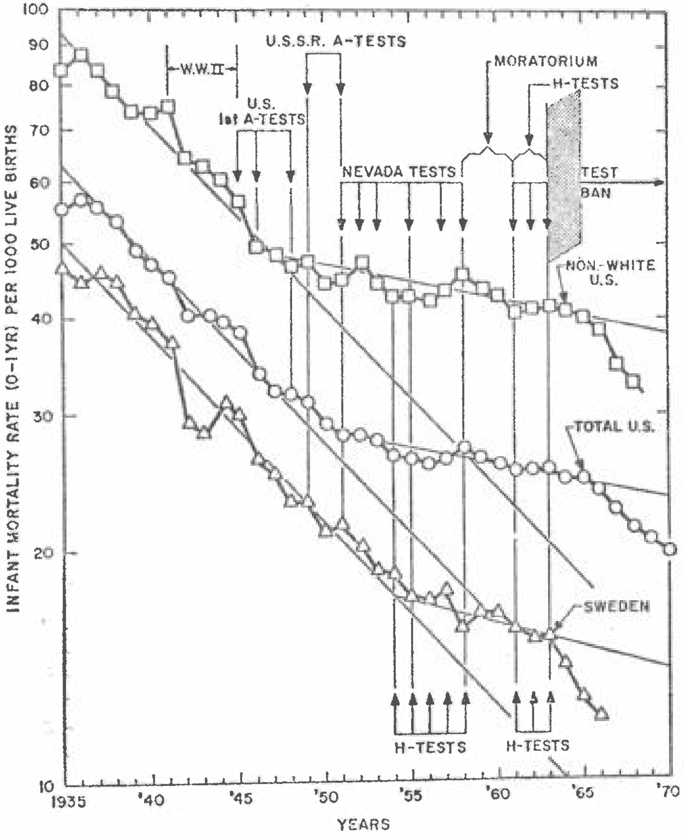

FIGURE 4

Infant mortality rate (0–1 year) per 1000 live births for the U.S. total population, U.S. nonwhite population and Sweden.

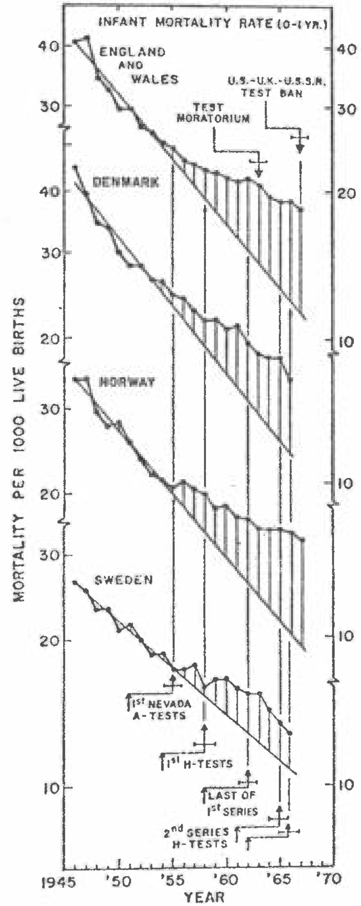

FIGURE 5

Infant mortality trends for northern European countries after World War II. Note onset of upward deviations peaking some three to five years after major test series. Least square fits to 1946–1955 trend.

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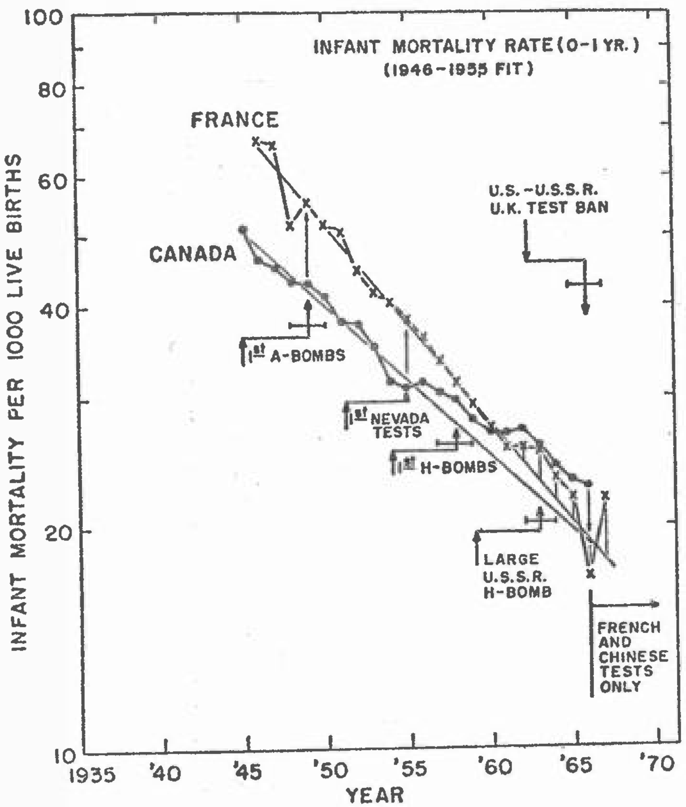

FIGURE 6

Infant mortality trend for France and Canada after World War II. Note smaller upward deviation than for the northern European countries, associated with the fact that the path of the intense, short lived Nevada fallout largely missed Canada to the north and France to the south of the prevailing fallout movement.

TABLE I

CORRELATION BETWEEN STRONTIUM 90 LEVELS AND EXCESS INFANT MORTALITY, SHOWING EFFECT OF DIFFERENT LEVELS OF SHORT LIVED ISOTOPES ON THE SLOPES OF THE REGRESSION LINES, AS WELL AS THE EFFECT OF UNREPRESENTATIVE MILK SAMPLING AREAS IN THE CASE OF CALIFORNIA, WASHINGTON STATE AND OHIO

State or country	Correl. Coeff.	Degrees of freedom	t Value	Slope
California	0.964	11	12.00	8.60 ± 0.63
Georgia	0.954	12	10.97	3.08 ± 0.27
Illinois	0.954	12	10.99	3.71 ± 0.32
Ohio	0.976	10	14.13	1.91 ± 0.13
Missouri	0.968	12	13.38	4.00 ± 0.29
New York	0.966	12	12.98	3.51 ± 0.26
Texas	0.967	12	13.19	4.64 ± 0.34
Utah	0.841	12	5.93	3.16 ± 0.56
Washington	0.911	11	7.30	1.09 ± 0.14
U.S. (HASL-214)	0.980	14	18.26	3.15 ± 0.17
England & Wales	0.922	10	7.51	3.74 ± 0.48
New Zealand	0.950	9	9.17	3.83 ± 0.40

analysis as used first by Moriyama to calculate "excess deaths" above normal expectations for all age groups in the U.S. was based on the expectation of a steadily declining infant mortality at least until levels are reached equal to those that had already been attained in other medically advanced nations of the world such as Sweden (see Figure 4). Such an assumption is however justified by the fact that in New Mexico, after the initial test in 1945, there was indeed a return to the same line of steady decline determined by the computer fit to the 1935-50 period, due to the low rainfall and therefore low levels of fallout in the milk after 1950, when nuclear testing was moved north to Nevada (Figure 8). Furthermore, the most recent data on infant mortality show that in a number of rural states such as Maine far from any nuclear facility, infant mortality rates have declined very sharply, reaching the levels predicted on the basis of the 1935 to 1950 rate of decline, as illustrated in Figure 9 for the case of Maine. Nevertheless, such large effects of relatively small amounts of radiation on infant mortality, which is also affected by many other factors, is difficult to accept, and it is therefore important to find other data that is not subject to the same criticism.

5. Fallout and congenital malformations

Such data exist in the case of childhood deaths associated with congenital malformations such as Down's Syndrome, microcephaly and congenital heart defects. For this particular category of infant and childhood deaths, there has

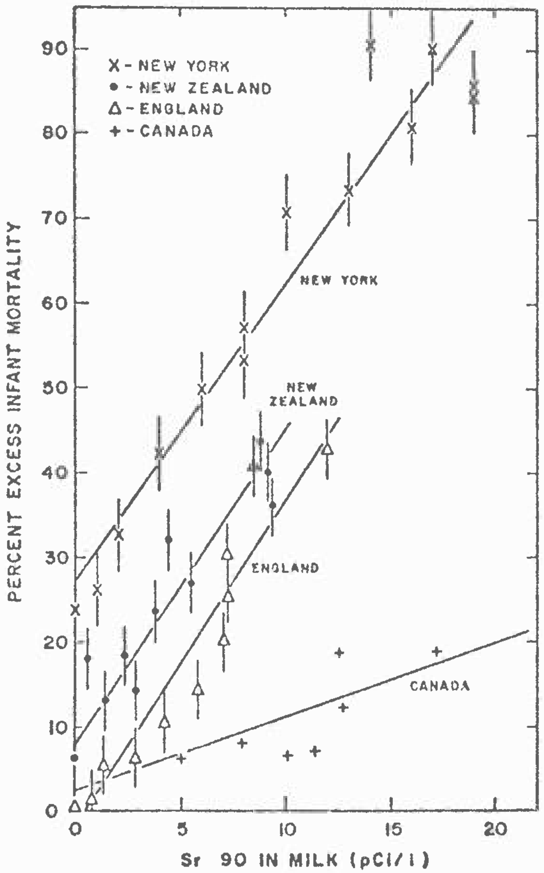

FIGURE 7

Correlation plots for excess infant mortality and strontium 90 in the milk (four year moving average). Note similarity in slope for geographical areas of high rainfall in the path of low altitude tropospheric fallout from tests in Nevada (New York and England) and tests in Australia (New Zealand). In contrast, note the small increase in mortality per unit strontium 90 for Canada, largely missed by the initial pass of the low altitude Nevada and Pacific fallout clouds with their high proportion of short lived isotopes.

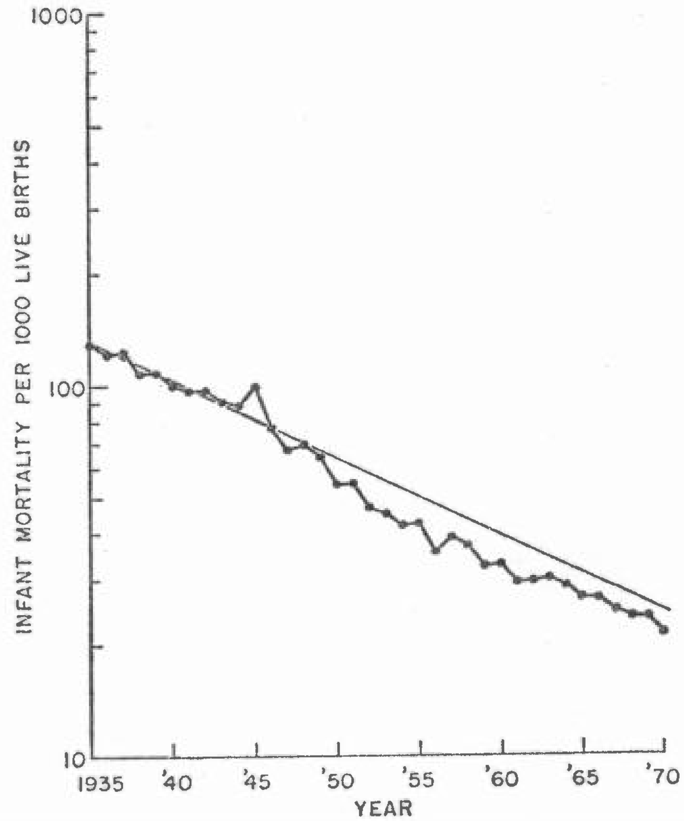

FIGURE 8

Infant mortality trend for New Mexico, 1935–1970. Note the degree to which rates continued to decline parallel to the 1935–50 projection, associated with the very low annual rainfall and geographical location south of the Nevada test site.

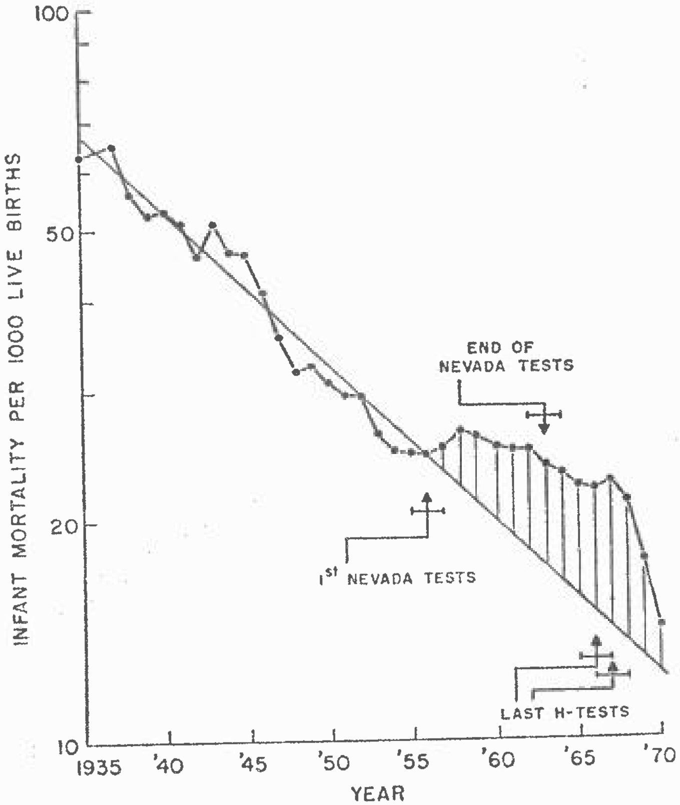

FIGURE 9

Infant mortality for Maine, 1935–1970. Note strong upward deviation beginning at the time of the Nevada tests (1951), followed by a return to the projected 1935–50 trend line a few years after the end of U.S. and U.S.S.R. atmospheric tests.

been only a slight downward trend over the last 20 years, and neither the introduction of new antibiotics, medical care methods nor the gradual improvement in diet and medical care has had significant effects on these mortality rates. As a result, there is here no need to extrapolate a rapid downward trend, and one has for every state and many foreign countries, a well established nearly horizontal base line to the onset of nuclear testing in 1945. Furthermore, it is well known that congenital malformations can be induced by relatively low levels of radiation in animals, and recent studies of such conditions as mental retardation published by the United Nations Scientific Commission on Radiation [11] have established that small amounts of radiation during certain critical periods of embryonic development and organ formation can produce detectable effects in children.

We therefore examined the incidence of deaths among congenitally defective children in relation to children who died of accidents as a control group at various distances from the Nevada test site, where relatively high local fallout was known to have occurred in a number of instances, documented both by the AEC [12] and independent studies by scientists at the University of Utah [13] and the St. Louis Center for Nuclear Information [14].

As an example, Figure 10 shows the annual number of deaths of congenitally defective children up to four years old in Utah directly east of Nevada and therefore generally downwind from the test site as taken from the published figures in the U.S. Vital Statistics, together with the deaths in this age group due to accidents other than those involving automobiles. It is seen that the average number of deaths of congenitally defective children per year in the pretesting period 1937–45 stayed relatively constant at about 75 cases per year. But it rose to a peak of 123 cases per year in 1958, some five years after a particularly large fallout incident in 1953, returning close to the pretesting rate of 80 per year five years after the end of atmospheric tests in Nevada. Such a rise and decline while accidental deaths remained constant is clearly not explainable in terms of a gradual rise in the number of births per year. Altogether, there seem to be some 480 children that are likely to have died of congenital malformations in Utah above expectations, based on a comparison with the number of accidental deaths since the onset of nuclear testing in 1945.

An even more striking peak in deaths of congenitally defective children relative to the number of accidental deaths took place in the five to fourteen year age group shown in Figure 11 for the case of Utah, which includes children who received radiation from the milk and food some time after birth. Again, a four to six year delay is seen to occur between exposure and death, quite similar to the case of Hiroshima and Albany-Troy, New York, corresponding to the fact that children born congenitally defective are much more prone to develop leukemia with its four to six year delay of peak incidence.

The rate of leukemia deaths for all children in the age group five to fourteen, which was shown by Stewart [1] and MacMahon [2] to reflect the effects of perinatal irradiation most strongly is plotted in Figure 12 for the same state.

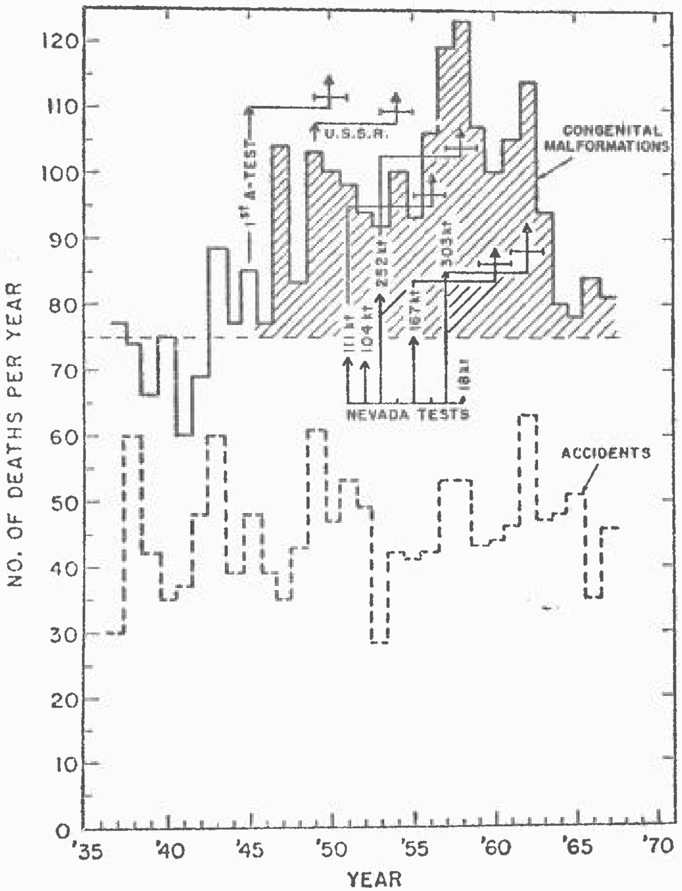

FIGURE 10

Changes in the annual number of deaths of congenitally defective children 0–4 years old in Utah, compared with the number of non-automobile related accidents.

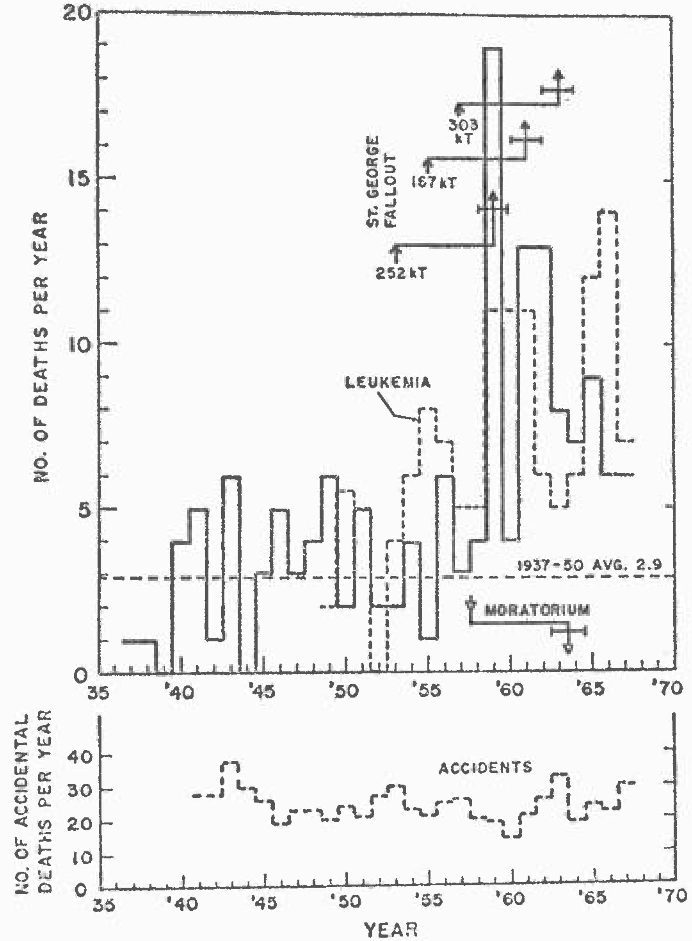

FIGURE 11

Annual number of deaths among children five to fourteen years old born congenitally defective, compared with the number of accidental deaths (non-automobile) [39].

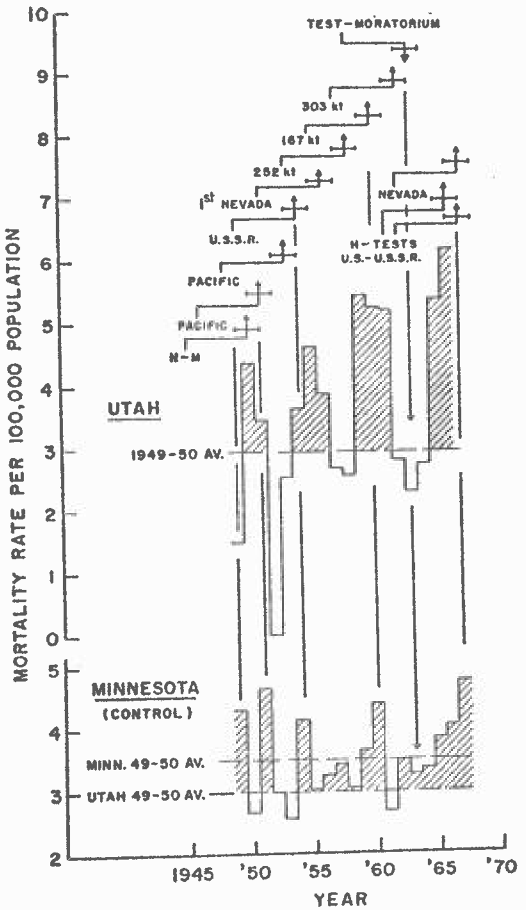

FIGURE 12

Annual rate of leukemia deaths per 100,000 population aged five to fourteen years for Utah near the Nevada test site compared with Minnesota as control. Major test series are indicated, together with the four to six year delay expected for leukemia [39].

It is seen that statistically significant peaks occurred some four to six years after known tests had deposited fallout in Utah, apparently affecting the infants both prior to and after birth. Furthermore, the relative increases were higher than those observed in Minnesota as a control as is to be expected from the great proximity to the test site. Thus, the effects are observed both for annual numbers and rates per 100,000 population, and they confirm the original findings in Albany-Troy.

No other explanation of these striking rises and declines in leukemia and congenital defect mortality rate is known.

As to the reason why such unexpectedly large effects of fallout should be observed when radiation levels were believed to be so low as to be regarded as completely safe, these are evidently connected with the much greater sensitivity of the embryo and infant compared with the adult.

Furthermore, the severity of the effects is also connected with the biological concentration of certain isotopes in the food chain, mainly via the milk, which was not widely recognized at the time when the tests were begun. Another reason is the selective concentration of certain isotopes in various critical organs of the human body, whose biological consequences were not fully appreciated for the sensitive developmental phase of the early embryo and fetus.

Thus, experimental studies on laboratory animals by Walter Müller published in 1967 [15] suggest that strontium 90 and other alkaline earth elements that were long known to seek out bone may also produce biological and possibly genetic effects through their daughter elements such as yttrium 90 into which they decay, and which are known to preferentially concentrate in such vital glands as the pituitary, the liver, the pancreas and the male and female reproductive glands [16], [17].

In any case, we are apparently confronted with still another unanticipated biological concentration effect similar to the surprises we received when we discovered the special hazard of iodine 131 going to the infant thyroid and strontium 90 and 89 going to the bone via the originally unsuspected pathway of milk produced by cows grazing on contaminated pastures.

6. Infant mortality and releases from nuclear reactors—early detection

That similarly unanticipated effects on the developing embryo and infant may have taken place as a result of fission products released from nuclear reactors and fuel processing facilities first became apparent in the course of our state by state study of infant mortality changes following the first nuclear weapons test in New Mexico in 1945.

As shown in Figure 13 each map for the four years following this test showing the per cent changes relative to the trend for the previous five years not only indicated an upward change in infant mortality directly to the east and northeast of New Mexico, but also in the states to the east of the Hanford Plutonium production facility in the state of Washington.

Not only were the Hanford reactors and plutonium production facilities

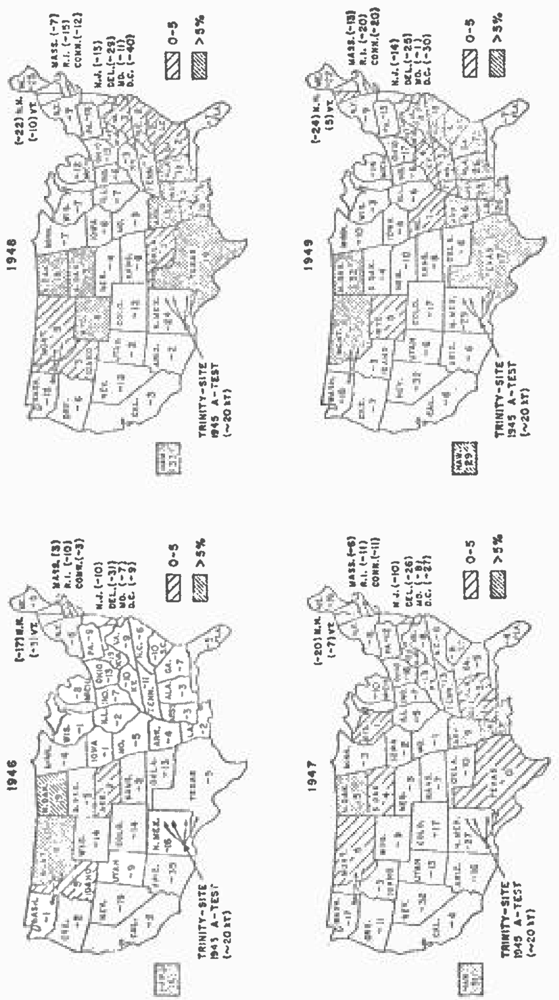

FIGURE 13

Per cent changes in infant mortality for the years 1946–1949 relative to the least square fitted 1940–45 trend just prior to the New Mexico test in 1945 for each state of the U.S. (Based on data from [39].)

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operating at very high levels since 1944, releasing into the environment the rare gases that could not be trapped readily, but on a number of occasions, there were serious accidents in the course of extracting the plutonium from the irradiated uranium fuel elements by chemical techniques, when fuel elements burst into flames and discharged large quantities of fission products into the environment [18].

The infant mortality changes were greater in North Dakota than in dry Idaho and Montana, just as they were greater in Arkansas and Louisiana compared with dry Texas closer to the test site in New Mexico. This fits the well known fact that 90 per cent of the fine tropospheric fallout comes down with the rain, since the line of heavy rainfalls passes down through the center of the United States just to the west of the Mississippi from North Dakota in the north to eastern Texas in the south.

This interpretation is further confirmed by a more detailed analysis of infant mortality changes in the counties near the Hanford plant before and after it went into operation between 1943 and 1945. As can be seen from the bar graph in Figure 14, the counties containing the plant as well as those immediately adjacent to the east and south showed sharp rises in infant mortality up to 150 per cent, while the more distant control counties, namely those in which water sampling stations were subsequently established, either rose less than ten per cent or actually declined between 1943 and 1945.

7. Infant mortality near boiling water reactors

A similar pattern of increased infant mortality has now been observed around three commercial nuclear power reactors of the Boiling Water type (BWR), in which the single coolant loop design does not permit as tight a containment of fission products leaking out of corroded fuel elements as in the naval submarine type Pressurized Water Reactor (PWR).

As described in recent publications of the Bureau of Radiological Health [19], these reactors have emitted as much as 800,000 curies of fission and neutron activation products in the form of gases per year [20], compared with as little as 0.001 curie per year for the prototype Pressurized Water Reactor at Shippingport, Pennsylvania.

The first of the BWR's studied is the Dresden Reactor located near Morris, Illinois in Grundy County, some 50 miles southwest of Chicago. Since close to two-thirds of the population of Illinois lives within a radius of some 60 miles from this reactor, one might expect to find detectable changes in infant mortality for Illinois as a whole relative to other nearby states that correlate with the rises and declines of emission when fuel elements are changed.

That this appears in fact to have taken place is illustrated by the plot of infant mortality for Illinois compared with Ohio some 200 miles to the east for the period 1959 to 1968 in Figure 15. It is seen that while during the time of Nevada testing, Ohio and Illinois showed the same infant mortality, within

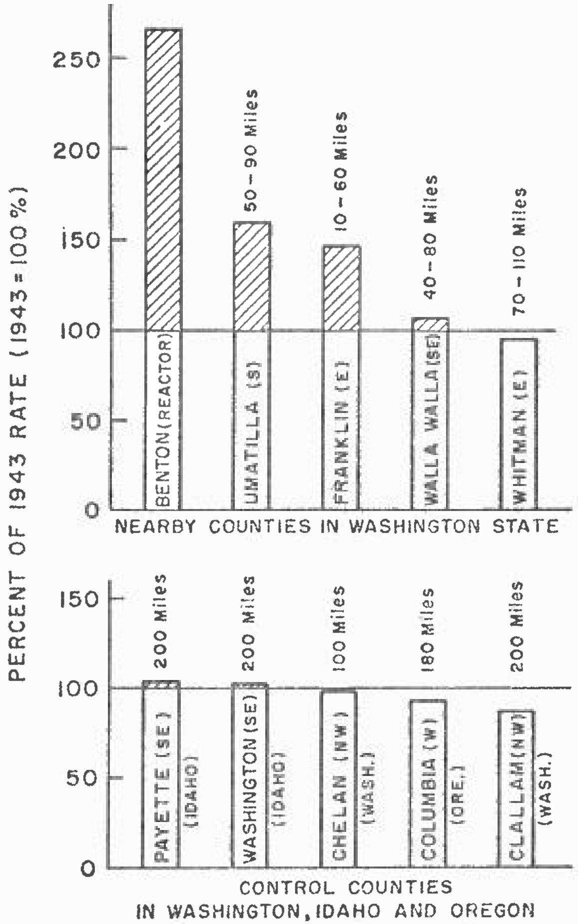
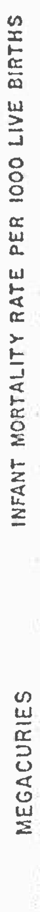


FIGURE 14

Percent change in infant mortality between 1943 and 1945 near the Hanford Reactor in the state of Washington before and after onset of operations in 1944. Control counties are those where water sampling stations were placed. (Based on data from [39].)



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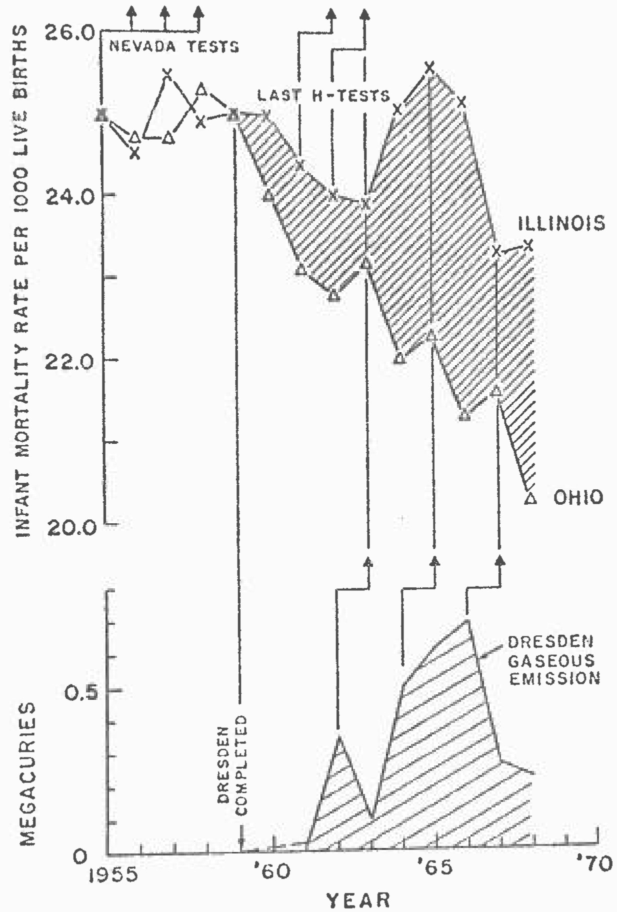


FIGURE 15

Infant mortality in Illinois compared with Ohio for the period 1955 to 1968. Also shown are the annual releases of gaseous activity from the Dresden Reactor [39].

a few years after the end of testing, Ohio began a steady decline, whereas Illinois showed a peak highly correlated with the peak of gaseous emissions between 1964 and 1967 (see Table II).

TABLE II

INFANT MORTALITY IN OHIO AND ILLINOIS FOR THE PERIOD 1955–1968 BEFORE AND AFTER ONSET OF GAS EMISSIONS FROM THE DRESDEN REACTOR IN 1961

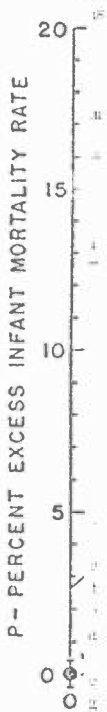
	Ohio			Illinois			
Year	Live births	Infant deaths	Inf. mort. rate/1000 live births	Live births	Infant deaths	Inf. mort. rate/1000 live births	Curies of gas emissions
1955	222,680	5530	24.8	217,041	5406	24.8	—
1956	234,517	5785	24.7	229,760	5630	24.5	—
1957	243,470	6008	24.7	238,734	6080	25.5	—
1958	234,010	5940	25.4	234,980	5859	24.9	—
1959	232,578	5799	24.9	240,208	6008	25.0	—
1960	230,219	5521	24.0	238,928	5923	25.0	—
1961	229,708	5298	23.1	237,382	5771	24.3	34,800
1962	217,465	4954	22.8	230,878	5538	24.0	284,000
1963	212,583	4938	23.2	225,062	5383	23.9	71,600
1964	209,480	4614	22.0	222,248	5585	25.2	521,000
1965	194,927	4346	22.3	208,188	5340	25.7	610,000
1966	190,444	4066	21.4	201,442	5066	25.4	736,000
1967	185,204	3824	20.6	193,745	4622	23.6	200,000
1968	185,580	3769	20.3	193,520	4536	23.5	240,000

The degree of correlation may be judged from Figure 16 where the difference in infant mortality rates between Illinois and Ohio has been plotted against the annual gaseous discharges. The correlation coefficient is 0.865, and the t test of significance gives $t = 4.565$, which for the seven degrees of freedom gives $P \ll 0.01$.

As in the case of Hanford it is of interest to see whether the effect can also be detected in the nearby states to the east, the direction in which the prevailing winds and weather patterns move. As seen in Figure 17, the infant mortality rate for nearby Indiana does indeed fall exactly between that for Illinois and Ohio on the other side of Indiana after the testing in Nevada ended and the discharges from the Dresden reactor produced significant external doses, comparable with those from distant tests (see Table III).

Likewise in Michigan, just to the north of Indiana, infant mortality began to fall consistently between Illinois and more distant Ohio when the general decline began after the end of nuclear testing in 1963 (see Figure 18 and Table III).

One would also expect on the basis of this hypothesis that a state far to the northwest of Illinois and therefore upwind would show an even more rapid decline after fallout from weapons testing decreased. That this is in fact the



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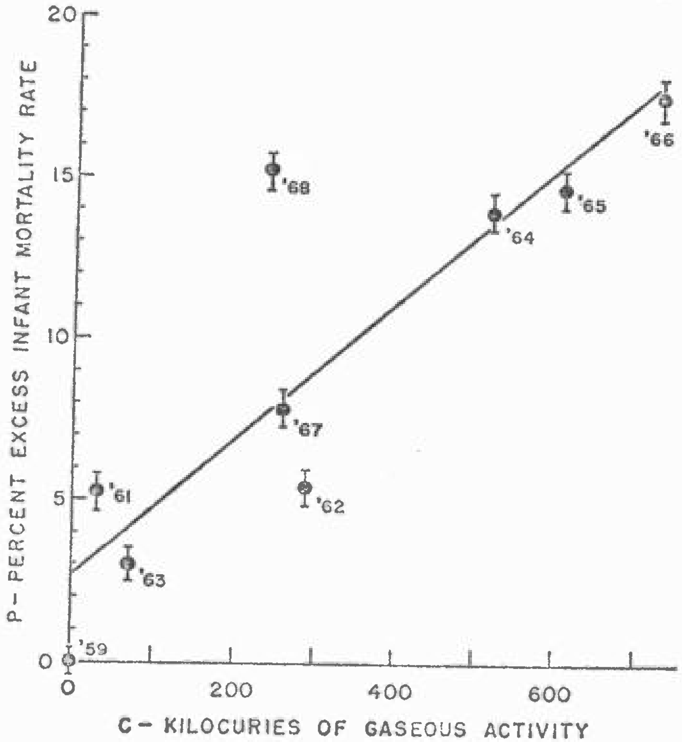


FIGURE 16

Correlation plot for the excess infant mortality in Illinois relative to Ohio vs. the annual average quantities of gaseous activity released from the Dresden Reactor. (1959–1968; no data for 1960.) Least square fitted line shown.

case is seen for the case of North Dakota compared with Illinois in Figure 19 (see Table III).

The rates for Illinois and North Dakota seem to have been identical during the period of heavy Nevada testing and plutonium production at Hanford prior to 1964, despite the great difference in ordinary air pollution and socioeconomic character of the two states. But after the end of nuclear testing by the U.S.

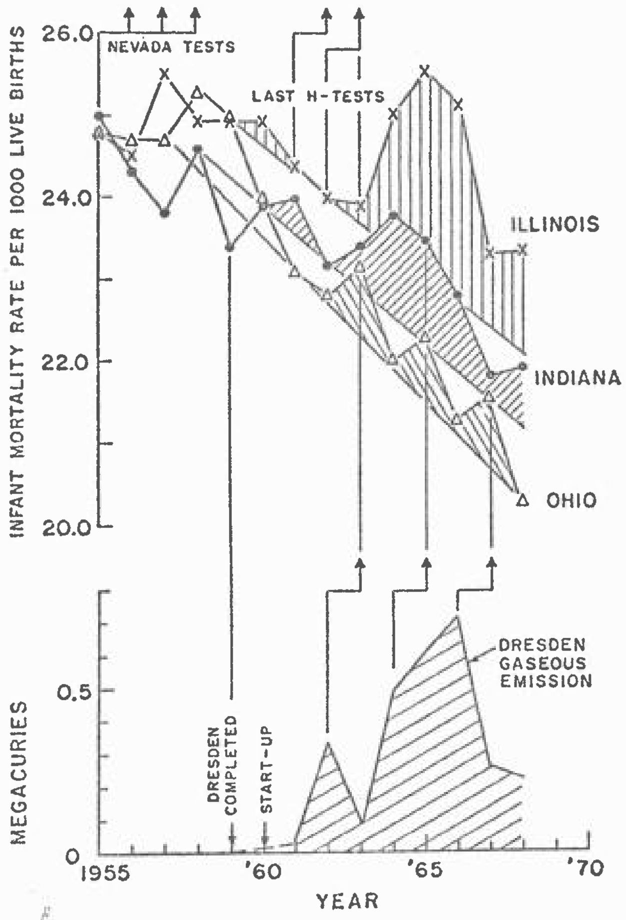


FIGURE 17

Infant mortality for Indiana compared with Illinois and Ohio [39].

TABLE III

INFANT MORTALITY RATES/1000 LIVE BIRTHS

Infant mortality rates for five states in the northern U.S. upwind and downwind from Illinois before and after onset of Dresden emissions in 1961.
Source: [39].

Year	Illinois	Indiana	Michigan	Ohio	North Dakota
1955	24.8	25.0	24.9	24.8	25.1
1956	24.5	24.3	24.5	24.7	24.8
1957	25.5	23.8	24.4	24.7	25.7
1958	24.9	24.6	24.6	25.3	24.9
1959	25.0	23.4	24.4	25.0	23.7
1960	25.0	23.9	24.1	24.0	24.8
1961	24.3	24.0	23.9	23.1	23.2
1962	24.0	23.2	24.0	22.8	22.6
1963	23.9	23.4	23.2	23.2	24.6
1964	25.1	23.8	23.0	22.0	23.1
1965	25.6	23.5	23.6	22.3	21.2
1966	25.1	22.8	22.5	21.3	20.8
1967	23.6	22.3	22.0	20.7	21.0
1968	23.1	22.2	21.8	20.0	17.7
	Population 1960				
	Illinois	Indiana	Michigan	Ohio	North Dakota
	10,081,000	4,662,000	7,823,000	9,706,000	632,000

and U.S.S.R., North Dakota declined rapidly from nearly 25 per 1000 births to under 18 per 1000 by 1968, despite the well known lack of sufficient medical care in rural areas such as North Dakota.

This suggests that although ordinary air pollution is undoubtedly detrimental to health, the radioactivity released by nuclear testing and nuclear plants appears to be significantly more serious in its effects on the early development of the embryo and infant.

In order to further test this hypothesis, the changes in infant mortality in the six counties immediately adjacent to the Dresden plant for the years following the sharpest rise in emission were compared with the changes in six control counties more than 40 miles to the west, Figure 20. They were chosen to be as far away as possible in northern Illinois, not bordering either on the Illinois or Mississippi Rivers that are known to be polluted by radioactive wastes (see Table IV).

The result of this test for 1966 relative to 1964 is shown in Figure 21. Again, the same general pattern is observed as for the Hanford Reactors, the nearby counties showing much greater rises than the more distant control counties of similar rural character and comparable medical care.

In the case of the Dresden reactor, it is possible to carry out a still more crucial test of the biological mechanism that may be involved in bringing

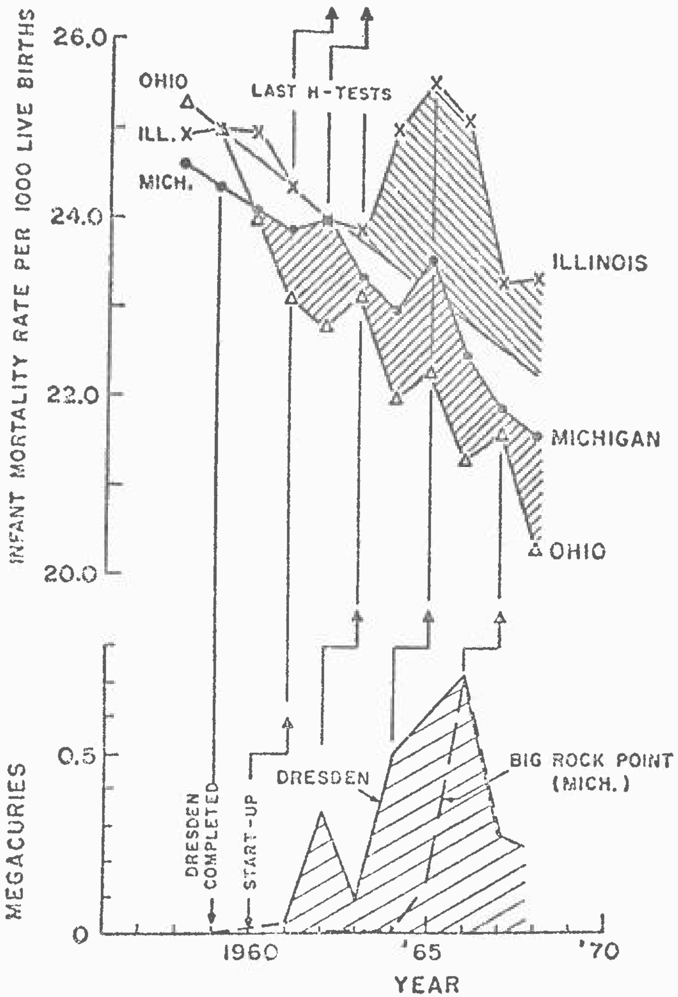


FIGURE 18

Infant mortality for Michigan compared with Illinois and Ohio [39].

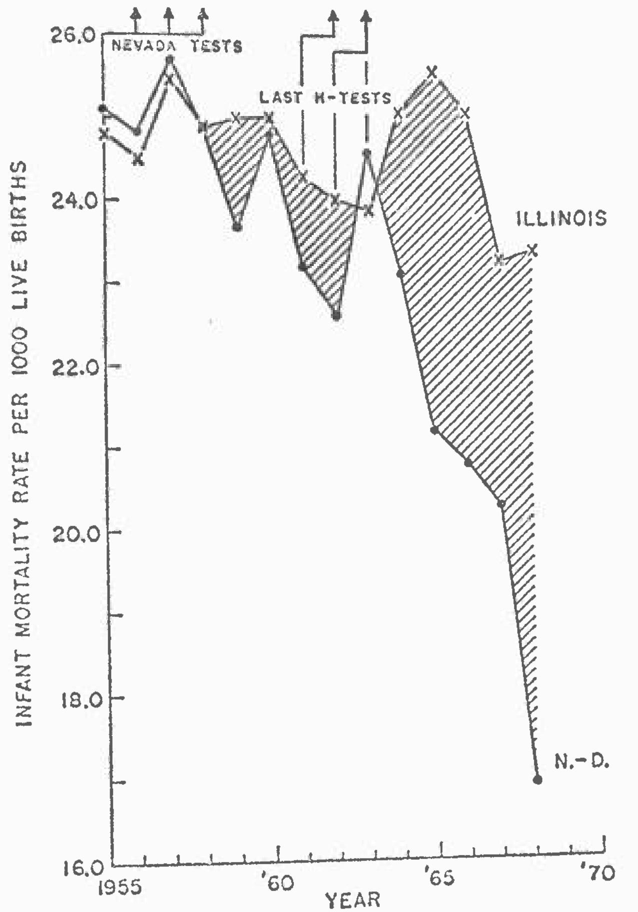


FIGURE 19

Infant mortality in North Dakota compared with Illinois [39].

FIGURE 20

Map of northern Illinois showing counties surrounding the Dresden Reactor, located in Grundy County, and the six control counties to the west.

TABLE IV

DRESDEN REACTOR AREA

Changes in infant mortality in six counties surrounding the Dresden Reactor compared with six control counties to the west following by one year the period of maximum rise in gaseous emissions (1963–1965).

		1964 Deaths	births	Rate 1000	1966 Deaths	births	Rate 1000	Per cent change in rates 1964–66	Pop. est. July 1964
Adjacent	Grundy (Reactor)	7	442	15.8	18	474	38.0	+141	23,500
	Livingston (S)	6	728	8.2	12	608	19.7	+140	41,200
	Kankakee (SE)	41	1976	20.7	54	1830	29.5	+ 43	98,500
	Will (NE)	109	4920	22.2	100	4294	23.3	+ 5	214,000
	LaSalle (W)	49	2176	22.5	39	1858	21.0	− 7	112,600
	Kendall (N)	11	460	23.9	7	422	16.6	− 31	20,000
								Avg. + 48	
Control	Ogle (NW)	16	854	18.7	20	808	24.8	+ 33	39,700
	Winnebago (NW)	122	5002	24.4	122	4788	25.5	+ 5	234,000
	Henry (W)	17	930	18.3	16	862	18.6	+ 2	50,000
	Stephenson (NW)	25	978	25.6	20	808	24.8	− 3	47,000
	Knox (SW)	22	1130	19.5	17	946	18.0	− 8	63,700
	Lee (W)	17	658	25.8	9	594	15.2	− 41	59,500
								Avg. − 2	

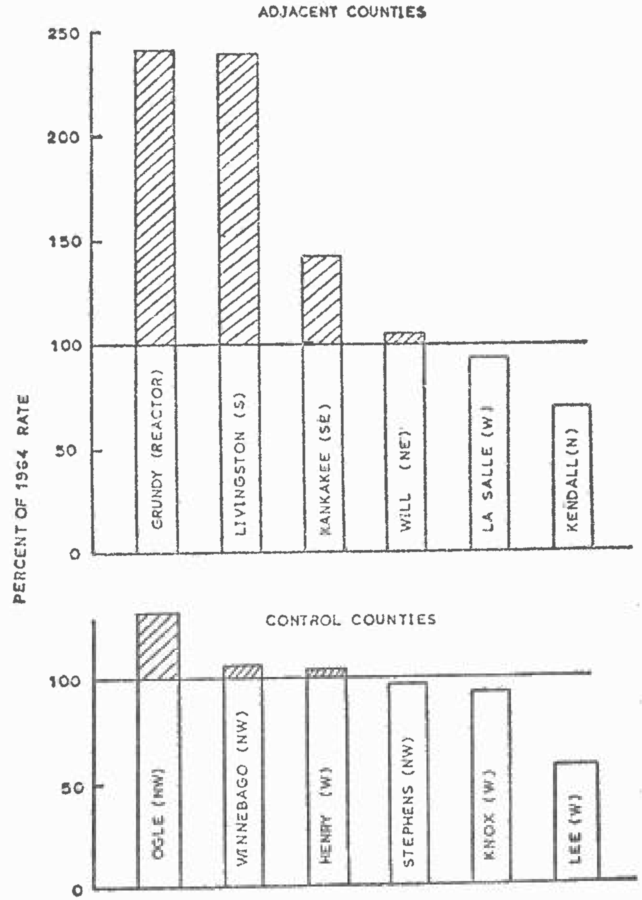


FIGURE 21

Per cent change in infant mortality in the six counties surrounding the Dresden Reactor (<30 miles distant) between 1964 and 1966 compared with the changes in six control counties to the west, following the rise in activity released from 71,600 curies in 1963 to 610,000 curies in 1965 [39].

about such a large effect for relatively small measured external doses, which even in the year of peak release (1966) did not exceed 70–80 mr at the plant boundary when the available measurements of 15–25 mr per year for 1967–68 are used to calculate the dose.

As discussed briefly above and elsewhere [21], the most serious effect is likely to be an indirect one, whereby the radiation acts on the key biochemical processes in such crucial glands controlling metabolism and growth as the pituitary and thyroid glands. Such action could lead to a small decrease in weight at birth, or to a greater frequency of prematurity, such as has in fact been observed in animal experiments and since the early 1950's, among infants born in the United States [22].

Such immaturity at birth results in a reduced ability to fight off infections and to a greater likelihood that a critical chemical or surfactant needed for proper functioning of the lung is missing, leading to respiratory distress and atelectasis [23] so that one would expect a higher mortality in early postnatal life.

To test this hypothesis, one can compare the changes in the fraction of all births that are classified as "premature" or under 2,500 grams for Grundy County as compared with the changes in the control counties to the west. If immature birth is indeed the principal mechanism leading to excessive infant deaths, one would then expect to find a greater rise in the fraction of such births during the period of peak emission in Grundy than in the distant control counties.

That this is indeed the case may be seen in the plot of Figure 22. A peak in the incidence of premature births of close to 140 per cent is seen to have occurred in coincidence with the peak of gaseous emission, declining again as the emissions declined, while the control counties showed no such rise. For Grundy, the increase was from 3.60 to 8.70 per cent of all births (Table V).

Thus, both radioactive releases from nuclear facilities and nuclear detonations seem to produce similar changes in the infant mortality through the indirect biochemical action of fallout on the crucial hormone producing organs of the mother and the fetus, leading to a lowered resistance to the environmental stress most critical shortly after birth.

Identical patterns of rises in infant mortality have now been found for two other Boiling Water Reactors, as shown in Figure 23 for the group of ten small counties 0–40 miles around the Big Rock Point Plant in Michigan and in Figure 24 for the Humboldt Reactor near Eureka in Humboldt County, Northern California [19]. Again there is a sharp halt in the normal decline of infant mortality from its peak during the 1961–62 test series following release of large quantities of gaseous activity comparable to those released at the Dresden Reactor, while more distant areas continue their decline, as shown for the State of Michigan as a whole between 1965 and 67 (see Figure 18 and Table III).

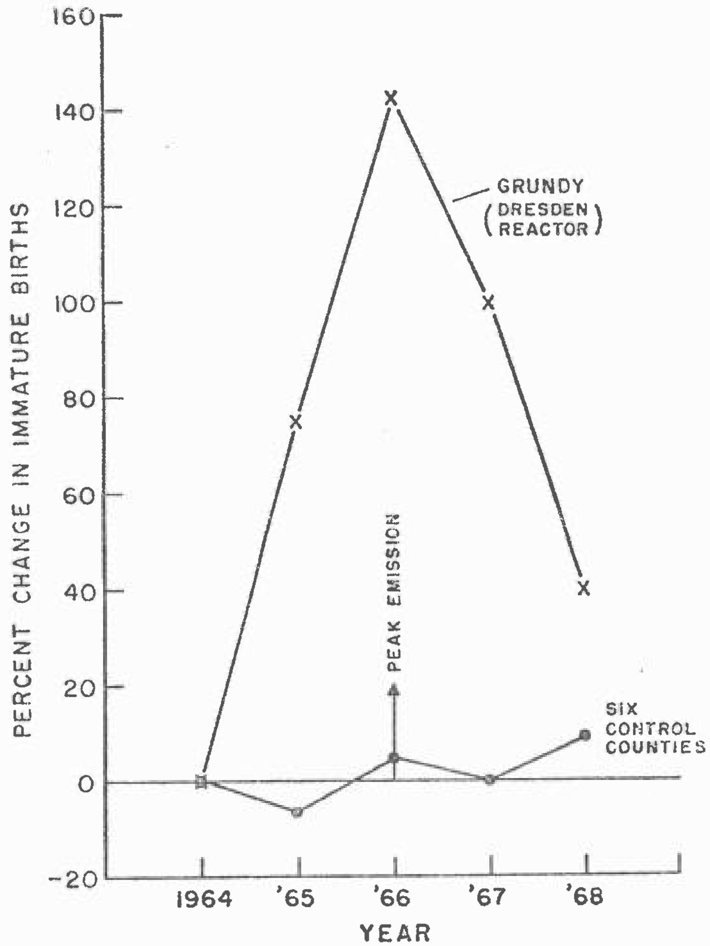


FIGURE 22

Per cent change in the fraction of births under 2500 grams for Grundy County and the six control counties to the west [40].

TABLE V

DRESDEN REACTOR AREA

Changes in the fraction of "premature" or underweight births in the county containing the Dresden Reactor (Grundy) compared with the control counties more than 40 miles to the west. Source: [40].

Counties	Live Births by Years				
	1964	1965	1966	1967	1968
Henry	947	915	862	892	798
Knox	1114	1002	946	895	901
Lee	665	606	594	612	610
Ogle	861	798	808	745	764
Stephenson	974	889	808	793	841
Winnebago	5004	4780	4788	4794	4324
Grundy	445	426	474	457	460
Counties	Premature Births less than 2500 Grams by Years				
	1964	1965	1966	1967	1968
Henry	52	57	49	65	53
Knox	84	68	78	56	66
Lee	46	28	30	41	37
Ogle	51	40	53	46	54
Stephenson	55	70	59	41	59
Winnebago	355	342	353	324	336
Grundy	16	27	42	33	23
Counties	Premature Birth Rate/100 Live Births (under 2500 grams)				
	1964	1965	1966	1967	1968
Henry	5.5	6.2	5.7	7.3	6.6
Knox	7.5	6.8	8.2	6.3	7.3
Lee	6.9	4.6	5.1	6.7	6.1
Ogle	5.9	5.0	6.6	6.2	7.1
Stephenson	5.7	7.9	7.3	5.2	7.0
Winnebago	7.1	7.2	7.4	6.8	7.7
Grundy	3.6	6.3	8.7	7.2	5.0

8. Infant mortality and nuclear fuel processing facilities

As described elsewhere in greater detail [24], the same pattern occurred also for the commercial fuel reprocessing plant operated by the Nuclear Fuel Services Company in West-Valley, N.Y. after it went into operation in April of 1966 [25]. Figure 27 shows that the counties of western New York within a 30-50 mile radius rose sharply in infant mortality the following year, while the more distant counties declined as did New York State as a whole. Like Humboldt County, the nearby areas had shown a peak near the height of weapons testing, then began to decline only to reverse this trend sharply after the onset of large radioactive waste releases.

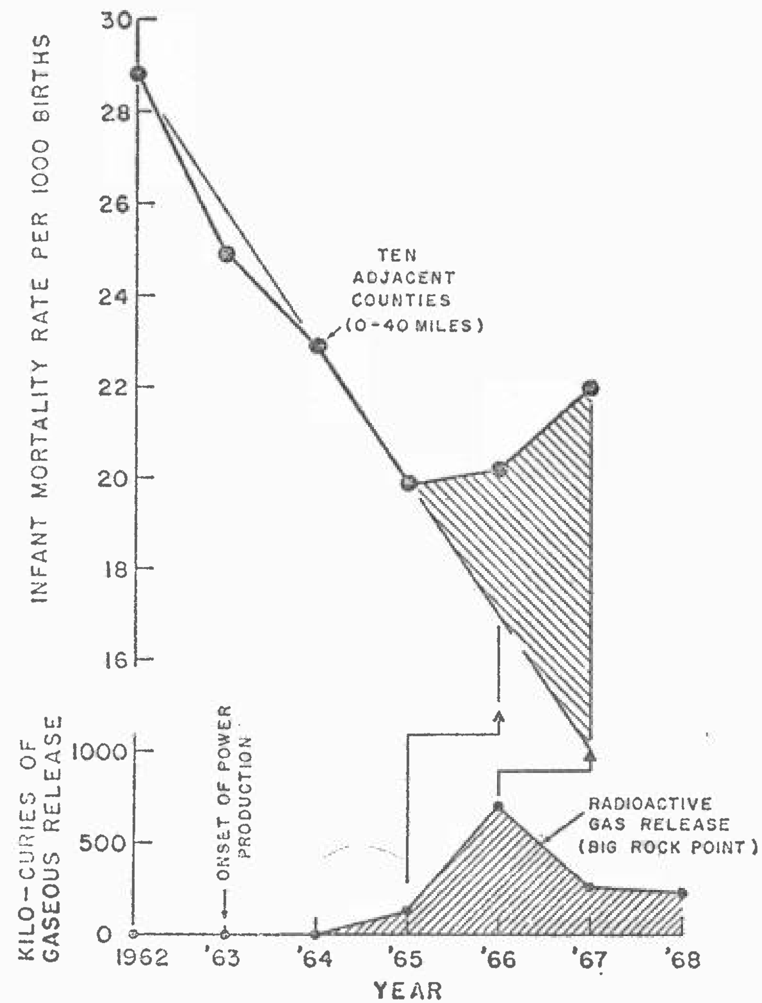


FIGURE 23

Infant mortality rate per 1000 live births for a group of ten counties within a radius of about 40 miles of the Big Rock Point Nuclear Plant in Charlevoix, Michigan, together with the yearly gaseous activity released. The total number of deaths in these counties was 45 in 1966.

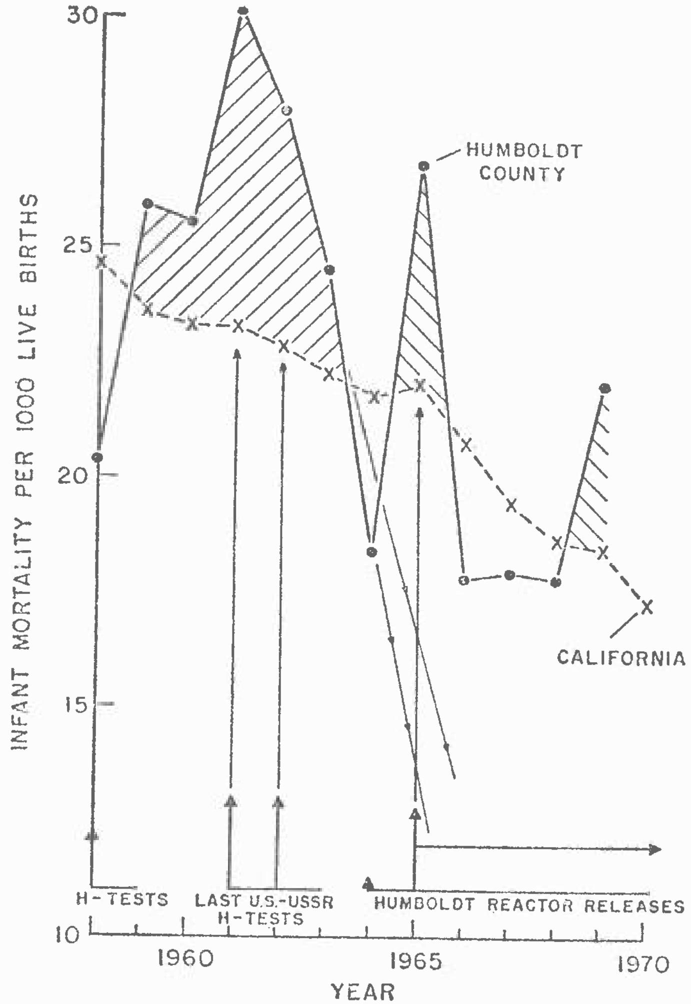


FIGURE 24

Infant mortality rate per 1000 live births in Humboldt County, California, 1958–1969 [39]. Releases from the Humboldt Reactor increased from 5975 curies gaseous waste in 1964 to 197,000 curies in 1965. Further rises took place in 1967–1968. Liquid waste discharges rose steadily to a peak of 3.2 curies in 1968, corresponding to 19.7 per cent of the permissible limit. Note the peaks corresponding to the 1961–62 nuclear tests, and the steady decline of California as a whole after 1961.

FIGURE 25

Map of northern California showing location of Humboldt Reactor and the counties along the Pacific Coast as well as in the dry area to the east of the coastal mountains.

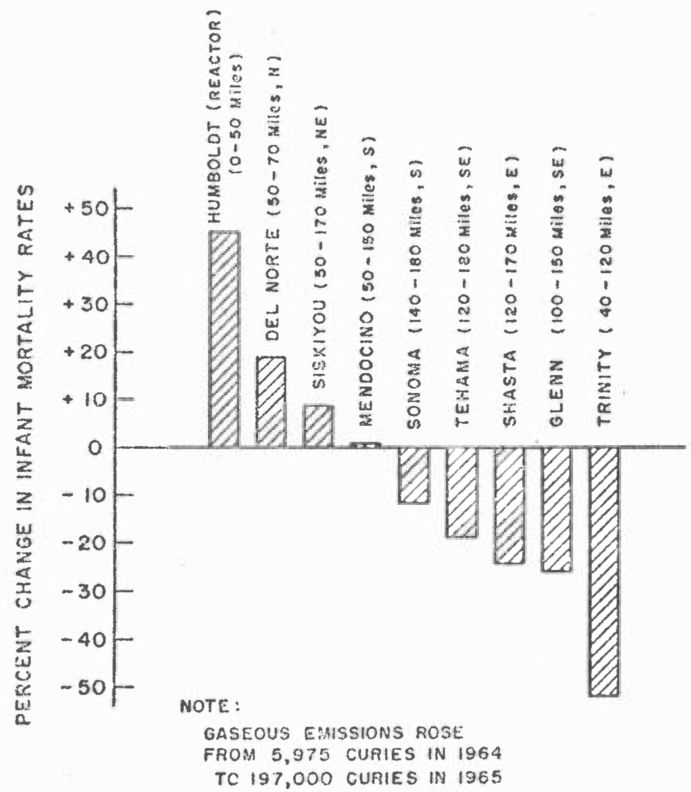


FIGURE 26

Per cent changes in infant mortality rates for the counties surrounding the Humboldt Reactor between 1964 and 1965, when gaseous releases rose from 5975 to 197,000 curies. Only Humboldt and Del Norte County immediately adjacent along the Pacific Coast showed significant rises greater than ten per cent. All other counties either remained constant or declined, especially those separated from Humboldt by the coastal mountain ranges such as Trinity, Shasta, Tehama and Glenn to the east and southeast. (Based on data from [39].)

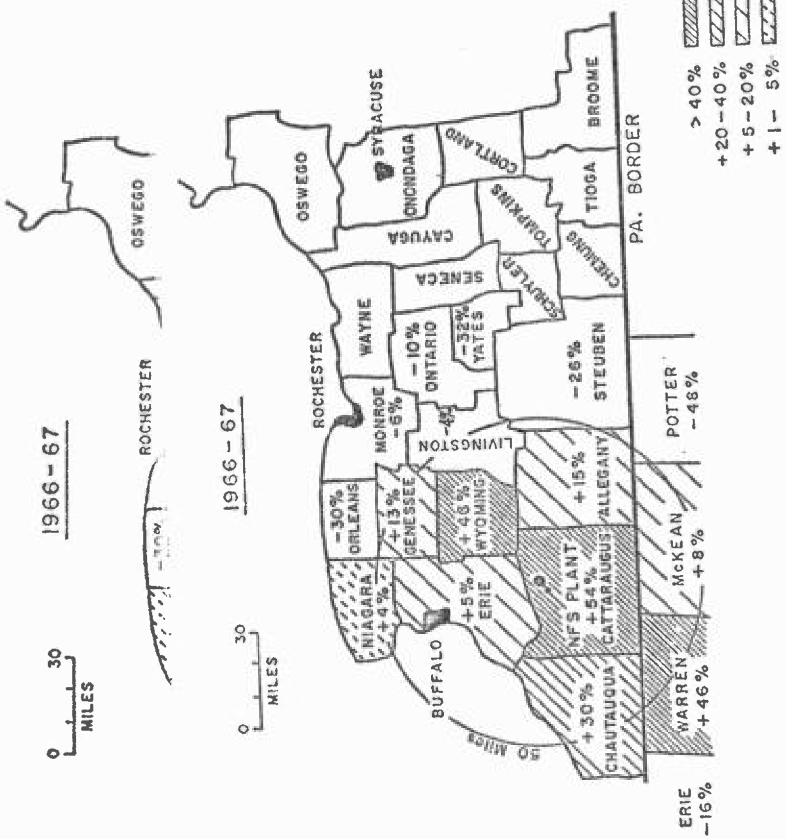


FIGURE 27

Change in infant mortality rates between 1966 and 1967 near the Nuclear Fuel Services Plant in Cattaraugus County, N.Y., after it went into operation in April 1966. Note rises for ring of counties within 40 to 60 miles, and declines at greater distances to the east and northeast in New York State. Counties in Pennsylvania along the Allegheny River flowing south from Cattaraugus County such as Warren and Venango, also showed sharp rises in this period.

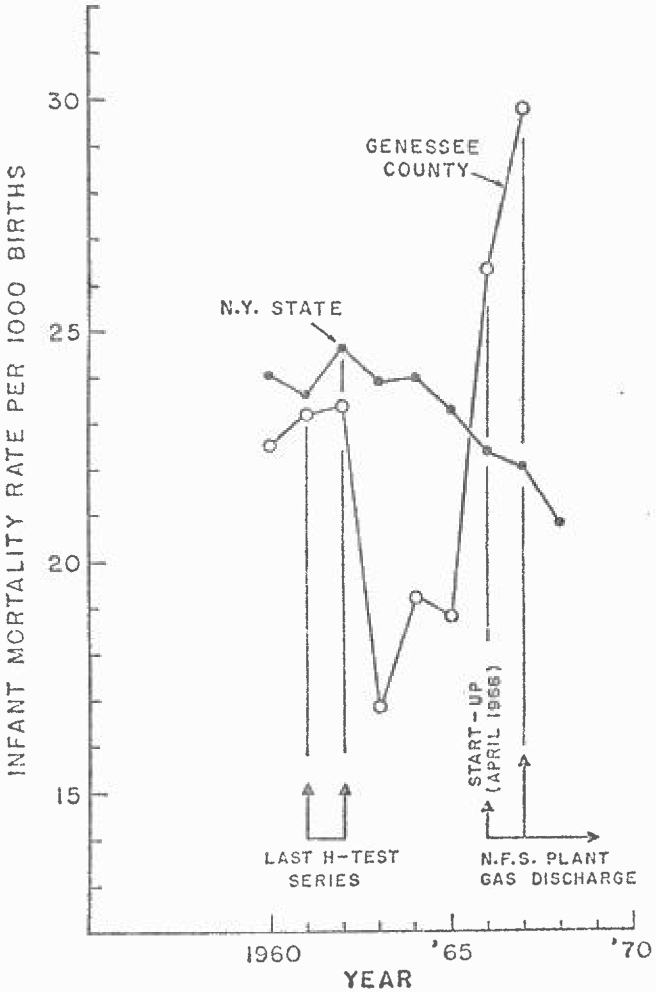


FIGURE 28

Infant mortality rates between 1960 and 1967 for a typical county in western New York State within 40 miles of the Nuclear Fuels Services Plant in Cattaraugus County. Note sharp rise above the rate for New York State as a whole when plant releases started in early 1966.

A typical case is Genessee County, N.Y., shown in Figure 28, where infant mortality rates began to exceed those of the rest of the state only after onset of plant operation. A similar time history was observed for Warren and Venango Counties downstream along the Allegheny River some of whose tributaries come within a few miles of the plant in Cattaraugus County.

9. Infant mortality near Gas Cooled Reactor

That even the relatively smaller radioactive gas releases from a Gas Cooled Nuclear Reactor appear to be capable of producing detectable rises in infant mortality is shown for the case of the Peach Bottom Reactor located on the Susquehanna River in York County, Pennsylvania. Figure 29 again shows the typical drop in infant mortality after cessation of atmospheric tests for the two counties on either side of the plant, namely York and Lancaster and the agriculturally similar control county, Lebanon, 30 to 50 miles to the north. The decline continued until the onset of a large increase in emissions resulting from fuel failure that started in 1968 and reached 100 curies in 1968 [19]. After 1967 York and Lancaster reversed their trend, while the more distant control county merely slowed its rate of decline.

Part of the reason why even the small releases from the Peach Bottom Reactor could have had such a strong effect seems to lie in the fact that the surrounding area is a major dairy farming region, where such biologically important but relatively short lived rare gas daughter products as cesium 138 and strontium 89 known to be produced in large amounts from the escaping xenon 138 and krypton 89 [19] can rapidly enter the body through the locally produced milk and other dairy products. Thus, the number of curies released able to produce serious biological effects can be much smaller than from a fuel processing plant discharging mainly Kr 85 that has no radioactive daughter product.

10. Nuclear air pollution and respiratory disease mortality

But the potential damage is not merely confined to the newborn and young child. There is evidence that suggests that the many radioactive gases presently released from nuclear reactors and nuclear tests may have a serious effect on the incidence of chronic diseases of the respiratory system such as bronchitis and emphysema that equal or even exceed the effects of conventional chemical air pollutants.

This is more strikingly shown in Figure 30, which shows the number of deaths due to respiratory diseases other than influenza and pneumonia per 100,000 population in New Mexico and New York State between 1942 and 1966.

It is clear that between 1945 and 1950, there was a sharp rise of deaths due to noninfectious respiratory diseases such that the incidence of these diseases previously very low in the pollution free air of New Mexico, exceeded the death

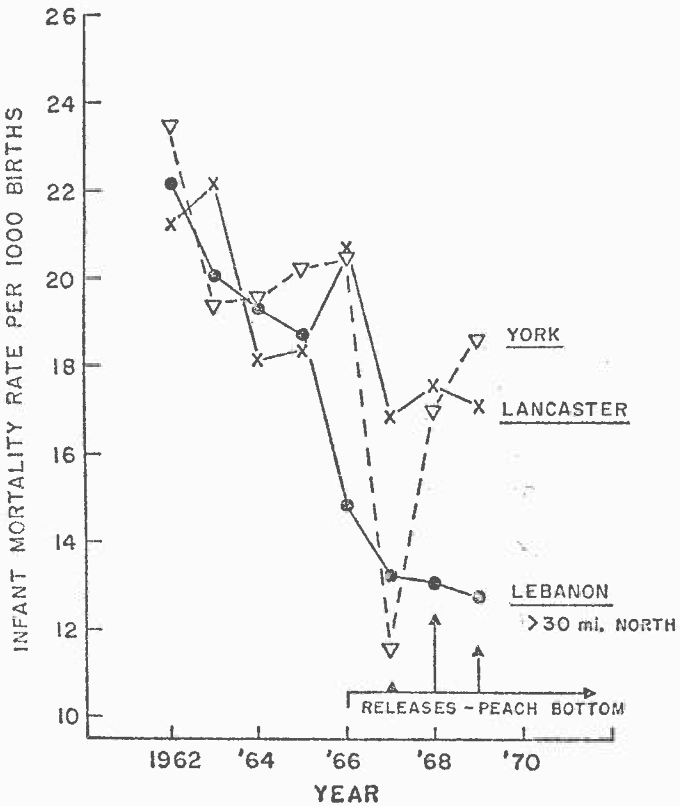


FIGURE 29

Infant mortality rates for the area near the Peach Bottom Reactor, York County, Pennsylvania, before and after onset of significant releases of gaseous activity in 1967–1968, compared with rates in nearby Lancaster, directly adjacent to the east of the reactor, and Lebanon, more than 30 miles to the north of Lancaster. Releases were 0.00126 curies in 1966, 7.76 curies in 1967, 109 curies in 1968 and 100 curies in 1969.

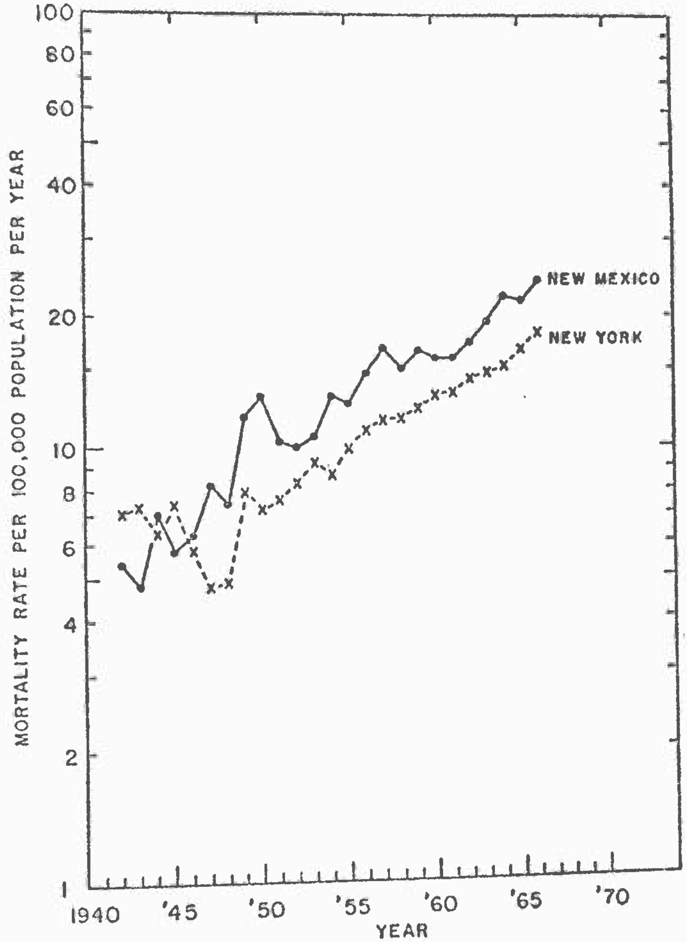


FIGURE 30

Mortality rate due to respiratory diseases other than pneumonia and influenza per 100,000 population for New York and New Mexico between 1941 and 1965. These diseases are principally emphysema, bronchitis and asthma.

rate for the same diseases in heavily polluted New York by as much as a factor of two.

That this is not an isolated case perhaps associated with a sudden influx of older people into New Mexico after 1950 follows from Figure 31 where similar data on deaths due to respiratory diseases have been plotted for Wyoming and Illinois. Again, there is the dramatic rise of chronic obstructive lung disease deaths in a state of almost no ordinary air pollution such as Wyoming to levels well above the death rates in heavily industrialized and polluted Illinois. And a similar situation exists for Wyoming relative to heavily polluted Pennsylvania, where respiratory death rates in 1944 were five times higher than in Wyoming before nuclear testing began, while in recent years the rate in Wyoming began to exceed that in Pennsylvania, despite the fact that the chemical pollution is much lower in Wyoming.

Such an apparently strong effect of radioactivity in the dry air of the west central part of the U.S., fits the observed high beta-radiation activity in the dusty areas of the western states relative to that in the high rainfall areas east of the Mississippi, where the activity sinks into the soil to give lower air concentrations but higher strontium 90 levels in the milk [26].

That the operation of Boiling Water Nuclear reactors with their discharge of large quantities of radioactive gases appears to have had a more serious effect on the rate of noninfectious respiratory disease than the operation of fossil fuel plants may also be inferred from Figure 31.

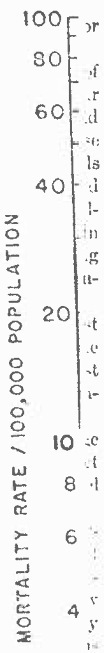
In the decade 1949 to 1959, prior to the start of Dresden releases, the mortality rate for these diseases rose only some 10 per cent despite a 100 per cent increase in power generated. But in the years following onset of Dresden operations, the rate of rise increased almost ten-fold, exceeding that of either New York or Pennsylvania. And since the onset of Dresden emissions, respiratory diseases and bronchitis as a cause of death in infants over 28 days in Illinois showed the sharpest rise among all causes of death [27].

Laboratory evidence that inhaled fission products such as the rare-earth isotopes can in fact produce chronic obstructive lung disease in animals such as fibroadenomas, severe chronic inflammatory changes and added susceptibility to infectious lung diseases, has recently been reported by H. L. Berke and D. Deitch [28].

That especially the newborn infant between 0 and 28 days old seems to be affected by fission products acting on the lung may be seen from a plot of the rate of respiratory disease deaths among infants in the U.S. other than pneumonia and influenza shown in [8].

This rate rose suddenly by a factor of ten between 1949 and 1957, the time of onset of heavy atmospheric testing, declining again after the end of atmospheric testing in Nevada in 1958.

That the rate of increase of respiratory cancer was also affected by the sharp rise in atmospheric radioactivity from nuclear testing is indicated in Figure 32, where the relative changes in lung cancer rates per 100,000 population have



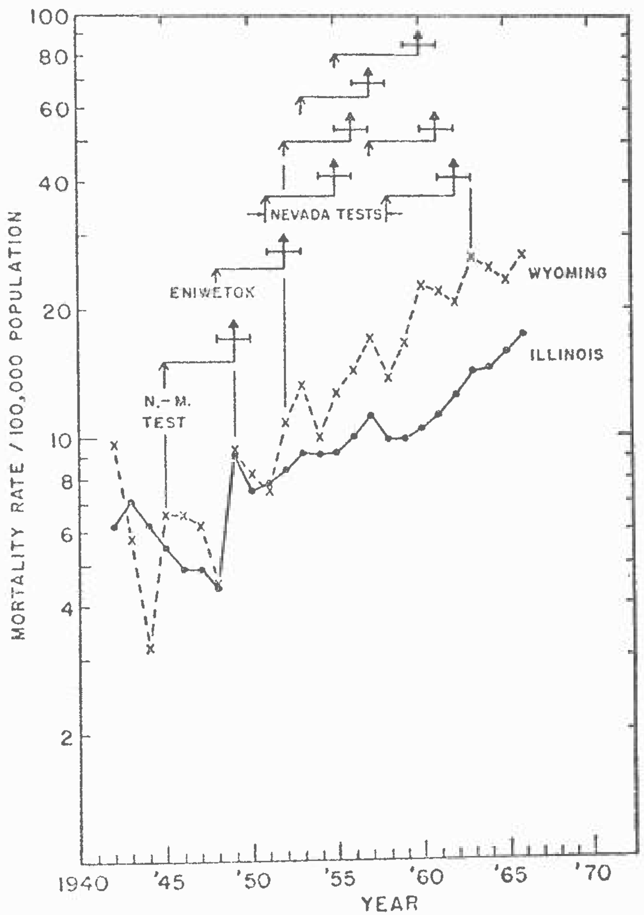


FIGURE 31

Mortality rate per 100,000 population for respiratory diseases other than pneumonia and influenza for Wyoming and Illinois. Note also sharp rise in Illinois after onset of Dresden operation in 1959.

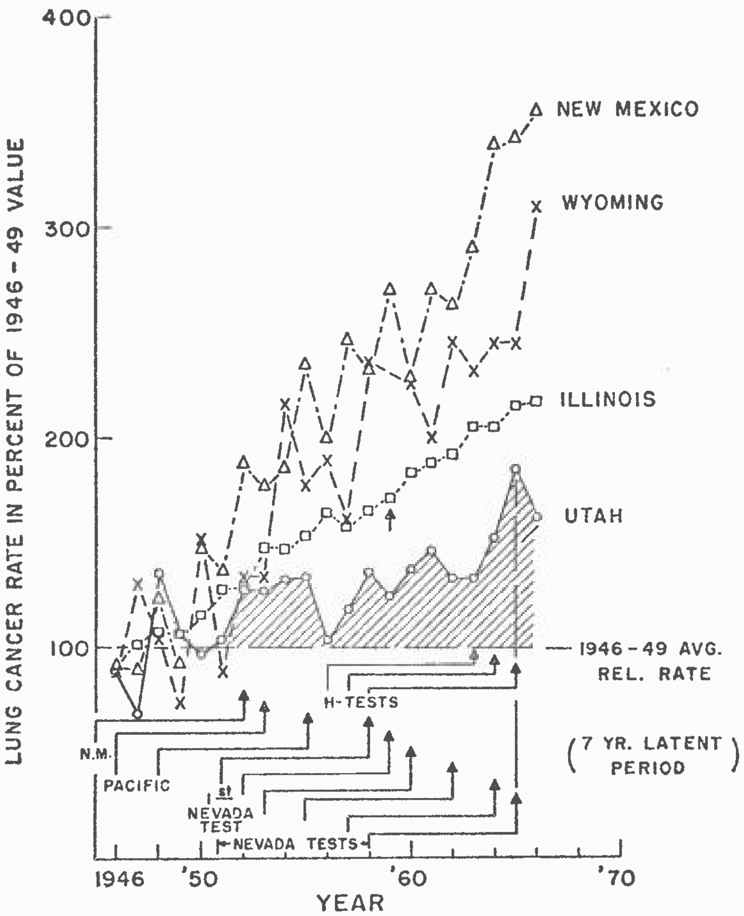


FIGURE 32

Relative changes in the rates of respiratory cancers per 100,000 population in Utah, Illinois, Wyoming and New Mexico, 1946–1966. Also shown are the principal atmospheric weapons test [39]. (1946–49 average rate = 100).

been plotted for Illinois and three dry western mountain states between 1946 and 1966. Using the average rate for 1946 to 1949 as reference rate equal to 100, rises in cancer rates for the lung, trachia and bronchus started to rise sharply some five to nine years after the first nuclear detonation in New Mexico. The greatest relative rise took place in New Mexico, followed by Wyoming, which showed its greatest rise some seven years after onset of Nevada testing.

Illinois, despite its heavy air pollution presumably acting synergistically with the radioactivity in the air rose about half as much as Wyoming and New Mexico by 1966 relative to 1946–49, while Utah, with its lower air pollution, nevertheless approached Illinois in its relative rise some seven to eight years after the peak of atmospheric testing in nearby Nevada. The observed lag of about seven years is consistent with the observed latency period of five to ten years for the uranium miners who developed lung cancer.

11. Infant mortality changes near a Pressurized Water Reactor (PWR)

In view of the proposed large increase in the amount of nuclear generating facilities to be installed near large metropolitan areas such as New York City, it seemed desirable to carry out a study of possible health effects on children in the greater New York Metropolitan Area from the releases of nuclear facilities that have been operating in this region for the past ten to fifteen years.

The most important sources of radioactive effluent close to the New York Metropolitan Area have been the Indian Point Pressurized Water Reactor located in Westchester County along the Hudson River some 20 miles north of New York City, and the Gas Cooled Nuclear Reactor at the Brookhaven National Laboratory near Upton, Suffolk County, Long Island 50 miles east of Manhattan.

The study was based on the available data for infant mortality rates for all the counties of New York State within a radius of 100 miles of New York City as published in the Annual Vital Statistics Reports of the New York State Department of Health [32]. Information on the releases from the Indian Point Unit number 1 were obtained from a report of the U.S. Department of Health, Education and Welfare [19], as well as official AEC summaries of reactor releases [33]. It is important to note that the releases of radioactive gases and liquids, with the exception of tritium, were much higher from the Indian Point Reactor than from Naval-type Pressurized Water Reactors such as Shippingport [19]. Figures on releases of wastes from the Brookhaven National Laboratory as well as on external radiation doses produced by gaseous releases and fallout were obtained from a report by A. P. Hull [34], using the average weekly dose rates at monitoring stations at the northeastern edge of the laboratory grounds and 4.8 miles away to the north.

The basic data on releases taken from these sources is reproduced in Tables VI and VII.

TABLE VI

RADIOACTIVE WASTE DISCHARGES FROM INDIAN POINT UNIT No. 1

Radioactive waste discharges from the Indian Point Pressurized Water Reactor, Unit No. 1. Note the large drop in liquid waste discharges expressed in per cent of permissible levels subsequent to the replacement of the original core in 1966.

Taken from U.S. Public Health Service Report BRH/DER 70-2 (March 1970). The 1969 data are taken from A.E.C. Report, testimony of Commissioner J. T. Ramey, Pa. Senate, Oct., 1970. The last three entries for 1 year average are based on radionuclide analysis. N.R. means not reported. Note that new fuel core installed in 1966.

	Gaseous waste noble and act. gases	Tritium in liquid waste	Liquid waste gross β and γ	Liquid waste-gross β and γ as % of permissible limit	
Year	Curies	Curies	Curies	1 yr. av.	2 yr. av.
1963	0.0072	N.R.	0.164	0.26	0.24
1964	13.2	N.R.	13.0	22.0	11.13
1965	33.1	N.R.	26.3	43.0	32.50
1966	36.4	125	43.7	70.1	56.50
1967	23.4	297	28.0	1.55	35.80
1968	59.7	787	34.6	1.65	1.60
1969	600	1100	28.0	1.50	1.58

In order to account for other factors known to affect infant mortality such as socioeconomic, medical care, diet, drugs, pesticides, climate, air pollution, infectious diseases, fallout and various unknown factors that might influence the changes in infant mortality besides low level radiation from plant releases, all mortality changes in the counties near the plant were compared with neighboring counties of similar socioeconomic character having no large sources of radioactive effluent.

Thus, Westchester and Rockland may be compared most closely with Nassau County, Long Island, since it has a similar total population of close to one million, similar suburban character, and closely similar fallout levels as well as similar socioeconomic characteristics.

Furthermore, as shown in the map of lower New York State (Figure 33), it is possible to use progressively more distant counties of New York State stretching in the form of a sector towards the northwest and north as control counties.

In order to correct for the fact that these counties further to the north have a more rural character than Westchester and therefore different socioeconomic situations, medical care and air pollution, one can normalize the infant mortality rates in a suitable fashion and then examine the per cent changes following the onset of emissions. Since a given small dose of radiation is expected to have closely the same relative effect on mortality changes regardless of the

TABLE VII

EXTERNAL BACKGROUND RADIATION DOSE RATES AND WASTE DISCHARGES AT BROOKHAVEN NATIONAL LABORATORIES (BNL)

Based on data by A. P. Hull [34]. The dose/year of BNL release is the difference between dose measured at Northeast Perimeter Station and station 4.8 miles north. The total dose and the fallout dose are measured at 4.8 miles north of BNL perimeter; the dose measures in 1952 are from station 3.5 miles south of BNL perimeter. The year 1951 has lowest background rate at station 4.8 miles north of BNL perimeter, taken as normal background rate prior to major weapons testing and releases from BNL.

Year	Total mr/wk	Fallout dose mr/wk.	Fallout dose mr/yr.	Dose/yr. BNL release mr/yr	Liquid waste input to BNL filter bed mCi/yr	Liquid waste released from BNL filter bed mCi/yr.
1949	1.80	0.21	10.9	—	—	—
1950	1.74	0.15	7.8	—	—	—
1951	1.59	0.00	0.0	5.2	160.5	21.5
1952	—	0.03	1.5	3.6	116.6	27.9
1953	1.73	0.14	7.3	3.1	132.9	35.8
1954	1.66	0.07	3.7	5.2	182.1	48.5
1955	1.70	0.11	5.7	13.5	223.8	75.0
1956	1.79	0.20	10.4	7.8	170.0	55.0
1957	1.89	0.30	15.6	10.4	300.8	105.1
1958	2.23	0.64	33.2	20.8	325.1	106.0
1959	2.58	0.99	51.5	6.8	586.6	169.5
1960	1.88	0.29	15.1	3.6	542.9	177.8
1961	1.73	0.14	7.3	7.3	384.4	219.1
1962	2.41	0.82	42.8	5.2	128.9	135.9
1963	3.05	1.46	76.0	29.6	127.5	99.4
1964	2.65	1.06	55.2	28.6	89.0	76.4
1965	2.07	0.48	25.0	15.6	66.8	41.8
1966	1.77	0.18	9.4	12.0	85.1	37.2
1967	1.73	0.14	7.3	4.7	81.2	47.9
1968	1.70	0.11	5.7	2.6	21.5	16.2
1969	1.65	0.06	3.1	0		

absolute rate, this technique allows one to detect changes in time as well as changes with distance from the source despite such differences as medical care and economic level.

The counties with smaller population can then be conveniently grouped into larger units with approximately the same distance from the point of release of the effluent.

The simplest and most direct test is to plot the pattern of mortality among infants born live and 0-1 year at death per 1000 live births for the two counties immediately surrounding the Indian Point Reactor and compare it with the time history in Nassau County 30 to 50 miles away (see Figure 34).

As can be seen from an inspection of Figure [34], for a period of six years

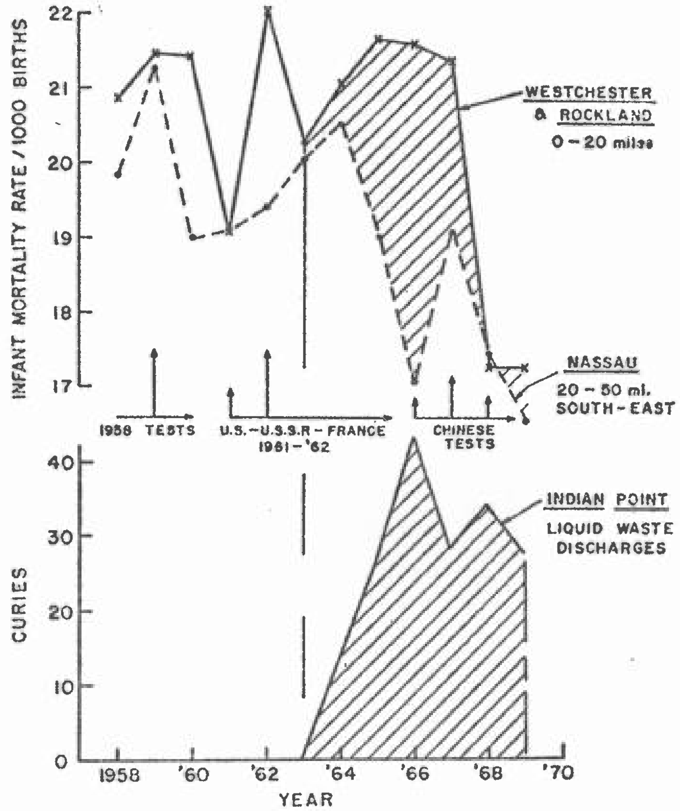


FIGURE 31

Infant mortality rates for Westchester and Rockland Counties compared with the rates for Nassau 1958–1969. Also shown is the liquid radioactive waste other than tritium released from the Indian Point Plant.

prior to the onset of large releases from the Indian Point Plant in 1964, the infant mortality rates for Nassau and Westchester-Rockland were essentially the same within the statistical fluctuation of about five per cent or ±1.0 per 1000 births that exists for the observed 300 to 500 deaths per year. There were rises apparently associated with the fallout from the large test series in 1958 and 1961-62 prior to the onset of large releases of the Indian Point Plant in 1964 but the two counties showed exactly the same infant mortality rates of 19.1 in 1961, the year of lowest fallout in the air and diet just prior to the resumption of atmospheric testing by the U.S.S.R. in the fall of 1961.

However, after the releases began from the Indian Point Reactor, while Nassau infant mortality moved downward as did most areas of the U.S. following the end of nuclear testing [6] [7], Westchester and Rockland moved upward and remained high for a period of four successive years. Not until after the emissions began to show a tendency to decline following the replacement of the original fuel core in 1966 that had developed serious leaks [19] did Westchester and Rockland infant mortality decline close to where Nassau had moved.

If one now plots the difference in infant mortality between the two counties nearest the reactor and compares it with the annual releases of liquid radioactive waste in the form of mixed fission products (beta and gamma emitters other than tritium) (Figure 35) expressed as per cent excess over the Nassau rate, one finds a direct linear relationship between excess mortality and the amount of activity as per cent of permissible limit of liquid releases.

Applying a least square fitting procedure to the data for the period 1963 to 1969 one obtains a correlation coefficient $C = 0.835$. A still better fit is obtained for the two year average, or $C = 0.974$. The t test of statistical significance gives $t = 9.96$ which for the present case of five degrees of freedom gives $P < 0.01$. Since, as Figure 36 shows, gaseous releases closely followed liquid releases in magnitude, not only areas bordering the Hudson River but also areas exposed to the gaseous releases would be expected to be affected.

As an independent check of this result, it is of interest to compare the changes of infant mortality for the two counties near the reactor with those counties more than 40 miles to the north and northwest, namely Columbia, Greene, Sullivan and Ulster, grouped together so as to provide a total population closer to that of Westchester and Rockland.

In order to allow such a comparison despite the more rural character of these control counties, their infant mortality rate was normalized to equal that for Westchester-Rockland in 1961, the year when Nassau showed the same infant mortality rate as the two counties next to Indian Point. Figure 37 thus shows the per cent changes relative to the year 1961, again both before and after the emissions began.

It is seen that as in the case of the comparison with Nassau County in Figure 34, the control group shows a very similar pattern prior to 1964, but as soon as the releases occurred, a gap between the nearby and the distant counties begins to appear amounting to about four standard deviations by 1966. The control

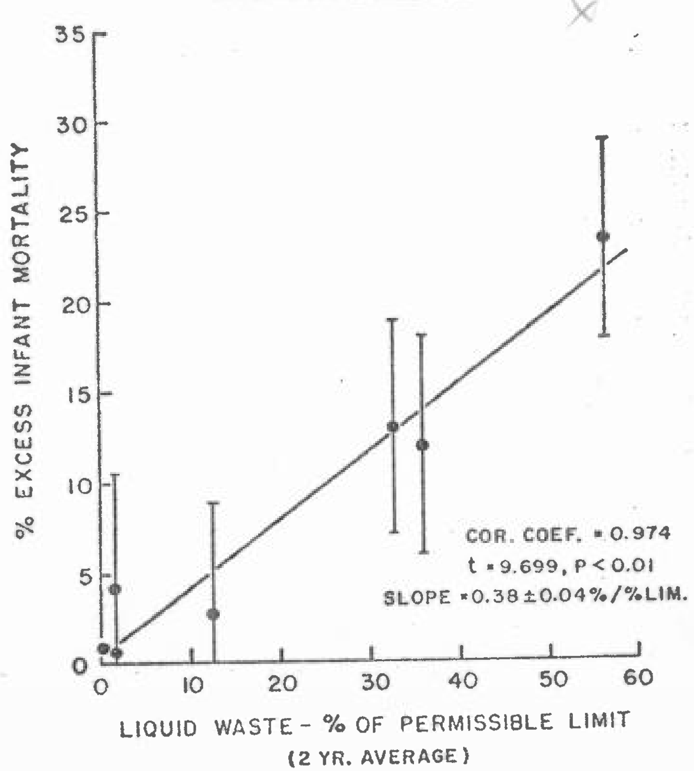


FIGURE 35

Per cent excess infant mortality for Westchester and Rockland Counties relative to Nassau *versus* the annual amounts of liquid waste discharged from Indian Point, expressed in per cent of permissible limit.

counties show a rapid decline in infant mortality while the nearby counties show a rise followed by years of failure to decline.

Once again, one can examine the correlation between the excess in the infant mortality of the exposed counties as compared to the more distant control counties, as shown in Figure 38. As in the case of the use of Nassau as a control,

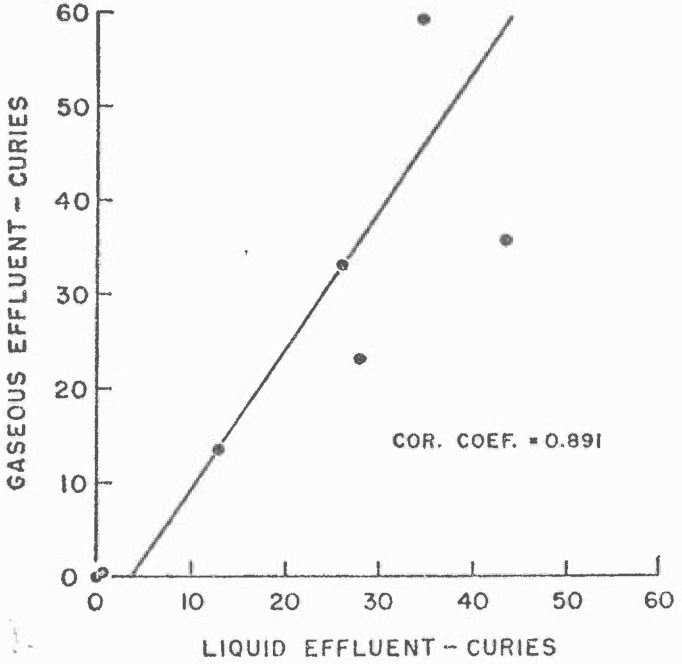
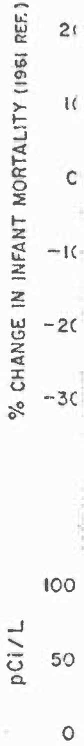


FIGURE 36

Correlation between liquid and gaseous effluent in the form of noble and activation gases from the Indian Point Plant 1963–1968 as reported in the P.H.S. Publication BRH-DER-70-2.

there is a strong, positive correlation between excess mortality and the quantity of radioactive wastes discharged in per cent of permissible limit. The correlation coefficient is found to be 0.957 and $t = 7.37$, which for the five degrees of freedom leads again to a small probability $P < 0.01$ that this association is a pure chance occurrence. Furthermore, the amount of change per unit radioactive discharge is found to be closely the same using this group of controls as when Nassau County was used, within the accuracy of the data.

Using the same normalization procedure for the group of intermediate counties to the north of Westchester and Rockland, namely Dutchess, Orange and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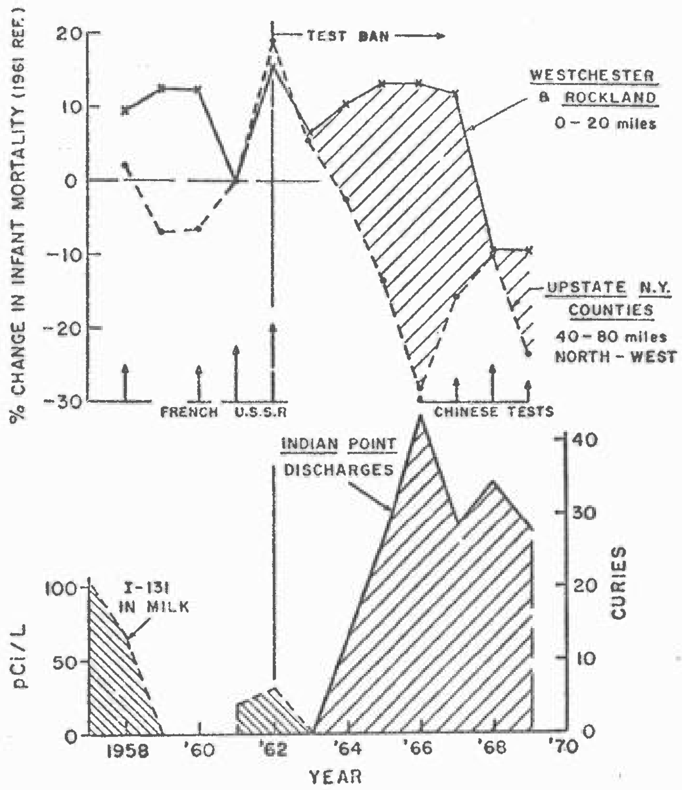


FIGURE 37

Changes in infant mortality relative to 1961 for Westchester and Rockland compared with four upstate control counties 40 to 80 miles north. Also shown are Indian Point liquid releases and iodine 131 in New York City milk in average monthly concentrations (pCi/liter).

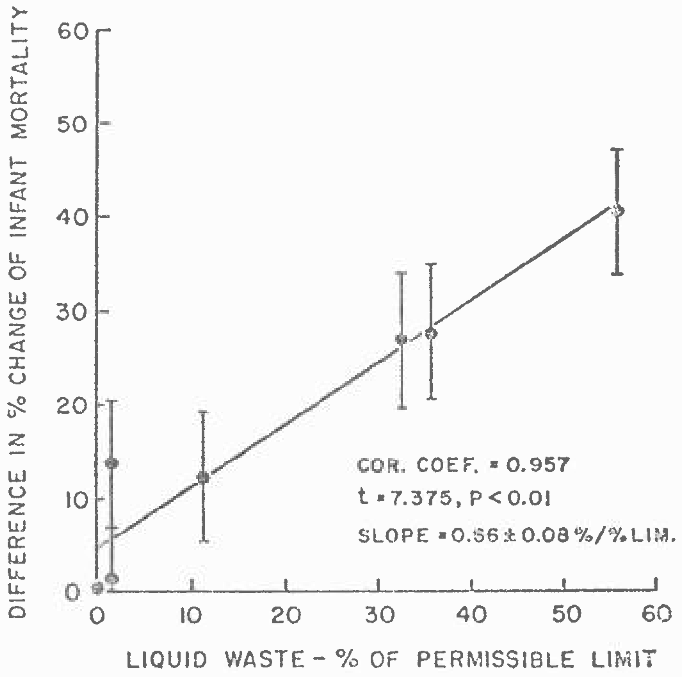
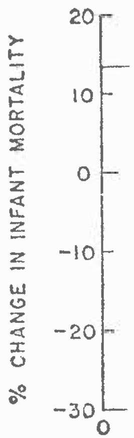


FIGURE 38

Correlation between per cent excess infant mortality for Westchester and Rockland relative to upstate control counties and liquid waste discharges from the Indian Point Reactor.

Putnam, it is now possible to test whether they show a pattern intermediate between the nearby and more distant counties during the period of peak emissions from the Indian Point Plant.

The result for the year of peak emission (1966) is shown in Figure 39, where the three groups of counties have been plotted according to their average distances from the Indian Point Plant in Westchester County. Not only do the intermediate counties show the required intermediate position in the change



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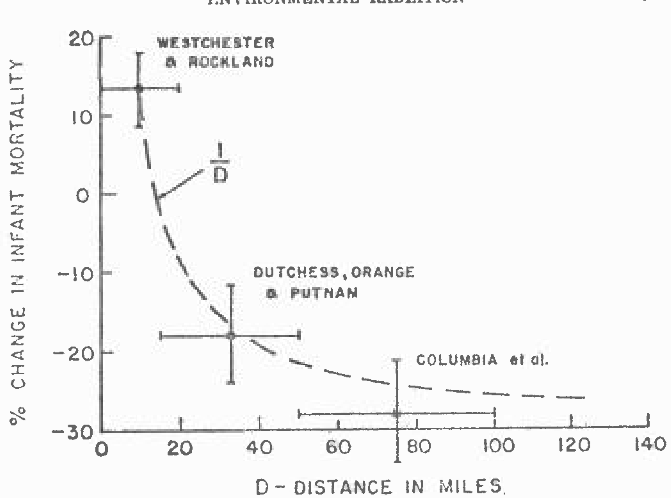

FIGURE 39

Per cent changes in infant mortality by 1966 relative to 1961 for counties at increasing distances from the Indian Point Plant moving north.

of infant mortality, but the three groups show a dependence on distance consistent with an inverse first power law expected for long lived gases diffusing from a stack [35].

As a further test of the hypothesis that the infant mortality changes are associated with releases from the Indian Point Plant, one can make the same plot for Nassau and Suffolk counties to the southeast as shown in Figure 40, and again the pattern of declining mortality fits the hypothesis.

It is of interest to see whether despite its much poorer socioeconomic pattern, air pollution problems and medical care, New York City shows a decline in infant mortality during the time that Westchester and Rockland showed a rise above the 1961 level. Using the same normalization procedure, the infant mortality for New York City shown in Figure 41 is in fact found to decline after 1964, though not as rapidly as the more remote counties to the north and east. Thus, the pattern of infant mortality changes following the onset of radioactivity releases from the Indian Point Plant as shown in the bar-graph of Figure 42 is consistent with a causal effect of the releases on infant mortality, similar to the effects already noted for seven other nuclear reactors and fuel processing facilities.

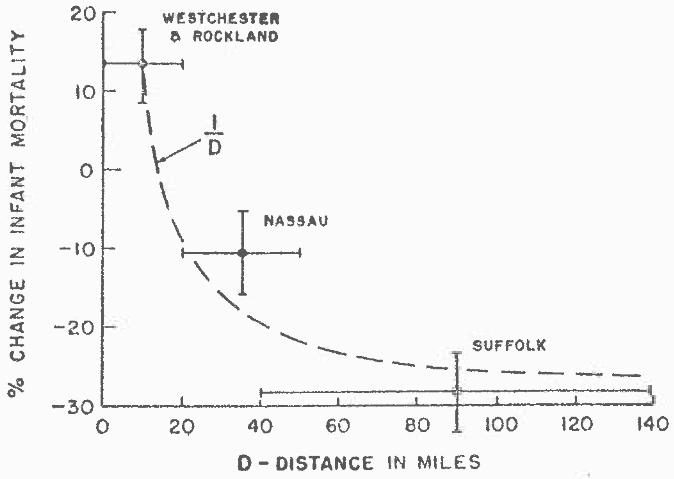

FIGURE 40

Per cent changes in infant mortality by 1966 relative to 1961 for counties at increasing distances from the Indian Point Plant moving southeast.

Taking either the control counties to the north or to the east as a reference, the excess infant mortality associated with a release of 43.7 curies per year of mixed fission products in liquid waste and 36.4 curies of noble and activation gases is 41 per cent. For the year 1966, this represents an excess mortality of approximately 100 infants 0–1 year old in Westchester and Rockland Counties combined out of a total of 367 infants that died in their first year of life during 1966.

For New York City, assuming that the relative changes shown for 1966 in Figure 42 can be attributed to the plant releases, the excess mortality would be approximately 26 per cent. This would mean that out of the total of 3,686 infant deaths in 1966 some 750 probably died as a result of the operation of the Indian Point Plant. Thus, although New York City is more distant than Westchester and Rockland, due to its large population, the total number of additional deaths is some seven times larger than for the nearby counties.

12. Effects of low level fallout from nuclear testing in Long Island, N.Y.

These results are so serious that it is essential to apply still further tests in an effort to see whether the observed association is likely to be of a causal nature.

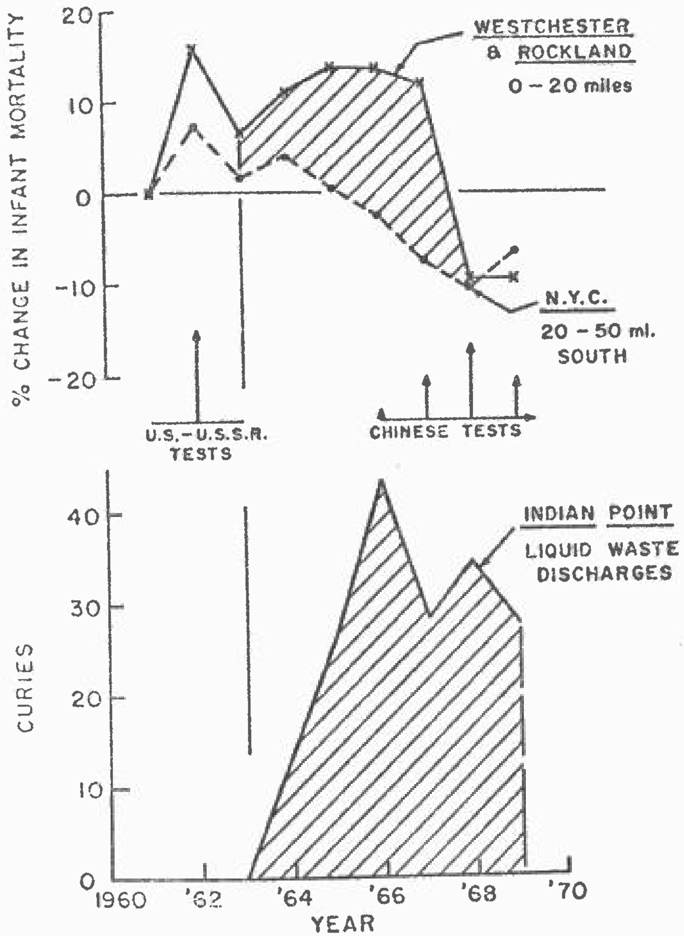

FIGURE 41

Changes in infant mortality for Westchester and Rockland compared with New York City relative to the 1961 rates.

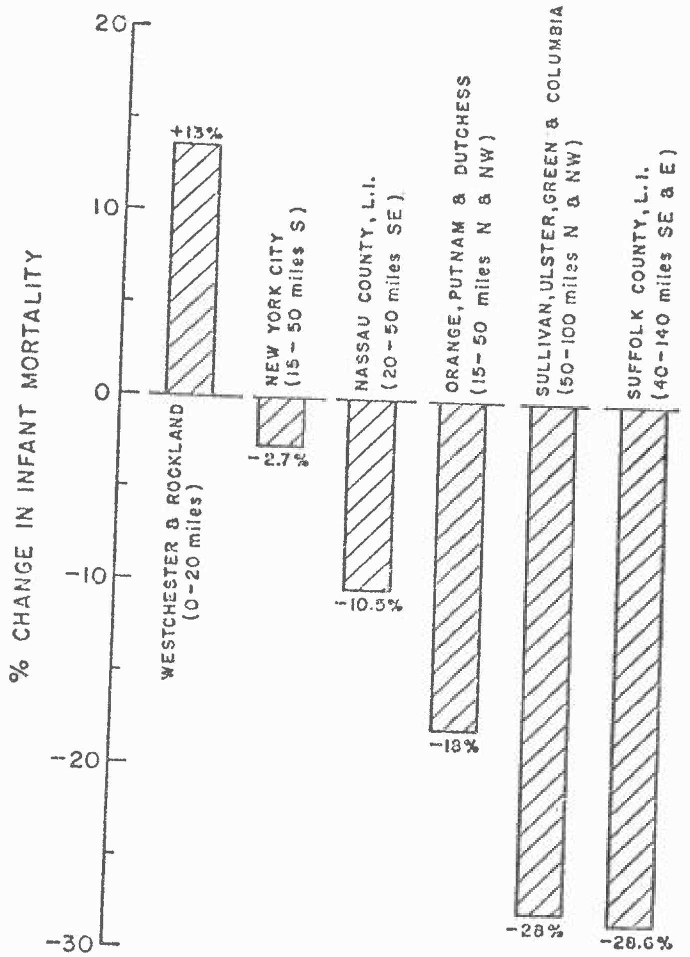

FIGURE 42

Per cent changes of infant mortality for the year of peak releases from the Indian Point Plant by 1966 relative to 1961 for all New York counties within a radius of 100 miles.

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Thus, if low levels of radiation near a nuclear plant, typically well below the 500 mr per year allowable to any individual or of the order of a few millirads per year, can indeed produce such serious effects on the early embryo, then effects should be seen for the low level fallout radiation measured at Brookhaven over a period of many years [32].

Assuming that Nassau County on Long Island just west of Suffolk County received essentially the same fallout levels as Brookhaven, it is possible to see whether the changing levels of annual fallout dose were in fact accompanied by corresponding changes in infant mortality in Nassau.

The data on infant mortality rates for Nassau are shown in Figures 43 and 44 for the period following the first large H-bomb tests in the Pacific in 1954, together with the annual external gamma radiation dose as measured at Brookhaven [34] (see Table VII).

It is seen that as the radiation dose rose from about 6 mr/year in 1955 to 51.5 mr/year in 1959, infant mortality rose 17 per cent from 18.1 to 21.2 per thousand live births. This first rise was followed by a second peak associated with the 1961–62 test series, again followed within a year by a renewed peak in infant mortality.

Using the line connecting the points for 1955 before the rise and 1966 after the end of large-scale testing as a reference, it is possible to arrive at estimates for the yearly excess infant mortality and compare them with the measured external gamma dose.

The result of this comparison is shown in Figure 44. It is seen that the excess infant mortality in Nassau is indeed highly correlated with the changing levels of fallout radiation varying up and down as fallout levels rose and declined repeatedly. The correlation coefficient is found to be 0.797, with a t value of 4.172, corresponding to $P < 0.01$, making it a highly significant association.

The slope of the line is found to be 0.22 ± 0.05 per cent per mr/year. Thus, this data suggests that a dose of as little as 1 millirad of fallout per year radiation from the ground, or only about one per cent of natural background radiation, leads to almost a ¼ per cent increase in infant mortality.

13. Leukemia in Nassau County, Long Island, associated with fallout

As still another test of the hypothesis that such small levels of radiation can in fact lead to detectable rises in leukemia even when given over a period of months instead of in a few seconds as occurs for diagnostic X-rays, one can examine the changes in leukemia in Nassau County and compare them with the changes in external gamma radiation from fallout.

Since the typical latency period for leukemia is some four to six years for the infant irradiated *in utero* or early postnatal life [1], [2], [3], [4], the comparison must be carried out with the radiation level existing five years earlier.

The leukemia data for Nassau County are shown in Figure 46, together with the measured external radiation dose five years prior to the reported leukemia mortality.

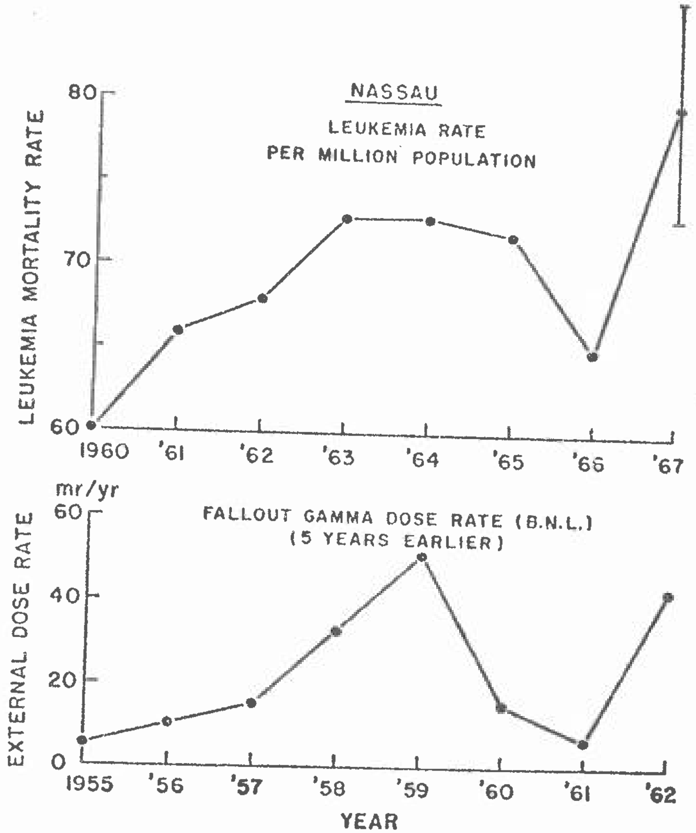
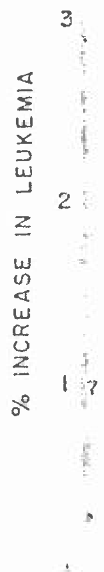


FIGURE 45

Leukemia rate per million population for Nassau County compared with the measured external gamma radiation rate from fallout five years earlier.



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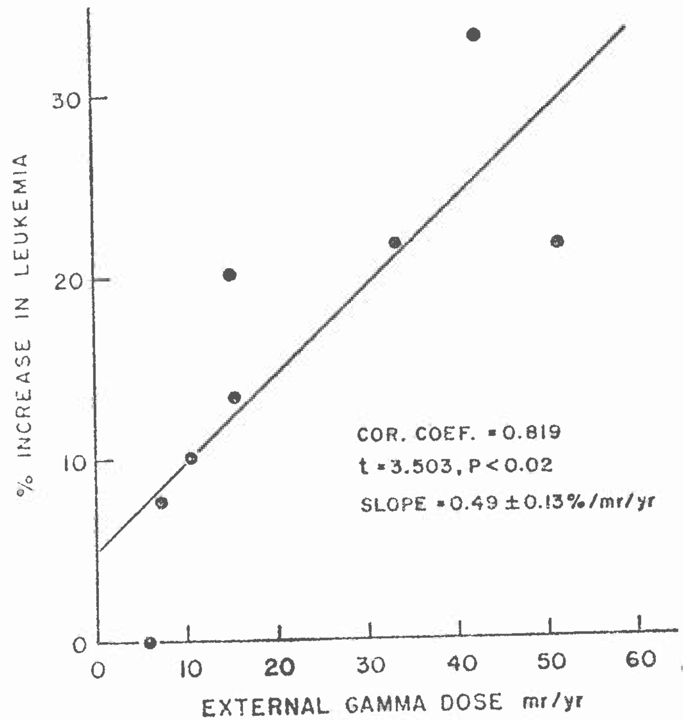

FIGURE 46

...on between the per cent increase in leukemia rates in Nassau County ...annual dose from external fallout radiation. The least square fitted line ...responds to an increase of 49 per cent for a dose of 100 mr per year.

...e dose of 80 mr to the early embryo in the first trimester as obtained ...e study of diagnostic X-ray effects is therefore not unreasonable for ... radiation as well. Thus there is no evidence for any decreased effective... protracted as compared with high dose rate radiation from diagnostic ... in the early embryo and fetus.

...hould therefore not be surprised to find similar changes in infant mor... ...that involve subtle genetic defects leading to slight immaturity at birth, which by itself tends to increase greatly the chance of death from respiratory or infectious diseases [22]. Such changes in immaturity or lowered weight at birth have in fact been observed in the county in which the Dresden Reactor is located and among children born in the U.S. since the early 1950's [22], the time when large scale nuclear testing began, a trend that has only recently begun to reverse itself.

In fact, mortality for all age groups showed sharp upward changes beginning in the early 1950's as first pointed out by I. M. Moriyama [9].

14. Infant mortality near Brookhaven National Laboratory, Long Island, N.Y.

These considerations therefore lead one to expect that the gaseous and liquid effluent from the Brookhaven Gas Cooled Reactor may also have led to detectable changes in infant mortality in Suffolk County.

That this appears in fact to have been the case is shown in Figure 47, where the infant mortality in Suffolk County is plotted together with the reported radioactive effluent produced and discharged at Brookhaven. The anomalous rise of infant mortality in Suffolk between 1953 and 1960 relative to Nassau is strongly associated with the reported activity produced at Brookhaven and the fraction released into the streams [34] which in turn reaches the wells serving for irrigation and drinking water supplies in Suffolk County. Both before and after this period, Suffolk and Nassau showed the same infant mortality rates. And with the drastic reduction in releases that took place since the peak of activity in 1959, infant mortality in Suffolk County dropped from a high of 24.1 in 1960 to 19.3 in 1963, an unprecedented drop of 25 per cent in only three years.

15. Infant mortality and underground tests

On a number of occasions, significant quantities of radioactivity have escaped into the atmosphere from underground nuclear detonations. The most serious of these occurred at the Nevada Test Site on December 18, 1970, in the course of a test of a so-called "tactical" weapon announced to be in the 20 kiloton range [36].

A radioactive cloud was reported to have risen to an altitude of some 8,000 feet, which drifted off towards the north and northwest [36] or towards Idaho and Montana.

As tabulated in Radiological Health Data and Reports [37], the levels of gross beta activity in surface air, the total deposition of beta activity on the ground and the levels of cesium 137 in the milk increased during the month of December 1970 over large areas of the northwestern and central United States as well as southern Canada shown for the case of milk in Figure 48.

Upward changes in the levels of cesium 137 in the milk were recorded for many states relative to the previous 12 months average. The highest levels were recorded in Montana, the rise being 13 pC/l, corresponding to an increase of

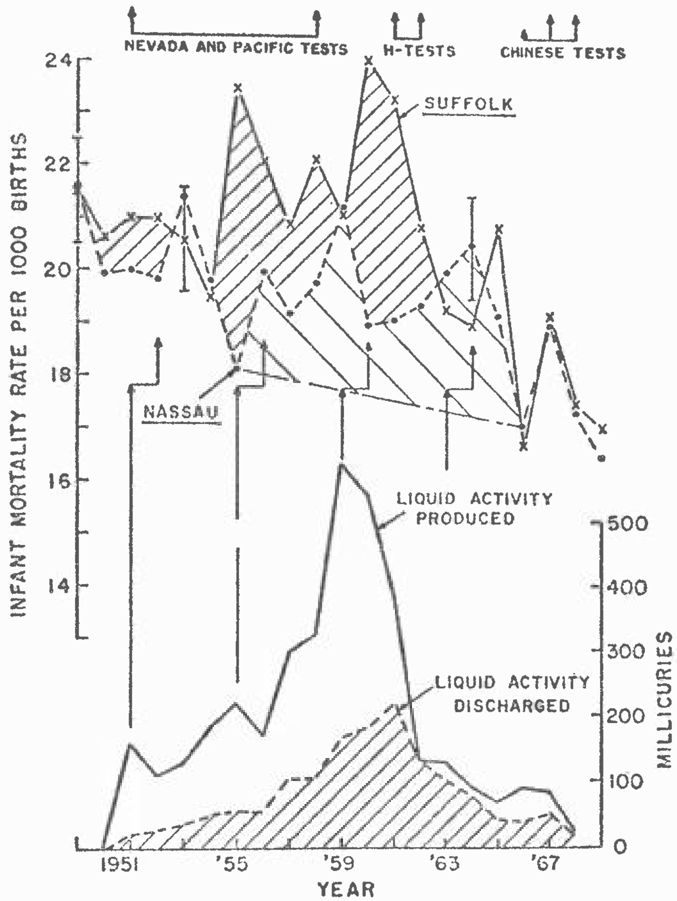

FIGURE 47

Infant mortality rates for Suffolk and Nassau Counties, 1949–1969, compared with the releases of liquid radioactive waste from the Brookhaven National Laboratory in Suffolk County.

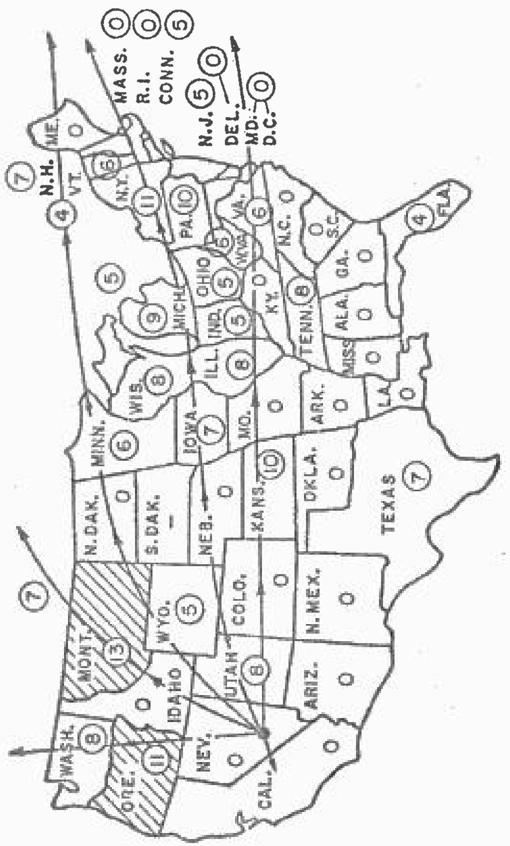

FIGURE 48

Rises in cesium 137 in the milk for the U.S. and Canada, in December 1970 relative to the previous 12 month average. Source: Radiation Health Data and Reports (April 1971). States showing no rises or declines are marked 0. Note largest increase in Montana.

186 per cent. No rises or actual declines took place throughout the entire southern United States, with the exception of Texas, Tennessee and Florida. Rises in the cesium content of milk took place also across a number of states in the northern United States and southern Canada, together with rises in ground deposition for areas more than 3,000 miles from the test site as shown in Figure 49 for Canada, although maximum air concentrations or ground deposition did not always result in maximum milk concentrations due to differences in precipitation and cattle feeding practices.

The Monthly Vital Statistics Reports published by the National Center for Health Statistics of the U.S. Department of Health, Education and Welfare for the first three months of 1971 were examined for changes in infant mortality rates in each state. Figure 50 shows that for the months of January and February 1971 relative to the average for January and February 1969 and 1970, infant mortality rose most sharply in the states immediately to the north and northeast of Nevada, while it declined for most of the more distant states of the South and East, with the exception of Maine, Connecticut and Kentucky where localized precipitation presumably led to higher contamination levels.

A similar pattern was found to hold for the months of January, February and March combined relative to the corresponding periods in 1969 and 1970, with a general decline in infant mortality excesses relative to the first two months following the detonation.

Thus, the most recent accidental release of radioactivity into the environment for which much more complete documentation of radiation levels exists strongly supports the hypothesis of a direct causal connection with infant mortality originally observed for the states downwind from the very first atomic test in New Mexico in July of 1945.

16. Summary and conclusion

The evidence of rises in infant mortality, congenital defects and childhood cancers associated with nuclear testing has recently been corroborated by similar rises in infant mortality in the vicinity of four different types of nuclear facilities known to release quantities of radioactive gases into the environment that led to nearby environmental activity levels comparable to those measured during nuclear weapons tests.

In both types of low level exposure, infant mortality was associated with increased frequency of underweight birth or immaturity. Thus it appears that low level radiation acting on the early embryo, fetus, and young infant can not only lead to significant rises in diseases previously known to be produced by radiation such as congenital defects and cancer, but it also appears to act indirectly so as to produce small decreases in maturity at birth that in turn can increase the chance of early death from various causes such as respiratory distress and infectious diseases.

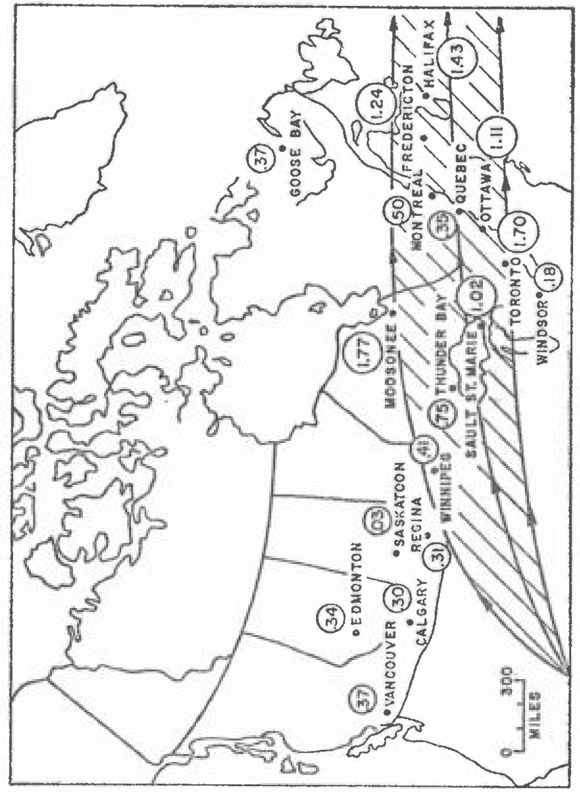

FIGURE 49

Total ground deposition of beta activity for December 1970 in Canada. Deposition is measured in units of nanocuries per square meter.

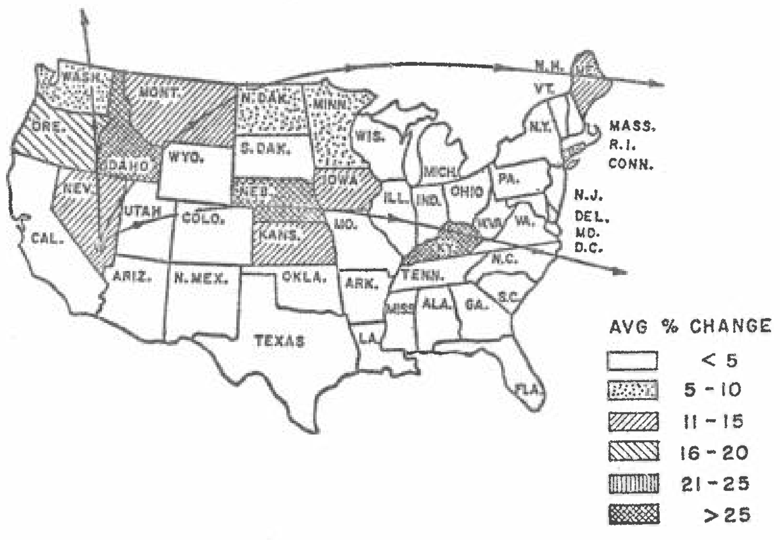

FIGURE 50

Pattern of infant mortality increases for January and February 1971 relative to the same months in 1969 and 1970. Note especially the rises along the northernmost path observed by ground deposition in Canada.

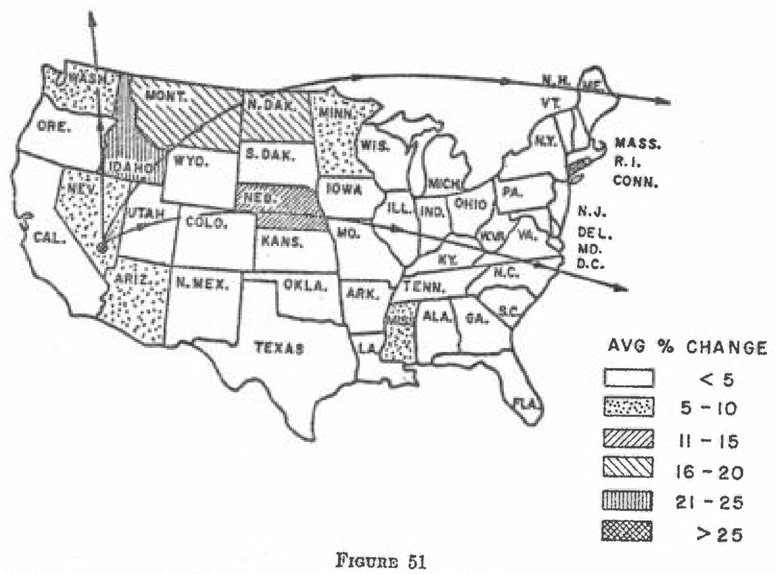

FIGURE 51

Pattern of infant mortality increases for period January-March 1971 relative to same period in 1969 and 1970. Note persistence of earlier pattern at lower intensity north and northeast of the Baneberry test site in Nevada.

In view of the present findings, it appears likely that both infant mortality and chronic diseases for all ages having genetic components and involving subtle disturbances of the cell chemistry may have been more seriously affected by low level environmental radiation than had been expected on the basis of high level radiation studies on laboratory animals carried out mainly with external X-rays and gamma rays.

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Discussion

Question: Alexander Grendon, Donner Laboratory, University of California, Berkeley

The brevity of the discussion period did not allow me to make any comment. Part of this comment was made after the close of the morning session; the rest is what I would have said, given time.

(1) You chose as your base the period 1935–1950. Sulfa drugs were introduced about 1935; penicillin about 1945. These treatments caused a sharp decline in the death rate. Why would you expect that sharp decline to continue rather than expecting a return to the gradual decline seen pre- 1935 and again post-1950?

(2) In one of your curves, included in the paper you prepared for the Health Physics Society meeting (Figure 13), you show a high correlation between radioactive gas releases from Dresden and per cent excess infant mortality rates in the same years. Since radiation does not kill *promptly*, except at rates $>10^6$ times those possible here, why relate mortality to emissions in the *same* year rather than, say, to emissions in the preceding year or earlier? I displaced your data by one year and, by eye, observe approximately zero correlation.

(3) In citing infant mortality around the Humboldt Reactor and relating it to gaseous emissions, you chose the years 1964–1965 to prove your point. The following data were supplied by the California Department of Public Health (slide shown):

Year	Humboldt infant mortality per 1000	Gaseous releases Ci(×100)	Del Norte infant mortality	Humboldt fetal mortality
1963	24.5	7	10/398	29
1964	20.0	60	7/369	27
1965	27.0	1,970	8/347	26
1966	18.4	2,820	8/281	21
1967	17.2	8,960s	4/285	19

You chose the only pair of years in which the data seem to support your hypothesis. How do you justify that choice? And did you know that there was a *rubella* epidemic in Humboldt County in 1965, cases having risen from 49 in all of 1964 to 626 in the first nine months of 1965?

Reply: E. J. Sternglass

(1) Indeed, in those areas of the United States where, due to low rainfall, there was very little fallout, such as New Mexico after 1945, infant mortality did continue to decline without any levelling off whatsoever. After 1963 in many states having no nuclear facilities (such as Maine), infant mortality resumed its decline, recovering or actually exceeding the rapid rate of decline characteristic of the period 1935–1950. Thus, it is clear that the halt in decline was a temporary phenomenon highly associated with fallout.

(2) For the case of fetal and infant mortality, deaths occur primarily in the

period up to a few days to a few weeks after birth. Therefore the delay period between exposure to radiation and the observed deaths can be as short as a few months. The deaths are of an indirect type such as hyaline membrane disease, not of the true radiation type observed at very high doses.

(3) With respect to *rubella* epidemics, such outbreaks of infectious diseases are precisely what are found whenever radiation exposure is high. It is found that the periods of very high fallout are followed by a weakening of the newborn expressed in a subsequent abrupt rise in all infectious diseases. Such a rise in *rubella* incidence and in the incidents of other diseases occurred around the Dresden Reactor following the period of its emission peak. Therefore, finding the same correlation in the case of the Humboldt Reactor actually confirms the hypothesis.

Furthermore, the evidence for increased premature births during the active period of the Dresden Reactor, and its decline during the inactive period contributes additional support to the hypothesis of an indirect effect.

The choice of the period 1964–1965 as the period of investigation of the Humboldt Reactor area was not made by me. The mortality rose for the first time according to the Bureau of Radiation and Health's publication, "Radioactive waste discharges to the environment from nuclear power facilities" (Figure 4-2, [19]) when the emission level rose from as low as a few hundred curies per month in 1964 to as high as 100,000 curies per month in August 1965. This, in fact, is why a comparison was made between the years 1964 and 1965; there had been a thousand-fold increase in the rate of emission. Cumulatively, this meant 197,000 curies per year, resulting in the forced shutdown of the reactor from September 1965 to December 1965. Subsequently, the reactor was not permitted to be operated at such high emission levels again until the end of 1966. Therefore, 1966 showed a sharp drop in infant mortality, fully confirming the hypothesis.

Toward the end of 1966, emission levels once more increased (see Figure 4-2 [19]), and so for 1966 as a whole, the total emission was approximately one third higher than in 1965. But the children who were irradiated did not begin to show the effects until 1967, when (instead of declining to 10–15 deaths/1000/year as expected from the 1961 to 1964 rate of decline), infant mortality remained high in 1967–1968, while emission levels were allowed to reach 100,000 curies/month once again. And so, by 1969 there was another sharp rise in infant mortality. The rate for Humboldt County was 22 infant deaths/1000, exceeding the rate for the rest of California which was 18 infant deaths/1000. Thus, the data for Humboldt County fully confirm the hypothesis that the large releases from boiling-water reactors result in anomalously high infant mortality in the adjacent areas.

Question: J. Neyman, Statistical Laboratory, University of California, Berkeley

While the graphs exhibited by Dr. Sternglass are impressive, the question in my mind is whether the indicated increases in infant mortality are really caused by radiation. It is well known that, as time goes on, the environment is increasingly affected by all kinds of pollution. Therefore, it is possible that the increases in mortality indicated by Dr. Sternglass represent a sum total of all the pollutants and, possibly, are not due to radiation.

In particular, with reference to the first slide of Dr. Sternglass illustrating an increase of deaths in parallel with the increase of X-ray films taken during pregnancy, the question arises whether the extra X-ray pictures were taken *because* of some difficulties in pregnancy which later manifested themselves in deaths of the newborn.

In general, causal relations can be established only through controlled experiments. With observational studies, a comprehensive statistical analysis concerned with many suspected pollutants and many localities may represent an approximation to an experiment.

Reply: E. J. Sternglass

With regard to X-ray examinations possibly being performed on disease-prone individuals, note that extensive examination of the question has been accomplished (see Brian MacMahon). In a study of 800,000 cases X-rayed in New England hospitals, it was concluded that no such association existed. Furthermore, the fact that there exists a direct relationship between the number of X-rays and the increase in risk could not be explained by a suggestion that the X-rayed individuals were cancer-prone. Since the number of X-rays taken was the same for all types of patients, and related to how many views the physician requested, and how many repeats were necessary due to improper exposures, there can be no association between the number of X-rays and any inherent characteristics of the mother irradiated.

With respect to causal association of low level radiation and leukemia and cancer incidence, there is no question that this has been established in laboratory experiments on all types of animals, and for the case of man one has the bombing effects in Hiroshima and the fallout incidents in Utah and Albany, N.Y. where everyone was irradiated regardless of prior medical history or tendencies. The direct dose response in Hiroshima makes it highly unlikely that the association of radiation and cancer, leukemia, and similarly genetically caused problems could be other than causal. Furthermore, the relationship between low level radiation and reduction in birth weight has been demonstrated in the laboratory. There is no question that low levels retard growth in animal litters, and, by inference from studies of children exposed in Hiroshima and accidentally to therapeutic radiation, in man. Furthermore, it has been observed in a series of about 1000 pregnant mothers irradiated in the course of regular pelvic X-rays (which had been prescribed for all pregnant women studied by Dr. M. L. Griem at the University of Chicago in the mid 1940's), that their offspring showed a significant increase in all types of illnesses and defects. Note that no selection of patients had been made in this study; every pregnant woman who requested normal prenatal care was irradiated. Similarly, no selection based on difficulties before or during pregnancy was involved in the case of some 800 pregnant women given tracer-doses of iron-59 in a study of nutritional requirements by

P. F. Hahn and co-workers at Vanderbilt University in the late 1940's. Here again a significant excess of leukemia and other cancer cases were observed among the 679 offspring (P = 0.03), despite the extremely small fetal doses that ranged from as little as 35.9 millirads to 1,780 millirads, comparable to doses received in many fallout situations and diagnostic X-rays [38]. Thus, it seems extremely unlikely that any other conclusion can be drawn than that low level radiation produces cancer, leukemia, and retarded growth leading to increased sensitivity to respiratory and other infectious diseases.

Question: T. Sterling, Department of Applied Mathematics and Computer Sciences, Washington University

It is true that Dr. Sternglass has used some poor data and some good data. It is also true that he has deferred to the judgment of recognized experts. For example, Dr. Stewart's data is based on a self selected sample and possibly biased. The thymus data (that is, children radiated for "thymus" disease when infants, and followed in a prospective study) has many of the same flaws pointed out ad nauseum by Saenger, Silverman and myself (E. L. Saenger, F. N. Silverman, T. D. Sterling, and M. E. Turner, "Neoplasia following therapeutic irradiation for benign conditions in childhood," *Radiology*, Vol. 74 (1960), pp. 889–904). *But*, the confrontations of Doctors Sternglass and Totter are part of a pattern. In the last 15 years we have been in controversy—to mention just a few: the birth control pill, low dose radiation, smoking, and now, pesticides and others. These controversies are based on a solid base of opinions and very little "hard" data. Constantly we review reviews. What are needed are (1) mechanisms to review data, and (2) authoritative statements of the kinds of data needed for inferences in the areas of controversy in question.

The American Statistical Association has had a splendid record for performing such public services through special commissions. Another source for authoritative criteria would be the newly formed section on Biostatistics of the National Academy of Science—National Research Council. They ought to be asked to consider such questions and act on them.

Reply: E. J. Sternglass

I am in full agreement that this information should be examined by the NAS, and it is my understanding that they are in the process of doing so. As to the data by Stewart and MacMahon, it is unlikely that some unrecognized factor crept into their selection of patients. That the very factors which epidemiologists are trained to recognize should have escaped the scrutiny of such noted epidemiologists is a remote possibility, which in the case of as serious a question as this seems out of place.

Question: J. R. Totter, Division of Biology and Medicine, Atomic Energy Commission

I have never before commented on Dr. Sternglass' presentation because I felt that he had so obviously and flagrantly misused data that his work should not be dignified by serious scientific comment. As statisticians or experimental biologists, you know that even in very well controlled experiments the data never fit the hypothesis being tested so beautifully as the data Dr. Sternglass has presented. I believe, therefore, that he has convicted himself of selection of data to fit his hypothesis. I shall mention only three examples.

He presented Stewart and Kneale's dose response curve for childhood cancers but did not mention the data from ABCC which appears to be totally at variance with it. Dr. Stewart's data was based on about 1800 person rads while the ABCC data was from about 35,000 person rads and, furthermore, was a relatively random sample.

Secondly, he used as a base for infant mortality the years 1935–1950. The slope of the line before 1935 was approximately the same as during the "fallout" years.

Thirdly, he did not mention the rubella epidemic during 1964–1965 in connection with the Dresden data.

Reply: E. J. Sternglass

With regard to the data of Stewart and Kneale, it should be pointed out that rad doses under conditions of medical examinations with well defined X-ray factors are far more precisely determined than could be done retrospectively for the cases from Hiroshima and Nagasaki. Furthermore, Stewart and Kneale's data was based on 15×10^6 children born in England and Wales of which ten per cent were irradiated, yielding a study population of 1.9×10^6 irradiated infants, of which 13,000 developed cancer. Some 7000 of the latter were followed up. By way of contrast, in the case of the Hiroshima-Nagasaki survivors, a mere handful of leukemia cases were born to known survivors of radiation exposure the dose of which could be accurately estimated. Thus, the ABCC study is vastly less reliable than fetal X-ray studies. Finally, the ABCC studies suffer from the fact that fallout doses which descended on suburbs and the surrounding area were considered to be zero, while E. T. Arakawa (see *New England Journal of Medicine*, Vol. 263 (1960), pp. 488–493) estimated that doses of 100 rads were experienced in the suburbs of Nagasaki from fallout alone. Thus, there exists a great uncertainty in both the exposure of the proximate Japanese population, and even of the so-called control population which supposedly (according to the ABCC) was not irradiated. From all these considerations, we must conclude that the ABCC data are far inferior to that obtained in fetal X-ray studies.

As to the choice of the baseline, 1935–1950, the choice was not mine. It was selected by Moriyama of the USPH Service, the National Center for Health Statistics, in his analysis of changes in trends in infant mortality which he first identified in the 1960's. Furthermore, this slope has now resumed its early value since the end of testing, and the totally unexpected renewed decline of infant mortality has followed the gradual decrease in radioactivity in the environment.

With regard to the question of the occurrence of *rubella* epidemics as an alternative explanation of the rises in infant mortality, note that such epidemics of childhood infectious diseases are in fact expected on the basis that the fetus and embryo are weakened by exposure to radiation so that the newborn has reduced ability to fight off infections of all types.