MASTER

BNL 16613

CONF-720310--1

STERNGLASS: A CASE HISTORY

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RECEIVED BY TIC APR 3 1972

Presented at the
Atomic Industrial Forum
Conference on Nuclear Public Information
Century Plaza Hotel, Los Angeles, California
March 5-8, 1972

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ABSTRACT

In recent years Dr. Ernest Sternglass has repeatedly questioned the AEC's limits for the radiation exposure of the public from the effluents of nuclear facilities. In several reports he has related the incidence of excess infant mortality adjacent to a number of these facilities, including nuclear power reactors, a fuel reprocessing facility, nuclear research and development laboratories, and college educational and testing reactors. On this basis he has called for the lowering of standards, a moratorium on the construction and operation of power reactors, and for extensive epidemiological studies to search for low-level radiation effects. Sternglass' current arguments are an extension of those he has previously made with regard to fallout and infant mortality.

A review of most of Sternglass' fallout-related presentations and of the accompanying commentary discloses much scientific disagreement with his hypotheses and questioning of the mechanisms adduced. A comparison of extended time series data for infant mortality with that for effluent releases from five principal facilities implicated by Sternglass, indicates that his correlations are instances of year to year statistical fluctuations about long term trends that do not support his arguments.

On the basis of established dose-effect relationships, the average population doses produced by nuclear facility effluents are found to be orders

*Research carried out in part at Brookhaven National Laboratory under contract with U. S. Atomic Energy Commission.

of magnitude too small to produce the claimed mortality. The explanatory mechanisms adduced by Sternglass are not confirmed by experimental research, and depend on intakes of radioactivity into the body which cannot be demonstrated. Infant mortality appears to be so strongly correlated with other variables such as socio-economic circumstances, as to obscure the possibility of making meaningful studies of low-level radiation effects of nuclear facility produced exposures.

INTRODUCTION

The first civilian nuclear power reactor in the United States, the Shippingport Atomic Power Station, became operational in 1957. During the next decade some fifteen additional light-water-cooled power reactors went on-line at sites across the United States, with minimal public apprehension related to the risks occasioned by their routine radioactive effluents.

In the late 1960's a growing public concern for the quality of the environment became manifest. Concurrently, unchallenged applications for the construction and operation of power reactors became the exception rather than the rule. The initiatives for these challenges were for the most part made by local environmentalist and conservation groups. However, they have called upon a small cadre of nuclear critics from the scientific community for expert support of their arguments, both in public hearings and in formal licensing proceedings.

Dr. Ernest J. Sternglass, a radiation physicist at the University of Pittsburgh, has been among the foremost of these critics. In an extension of his previous much publicized arguments with respect to fallout, he has more recently turned his attention to infant mortality in the vicinity of nuclear facilities in general, with particular emphasis on nuclear power reactors.

On one or more recent public appearances as a scientific expert, Sternglass has presented the findings of reports⁽¹⁻¹²⁾ in which he has related the incidence of excess infant mortality to the routine radioactive emissions from several boiling water reactors (BWR's) including Dresden I at Morris, Illinois, Big Rock near Charlevoix, Michigan, Humboldt Bay at Eureka, California; from several pressurized water reactors (PWR's) including Shippingport at Shippingport, Pennsylvania and Indian Point I at Buchanan, New York; from the reprocessing facility operated by Nuclear Fuel Services at West Valley, New York; from the Atomic Energy Commission's

nuclear research and development facilities including the Hanford Atomic Production Works at Richland, Washington and Brookhaven National Laboratory at Upton, New York; and from the small educational and testing reactors at the Pennsylvania State University in State College, Pennsylvania, and at the University of Illinois in Urbana, Illinois, and at the Gulf General Atomic Corp. research laboratory in San Diego, California.

In common with most of the other more outspoken nuclear critics, Sternglass has not utilized first-hand research to buttress his claim that the effects of low-level radiation have been underevaluated in the U. S. Atomic Energy Commission's protection standards⁽¹³⁾ of 500 milliroentgens per year to individuals adjacent to nuclear facilities and 170 milliroentgens per year average to large populations. These essentially follow the recommendations of the International Commission on Radiological Protection⁽¹⁴⁾ and the National Committee on Radiation Protection and Measurements⁽¹⁵⁾. His principal evidence consists of his interpretations of yearly infant mortality data, as reported in the U. S. Vital Statistics and by individual state health departments.

In several studies he has made time series correlations of infant mortality with nuclear facility effluent releases, and has thus hypothesized a relationship between them. Dr. Sternglass has not defined a precise dose-effect relationship, nor has he indicated a mechanism to account for the extreme sensitivity of the infant in utero which his observations imply. Rather, in his current studies he has essentially repeated suggestions made earlier in his similar studies of fallout and infant mortality, that unsuspected high concentrations of effluent radionuclides may occur in certain glands of the body that are critical to reproduction and development, such as the gonads and the pituitary.

As was the case with his fallout and infant mortality claims, many aspects of Sternglass' current reactor-related studies have been strongly disputed. For the most part this argument has taken place in public hearings and proceedings. Little if any of it has appeared in scientific channels, where it could be widely subject to the peer group evaluation customarily used to establish the validity of a controversial scientific hypothesis.

Although it has received little scientific review, Sternglass' arguments, along with those of his fellow critics, appear to have been effective in creating a climate of public concern about radiation protection standards, particularly in the context of their application to nuclear power reactors. The AEC has recently proposed⁽¹⁶⁾ a reduction in these limits, specifically for exposures of the public from light-water-cooled power reactor effluents, to 1% of the above amounts. Although denied by the Commission, in the minds of many persons⁽¹⁷⁾ this proposal appears to be a response to critic-generated pressures.

On various occasions Sternglass has called for a substantial lowering of radiation protection standards, for the discontinuance of the operation of all BWR's, for a moratorium on the construction of additional reactors and other nuclear facilities, and for the extension of the AEC's proposed limits for light-water-cooled power reactors to all other nuclear facilities. This has been coupled with a call for far more extensive epidemiological studies than his, to be conducted by independent scientists (not connected with agencies responsible for standards setting or enforcement) to search for low-level radiation effects. In a recent popular magazine article⁽¹⁸⁾ Sternglass was portrayed as a "controversial scientist, waging a stubborn battle against nuclear pollution" who "raises serious questions about our safety, the health of our children and the future of babies yet unborn". In

this article, the authors were critical of the "AEC's reluctance to investigate Dr. Sternglass' findings".

The foregoing leads to several related questions:

1. Do the data support Sternglass' call (and the AEC's current proposals) for lowering radiation exposure limits?
2. Do they substantiate calls for emergency actions, such as a shutdown of existing power reactors and for a moratorium on power reactor construction?
3. Do they constitute a reasonable basis for making more extensive epidemiological studies to search for low-level radiation effects?

In what follows, from an examination using the Sternglass methodology of vital statistics and effluent release data from several of the facilities adjacent to which he has found excess mortality, from an examination of the related effluent doses and of the indicated incidence of infant mortality in the light of established dose-effect relationships, and by a consideration of other factors which have been correlated with infant mortality, answers in the negative are suggested.

Sternglass has relied heavily on his previous output dealing with infant mortality and low-level radiation to support his recent presentations. A review of it therefore seems essential to an overall understanding of his current position.

X-RAYS, FALLOUT AND INFANT MORTALITY

Sternglass has for some time been particularly concerned about the sensitivity of the foetus to irradiation in utero. As far back as 1963, he argued⁽¹⁹⁾ that experimental evidence previously set forth by Stewart and MacMahon on the effects of prenatal diagnostic x-ray exposure indicated a linear response and the absence of a threshold for the development of childhood cancer and leukemia, for total doses well below one roentgen. At that time he also suggested that this sensitivity should make it possible to observe

the effects of comparable exposure in utero to normal background and to fallout. It should be noted that Sternglass was shortly thereafter criticized by several scientists including MacMahon⁽²⁰⁻²²⁾ for making numerous arbitrary assumptions to support his argument, as well as for ignoring other studies using other methods for selecting controls.

Although Sternglass does not appear to have followed up his earlier suggestion with any studies of background radiation level effects, he subsequently made a number of presentations⁽²³⁻³⁰⁾ in which he associated radioactive fallout with childhood leukemia and/or infant mortality. In these presentations he depicted increases in successive yearly mortality rates as being fallout-related, considering years prior to and years in which or after which atmospheric nuclear weapons tests were conducted. However, his principal evidence for this relationship was based on the occurrence of a less steep decline in infant mortality after the advent of large scale weapons tests around 1950, than the decline during the period from 1935-1950. By comparing the post 1950 data with a projection of the 1935-1950 rate, he arrived at numbers of "excess" infant deaths, which were graphically correlated in time with current or previous years in which weapons tests had been conducted.

As a causal link, Sternglass postulated an extra effect of fallout, in addition to the external radiation effects of in utero exposure of the foetus from its and/or its mother's internal body burden of short-lived fallout nuclides. He cited a 1963 study by Luning in support of a hypothesis that ^{90}Sr and its daughter ^{90}Y posed an unsuspected potential for "genetic" damage to the newly developing foetus.

As indicated by Graham and Thro⁽³¹⁾ and Boffey⁽³²⁾, in their reviews of this phase of Sternglass' activities, this development of his earlier arguments were extensively and vigorously challenged by other scientists⁽³³⁻⁴²⁾. He was charged with making arbitrary assumptions, particularly in his choice

of baselines and of comparison years. His use of epidemiological statistics and his neglect of other probable causes for infant mortality were also questioned. In addition, Luning is reported by the above reviewers to have repudiated the pertinence of his investigations to Sternglass' hypothesis.

As was indicated by some of his critics at that time, Sternglass had on some occasions suggested that the relationship between his infant mortality and fallout levels was an immediate one, and on other occasions that it had about a five-year lag. The excess infant mortality for the United States during the 1950's and 1960's, as arrived at by Sternglass, is shown in Figure 1. For comparison purposes, the pattern of the cumulative fallout in the United States, as suggested by external background measurements previously reported⁽⁴³⁾ for Brookhaven National Laboratory on Long Island, has been added. Whichever is postulated, an immediate or five-year lag, the fit between the patterns of excess mortality and background seems less satisfactory for the post 1960 data, than for the earlier period for which Sternglass first propounded a relationship.

Since it represented an independent counterpart approach, rather than a critique of Sternglass' fallout and infant mortality studies, Shaw and Smith's study⁽⁴⁴⁾ of ^{90}Sr and infant mortality in Canada has perhaps cast the greatest doubt on his fallout findings. In this study they found that, although ^{90}Sr levels there were somewhat higher than in the United States, no association was apparent between them and provincial or overall Canadian infant mortality.

A review of the literature relative to the controversy over fallout and infant mortality discloses no authoritative scientific support at that time for Sternglass' case beyond statements^(31,32) to the effect that the possible connection between fallout and infant mortality should be fully investigated. More recently⁽¹²⁾ Sternglass has indicated that an unpublished epidemiological

study by Lave et al.⁽⁴⁵⁾ has also found infant mortality to be "strongly associated with strontium-90 levels in milk". Although these studies do suggest a positive correlation, it does not appear sufficient to explain the "excess" infant mortality Sternglass has postulated. In addition, the authors indicate that their estimates may not be substantiated by additional analyses, since the data employed were incomplete, inadequate and possibly inconsistent.

NUCLEAR FACILITY EFFLUENTS AND INFANT MORTALITY

Most recently, Sternglass has shifted his attention to nuclear facilities and to an examination of infant mortality rates in their vicinities. In a series of presentations^(2-4,6,11), he has made comparisons between infant mortality rates for pre-startup or pre-peak release years with the rates for post-startup or peak release years, for more than a dozen nuclear facilities. These comparisons have been made for counties or states in which the facilities were located, in relation to those of adjacent counties or states. He has found one or more instances of a correlation between infant mortality and the effluent releases associated with the routine operation of most of the facilities he has considered.

It is important to an evaluation of Sternglass' allegations that one understands the use of vital statistics data and the central assumptions that can be made about the statistical variation these data exhibit as they are observed in a time series. A discussion of this topic can be found in the Vital Statistics of the United States⁽⁴⁶⁾. It suggests that the numbers of births or deaths represent complete counts of such events and as such are not subject to sampling error. However, when the figures are used for such purposes as the comparison of rates over a time period or for different areas, the number of events that actually occurred may be considered as one of a large series of possible results that could have arisen under the same

circumstances. The probable range of values may then be estimated from the actual figures according to elementary statistical assumptions.

From these assumptions, it follows that when the number of events is small they may be assumed to follow a Poisson probability distribution. Accordingly, the standard error of an observed number of live births, B_1 , may be taken to be $\sqrt{B_1}$, of deaths, D_1 , to be $\sqrt{D_1}$, etc. The standard error of mortality rate, $M_1 = \frac{D_1}{B_1}$, may be taken to be $\sqrt{\frac{M_1}{B_1}}$, where by definition of infant mortality, D_1 includes those occurring between 0 and 1 year. The Vital Statistics guidance is that the difference between the two rates may be regarded as statistically significant if it exceeds two standard errors, that is (2) $\sqrt{\frac{M_1^2}{D_1} + \frac{M_2^2}{D_2}}$.

Some estimates of anticipated variations in mortality rates and of the difference required to establish statistical significance may be useful in evaluating what follows. To a first approximation, the birth rate in the United States during the period under consideration was about 20 per 1,000 total population, and the 0-1 year infant mortality rate was about 20 per 1,000 live births. Using these approximations, projections of the total yearly births, the total infant mortality, the anticipated two standard deviation error for the assumed infant mortality rate (20/1,000 live births), and the required difference in rates to demonstrate statistically significant departure from the assumed mean have been calculated, for a number of census units ranging in population from 2,500 to 1,000,000. The results are shown in Table I. The indicated differences are assumed to be particularly applicable to assessing significant differences in mortality rate from year to year within a given locale, in which the total population and total births change only slightly.

In the paper⁽⁹⁾ which he presented before the Health Physics Society in 1971, Sternglass made the following statement:

TABLE I

Estimated Difference in Infant Mortality Rates
Required to Establish Statistical Significance

Total Population	Total Projected Yearly Births at 20/1,000 Total Population B	Total Projected Infant Mortality at 20/1,000 Live Births D	Infant Mortality Rate/1,000 Live Births with Error $= \pm (2) \sqrt{\frac{M_1 (10^3)}{B_1}}$	Required Difference in Rates for Statistical Significance $= (2) \sqrt{\frac{M_1^2}{D_1} + \frac{M_2^2}{D_2}}$
2,500	50	1	20 ± 40	57
5,000	100	2	20 ± 28	40
10,000	200	4	20 ± 20	28
25,000	500	10	20 ± 13	18
50,000	1,000	20	20 ± 8.9	13
100,000	2,000	40	20 ± 6.4	8.9
250,000	5,000	100	20 ± 4.0	5.7
500,000	10,000	200	20 ± 2.8	4.0
1,000,000	20,000	400	20 ± 2.0	2.8

NOTE:
$$\sigma_{M_1} = \sqrt{\left(\frac{\delta M_1}{\delta D_1}\right)^2 (\Delta D_1)^2 + \left(\frac{\delta M}{\delta B_1}\right)^2 (\Delta B_1)^2} = \frac{D_1}{B_1} \sqrt{\frac{1}{D_1} + \frac{1}{B_1^2}}$$

if $B_1 \gg D_1$,
$$\frac{D_1}{B_1} \sqrt{\frac{1}{D_1} + \frac{1}{B_1^2}} \approx \frac{D_1}{B_1} \sqrt{\frac{1}{D_1}} = \sqrt{\frac{M_1}{B_1}}$$

and

$$\begin{aligned} \sigma (M_1 - M_2) &= \sqrt{(\Delta M_1)^2 + (\Delta M_2)^2} \approx \sqrt{\frac{M_1}{B_1} + \frac{M_2}{B_2}} \\ &= \sqrt{\frac{M_1^2}{D_1} + \frac{M_2^2}{D_2}} \end{aligned}$$

"A similar pattern of increased infant mortality has now been observed around three commercial nuclear power reactors of the boiling water reactor type"

and he went on to identify Dresden I, Humboldt Bay and Big Rock Point as being responsible for excess infant mortality. This evaluation of Stern-glass' claims will again discuss some of the data he presented in that paper. It is supplemented by the presentation of a more complete time series, in order to put it into perspective in terms of fluctuations and a more comprehensive statistical analysis.

With regard to the Dresden I reactor, located in Grundy County, Illinois, Sternglass showed for the counties adjacent to the reactor that, corresponding to an increase in the yearly release of gaseous effluents, the infant mortality rate increased substantially in the year 1966, as compared to 1964. Included were control counties in northwestern Illinois. These data are shown in the left hand portion (1966/64) of Figure 2 (which corresponds to Sternglass' Figure 17). In Grundy the percentage increase was 141% for 1966 over 1964. Was this a significant matter? At the 95% confidence level, the percentage change was $141 \pm 216\%$. The gaseous emissions from the reactor for the various years are also included. Examination of the figure indicates that for the years 1964 and 1966 (chosen by Sternglass) the gaseous emissions increased from 500 to 700 curies, an increase of 40%.

Table II is based on information offered by Sternglass as evidence that marked changes occurred in infant mortality for Grundy County and for some adjacent counties such as Livingston and Kankakee, whereas the so-called control counties did not show such changes. In addition to the data shown originally, the births and deaths in the adjacent counties and in the control counties have been totaled. It can be seen that the adjacent counties increased by $(16.8 \pm 22)\%$ and controls by $(1.1 \pm 20.2)\%$. If this increase in infant mortality is actually due to a 40% increase in radioactive gaseous

TABLE II
Infant Mortality Changes 1964-1966 Near Dresden, Illinois

County	1964			1966			$\frac{1966-1964}{1964} \times 100$
	Deaths	Births	Rate/1000	Deaths	Births	Rate/1000	
Grundy	7	442	15.8	18	474	38.0	$(141 \pm 216)\%$ *
Livingston	6	728	8.2	12	608	19.7	+140.
Kankakee	41	1,976	20.7	54	1,830	29.5	+ 43.
Will	109	4,920	22.2	100	4,292	23.3	+ 5.
LaSalle	41	2,176	22.5	39	1,858	21.0	- 7.
Kendall	11	460	23.9	7	422	16.6	- 31.
Adjacent Sum	223	10,702	20.8	230	9,486	24.3	$(16.8 \pm 22)\%$
Ogle	16	854	18.7	20	808	24.8	+ 33.
Winnebago	122	5,002	24.4	122	4,788	25.5	+ 5.
Henry	17	930	18.3	16	862	18.6	+ 2.
Stephenson	25	978	25.6	20	808	24.8	- 3.
Knox	22	1,130	19.5	17	946	18.0	- 8.
Lee	17	658	25.8	9	594	15.2	- 41.
Control Sum	219	9,552	22.9	204	8,806	23.15	$(1.1 \pm 20.2)\%$

Source: E. Sternglass Table I of Ref. 12, except addition of sums of numbers for adjacent and control counties and uncertainties in percentages indicated.

* If $M = \frac{D}{B}$, and $P = \frac{M_2 - M_1}{M_1} 100$, $\Delta P = 100 \frac{M_2}{M_1} \sqrt{\frac{1}{D_1} + \frac{1}{B_1} + \frac{1}{D_2} + \frac{1}{B_2}}$

emissions, then it should be even larger for a larger percent increase in emissions. But this expectation is contrary to fact. If, instead of 1964, the year 1960 (in which essentially no emissions occurred) or 1963 (in which only 90 kilocuries were emitted) are chosen for comparison with 1966, one finds that the adjacent counties decreased relative to them. In addition to the results for 1966 relative to 1964, Figure 2 shows comparisons for 1966 relative to 1963 and 1960. It is apparent that the logic which gave Sternglass the "large" 1966/1964 effect, yields inconsistent results when applied to 1966/1960 or 1966/1963. When compared with the closest corresponding row of Table I, it is also apparent that none of the infant mortality rates shown departs significantly from the overall averages of slightly more than 20 per 1,000 live births.

The results of any analysis of a larger sample of years, those from 1955 through 1967, for which Vital Statistics records were available, are summarized in Table III and Figure 3. To minimize the fluctuations because of small numbers, the mortality rates for the combined counties immediately surrounding the reactor were chosen, and similarly the rate for the sum of the six Sternglass control counties. It is apparent that 1964 was the year of smallest infant mortality rate, of all the years 1955 to 1967. Use of this year would therefore give the largest numerical change if one used ratios in the same manner as Sternglass has. However, it appears more consistent with the increase in releases to compare 1966 with the years 1960 or 1963. One might also inquire about a larger control area, both population-wise and geographically. The rural counties are primarily white. It therefore seems appropriate to use the white population of Illinois, since its infant mortality rate is only half that of the non-white population. Local trends due to geographical peculiarities within the state would presumably be averaged out by taking its entire white population as a control.

TABLE III
Dresden I Infant Mortality Comparisons *

Year	Infant Death Rate			Infant Death Rate			
	Adjacent Counties**	Control Counties***	<u>Adjacent Counties</u> Control Counties	Illinois Total	Illinois White	Illinois Non-White	<u>Adjacent Counties</u> Illinois White
1955	27.1	22.8	1.190	24.8	22.0	42.1	1.23
1956	27.2	23.4	1.162	24.5	21.8	40.8	1.25
1957	24.8 ± 3.0	24.3 ± 3.0	1.019	25.5	22.2	44.0	1.111
1958	24.3	24.2	1.004	24.9	22.4 ± 0.68	38.7	1.085
1959	23.5	26.9	0.874	25.0	22.4	38.6	1.050
1960	26.0	25.6	1.014	25.0	22.2	39.6	1.17
1961	24.4	22.4	1.089	24.3	21.8	37.2	1.12
1962	21.1	22.6	0.934	24.0	21.2	37.6	0.995
1963	24.0	23.1	1.039	23.9	20.9	38.7	1.15
1964	20.8 ± 2.6	22.9 ± 3.2	0.908	25.1	21.4	43.5	0.97
1965	26.4 ± 3.2	21.5	1.228	25.6	21.4 ± 0.70	44.5	1.23
1966	24.3 ± 3.2	23.2	1.045	25.2	21.2	41.9	1.15
1967	21.6	23.4	0.925	23.6	20.4	36.9	1.06
1968†	23.0	19.4	1.185	-	N.A.	-	-
1969†	21.4	23.3	0.920	-	19.1	-	0.92
1970†	24.6	19.6	1.254	-	18.5	-	1.25

* Note: In 1969 for Grundy and Livingston counties, infant deaths consisted of 99.8% white children. The 6 adjacent counties had 92.4% white deaths and the controls had 92.9% white deaths. Illinois had 80.2% white deaths. Source: Vital Statistics of Illinois, 1969.

** Adjacent Counties: Grundy, Livingston, Kankakee, Will, LaSalle and Kendall

*** Sternglass Control Counties: Ogle, Winnebago, Henry, Stephenson, Knox and Lee

† Data for 1968, 1969 and 1970 from Vital Statistics, Illinois, 1969, and supplemental information provided by C. Bridger, Dept. of Public Health, State of Illinois.

In any event, when divided by the Illinois white population rate, the adjacent county death rate does not show any increase after plant startup. Rather the rate decreases for both cases, when compared with either the rate for Sternglass control counties or for the white population of the state.

Continuing to other nuclear power stations in this same presentation, Sternglass stated:

"Identical patterns of rises in infant mortality have now been found for two other boiling water reactors, as shown in Figure 19 for the group of small counties around the Big Rock Point Plant in Michigan, and in Figure 20 for the Humboldt reactor near Eureka in Humboldt County, Northern California. Again there is a sharp halt in the normal decline of infant mortality following release of large quantities of gaseous activity comparable to those released at the Dresden Reactor, while more distant areas continue their decline, shown for the Humboldt area in Figure 21."

At the top of Figure 4, the infant mortality rate for the ten nearest counties to the Big Rock Point Reactor for the years 1955-1967 is shown. The 95% limits of confidence are shown, and in addition the rate for the white population of the State of Michigan is given. At the bottom the gaseous emissions for the same years are shown. It is evident that for the years prior to startup, the infant mortality rate in the adjacent counties tended to be approximately one standard deviation higher than for the white population in the state. But after reactor startup one finds that the adjacent county death rate approximated that of the state. The middle section of Figure 4 depicts the ratio of the mortality rates for the adjacent counties divided by the statewide white infant mortality rate. It appears that instead of a sharp halt in the normal decline in the rate for the nearby counties, as stated by Sternglass, if anything there was in fact an accelerated decline after reactor startup. For example, for the three years 1960, 1961 and 1962, just prior to reactor emissions, the ratio is $1.25 \pm .12$, whereas by comparison, for the years 1965, 1966 and 1967,

straddling the years of greatest gaseous emissions, the ratio is $1.01 \pm .16$. These data are summarized in Table IV.

In the center of Figure 5, the percent change in infant mortality rates for counties near the Humboldt Bay Reactor in the years 1965 over 1964 is shown. It is similar to Figure 8 in Sternglass' presentation. From it one obtains the impression that infant mortality increased near the reactor, whereas for more distant counties it decreased. Taking the year 1964, in which emissions were almost zero, as the normalizing year, and comparing it as Sternglass has with 1965 in which the emissions were approximately 300 kilocuries, seems reasonable enough. But what happens when one compares the mortality rates for other years with those for 1964? Figure 5 also shows the result of doing this. In 1967, when emissions were three times larger than in 1965, the three nearest counties had even smaller death rates than before the reactor started significant emissions. Note that with no emissions, 1963 relative to 1964 gives somewhat similar results to the years chosen by Sternglass. The changes appear to be the typical statistical fluctuations in vital rates.

The infant mortality rate for the years 1958-1969 are shown in Figure 6. Included are the rates for Humboldt County, in which the reactor is located, the aggregate mortality rates for the nine nearby counties chosen by Sternglass, and the rates for the white children in the state. The 1961 point for Humboldt County also shows the two standard deviation range. These data are summarized in Table V.

The years 1964 and 1965 chosen by Sternglass for comparison were the years in which the largest change in infant mortality occurred in Humboldt County. The number of deaths in this county is small, typically about 50 deaths per year. By reference to Table I, a considerable scatter in the Humboldt County points would be anticipated. However, after 1964 the

TABLE IV

**Infant Mortality Rates/1000 for Counties
Near Big Rock Point, Michigan***

Year	Ten County Rate	Michigan White	<u>Ten County Rate</u> <u>Michigan White Rate</u>
1955	24.2	23.2	1.04
1956	26.1	22.9	1.14
1957	28.9 $\pm$ 6.4	23.0	1.26 $\pm$ 0.32
1958	25.8	23.3	1.11
1959	24.4	23.0	1.06
1960	26.0	22.1	1.18
1961	30.1	22.6	1.33
1962	27.6	22.4	1.23
1963	25.1	21.5	1.17
1964	23.5	21.0	1.12
1965	19.9 $\pm$ 5.8	21.6 $\pm$ 0.8	0.92 $\pm$ 0.28
1966	20.1	20.0	1.00
1967	22.2	19.8	1.12

*Used data from U.S. Vital Statistics

Humboldt County rate appears smaller and closer on the average to the death rate for the state, than it was before reactor emissions commenced. For the nine nearby counties it is evident that the rate is statistically close to that for the white children in the state. However, prior to 1963 the adjacent county rate tended to be significantly above the white state-wide rate. These qualitative statements for the nearby counties are better indicated by the plot in the middle of Figure 6, which gives the ratio of the adjacent counties infant death rate to that of the state's white population. It is evident that this ratio was less from 1965 onward than from 1958 to 1964. This observation is opposite to the impression given by the Sternglass data.

Other allegations about infant mortality in metropolitan New York and environs due to the operation of Indian Point I and the Brookhaven Graphite Research Reactor (BGRR) were presented⁽⁸⁾ by Sternglass at the Shoreham Atomic Safety and Licensing Board (ASLB) hearings. A considerable listing of tables of data for the years 1958-1969 of infant mortality in many New York State counties and also a table, which gave the radioactive waste discharges from Indian Point Unit No. 1 for the years 1963-1969 were included. Several graphs based on the tabulated data were included, and mention was made of statistical fluctuations, correlation coefficients and levels of significance. As a means of cancelling out socio-economic differences between the reactor environs in the Westchester-Rockland area and that in any distant control county, Sternglass indicated:

"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 socio-economic characteristics."

In Figure 7 the calculated ratio of infant mortality rates in Westchester plus Rockland to that in Nassau for the years 1969 is shown. The least squares

fitted straight line has a negative slope, suggesting that the ratio of infant mortality near the Indian Point Reactor, when compared to Nassau, was larger in 1955 than in 1969. The yearly gaseous emissions are also indicated. It may be noted that these are miniscule compared to the previous cases. Sternglass selected 1966 and compared it with 1961. When many years data are examined, it appears that the year 1965 had the smallest mortality ratio of any before startup, while 1966 had the largest mortality ratio. The fluctuations for all fifteen years fall within two standard deviations of the trend, and there is an inverse correlation between gaseous emissions and infant mortality near the reactor. Sternglass asserted in his testimony and showed graphically that if one chose the years 1961 and 1966 for comparison, and calculated the percentage change in infant mortality for selected counties, that the mortality changes decreased with a "one divided by distance" ($\frac{1}{D}$) behavior. If radioactive gaseous emissions were causative this might be a reasonable first assumption, and on its face, it could be persuasive. The percentage change of the infant mortality of 1966 over 1961 in the various county groups selected by Sternglass, and which are at various distances to the north and south of Indian Point I, are shown in Figure 8. The changes can be seen to be greatest near the reactor and decrease with distance, as asserted by Sternglass. Pursuing this logic further, since in 1968 compared to 1962 the increase in gaseous reactor emissions was even greater (59.7 curies) than for 1966 compared to 1961 (36.4 curies), greater magnitude changes (167%) would be expected, but the 1/D dependence should be the same. The results, as also shown in Figure 8, are otherwise, suggesting that any pattern in these changes is an artifact of the annual variation in mortality rates.

The dangers in drawing inferences from selected comparisons in vital rate time series were well illustrated when in this same presentation

Sternglass associated "the anomalous rise of infant mortality in Suffolk between 1953 and 1960 with the reported activity produced at Brookhaven and the fraction released into the streams". The annual infant mortality rates for Suffolk County from 1949 to 1969 are shown in Figure 9 (the BGRR operated from 1951-1968). Also shown are similar data for neighboring Nassau County on Long Island, and for New York State, minus New York City. It is difficult to ascertain what is "anomalous" about the Suffolk data. The curves appear consistent with the anticipated annual fluctuations and with the expectation that as the population unit increases these fluctuations decrease. In 1950, Suffolk County was still largely rural, with a population of 276,129. By 1960 this had increased to 666,742, and by 1970 to 1,127,030. For the corresponding years the Nassau County populations were 672,765, 1,300,171, and 1,428,838, while the New York State populations (except New York City) were 6,938,235, 9,000,320, and 9,346,703.

The yearly amounts of BNL liquid effluent activity, which Sternglass associated with the increases in infant mortality between 1953 and 1960, are also shown in Figure 9. The Peconic River flows easterly through very sparsely settled territory. Most of Suffolk's population was and is located to the west of the Peconic water shed. In addition, this stream is nowhere used for drinking or irrigation. The maximum possible exposure attributable to Brookhaven effluents in it was a few millirem/year to the consumers of fish obtained by a few sports anglers in the comparatively unproductive upper reaches of the stream. The average dose to infants in Suffolk County from this source was essentially zero.

Sternglass appears to have incorrectly assumed that the gaseous and liquid effluents at BNL were in correspondence. The average yearly exposure rates at the BNL perimeter, primarily from the BGRR effluent ⁴¹Ar, are also shown in Figure 9, as are the external backgrounds, including the increments

from fallout as measured at the same location. A comparison of the latter with the infant mortality in Suffolk County shows, if anything, an inverse correlation. Infant mortality in Suffolk declined during the early 1960's when the BNL effluent and fallout doses were at their maximum rates.

In the preceding discussions, methods corresponding in principle to those utilized by Sternglass for investigating infant mortality and the effluent releases have been employed. When the data are analyzed in the context of an extended time series, most of the comparisons cited by Sternglass seem readily explainable as normal statistical fluctuations in infant mortality rates.

In several cases there are logical reasons for selecting other portions of the data, which happen to show an inverse correlation between emissions and infant mortality. On the reasoning that Sternglass has employed, this ~~could lead~~ to the conclusion that low-level radiation decreased infant mortality. It seems doubtful that any scientist propounding this notion on such limited evidence would have been seriously listened to by either his peers or by the public.

Sternglass' studies with regard to one or more individual nuclear facilities adjacent to which he has found excess infant mortality have been examined by others⁽⁴⁷⁻⁵³⁾. Their conclusions are in essential agreement with those presented herein. He has also been charged with presenting selected data^(51,54), with changing facts⁽⁵⁵⁾, and with making misleading comparisons⁽⁵⁶⁾. Stewart⁽⁵⁷⁾ has also questioned Sternglass' assumptions and interpretations of her data.

Little if any scientific support of Sternglass' recent studies has been apparent, beyond some indications⁽¹⁸⁾ that his data are suggestive and should be explored. Sternglass has recently cited a presentation by DeGroot⁽⁵⁸⁾ as

a separate detection of infant mortality in the vicinity of Dresden I, Indian Point I and Brookhaven, even though the latter summarized them as preliminary and inconclusive.

DOSE

If the Sternglass claim that he has detected a relationship between infant mortality and nuclear facility effluents appears to be questionable on statistical grounds, it seems even more so from dose "signal to noise" ratio considerations. He has claimed⁽⁷⁾ the "extra risk" of infant mortality at the presently permitted maximum exposure rate (500 mR/yr) is 61,880 deaths per million children born. If this is so, then the normal background radiation caused component of infant mortality rates should vary from about 10/1,000 in such states as Louisiana and Texas, where the background levels are about 75 milliroentgens per year, to about 25/1,000 in such states as Wyoming and Colorado where background levels exceed 200 milliroentgens per year⁽⁵⁹⁾. No such correlation of infant mortality with background is apparent. In the years 1960-64, inclusive, data published by the National Center for Health Statistics⁽⁶⁰⁾ indicated that for Texas and Louisiana the mortality rates were 27.1 and 31.0 per 1,000, whereas in Wyoming and Colorado they were 28.5 and 25.3.

Although natural background makes for the largest ascertainable variations in general population exposures, there are other systematic differences. For example, weapons testing related doses to persons in "dry" areas of the United States were estimated by the Federal Radiation Council⁽⁶¹⁾ to be about one-third to one-half those for people in "wet" areas, or for 1962 alone a difference in whole body dose of about 10 millirem between these areas. It does not appear that Sternglass has demonstrated an unequivocal correlation of infant mortality with it.

Seldom does Sternglass quantitatively consider actual dose received by

TABLE V
Infant Mortality Rates/1000 for Counties
Near Humboldt Bay, California*

Year	Nine Counties**	Humboldt County	California (White)	<u>Nine Counties</u> <u>California White</u>
1958	23.4	20.5	23.3	1.00
1959	26.2	26.0	22.8	1.19
1960	26.7 $\pm$ 3.2	25.6 $\pm$ 6.2	22.5 $\pm$ 0.52	1.19
1961	25.4	29.9	22.5	1.13
1962	26.4	28.0	21.9	1.20
1963	22.3	24.6	21.5	1.04
1964	23.3	18.4	20.8	1.12
1965	21.6	26.8	21.2	1.02
1966	20.8	17.9	20.0	1.04
1967	17.1	18.0	18.8	0.91
1968	17.6	17.9	18.5	0.95
1969	17.6	22.1	17.6	1.00

* Used data for 1958-1967 from U.S. Vital Statistics
for 1968-1969 from California Dept. of Public Health, Courtesy
of Mrs. M. V. Ruffin

**Deaths were almost all white children, e.g. in 1968 142 out of 143 infant
deaths were white children.

the population under consideration in his nuclear facility studies. In the one instance of Dresden, for which he cited nearby dose rates, according to Davis and Kahn⁽⁴⁷⁾ the rates were misrepresented as being 50 times greater than those given in the original source of the information. They also pointed out several other inconsistencies in Sternglass' use of their data.

Nowhere has Sternglass taken into account the average dose to the involved populations. Some calculated average gaseous effluent related doses to the population within 50 miles of a number of the facilities implicated for certain years by Sternglass are shown in Table VI, along with his indicated excess mortality or risk thereof.

If the effects Sternglass concerns himself with cannot be satisfactorily demonstrated at dose differences of 10-100 millirem per year, it is indeed difficult to understand how they can be discerned in connection with average population doses from nuclear facility effluents ranging from one to several orders of magnitude lower.

Even if one accepts Sternglass' postulated dose-effect relationship, although it is about 100 times larger than that derivable from data published by the ICRP^(64,65), the almost infinitesimal nature of the average population doses, as shown in Table VI, appear insufficient to produce the claimed excess infant mortality. Using a dose-effect relationship of 10 cases per 10^6 man-roentgens, Buck⁽⁶⁶⁾ has estimated that an accrued exposure of 3×10^7 man-rem would be required to observe radiation-induced leukemia. Even at a much larger dose-effect relationship, the accrued population doses shown in Table VI do not approach those at which observable additional infant mortality would be anticipated, above its base-line incidence (which is almost 1,000 times that for leukemia).

MECHANISMS

An unsatisfactory aspect of the entire corpus of Sternglass' allegations of excess infant mortality from low-level radiation is his inability to adduce

TABLE VI

Indicated Excess Risk or Mortality and Calculated Effluent Doses
to Populations in the Vicinity of Selected Nuclear Facilities

<u>Facility</u>	<u>Years</u>	Indicated Excess Risk or Mortality as <u>Indicated by Sternglass</u>	Effluent Dose Within 50 miles Average Total		<u>Ref. #</u>
			(millirem)	(man-rem)	
Big Rock	1966 - 67	+ 44.5% (~ 9)	0.1	6*	62
Brookhaven	1954 - 60	Unspecified Upward Trend	~ 0.1	~ 125**	43
Dresden	1959 - 68	2,500	0.025	140**	62
Humboldt	1964 - 65	+ 45%	1.1	69*	62
Indian Point: Westchester-Rockland New York City	1966	+ 41% (~ 100) + 26% (750)	< 0.002 ~ 0.00001	0.1*	62 62
Peach Bottom	Post 1967	Unspecified Upward Trend	< 0.001	3*	62
West Valley	1966 - 67	~ 200	< 0.1	-	63

* Calculated for the year during which excess mortality indicated.

** Calculated yearly average during period in which excess mortality is indicated.

a satisfactory radiation-induced mechanism and his neglect of other possible causes. A principal mechanism which he has suggested^(1,6,8,9) is the circulation in the body and uptake by the genetic organs and other sensitive glands of short-lived ^{90}Y , which presumably emanates from ^{90}Sr contained in the bones. As has been indicated earlier, Luning has disavowed the pertinence of his experimental investigations to this Sternglass hypothesis. Other investigators^(67,68) have been unable to find any indication of a transfer of ^{90}Y from bone to soft tissue. At the ASLB hearings on the Shoreham Nuclear Power Station, Goldman⁽⁶⁹⁾ made a review of the known studies of radioactive strontium in animals and its relevance to man, in none of which was there any indication of any "extra" genetic or infant mortality effects.

In several of his nuclear effluent related presentations^(6-7,8-9,11), Sternglass repeated earlier suggestions that radiation acts on the glands in such a way as to lead to a greater frequency of immaturity at birth, in turn leading to an increased susceptibility to infections and to the diseases of early childhood. A medical authority contacted by Graham and Thro⁽³⁰⁾ indicated that there has been no such increase in immaturity. Even if it had occurred, it would not be at all certain that radiation would be unequivocally implicated. For example, in a recent study Rosenwaks⁽⁷⁰⁾ found an inverse correlation between socio-economic status (as inferred from educational level) and the proportion of births of low weight.

All the foregoing speculations as to mechanism imply the intake by the mother, and in some cases the transfer to the foetus, of radioactivity contained in the effluents of the nuclear facilities in the vicinity of which excess infant mortality is claimed. There is a considerable body of evidence to suggest otherwise^(43,71-73), and that such intakes have been too small to be quantifiable, even in the immediate vicinity of power

reactors. They therefore appear to have constituted a negligible exposure pathway to any large number of persons further removed.

In assessing the probability that observable radiation-induced infant mortality might be produced by the nuclear facility effluent radiation levels, other causes which might also constitute a signal to noise problem must be considered. A significant correlation between socio-economic status and infant mortality has been referred to by Tamplin⁽³⁵⁾ in his comments on the Sternglass fallout presentation. An epidemiological study, conducted within New York City by Erhardt, et al⁽⁷⁴⁾ in 1966-67, disclosed a range of infant mortality rates from 41.5/1,000 live births in Central Harlem to 13.0 in Maspeth-Forest Hills. The authors comment that low birth weight introduces a special hazard for infants, and that there are larger proportions of very tiny babies among non-white infants. They also suggest that women who have no prenatal care produce infants with an extremely high risk of dying. In addition, they indicate that repeated childbearing at young ages involves an augmented risk of loss of the infant. Another relevant factor, stress of medical facilities, is suggested by the correlation which Bateman⁽⁷⁵⁾ has made between the successively yearly changes in births and the trend of infant mortality rates in Suffolk County, which is shown in Figure 10.

From this it appears that a far more sophisticated analysis than a simple time series correlation of effluent releases with infant mortality is necessary in order to demonstrate a reasonable basis for belief that a cause-effect relationship is operative.

CONCLUSIONS

The authors conclude that the primary data on which Sternglass has built most of his correlations of nuclear facility effluents and infant mortality are instances of statistical fluctuations. A more extensive analysis of many

years of data, rather than selected years, show mortality changes which fluctuate to give contrary results as well as positive. The latter is exactly what one expects from the small doses and small populations involved. On balance, there simply is no consistent evidence to support his call for the AEC to tighten current radiation exposure limits.

Furthermore, the data do not substantiate Sternglass' plea for a shutdown of or a moratorium on nuclear facilities. Whatever the causes of the infant mortality, when examined in the light of reported dose-effect relationships, nuclear facility effluents cannot on the basis of the evidence adduced be held to account for any of the total observed infant mortality.

Finally, when effluent release and dose data are considered in the context of established dose-effect relationships, it appears that even the most massive imaginable nuclear facility oriented epidemiological studies would be unlikely to lead to conclusive knowledge of low-level radiation effects. Curtis⁽⁷⁶⁾ has estimated that at an in utero exposure of three millirads, at least 2×10^8 children would have to be followed for ten years to obtain positive information about abnormal mortality.

Although infant mortality in the United States has decreased over the past several decades, as has been indicated by Shinkin⁽⁷⁷⁾, the position of the United States in this regard, relative to other advanced nations, has worsened over the same period. The causes for this, and especially for the excess infant mortality among lower socio-economic groups and non-white over the more privileged in our society, call for elucidation by a careful epidemiological study, so that we can act responsibly to alleviate them.

FIGURES

- Fig. 1 U. S. infant mortality and external background radiation levels, including fallout increments, at Brookhaven National Laboratory (1935-1969).
- Fig. 2 Infant mortality near Dresden 1966/64, 1966/63 and 1966/60.
- Fig. 3 Infant death rates per 1,000 live births, for Grundy and adjacent counties, for control counties, and for Illinois whites; ratio of adjacent to control county death rates and of adjacent to Illinois white death rates, and Dresden I gaseous emissions (kCi/yr), 1954-68.
- Fig. 4 Infant death rates per 1,000 live births, for ten counties nearest the Big Rock Point Reactor and for Michigan whites; ratio of ten nearest counties to Michigan white death rates, and Big Rock gaseous emissions (kCi/yr), 1955-68.
- Fig. 5 Infant death rates in California near Humboldt (1964 = 100), and Humboldt reactor gaseous emissions (1963-67).
- Fig. 6 Infant death rates per 1,000 live births for Humboldt County, for nine adjacent counties, and for California whites; ratio of adjacent county to California white death rates, and Humboldt Reactor gaseous emissions.
- Fig. 7 Ratio of infant mortality rates for Westchester and Rockland counties to infant mortality rates for Nassau County, Indian Point I gaseous emissions (1954-69).
- Fig. 8 Changes in infant mortality rates vs. distance from Indian Point I, 1966-1961 and 1968-1962 .
1961 1962
- Fig. 9 Infant mortality rates for Suffolk County, Nassau County and New York State (except New York City), 1949-69; Brookhaven liquid effluent activity (mCi/yr), and average exposure from BNL effluent ^{41}Ar , and external background at BNL perimeter (milliroentgens/yr), 1949-69.
- Fig. 10 Relation of strain on facilities to fetal death rate for Suffolk County, 1950-1970.

FIG. 1

1966 INFANT MORTALITY NEAR THE DRESDEN I REACTOR

FIG. 3

FIG. 4

INFANT DEATH RATES IN CALIFORNIA NEAR HUMBOLDT (1964 = 100)

GASEOUS EMISSIONS

FIG. 5

FIG. 6

ROCKLAND+WESTCHESTER
NASSAU

INDIAN POINT INFANT MORTALITY

STERNGLASS
SELECTION

GASEOUS EMISSIONS (kCi)

FIG. 7

FIG. 8

A COMPARISON OF INFANT MORTALITY IN SUFFOLK COUNTY, NASSAU COUNTY AND NEW YORK STATE WITH EXTERNAL RADIATION LEVELS AND EFFLUENT RELEASE AT BROOKHAVEN NATIONAL LABORATORY

FIG. 9

RELATION OF "STRAIN" ON FACILITIES TO FETAL DEATH RATE

FIG. 10

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