INFANT MORTALITY AROUND THREE NUCLEAR POWER REACTORS

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A part of the continuing epidemiologic research program on the effects of radiation exposure to humans is the occasional use of published vital statistics data to test the validity of the magnitude of a specific risk which has been proposed. The difficulties inherent in using vital statistics data to test a hypothesis of an association of a specific disease entity with radiation exposure are well recognized by our staff. None of the disease conditions which have been identified as being possible long term effects of exposure to radiation are unique, and therefore, no inferences about changes in rates of a specific disease following exposure can be made without looking at all of the factors which are known to influence the occurrence of that disease. However, occasionally, the magnitude of risk which has been proposed to be associated with radiation exposure is so large that it is possible to do a qualitative study. It can be hypothesized that if the risk of a specific effect associated with exposure is large enough, a change in the rate in the vital statistics data should be detectable despite all the other factors which might be influencing that effect.

In the papers presented by Dr. Ernest J. Sternglass and Dr. Morris H. DeGroot at this symposium, it has been suggested that the developing fetus is so uniquely sensitive to radiation damage that relatively very low levels of exposure to radiation from the operation of nuclear power plants are reflected in fairly large increases in infant mortality. If this is true, one can hypothesize that a comparison of infant mortality rates around a nuclear power plant before and after the beginning of operation should show differences in rates graded according to the distance from the plant. Increases in rates can be expected close to the facility with no change or decreases in rates at remote distances.

Three nuclear power facilities were selected for study: the Humboldt Bay Plant Unit 3 at Eureka, California; the Dresden Nuclear Power Station Unit 1 at Morris, Illinois; and the Big Rock Point Nuclear Power Station at Charlevoix, Michigan. These reactors were selected because they were among the first plants to be constructed and therefore provide data for several years of infant mortality experience since they began operation. In addition, they are all boiling water reactors with subsequent higher rates of radioactive gas discharge to the environment as compared to discharges from pressurized water reactors. These plants, therefore, have a history of the highest potential exposure to the population in the area of the reactor of any of the operating facilities, and thus provide the best opportunity for detecting an increase in infant mortality associated with this exposure, if it exists.

The method of study was identical for each reactor. Four concentric geographical bands were defined around each reactor site: one from 0 to 25 miles, one 25 to 50 miles, one 50 to 100 miles, and one from 100 to 200 miles. The wider bands were used more distant from the reactor to provide larger populations at risk to offset the smaller increased risk which would be hypothesized at the low exposure levels calculated for these distances. The concentric bands were then further divided into compass sectors, northeast, southeast, northwest, and southwest to permit evaluation of the effect of prevailing winds on the distribution of the gaseous wastes.

The appropriate population of live births and infant deaths within each band and sector was then estimated for each reactor. When a total county was included in one band sector, the published vital statistics for the county were used. When the vital statistics for a county needed to be divided between band sectors, it was done by crude population weighting. Using the Bureau of the Census data for 1960, the population of each minor civil subdivision within a county was determined and assigned to the relevant band sector. The percentage of the total population of a county which resided in each band sector in 1960 was then calculated, and the same percentage was used to allocate the live births and infant deaths for the county to the appropriate band sector. When the vital statistics for a municipality within a county were reported separately, these data were handled similarly to the county data.

Having obtained the number of live births and infant deaths for each band, and each band sector, four infant mortality rates were calculated: the rate of deaths under one year of age per 1000 live births (infant mortality) for the total experience during the five years before the reactor started operation and a similar rate for the five years after operation began. The same two rates were calculated for deaths under 28 days of age per 1000 live births (neonatal mortality.) More than half of infant mortality deaths occur within the first 28 days, and most of these deaths are due to conditions associated with prematurity [5]. The five year period was used to minimize the effect of small number variability and real annual fluctuations caused by such factors as local epidemics.

The infant mortality rates around the Big Rock Point plant are shown in Table I. The live births, deaths under one year of age, and the mortality rates per thousand live births are shown for each concentric band, going out from the reactor site, and for the compass sectors within each band for the five years before the reactor went operational, 1957 through 1961, and the five years after operation began, 1963 through 1967. The differences and directions of change in rates in the two time periods are also shown. It should be noted that three band sectors are contributing practically no data to these rates. The Big Rock Point plant is located on the shores of Lake Michigan so the northwest sectors

TABLE I

INFANT MORTALITY—BIG ROCK POINT NUCLEAR POWER STATION

Distance & direction from reactor	1957–1961 Live births	Deaths <1 yr.	Rate/1000 live births	1963–1967 Live births	Deaths <1 yr.	Rate/1000 live births	Difference in rates
<25 miles							
NE	1,619	44	27.1	1,246	25	20.1	−7.0
SE	1,414	40	28.3	1,270	25	19.7	−8.6
SW	802	20	24.9	702	13	18.5	−6.4
NW	5	0	—	5	0	—	—
Total	3,840	104	27.1	3,223	63	19.5	−7.6
25–50 miles							
NE	2,751	71	25.8	1,825	44	24.1	−1.7
SE	1,893	50	26.4	1,646	35	21.3	−5.1
SW	4,138	94	22.7	3,539	79	22.3	−0.4
NW	20	0	—	23	0	—	—
Total	8,802	215	24.4	7,033	158	22.5	—1.9
50–100 miles							
NE	6,425	168	26.1	5,573	129	23.1	−3.0
SE	11,347	283	24.9	8,979	182	20.3	−4.6
SW	4,354	85	19.5	3,117	72	23.1	+3.6
NW	5,645	137	24.3	3,906	84	21.5	−2.8
Total	27,771	673	24.2	21,575	467	21.6	−2.6
100–200 miles							
NE		Canada			Canada		
SE	196,068	4,711	24.0	170,541	3,700	21.7	−2.3
SW	198,151	4,349	21.9	166,254	3,624	21.8	−0.1
NW	20,506	432	21.1	17,309	392	22.6	+1.5
Total	414,725	9,492	22.9	354,104	7,716	21.8	−1.1

under 50 miles are principally lake, and the northeast sector in the 100–200 mile band is completely in Canada and was excluded.

The figures in this table reflect certain patterns of infant mortality which are common throughout the country for these time periods. First, that the number of births is lower in the second time period than in the first which is reflecting the decreasing birth rate in this country. Secondly, most of the mortality rates in the second time period are lower than in the first time period. Again, this is consistent with the continuing declining infant mortality rates in the United States. And finally, the areas with the highest starting infant mortality rates in general show the largest absolute decrease in rates. This latter phenomenon is believed to reflect better application of developed medical practice. As the preventable or treatable conditions are no longer leading to death, the rates are asymptotically approaching the so-called hard core causes of infant mortality—congenital malformations and the diseases of early infancy such as birth injuries, postnatal asphyxia, and the premature delivery of infants. A significant medical breakthrough in dealing with these conditions will have to be made before further sharp decreases in infant mortality can be expected [5].

There is no evidence in the pattern of the rates of infant mortality after the plant began operation, nor in the differences in the rates before and after operation to suggest an increase in infant mortality associated with the operation of the Big Rock Point reactor. The rates for neonatal mortality, which most strongly reflect the effects of prematurity and congenital malformations are shown in Table II and similarly show no trend or differences in rates which can be associated with the operation of the reactor.

TABLE II

NEONATAL MORTALITY—BIG ROCK POINT NUCLEAR POWER STATION

Distance & direction from reactor	1957–1961			1963–1967			Difference in rates
	Live births	Deaths <28 days	Rate/1000 live births	Live births	Deaths <28 days	Rate/1000 live births	
<25 miles							
NE	1,619	35	21.6	1,246	20	16.1	−5.5
SE	1,414	29	20.5	1,270	16	12.6	−7.9
SW	802	14	17.4	702	8	11.4	−6.0
NW	5	0	—	5	0	—	—
Total	3,840	78	20.3	3,223	44	13.6	−6.7
25–50 miles							
NE	2,751	53	19.3	1,825	33	18.1	−1.2
SE	1,893	35	18.5	1,646	21	12.8	−5.7
SW	4,138	78	18.8	3,539	58	16.4	−2.4
NW	20	0	—	23	0	—	—
Total	8,802	166	18.8	7,033	112	15.9	−2.9
50–100 miles							
NE	6,425	118	18.4	5,573	104	18.7	+0.3
SE	11,347	199	17.5	8,979	128	14.2	−3.3
SW	4,354	75	17.2	3,117	47	15.1	−2.1
NW	5,645	107	19.0	3,906	63	16.1	−2.9
Total	27,771	499	18.0	21,575	342	15.9	−2.1
100–200 miles							
NE		Canada			Canada		
SE	196,068	3,528	18.0	170,541	2,869	16.8	−1.2
SW	198,151	3,252	16.4	166,254	2,705	16.3	−0.1
NW	20,506	336	16.4	17,309	280	16.2	−0.2
Total	414,725	7,116	17.2	354,104	5,854	16.5	−0.7

Similar data for the Humboldt Bay plant at Eureka, California are shown in Tables III and IV. This reactor went operational in 1963, and the two time periods used are 1958 through 1962, and 1964 through 1967. Only four years of experience are included in the later time period because 1968 mortality data

TABLE III

INFANT MORTALITY—HUMBOLDT BAY PLANT UNIT 3

Distance & direction from reactor	1958–1962 Live births	1958–1962 Deaths <1 yr.	1958–1962 Rate/1000 live births	1964–1967 Live births	1964–1967 Deaths <1 yr.	1964–1967 Rate/1000 live births	Difference in rates
<25 miles							
NE	6,411	191	29.8	3,646	73	20.0	−9.8
SE	3,262	72	22.1	1,849	37	20.0	−2.0
Total	9,673	263	27.2	5,495	110	20.0	−7.2
25–50 miles							
NE	1,555	34	21.9	875	18	20.6	−1.3
SE	1,561	35	22.4	873	18	20.6	−1.8
Total	3,116	69	22.1	1,748	36	20.6	−1.5
50–100 miles							
NE	4,696	138	29.4	2,798	59	21.1	−8.3
SE	5,757	164	28.5	4,203	88	20.9	−7.6
Total	10,453	302	28.9	7,001	147	21.0	−7.9
100–200 miles							
NE	32,523	760	23.4	22,441	471	21.0	−2.4
SE	64,857	1,544	23.8	49,239	1,073	21.8	−2.0
Total	97,380	2,304	23.7	71,680	1,544	21.5	−2.2

TABLE IV

NEONATAL MORTALITY—HUMBOLDT BAY PLANT UNIT 3

Distance & direction from reactor	1958–1962 Live births	1958–1962 Deaths < 28 days	1958–1962 Rate/1000 live births	1964–1967 Live births	1964–1967 Deaths <28 days	1964–1967 Rate/1000 live births	Difference in rates
<25 miles							
NE	6,411	127	19.8	3,646	45	12.3	−7.5
SE	3,262	43	13.2	1,849	22	11.9	−1.3
Total	9,673	170	17.6	5,495	67	12.2	−5.4
25–50 miles							
NE	1,555	20	12.9	875	10	11.4	−1.5
SE	1,561	22	14.1	873	10	11.4	−2.7
Total	3,116	42	13.5	1,748	20	11.4	−2.1
50–100 miles							
NE	4,696	89	19.0	2,798	37	13.2	−5.8
SE	5,757	115	20.0	4,203	60	14.3	−5.7
Total	10,453	204	19.5	7,001	97	13.8	−5.7
100–200 miles							
NE	32,523	531	16.3	22,441	332	14.8	−1.5
SE	64,857	1,109	17.1	49,239	751	15.2	−1.9
Total	97,380	1,640	16.8	71,680	1,083	15.1	−1.7

are not yet published. Again the data show decreasing birth rates, decreasing infant mortality rates, and the largest decrease in rates occurring in the area with the highest starting rates. But neither the pattern of rates after the reactor began operation, nor the differences in the rates before and after operation suggest any change in infant or neonatal mortality associated with the operation of the reactor.

Despite the sizes of the geographical bands and the accumulation of five years experience, some of these rates are based on relatively few deaths, particularly in the 25–50 mile band. This band is primarily the coastal mountain region of northern California and southern Oregon which is sparsely populated. Also, the reactor is located on Humboldt Bay and as the two western sectors are in the Pacific Ocean, only two compass sectors in each band are contributing data.

Tables V and VI show the data around the Dresden Nuclear Power Station. This plant began operation in 1960 so the two time periods used are 1955 through 1959, and 1961 through 1965. The Dresden reactor is located in Morris, Illinois,

TABLE V

INFANT MORTALITY—DRESDEN NUCLEAR POWER STATION UNIT 1

Distance & direction from reactor	1955–1959 Live births	1955–1959 Deaths <1 yr.	1955–1959 Rate/1000 live births	1961–1965 Live births	1961–1965 Deaths <1 yr.	1961–1965 Rate/1000 live births	Difference in rates
<25 miles							
NE	29,430	775	26.3	31,045	794	25.6	−0.7
SE	1,429	33	23.1	1,639	36	22.0	−1.1
SW	3,358	72	21.4	2,950	56	19.0	−2.4
NW	2,782	58	20.8	3,159	66	20.9	+0.1
Total	36,999	938	25.4	38,793	952	24.5	−0.9
25–50 miles							
NE	643,007	16,711	26.0	621,494	16,150	26.0	±0.0
SE	12,143	296	24.4	12,381	291	23.5	−0.9
SW	14,576	329	22.6	12,979	285	22.0	−0.6
NW	8,607	175	20.3	8,220	174	21.2	+0.9
Total	678,333	17,511	25.8	655,074	16,900	25.8	±0.0
50–100 miles							
NE	126,947	3,250	25.6	131,063	3,182	24.3	−1.3
SE	37,768	921	24.4	34,155	836	24.5	+0.1
SW	50,807	1,126	22.2	45,820	999	21.8	−0.4
NW	35,732	855	23.9	35,081	786	22.4	−1.5
Total	251,254	6,152	24.5	246,119	5,803	23.6	−0.9
100–200 miles							
NE	123,956	2,792	22.5	125,849	2,723	21.6	−0.9
SE	48,893	1,069	21.9	45,725	988	21.6	−0.3
SW	68,780	1,587	23.1	60,848	1,379	22.7	−0.4
NW	63,884	1,368	21.4	61,095	1,314	21.5	+0.1
Total	305,513	6,816	22.3	293,517	6,404	21.8	−0.5

TABLE VI

NEONATAL MORTALITY—DRESDEN NUCLEAR POWER STATION UNIT 1

Distance & direction from reactor	1955–1959			1961–1965			Difference in rates
	Live births	Deaths <28 days	Rate/1000 live births	Live births	Deaths <28 days	Rate/1000 live births	
<25 miles							
NE	29,430	566	19.2	31,045	598	19.3	+0.1
SE	1,429	21	14.7	1,639	25	15.2	+0.5
SW	3,358	61	18.2	2,950	41	13.9	−4.3
NW	2,782	50	18.0	3,159	47	14.9	−3.1
Total	36,999	698	18.9	38,793	711	18.3	−0.6
25–50 miles							
NE	643,007	11,945	18.6	621,494	11,680	18.8	+0.2
SE	12,143	203	16.7	12,381	208	16.8	+0.1
SW	14,576	245	16.8	12,979	215	16.6	−0.2
NW	8,607	126	14.6	8,220	136	16.5	+1.9
Total	678,333	12,519	18.4	655,074	12,239	18.7	+0.3
50–100 miles							
NE	126,947	2,373	18.7	131,063	2,333	17.8	−0.9
SE	37,768	677	17.9	34,155	639	18.7	+0.8
SW	50,807	853	16.8	45,820	759	16.6	−0.2
NW	35,732	626	17.5	35,081	583	16.6	−0.9
Total	251,254	4,529	18.0	246,119	4,314	17.5	−0.5
100–200 miles							
NE	123,956	2,202	17.8	125,849	2,066	16.4	−1.4
SE	48,893	762	15.6	45,725	724	15.8	+0.2
SW	68,780	1,172	17.0	60,848	1,052	17.3	+0.3
NW	63,884	1,136	17.8	61,095	1,030	16.9	−0.9
Total	305,513	5,272	17.2	293,517	4,872	16.6	−0.6

about 30 miles southwest of Chicago, and the patterns of live births, as well as infant and neonatal mortality rates, are quite different in this strongly urbanized area from those in the relatively sparsely populated areas of the upper Michigan peninsula and northern coastal California. Although the three distant bands reflect the decreasing birth rate of the country, the under 25 mile band has an increase in number of live births and is apparently reflecting a growth in population during the time period under study. The three compass sectors in this band as well as the southeast sector in the 25–50 mile band and the northeast sector in the 50–100 mile band which have had an increase in number of births all include suburban counties around Chicago. These data are consistent with the known population growth surrounding large metropolitan areas.

It should also be noted that none of the bands have had any significant change in mortality rates between the two time periods studied. As most of these rates are dominated by the Chicago metropolitan area, the data may simply be reflecting the higher rate of hard core causes of infant mortality which has been associated with urban places. It might also be reflecting a change in the ratio of nonwhite births in the population with their associated increasing rate of prematurity [2]. Whatever the real explanation is for the differences in the pattern of rates around the Dresden nuclear power facility as compared to that around Big Rock Point and Humboldt Bay, there is no evidence for an increase in infant mortality rates associated with the operation of this nuclear plant.

Although the data around each of these reactors do not support a hypothesis of an increase in infant mortality in these areas, it was felt that two possible artifacts in the data should be investigated. The first was the remote possibility that the lack of association was a chance occurrence resulting from the choice of the arbitrary geographical bands which were used. Bands at different distances could have been defined and the births and deaths reapportioned. However, analysis of the data within compass sectors around each reactor should accomplish the same result. Using the mean distance from the reactor for each band as the x-value and the difference in mortality rates as the y-value, a regression line was fitted, the slope of the line estimated and then tested to see if it was significantly different from zero. This was done for the infant mortality rates and the neonatal mortality rates for each sector around each reactor. Only one slope was significantly different from zero at the .05 level—the southeast sector of the Big Rock Point Power Station. Examination of the data revealed that all of the differences in this sector were negative and the magnitude of the difference in rates was decreasing with distance from the reactor. This was not consistent with the hypothesis being tested.

Surveillance measurements around operating boiling water reactors have indicated that most of the radioactivity dispersed in the environment comes from the stack effluents [4]. Therefore, the second possible artifact was that effects on the rates in the downwind direction could be washed out by the lack of effects in other directions. The annual records of the direction of the wind at the plant were obtained for each of the reactors under study and are shown in Table VII. The slopes of the regression lines for the prevailing downwind sector and the sector which was downwind the minimum period of time for each reactor were tested for equality. No difference in the slopes was found.

TABLE VII

WIND DIRECTION FREQUENCY (PERCENTAGES)

Southwest includes winds from S, SSW, SW, WSW; Northwest includes W, WNW, NW, NNW; Northeast includes N, NNE, NE, ENE, and Southeast includes E, ESE, SE, SSE.

	Big Rock Point	Humboldt Bay	Dresden
Southwest	24.3%	20.6%	33.5%
Northwest	23.8	22.9	31.7
Northeast	17.7	39.8	15.0
Southeast	21.2	12.1	18.1
No Wind	13.0	4.6	1.7

Although no evidence for an increase in infant mortality associated with the operation of these three nuclear facilities could be detected, one must seriously question whether one would expect to, based on our knowledge of radiobiology and the dose involved. All of the experimental evidence on radiation effects indicate that the risk of effects is a function of dose, the lower the dose, the lower the risk of an effect. This relationship holds because injury to tissue which may lead to an observable effect is a direct result of the absorption of energy in the tissue. As injury results only from this absorption of energy, independent of the source of the energy, one cannot look for effects from exposure to one source of radiation and ignore other sources of exposure. Medical uses of radiation and natural background radiation are the two primary contributors to radiation exposure in this country [1]. Many surveys have shown that medical exposure of fetuses and infants is relatively rare, so the contribution of exposure to this population of infant from medical uses is probably very small and can be ignored. However, the contribution from natural background radiation must not be ignored.

Carefully conducted studies around the Dresden reactor have provided us with data which can be used to evaluate the relative contribution to the population exposure of radiation from the gaseous discharges from the plant and from natural background [3]. Calculated exposures to people due to naturally occurring radioactive materials in the ground and from cosmic rays around Dresden ranged from 46 to 110 millirads per year, with an average exposure of 80 millirads per year. The maximum calculated exposure resulting from gaseous discharges from the reactor was only 10 millirads per year at a distance of 1½ to 3 miles from the plant. Therefore, the maximum calculated exposure from the reactor effluents represents only a 12.5 per cent increase over the average exposure from background and is considerably less than the variability within the background exposure.

Radiation from the gas plume decreases continuously with distance from the reactor due to horizontal and vertical dispersion of the gas and radioactive decay of the short lived radionuclides. At a distance of 16 miles from the reactor, the additional exposure to the population from air effluents was calculated to be 1 millirad per year, and at 29 miles it had fallen to 0.4 millirad per year. Beyond this distance no activity above background could be detected even in the direct line of the plume, although one could calculate probable exposures beyond this point which would be diminishingly small. Thus, one is in the position of trying to detect an effect attributed to exposure due to radioactivity from the nuclear reactor which, for the mass of the population studied, is only a very small fraction of the exposure everyone in the population received from natural sources.

One must also question the rationale of using infant mortality as a health indicator of low dose, low dose rate radiation exposure. Studies of children exposed *in utero* to radiation for medical reasons have provided no evidence of increased infant mortality resulting from these exposures, although the dose is considerably higher than even the maximum potential exposure from the operation of a nuclear power plant. Studies in animals at comparable doses have also been negative.

When considering infant mortality as a possible effect of postnatal irradiation of the young child, the very definition of infant mortality, that is that death must occur within the first year of life, implies that one is expecting acute lethal effects. Laboratory studies of various animal species have demonstrated that the LD_{50}—the dose at which 50 per cent of the exposed population will die in a given time period—is lower for the young animal than the adult. However, the LD_{50} for man is accepted to be between 300,000 and 400,000 millirads. Even a greatly increased sensitivity of the human infant to radiation as compared to other animal species would not lead one to expect to observe this acute effect at doses of less than ten millirads.

Although infant mortality does not appear to be a profitable health indicator for the study of radiation effects, the need for study of low level effects is paramount. There is good evidence that radiation does increase the risk of certain malignancies, and in particular leukemia, at relatively high doses. There is also good evidence in animals that relatively high doses of radiation early in the gestation period can increase the incidence of congenital malformations. Before it will be possible to quantitate the risks of these and other effects associated with low doses, new methods of study must be devised. The effects to be investigated occur relatively rarely, and when investigating low dose effects, the size of population required for definitive study, using established statistical and epidemiologic techniques, is so large that studies are simply not feasible. It is hoped that as a result of this conference, ideas for the development of new approaches to the study of the occurrence of rare diseases will be generated.

In conclusion, the patterns of infant mortality around three boiling water nuclear power plants do not support a hypothesis of an increase in infant mortality associated with the operation of these three reactors. However, in the spirit of this conference, three factors should be mentioned which must be considered in planning a study of the health effects of pollutants including radiation.

(1) Pressurized water reactors and newer reactors with hold-up tanks for gaseous discharges have much lower discharge rates than the Dresden Nuclear Power Station Unit I. Therefore the potential exposure to a population is considerably lower than the maximum of ten millirads calculated for Dresden.

(2) The malignancies which have been associated with exposure to radiation have long latent periods. In the case of leukemia, the peak occurrence in the Japanese was at 6 to 12 years [6] after exposure and there is a suggestion that lower exposures may have longer latent periods. Other malignancies may just now be showing up at increased frequencies 26 years after exposure. It must be remembered that this evidence is coming from acute exposures in the range of somewhere below 100 up to around 300 rads—or 100,000 to 300,000 millirads.

(3) Background radiation is highly variable. One must consider the gross average differences of exposures to populations to be studied resulting from

differences in altitude and basic geological formations. But differences in exposure of individuals within the populations due to the variability of the concentration of natural radionuclides in the soil as well as in the building materials of structures in which they live and work must also be considered.

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Discussion

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Mrs. Tompkins, you indicate that the new reactor will have even lower releases than current reactors. We could even assume that new reactors will release no radioactivity. This does *not* address the problem of nuclear power, since all the steps in the cycle of nuclear power create the real problem.

A 1000 megawatt reactor generates 22 megatons of long lived fission products *per year* of operation. If the AEC optimistic projection of 1000 reactors by the year 2000 occurs, we will generate 22,000 megatons (TNT equivalent) of long lived fission products.

Assuming the engineering is 99.99 per cent perfect at every step along the way, this means 0.01 per cent release of radioactivity. Therefore 0.01 per cent of 22,000 megatons is 2.2 megatons of long lived fission products *per year* distributed to the U.S. biosphere. This is clearly not acceptable, even if we are so optimistic as to accept 99.99 per cent containment.

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Data produced by Mrs. Tompkins suggest conclusions contrary to those indicated by the data of Dr. Sternglass. This is a conflict of facts which is impossible to solve at a meeting like the present, but possible to clarify at a leisurely conference of only a few interested people.

This incident illustrates the reason why I suggest that, if a broad comprehensive statistical study is ever attempted, it should be conducted not just by one but by several statistical groups, working independently on the same data.

E. J. Sternglass, School of Medicine, University of Pittsburgh

There would appear to be a number of reasons why the methodology chosen in Mrs. Tompkins' paper tends to show no effects of plant emissions from boiling water type of reactors, while the studies of Dr. DeGroot as well as our own do show an effect on infant mortality.

The first and major reason would appear to be the choice of concentric circles in the search for a spatial gradient, since this choice implies that the entire area studied is assumed to be homogeneous with regard to the major parameters known to influence, or assumed to affect, the rate of infant mortality. These include the following:

(1) Plant emissions are not geographically uniform into all directions of the compass because

(a) Prevailing winds tend to favor certain directions.

(b) Release practices by the operator are often designed to minimize the exposure of the larger population centers lying in certain wind directions.

(c) Since fallout particles are mainly brought down by rainfall, widely different patterns of annual rainfalls, as for instance along a narrow coastal strip in the case of the Humboldt plant in California, will result in very different exposure patterns for the population at risk, both from the plant emissions and test fallout.

(d) Major geographical features, such as mountain regions along the coast, will have major effects on the radiation exposure from heavy gases, and particularly in regions only a few miles apart.

(e) The presence of large bodies of water or rivers into which liquid discharges take place will greatly influence the radiation exposure in a way that will often tend to dominate. Thus, again as in the case of Humboldt, heavy exposures along a coastal strip will tend to be masked by a pattern of circular regions that include areas far from the coast.

(2) Socioeconomic and medical factors are not homogeneous with directions around a nuclear plant, particularly when such a plant is located to one side of a major metropolitan area as in the case of the Dresden plant. The inclusion of upwind rural areas to the west with polluted and socioeconomically much poorer areas to the east of Dresden in southern parts of Chicago generally downwind will tend to mask out any decrease with increasing distance, as we have found when one takes these factors into consideration. Another problem in the methodology is the use of five year time periods before and after onset of operations since peak emissions often occur only for single months or years, and the five year period before releases began was a period of heavy nuclear weapons testing when infant mortality would be expected to be high.