MORTALITY TRENDS IN COUNTIES SURROUNDING THE OAK RIDGE NUCLEAR FACILITIES

Clifford H. Patrick, U.S.ERDA

With the anticipated growth of nuclear facilities in the coming decade, it is imperative that the public health effects of nuclear power-plant operations be ascertained. In this study, changes in selected measures of ill health in the population surrounding the Oak Ridge plants are compared to changes in Tennessee as a whole for the period from 1929, prior to Oak Ridge's existence, through 1971. Tennessee is used as a control population against which to measure changes induced by strictly localized factors, such as the nuclear facilities, as opposed to statewide or national epidemics or trends. Because of the myriad potential causes of the measured effects and the paucity of actual measurements for these competing factors in the general public, a quantification of a dose term is not included in this analysis.

Potential Health Effects of Low-Level Exposure

The somatic and genetic effects associated with radiation exposure are briefly enumerated herein to indicate the types of public health changes which might be induced by increased radiation exposure in the population at risk (6, 16). The possible somatic effects of low-level radiation include cancers which have relatively long latent periods. The specific cancers most often cited in relation to radiation exposure are leukemia, thyroid, bone, breast, lung, and gastrointestinal tract. The noncarcinogenic diseases associated with radiation (based on studies at high levels of exposure) include cataracts, central nervous system disorders, premature aging ("life shortening"), fertility impairment, congenital malformation, and increased incidences of cardiovascular-renal diseases. The possible genetic effects of radiation exposure may be seen in the population as increased rates of spontaneous abortion or fetal wastage, neonatal and infant mortality, infertility, and congenital malformations, including rare syndromes such as Mongolism. In this study, four measures relating to possible radiation effects (cancer, infant mortality, congenital malformations, and fetal deaths) are examined.

Past Studies of Public Health and Radiation

The potential health effects of Oak Ridge's nuclear operations have been examined in three previous studies. One study attempted to determine if there is a relationship between cancer morbidity in the public and potential radiation exposure (5), while two later studies examined the relative mortality of Oak Ridge nuclear facilities' employees (2, 12).

The study by Moshman and Holland only examined the Oak Ridge resident population for a single year, 1948; the incidence of cancer morbidity in the Oak Ridge population was compared to expected rates to determine if Oak Ridge residents were more susceptible to cancer than the U.S. population. Computed age-adjusted cancer incidence in Oak Ridge was only 123 per 100,000 compared to the national average of 230, reflecting the highly selected Oak Ridge population.

Incidence rates of cancer for both males and females in Oak Ridge were lower than the national norms. On a relative basis, the proportions by primary sites of cancer occurrence in white females in Oak Ridge were not significantly different from nationally based expected values. Only one significant difference was found in males; a higher proportion of respiratory cancer was found in white males than would have been expected, using 1938 cancer data to compute expected values. The authors felt the continuous upward trend in respiratory system cancer among males since 1938 would account for this higher incidence in 1948 in Oak Ridge. The study was rather limited because it covered only one year and used prewar bases for computing expected values. However, it was perhaps the first study to test the hypothesis that the nuclear facilities at Oak Ridge might be a potential source of ill health.

The 1966 study by Larson *et al*. compared the number of actual deaths in the three Oak Ridge nuclear plants from 1950 through 1965 with the number expected by applying 1962 U.S. age-specific mortality rates to the age distribution of workers. Based on 207,204 man-years of employment, 692 deaths occurred compared to the 992 expected using the 1962 U.S. rates. Thus, workers exposed to the environment of the Oak Ridge facilities appear to live longer than their cohorts in the general population.

Such a result seems to indicate a low dose of radiation exposure is healthy, but such an interpretation of the results may be erroneous. The result only shows the workers to be less likely to die at a given age than the control population (in this case, the 1962 U.S. population of the same age distribution). This control population includes the disabled and institutionalized segments who are in a much lower state of health than any normal work force, and especially workers at the Oak Ridge facilities who have on-site medical care and periodic plant physicals. While it is valid to conclude that these workers have better health than the control group, further analysis is required to test whether potential exposure to low-level radiation is related to the better state of health.

Such an analysis, based on age-adjusted data, has been attempted by Scott *et al*. Workers from two Oak Ridge facilities involved with uranium processing were separated into two groups based on their work areas at the plants. The uranium workers were predominantly technicians and craftsmen, while the nonuranium workers covered a broader spectrum of job classifications. The study covered employees from 1951 through 1969 and applied the 1960 U.S. mortality tables to each of the two distributions to determine expected deaths in each group. As in the Larson study, one would have expected to find the actual number of deaths to be less than for the U.S. average; but the critical question, which the earlier study did not consider, is whether the uranium workers are relatively more healthy than the nonuranium workers.

Scott et al. found the uranium workers had a mortality experience 59% as high as the general population, while the nonuranium workers had a mortality rate 76% as high. Thus the uranium workers appear relatively less subject to the risk of dying at a given age than the nonuranium workers. This result could be even more significant, because the average age of the uranium workers was about five years greater than that of the nonuranium workers, potentially giving radiation workers a longer period of exposure.

Though these studies uncovered no adverse health effects, the evidence is not overwhelming and indicates the need for in-depth epidemiological studies. While research of this type still appears to be in its infancy, research in the areas of occupational and medical exposures and by the Radiation Effects Research Foundation (RERF) suggests a well-trod path to follow (6, 16).

Methodology for Examining Mortality Trends in the Public

Methodology is important, particularly in studies of public health, because of the paucity of both reliable exposure data and knowledge of dose-response at low level chronic exposures (3). Data available for examining health effects in the public include time series of vital statistics for both the local area in which the facility is located and a comparable nonimpacted area to act as a control. Included under the rubric of vital statistics are data on population size, births, deaths, illness, and migration. These data ideally should be categorized by demographic variables such as age, race, sex, and socioeconomic characteristics. Vital statistics data are generally published annually by each state for counties and larger cities in a Vital Statistics series, usually by race, but seldom by other traits (15). Annual vital statistics and related data also are available from the National Center of Health Statistics of HEW and the Bureau of the Census (7, 17). Vital Statistics usually contain very limited information on morbidity, but seldom contain migration data. The Census Bureau, however, publishes estimates of population change and migration; some morbidity data is available through the U.S. Public Health Service (8, 10, 11).

In this study, time series data from 1929 to 1971 for four types of mortality and for total population in each area examined are taken from Tennessee Vital Statistics for the given year. Stillbirths (fetal deaths), infant mortality, cancer deaths, and congenital malformations were chosen because they are representative of effects of radiation found in the literature. Age, sex, and race breakdowns of the data are preferred because of the differential mortality among demographic groups but were not available in necessary detail in the published sources provided by the State (1).

Given the data in hand, separated by race for all years except 1959 and 1970, we restricted the analysis to the white population for two reasons: (1) The nonwhite population is quite small, generally younger and subject to much larger errors in reporting than the white population, especially prior to the 1950's; and (2) Rates of age-specific mortality by cause are probably based on more reliable data for whites. An effect in the largest, most statistically reliable group should be present in other demographic groups unless a race-specific selection of radiation-induced ill health exists.

The absence of age structure for the local populations is a severe shortcoming, because differences in age structure should be taken into account in comparing death rates for different areas. Older populations tend to have higher cancer rates, while younger populations tend to have greater incidences of death due to congenital malformation, fetal deaths, and infant deaths. Although these age factors may be offsetting, we do not know this for sure. For the purposes of this analysis, we are assuming (1) the age effects are sufficiently reflected using alternative measures with old age and young age biases and (2) the statistics will show offsetting trends where age structure *per se* creates an effect. The age structure problem may be more acute for analysis of cancer trends than for analysis of natality related measures. The lack of age structure is probably the largest drawback to the use of this annual data, because neither direct nor indirect standardization can be applied to develop measures unless decennial Census figures are used as estimators.

Given these limitations, we examine the yearly statistics for population, deaths, and death rates for both the local plant area and the control area--here the State (national statistics are often used as controls). The death rates for smaller areas almost always appear much more variable than the rates for larger areas because of the smaller number of deaths and the smaller base populations. Nonetheless, a steady rise in death rates could indicate that the local area is either getting older or that the relative risk is increasing and needs to be analyzed more closely to determine what factors have induced this comparative rise. Wide fluctuations around a generally constant trend should occur under normal circumstances. Given these factors, let us now examine the trends in the Oak Ridge area to determine the direction of the mortality trends.

Trends in Selected Mortalities in the Oak Ridge Area

Trends in mortality from 1929 to 1971 include a 14-year period prior to the existence of Oak Ridge and its three nuclear facilities and a 29-year period after its founding in 1943. Fetal deaths, infant deaths, and deaths from congenital malformation have been declining slowly over time in the white populations of the Oak Ridge area and Tennessee (14). Trends in cancer among whites in the Oak Ridge area and in Tennessee have been increasing over the period; this reflects the conquest of competing causes of death resulting in rising rates for chronic diseases such as cancer as longevity increases (3).

The first vital statistics for Oak Ridge became available in 1949. If the data for the period 1949 to 1971 are examined, the trends in deaths for the four causes reflect no particular sequence which would suggest that the Oak Ridge area has been or is becoming a relatively hazardous locale. Since the number of deaths is small, the variability is large; but the trends are fairly consistent. The city of Oak Ridge, which is closest to the nuclear facilities, does not show any consistent increasing trend, nor do Anderson and Roane Counties in which the facilities are located. All three areas reflect the same general trends as the State of Tennessee. However, rates (the ratio of deaths to population) are more appropriate for comparative purposes in relation to ascertaining a radiation effect or any other type of health effect gradient. Note well that cancer rates are total cancer deaths per 10^5 total population, while the rates for infant and fetal deaths are per 10^3 live births (18).

An examination of trends of cancer mortality rates among whites reveals nothing that would indicate the presence of a radiation effect. The rates for the Oak Ridge white population which would be the closest to the releases of radioactive materials--hence, most exposed--are the lowest rates depicted. They also have undergone wide fluctuations, not the consistent upward trend expected if cumulative radiation exposure were a primary etiologic agent. In only two periods, 1964-65 and 1968-69, are the cancer rates higher than in the previous year. At least since 1949, the trends in cancer mortality, though rising in the Oak Ridge area (and in the State), have not shown a consistent pattern that might suggest a radiation problem. In fact, the 1929-43 trends in Anderson and Roane Counties would appear to naturally extend into the 1949-71 trend in the same general upward flow as demonstrated by the State trend.

The trends in rates of fetal deaths (stillbirths), infant deaths, and congenital malformations appear to be equally consistent as cancer in not revealing a trend which would suggest an effect subsequent to Oak Ridge operations. Oak Ridge has consistently had lower mortality rates than either Anderson or Roane Counties, suggesting an inverse distance gradient. Trends for all three causes, though showing wide fluctuations, have been downward which is not suggestive of an adverse or cumulative radiation effect. All three areas tend to reflect the experience shown by the trend in the State rates.

In addition, the "relative risks" of death in the Oak Ridge area have also been computed using the local population rates and Tennessee rates. Oak Ridge appears to have consistently had a lower relative risk from each cause. Anderson County appears to have shifted in the 1940's from an area of relatively higher risks to an area of relatively lower risks for all causes except cancer, while actual cancer risks have been lower than expected since 1929. Roane County appears to have had higher risks due to infant deaths and congenital malformations and lower risks due to cancer since 1929; while risks of fetal deaths were, more often than not, lower in the pre-Oak Ridge years and higher in the post-Oak Ridge years. In the post-Oak Ridge years, Oak Ridge has consistently had the lowest relative risk for each cause, no doubt a reflection of age and socioeconomic factors.

The upward convergence of the Oak Ridge and Anderson County crude cancer death rates toward the State rate is consistent with several hypotheses, including an effect due to the nuclear facilities, though such an effect is not shown in any of the other mortalities or in Roane County. Since the most obvious reason for such an increase in cancer rates is the increasing age of the local population, the age-adjusted cancer mortality data by county for the 1950-69 period produced by the National Cancer Institute were analyzed statistically (Chi square) to compare Anderson County, Roane County, and Tennessee (4). These age-adjusted data (Table 1) indicated that there are no significantly greater rates in Anderson and Roane Counties and suggest that the nonage-adjusted temporal trends seen in the convergence of the cancer rates in Oak Ridge and Anderson County toward the State rate are probably due to the increasing proportion of older ages over time in Oak Ridge and Anderson County.

Conclusion

Thus, the statistical evidence, through preliminary and certainly not conclusive, suggests that Oak Ridge's nuclear facilities have not adversely affected mortality from selected causes often associated with high doses of radiation. Further analysis is needed to insure that instances in which rates of mortality were greater than those of the State were either (1) in response to relative changes in age structure of the local population over time, as seems to be indicated by independent verification using NCI age-adjusted figures, or (2) due to convergence as socioeconomic differentials between the State and Oak Ridge area have narrowed over time, rather than to environmental agents such as radiation.

In essence, the mortality trends do not show a pattern in time or space which would suggest that the presence of the Oak Ridge nuclear facilities has resulted in adverse impacts on the health of the local population. While the statistical results seem to imply the local environment is relatively safe, as in the studies previously cited, there remain potentially serious limitations in the data which are being more fully assessed, including the roles of migration, age structure, and socioeconomic factors (1, 9). Although high levels of radiation are a proven threat to man's health, no evidence of harm to the general public has yet been found to be due to low levels of radioactivity such as might result from Oak Ridge's nuclear facilities (6, 9, 13, 16). Nevertheless detailed epidemiological analysis is still needed in this area because existing studies have been unable to detect consistent changes in measures of health in the area from preoperational years. Using measures of both potential somatic and genetic effects, this study of the Oak Ridge nuclear facilities has found no adverse impact on public health that can be attributed to the operation of the facilities. The low-level radiation effects from nuclear facilities remain relatively unknown but appear to be less a hazard than the fossil fuel pollutants. Nonetheless, further indepth epidemiological research is needed before this issue is settled and risks of alternative energy technologies are preceived fully by the public and policy makers.

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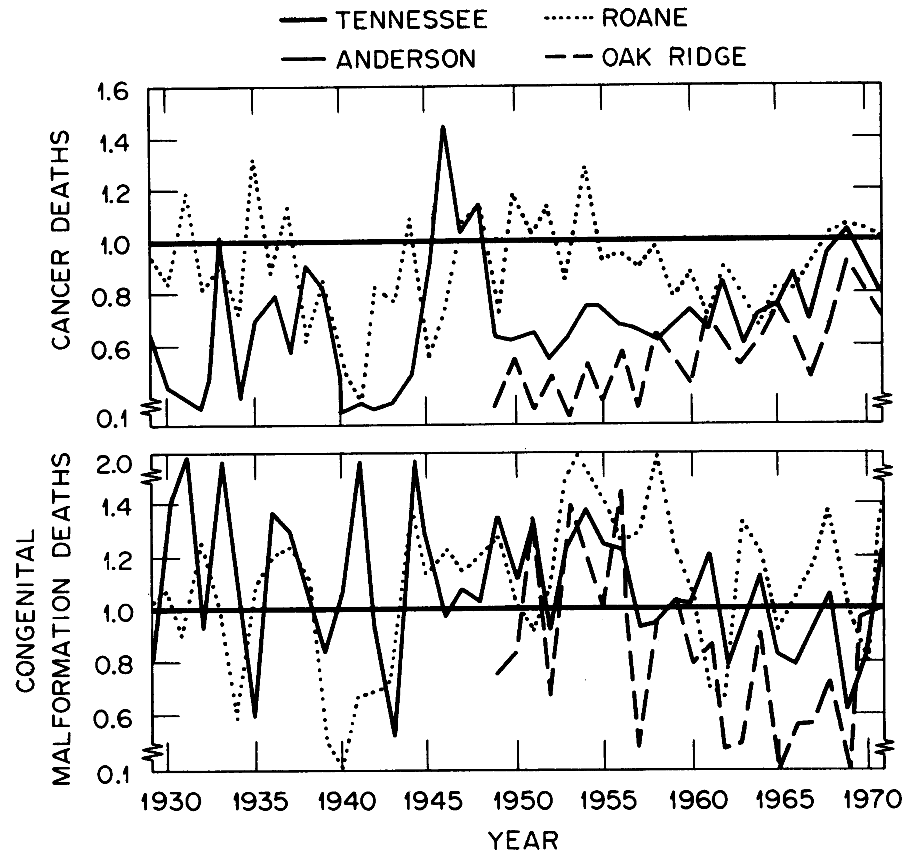
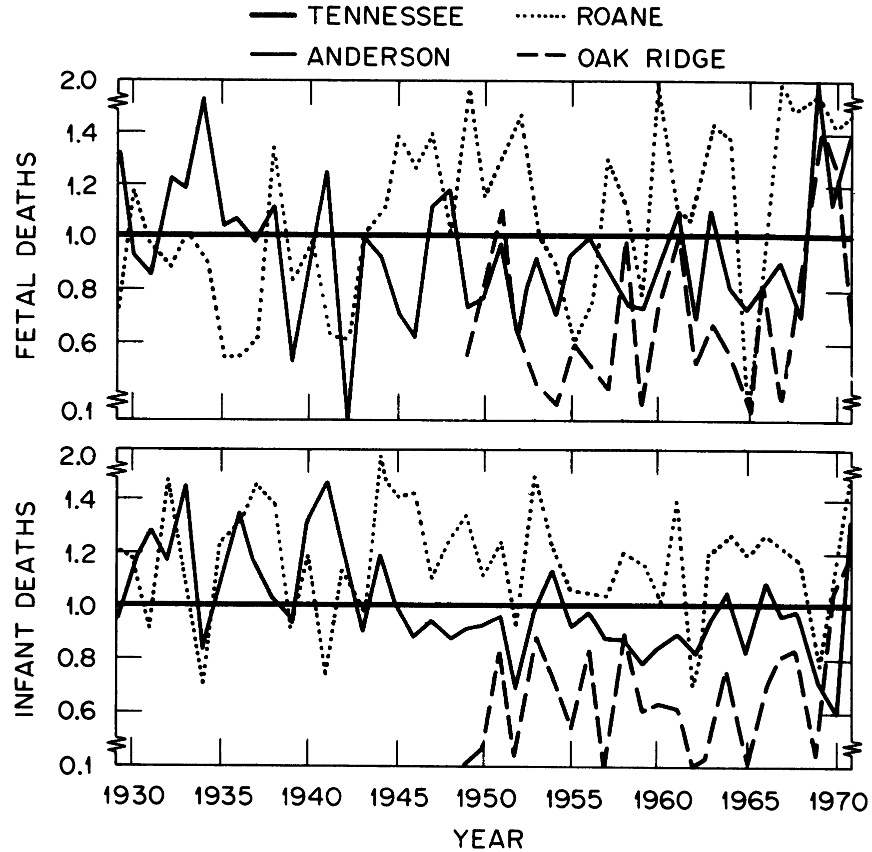


SOURCE : TABLE 4

Ratio of Actual to Expected Cancer and Congenital Malformation Deaths in the Oak Ridge Area and the State White Populations, 1929–1971.



SOURCE : TABLE 4

Ratio of Actual to Expected Fetal and Infant Deaths in the Oak Ridge Area and the State White Population, 1929–1971.

Table 1. Age-Adjusted Mortality Rates and Actual and Expected Deaths for Selected Cancer Types by Sex and Rate in Tennessee, Anderson County and Roane County -- 1950-1969

Type	Tennessee		Anderson County				Roane County			
	No.	Rate	No.	Rate	Expected	x^2	No.	Rate	Expected	x^2
ALL CANCERS										
WM	38,356	146.3	544	143.8	553.5	0.16	432	154.4	409.3	1.25
WF	35,763	116.0	510	117.4	503.9	0.07	384	120.2	370.6	0.49
NM	7,874	163.8	22	236.3	15.3	2.99	22	145.3	24.8	0.32
NF	2,268	142.5	22	213.3	14.7	3.63	26	165.8	22.4	0.60
LEUKEMIA										
WM	2,268	8.4	39	8.7	37.7	0.05	20	6.4	26.3	1.49
WF	1,700	5.6	32	6.2	28.9	0.33	20	6.0	18.7	0.10
NM	301	6.0	1	9.6	0.6	0.23	2	12.5	1.0	1.13
NF	222	3.9	2	16.7	0.5	5.03[a]	0	--	--	--
LUNG										
WM	8,885	33.5	151	38.6	131.1	3.04	111	38.7	96.1	2.32
WF	1,673	5.5	23	6.0	21.1	0.17	15	4.7	17.6	0.37
NM	1,387	28.8	6	59.0	2.9	3.22	2	11.7	4.9	1.74
NF	300	5.5	2	20.8	0.5	4.09[a]	1	6.0	0.9	0.01
BONE										
WM	371	1.4	8	1.7	6.6	0.30	5	1.4	5.0	0.0
WF	366	1.2	4	0.7	6.9	1.19	6	1.8	4.0	1.00
NM	59	1.2	0	--	--	--	0	--	--	--
NF	43	0.8	0	--	--	--	0	--	--	--
THYROID										
WM	91	0.3	2	0.6	1.0	1.00	0	--	--	--
WF	195	0.6	2	0.6	2.0	0.0	2	0.6	2.0	0.0
NM	12	0.3	0	--	--	--	-	--	--	--
NF	28	0.5	0	--	--	--	0	--	--	--

*$x^2 = \frac{(\text{Observed} - \text{Expected})}{\text{Expected}}$, with one degree of freedom; expected number based on the state rate applied to the local population.

**WM (white male), WF(white female), NM (nonwhite male), NF (nonwhite female).

[a]Significant at the 0.05 level ($x^2 \geq 3.84$).