Section on Environmental Health Policy

NUCLEAR FALLOUT, LOW BIRTHWEIGHT, AND IMMUNE DEFICIENCY

Jay M. Gould and Ernest J. Sternglass

An investigation of the mortality rates of young adults born in the postwar period of large-scale atmospheric nuclear testing (1945–1965) in the United States and other western industrial nations reveals an increasingly anomalous rise in mortality from its previous secular decline. Beginning in the late 1970s and particularly since 1983, the deterioration in the health of the 25–44 age group is related to in utero exposure to fission products in the milk and diet, associated with an unprecedented rise in underweight births and neonatal mortality known to be accompanied by loss of immune resistance. The 1945–1965 rise in the percentage of live births below 2500 grams is highly correlated with the amount of strontium-90 in human bone, both peaking in the mid-1960s. In the 1980s, for the baby boom generation (those born between 1945 and 1965), cancer incidence and mortality due to infectious diseases associated with a rising degree of immune deficiency, such as pneumonia, septicemia, and AIDS, increased sharply. This process of increasing immune deficiency appears to have been exacerbated by continuing secondary exposures to accidental reactor releases and by an acceleration of radiation-induced mutation of pathogenic microorganisms increasingly resistant to drugs.

Within the last decade there has been an unprecedented rise in the mortality rate of young adults in the United States and a number of western industrialized nations, due to both cancer and infectious diseases. It is the purpose of this article to examine the hypothesis advanced by Andrei Sakharov in 1958 that this phenomenon may be related to the exposure of these individuals to nuclear fallout impairing the normal function of the immune system, and to an accelerated mutation of microorganisms that could lead to new or more deadly forms of infectious diseases.

This work was aided by grants from the CS Fund, the Deer Creek Foundation, and the Friedson Philanthropic Funds.

International Journal of Health Services, Volume 24, Number 2, Pages 311–335, 1994

doi: 10.2190/9QJP-DRXW-NLVA-Q06D
http://baywood.com

METHODOLOGY

We shall use official vital statistics to support predictions made by Sakharov in 1958 (1), and repeated in his recently published *Memoirs* (2), that the fission products released by atmospheric bomb tests from 1945 to 1962, estimated by the Natural Resources Defense Council to be equivalent to the explosion of some 40,000 Hiroshima bombs (3, 4), would cause immediate and delayed damage to the immune systems of millions worldwide. Sakharov also predicted that bomb-test radiation would accelerate the mutation of bacteria and viruses, leading to the inference that persons whose immune systems had been damaged would in time succumb more easily to these new and more lethal strains of microorganisms. He states in his *Memoirs* that "During the 1950s, I had come to regard testing in the atmosphere as a crime against humanity, no different from secretly pouring disease-producing microbes into a city's water supply" (2, p. 225).

Four articles recently published in *Science* describe the current public health crisis set off by the increasing resistance to antibiotics of the rapidly mutating microorganisms responsible for AIDS, tuberculosis, shigellosis, salmonella, toxic shock syndrome, Lyme disease, and many other newly emerging infections (5–8).

In Chapter 14 of his *Memoirs* Sakharov writes that after the success of the 1955 Soviet H-bomb test, he worried so much about the biological effects of the bomb tests that he was impelled to calculate the number of premature deaths from ingested fission products (2, p. 197). Considering only such fission products as radioactive carbon, strontium, and cesium, and drawing heavily on the work of his biologist colleague, Osvei Leipunsky, he calculated that genetic damage, plus damage to immune systems, would accelerate the deaths of between 500,000 to 1 million persons for every 50 megatons of nuclear explosive power. As we have begun to show for the case of breast cancer using currently available mortality data (9), Sakharov's article, published in June 1958 (1), along with similar concerns expressed by Linus Pauling in *No More War* (10), also published in 1958, can be regarded today as extraordinarily prescient.

An important consideration in Sakharov's calculations was what he termed "nonthreshold effects," by which he expressed his conviction that every radioactive particle had a statistical probability of doing damage to either the DNA of reproductive cells or cells of the immune system by low-level internal radiation from the ingestion of such particles. He states (2, p. 201):

> I posited that cancer and damage to the body's immune system (resulting in premature death) may also be due to nonthreshold effects. . . . I also suggested that a global increase in mutations of bacteria and viruses (irrespective of the cause of the mutations) might have been an important factor in the spread of such diseases as diphtheria in the 19th century, or the influenza epidemic, and that low-level radiation might further increase the rate of mutations.

Most recently, evidence supporting Sakharov's prediction of immediate biological damage of bomb-test fission products comes from an article published by the Canadian pediatrician R. K. Whyte in the *British Medical Journal* (11). He found significant upward divergences in the steady decline of 0–1 day and 0–28 day neonatal mortality in the United States and United Kingdom after 1950 that peaked in the mid-1960s and ended in 1980, for which he considered atmospheric bomb-test fallout to be the most probable causal factor; infant mortality had previously been associated geographically and temporally with strontium-90 concentrations in milk (12, 13).

IMMUNE SYSTEM DAMAGE IN EARLY INFANCY

An early link between low-level fallout and immune system damage was the finding that the rapidly declining portion of 0–1 year infant mortality due to pneumonia and influenza showed an anomalous rise during the period of heavy atmospheric fallout in the late 1950s, which ended in about 1980 following the cessation of all atmospheric tests (14). Furthermore, sharp rises by as much as a factor of ten occurred in such infectious diseases of early childhood as encephalitis in New York City following the onset of atmospheric testing by the Soviet Union and U.S. tests in Nevada between 1949 and 1951. These rates also declined to prewar levels after the largest Nevada and Pacific nuclear tests.

Still another link to immune system damage by small amounts of bone-seeking fission products such as strontium-90 is provided by the fact, increasingly recognized in the last few decades, that damage to the mother's immune system during pregnancy can lead to the rejection of the fetus as a foreign body and thus to premature birth and an increased risk of neonatal mortality (15). The incidence of low birthweight, defined as birth below 2500 grams and known to be strongly associated with neonatal mortality (16), represents an even more sensitive indicator of radiation-induced harm to the fetal hormonal and immune systems than neonatal mortality; advances in the medical care of the newborn have greatly increased the survival rate of neonates in developed nations during the last few decades (17, 18).

For the period 1955–1970, there was a parallel rise and decline in the percentage of low birthweights (19, 20) and the concentration of strontium-90 in adult human bone as measured in New York City (Figure 1), for which the strontium-90 levels in the diet are known to have been close to the average for the United States as a whole during this period (21). The correlation factor is very high ($r = 0.96$) with the probability of being due to chance very low ($P < 0.001$).

Sakharov's view of the dangers of these nonthreshold effects is in basic agreement with the conclusion reached by many other scientists that there is no "safe" level of radiation below which no harm could be expected. The fact that high doses of radiation impair the immune defenses of animals and humans was of course well-known, since many of the survivors of the Hiroshima and Nagasaki

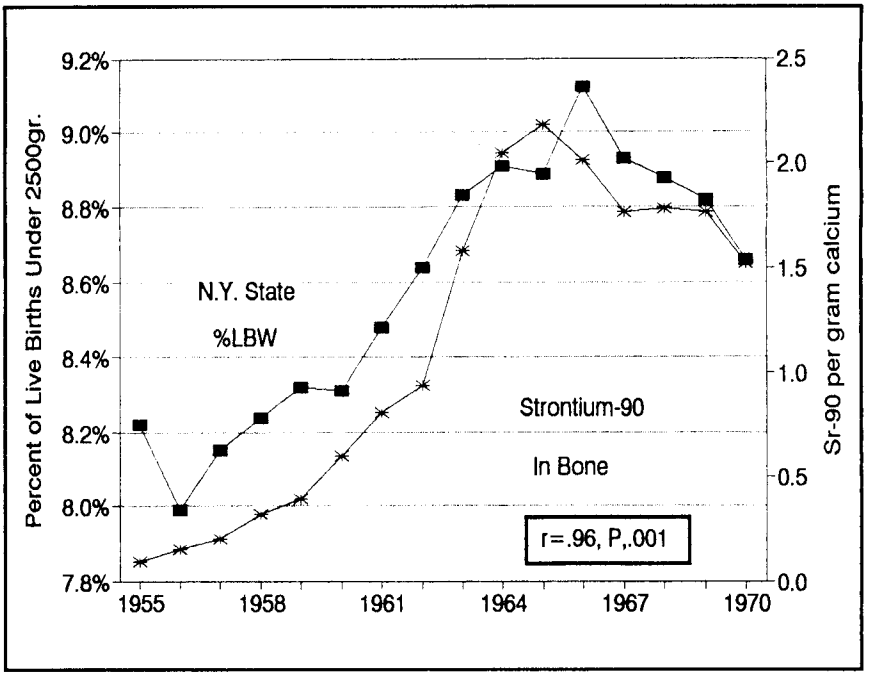

Figure 1. The percentage of low birthweight live births in New York State is significantly correlated with a corresponding rise and fall in the strontium-90 levels in the bones of New York City adults for the period 1955–1970. (*Note*: $P < 0.001$.)

died of infectious diseases in the months and years after 1945. Also, more recently it was realized that following the massive fallout doses from a nuclear war, there would be world-wide epidemics of infectious diseases decimating the surviving population (22).

However, the possibility that very low doses of radiation such as occurred from nuclear testing or reactor releases that are hundreds to thousands of times smaller could have detectable effects on the immune response was only recognized in the last few decades. This came about largely as a result of the pioneering work of Petkau (23, 24) who discovered that extremely low levels of chronic internal radiation lead to the formation of free-radical oxygen (O_2^-) that dissolves cell membranes much more efficiently at low than at high dose rates. Thus the cells of the immune system originating in bone marrow exposed to the long-range beta rays produced by strontium-90 would be damaged by much lower doses than previously believed.

Sakharov's 1958 paper even anticipated Petkau's discovery of the crucial role of free radicals to a surprising degree (1):

> It has been shown experimentally that the carcinogenic effects of various carcinogenic substances are additive. There is no reason to believe that the active radicals which arise as a result of ionization will behave in a qualitatively different way. Therefore, the increase in the amount of cancer, or equivalently, the drop in the age at which cancer occurs, will be a linear function of the dose to which humanity is subjected.

The only important aspect of Petkau's discovery not anticipated by Sakharov was the fact that the sensitivity to free-radical damage turned out to be inversely related to the dose rate, which causes the dose-response curve due to environmental radiation to have a concave downward or logarithmic rather than a linear form. As a result, very small chronic doses are much more serious than anticipated from studies carried out at high doses and dose rates, as discussed in connection with the recent rise in breast cancer linked to low doses of fission products in the diet (9).

There are by now numerous studies, as cited in the article on breast cancer (9), supporting Sakharov's prediction of the harmful effects of small amounts of radiation such as occurred from the fallout experienced by the generation born in the bomb-test years (1945–1965) that followed World War II, when all-time peak levels of strontium-90 were measured in human bone (21). Among these earlier studies, some of the most significant to the present study are those involving childhood leukemia and cancer associated with very low doses.

Thus, after testing began, along with the anomalous rise in neonatal mortality found by Whyte (11), both in Japan (25) and in the United States (26, p. 108) there were significant anomalous increases in leukemia and cancer among children aged 5–9 for which an initial insult can be inferred to have begun in 1945. This inference is based on the subsequent discovery by Stewart and associates (27) that very small doses from a few diagnostic X-rays during early development in utero lead to a significant increase in childhood cancer rates that peaked some 5 to 6 years after birth. More recently, Knox, Stewart, and coworkers (28) found an even greater sensitivity of childhood cancers to background radiation in the United Kingdom, independently confirmed by a study of Hatch and Susser (29) in the United States.

Another study (30) revealed that learning disabilities among those born during the years of atmospheric bomb-testing, known to be more frequent in children born underweight (31), were reflected in the otherwise inexplicable decline in Scholastic Aptitude Test (SAT) scores observed for the years 1967–1980 (32). There was then a brief upturn in SAT scores for children born after the cessation of atmospheric tests in 1963, as expected for the hypothesis that fallout was the principal factor in the decline. Since then, a study in Norway found a decline in school performance for children living in the western, mountainous high-rainfall and high-fallout region relative to that of children living in the eastern, low-fallout area (33).

Perhaps of greatest relevance to the present study is the observation that even very small doses of radiation received during embryonic or fetal development can produce a long-lasting decline in immune resistance, as observed in both human and animal studies. Thus Diamond and coworkers (34), in a follow-up study of a group of 5,264 white children whose mothers were exposed to diagnostic X-rays during pregnancy and observed for ten years, found that not only was there a tripling in the leukemia rate, but the rate of infectious diseases was twice that in a carefully matched control group, and for respiratory diseases the rate was more than three times as high.

Similar permanent effects on the immune system were found by Strand and coworkers (35) in a laboratory study of fish exposed in the embryonic stage to low levels of radioactive tritium at concentrations close to those presently permitted by government regulations.

EVIDENCE FOR FALLOUT DAMAGE TO ADULT IMMUNE SYSTEMS

We now turn to the evidence suggesting that the Sakharov thesis is supported by the surprising finding that mortality rates for both men and women aged 25–44 stopped declining in 1979 and actually started to rise sharply in the United States, after seven decades of steady annual declines.

In the United States, the anomalous trend for men in this age group was first discussed in a recent article by epidemiologists of the Atlanta Centers for Disease Control (CDC) and attributed to AIDS, although the article admitted that in states with high AIDS mortality rates, there are "associated" abnormal increases in septicemia, pneumonia, pulmonary tuberculosis, diseases of the central nervous system, heart and blood disorders, drug abuse, and "other immune defects" among individuals not infected with the human immunodeficiency virus (36).

Figure 2 illustrates the methodology used by the CDC to establish the anomalous character of the mortality change since 1983, here applied to both men and women aged 25–44, for internal causes of death, excluding such external causes as accidents, suicide, and homicide. Although the CDC centered its attention on men, mortality rates from internal causes of both men and women in the age groups 24–34 and 35–44 are seen to have been declining in the 1970s. The projection of these baseline trends into the 1980s reveals a growing gap between observed and expected rates since 1983, which would include AIDS-related deaths along with premature deaths from other infections and chronic diseases.

The upward divergence after 1983 is more marked for men than for women, probably because their greater degree of promiscuity may promote the sexual transmission of the mutated infectious organisms foreseen by Sakharov.

In Figure 2 we include figures for each observed mortality rate for the years 1970–1988 indicating when the persons making up the age groups 25–34 and 35–44 were born. This shows that in each case the greatest upward deviation of the

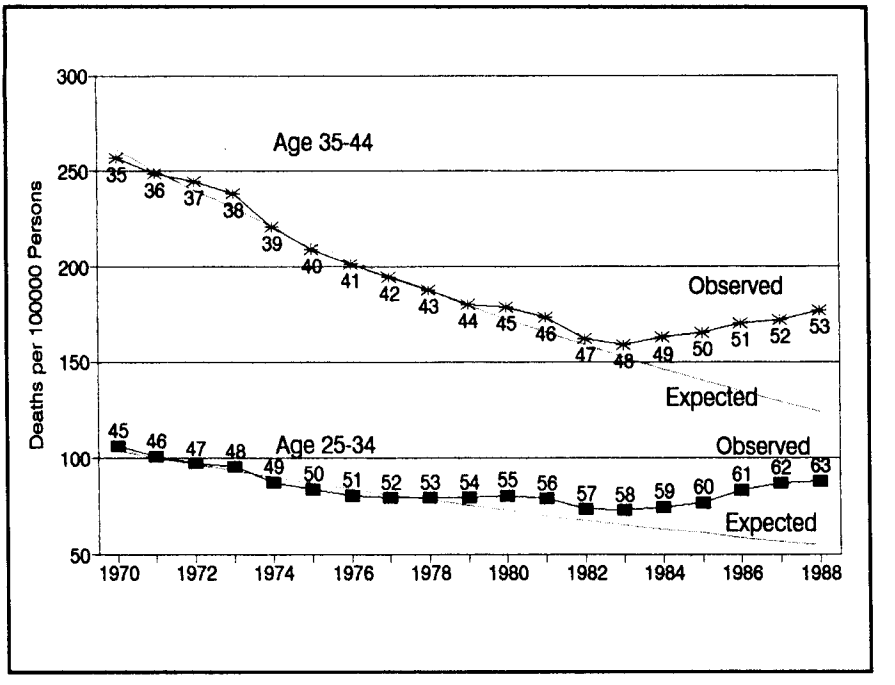

Figure 2. Observed mortality rates for deaths due to internal causes for males and females aged 25–34 and 35–44, 1970–1988. Solid lines represent the expected rates based on projecting the 1970–1979 trends fitted by an exponential function. The end year of birth is indicated for each 10-year cohort.

observed mortality rate from the expected rate based on the projection of the 1970–1979 trend came in the 1980s, when an increasing proportion of persons aged 25–44 had been born in atmospheric bomb-test years after 1945. This is most clearly shown for the age group 35–44. In 1970 persons comprising this age group had been born in the prenuclear period between 1925 and 1935. Throughout the 1970s the individuals making up the 35–44 age group registered declining mortality rates from disease, having been born well before the onset of the Nuclear Age; by 1983, these cohorts had been born in the years 1938–1948 and were including more and more baby boomers. By 1988, these cohorts had been born between 1943 and 1953 and were almost all baby boomers, exposed to the early bomb-test emissions, and they displayed the widest difference between observed and projected mortality rates.

Persons comprising the 25–34 age group in the 1970s also increasingly included baby boomers born between 1945 and 1965, but only began to show wide differences between observed and projected mortality rates in the late 1980s when all

cohorts had been born in the later peak years of bomb testing. Although all persons born in the two bomb-test decades were exposed to a statistical probability of undergoing some hormonal or immune system damage at birth (see Figure 1), the delayed consequences would be more likely to emerge in the form of premature death when persons reached the age of 35–44 rather than 25–34, because the older age group had a much higher absolute mortality rate indicative of a lower degree of resistance to disease.

Further support for the fact that the 35–44 age group, an increasing proportion of whom had been born in the early years of the Nuclear Age, registered clear evidence of increasing immune deficiency in the 1980s is offered in Figure 3. Both in the United States as a whole (37) and in Connecticut (38), individuals in this age group had declining trends of cancer incidence rates in the 1970s when their birth years were before 1945, but increasing trends after 1981 when a growing proportion were born after fallout began. For the case of Connecticut, for which the most recent data are available, the peak cancer incidence rates for this age group occurred in the late 1980s when all its members had been born between

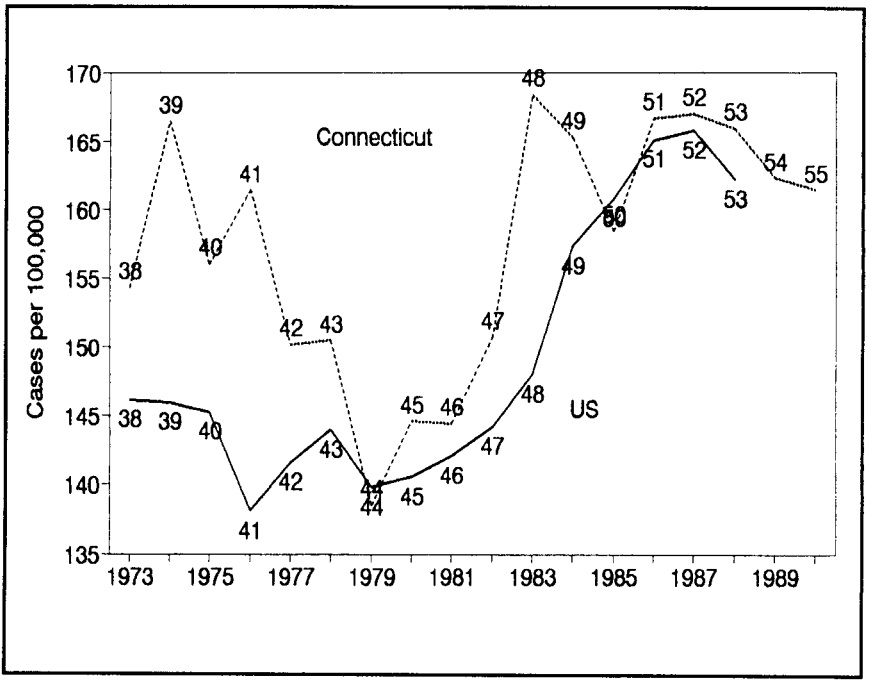

Figure 3. Cancer incidence rates for individuals aged 35–44 in the United States for 1973–1988 and in Connecticut for 1973–1990. The end year of birth is indicated for each 10-year cohort.

1948 and 1955—the beginning of nuclear fallout exposure during early development that affected the ability to fight the spread of cancer cells in later life. Secondary insults from large Millstone releases in 1975 and the Three Mile Island accident of 1979 may also have accelerated cancer incidence in the late 1980s.

Turning next to mortality due to AIDS, which is classified with "Other Infectious and Parasitic Diseases," for the age group 35–44, we see (Figure 4) that from 1983 to 1988 there was about a tenfold rise in such mortality for persons born in the early years of the nuclear age that can be traced back to a minimum in 1979, for persons born between 1934 and 1944. Smaller rising trends were also registered for deaths from pneumonia and septicemia, indicating a growing general immune deficiency in this age group in the 1980s compared with the 1970s, even in the absence of HIV.

In summary we can say that since 1980 the age groups 25–44 were increasingly made up of individuals born between 1945 and 1965 and therefore most heavily exposed in utero or in early childhood to the low-level bomb-test radiation that

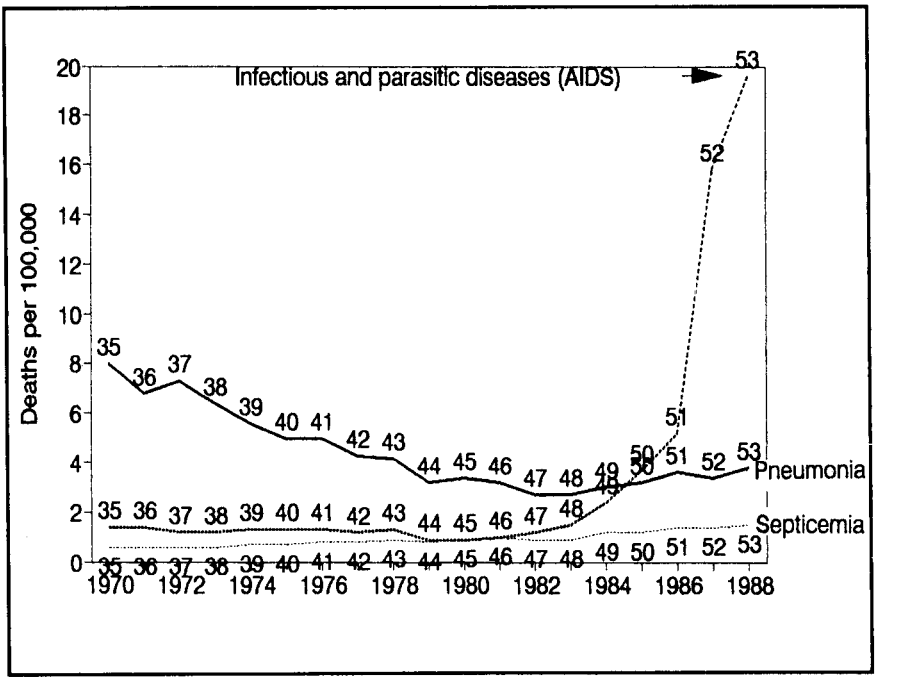

Figure 4. Mortality rates for deaths due to septicemia, pneumonia, and AIDS in the United States for males and females in the 35–44 age group, 1970–1988. The end year of birth is indicated for each 10-year cohort.

most worried Sakharov and Pauling because of its lowering of individuals' ability to fight both cancer and infectious diseases.

Another way of demonstrating the current anomalous nature of the deterioration in mortality rates of young people is to trace the percentage share of all deaths since 1970 accounted for by the age group 25–44, as shown in Figure 5 for both males and females. In 1910 this age group had accounted for 29 percent of all deaths, but since in an aging population old people live longer and consequently account for rising shares of all deaths while advances in medical care lower the mortality rate for young adults, by 1970 the percentage share for the age group 25–44 had declined to 5.8, and by 1976 to an all-time low of 5.35 percent. But thereafter the accelerating rise to 6.6 percent in 1989 clearly demonstrates the recent anomalous deterioration in the mortality of young people, who by 1989 had all been born in the bomb-test years between 1944 and 1964.

It is apparent that the baby boom generation was born at the worst possible time, an insight supported by Figure 6. Here we note the remarkable correspondence between the annual movements of the percentage of low-birthweight live births in

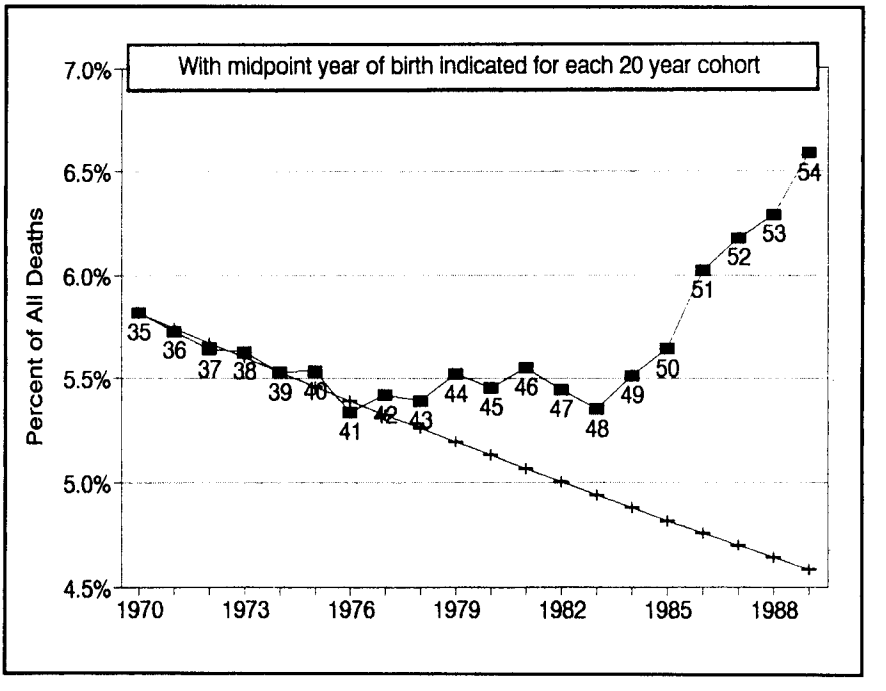

Figure 5. The percentage share of all deaths accounted for by males and females aged 25–44 for the years 1970–1989. The line indicated by the crosses represents the linear trend fitted to the period 1970–1976.

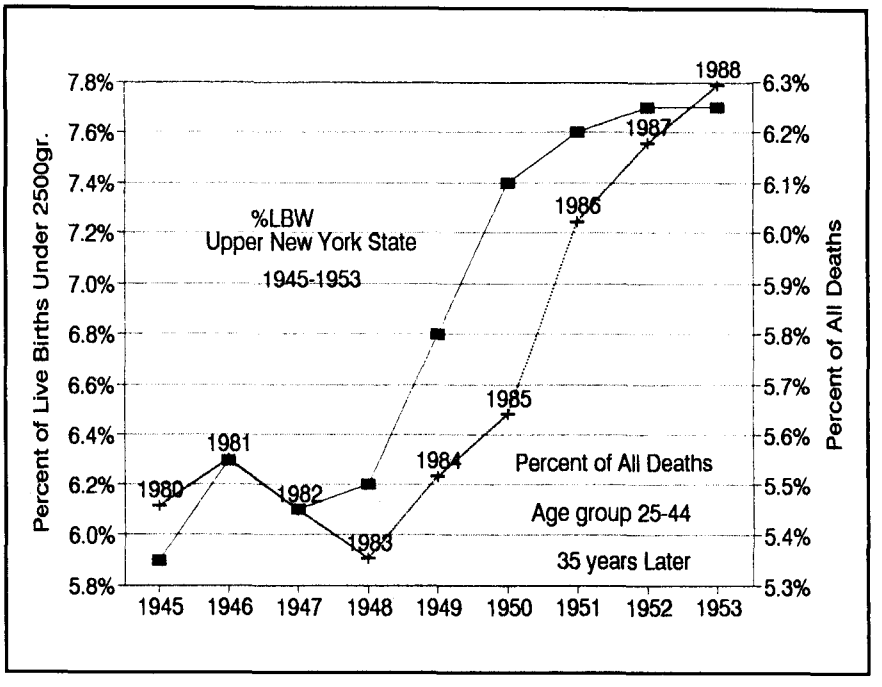

Figure 6. The percentage share of all U.S. deaths accounted for by the 25–44 age group since 1980 is plotted with the annual movement of the low birthweight percentage (%LBW) in upper New York State 35 years earlier (1945–1953).

upper New York state from 1945 to 1953 and the average mortality experience 35 years later of individuals born in those traumatic years when the human fetus was first exposed to artificial fission products. As in the case of low birthweight and strontium-90 levels in bone, the correlation coefficient is very high ($r = 0.88$) and the probability that this association is due to chance is very small ($P < 0.001$).

Thus Figure 6 provides strong quantitative support linking the deterioration in health of the baby boom generation in the 1980s to radiation-induced damage during early development in the decades of heavy fallout, beginning in 1945. As shown in Figure 5, the share of all deaths in the 25–44 age group in the United States rose from 5.34 percent in 1983 to 6.3 percent in 1988, representing a ratio of change of 1.18. This ratio can be taken as a measure of the anomalous rise in mortality of young Americans in the 1980s. Because mortality data by age are universally available for geographic units such as counties, states, regions, and nations, it is possible to secure geographic measures of the degree of change in the mortality of young people everywhere, to throw further light on the validity of the Sakharov hypothesis of worldwide fallout damage to the immune response.

In Figure 7 we have plotted this ratio of the change in mortality between 1983 and 1988—which we call the anomalous mortality ratio (AMR)—for the 25–44 age group for all 49 contiguous states and compared it with the 1988 AIDS mortality rate. The AMR measure of mortality deterioration is highly correlated with the 1988 AIDS mortality rate ($r = .74$; $P < .001$). Thus, even though in 1988 AIDS deaths accounted for only about one-quarter of all deaths in this age group, the high correlation indicates that both measures relate to the same underlying biological cause: a widespread increase in immune deficiency and hormonal problems among young adults, acquired in infancy, that expresses itself in deaths due not only to AIDS but also to such immune-deficiency-related conditions as tuberculosis, pneumonia, sexually transmitted diseases, septicemia, and cancer, and to such external causes as accidents, suicide, homicide, and drug abuse. External causes constitute about half of all causes of death for the 25–44 age group, in the 1970s and 1980s. The sociologist R. J. Pellegrini (39), in a study of the Uniform Crime Reports going back to 1945, has determined that rates of

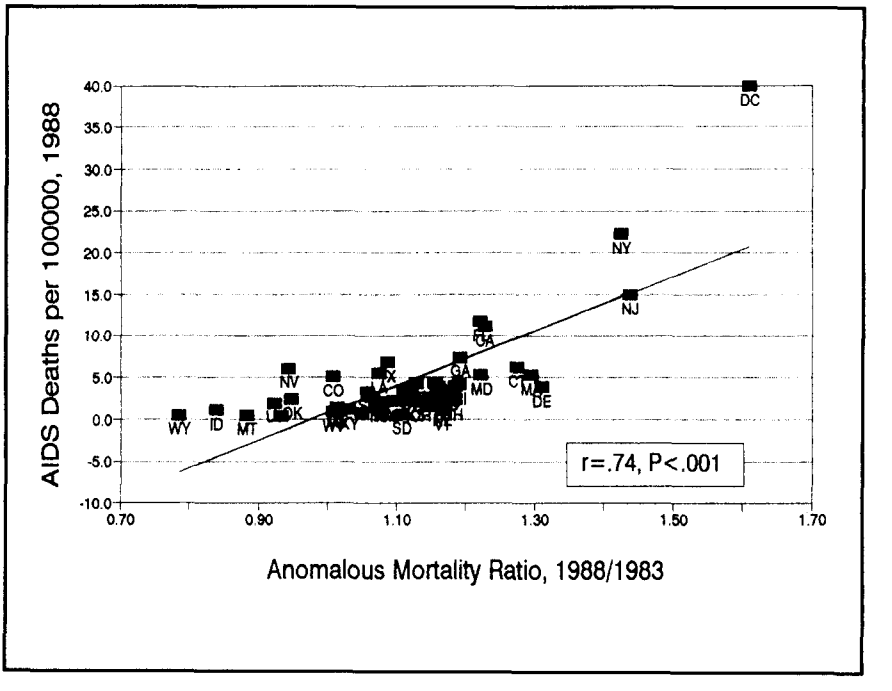

Figure 7. A significant correlation is shown between the officially recorded 1988 AIDS mortality rates and the anomalous mortality ratios (AMR) derived by dividing the 1988 percentage share of all deaths for the 25–44 age group in each of the 49 contiguous states by the corresponding 1983 percentage.

criminal homicide, forcible rape, and aggravated assault doubled in the 1970s for teenagers and young adults compared with previous decades, just as the baby boomers entered the age group 15–24 for which violent crime showed the greatest rise. Crime rates for those aged 25–44 are now at all-time peaks, a fact that Pellegrini attributes to the exposure of this group to fallout radiation in utero, producing neurological, cognitive, and behavioral problems known to increase the risk of school failure, involvement with recreational drugs, and violent crime.

As shown in Figure 7, New York, New Jersey, Washington, D.C., Florida, and California have both the highest rates of AIDS mortality and the highest increases in mortality due to all causes among young adults 25–44 years old. It is interesting to note that in the lower left quadrant of Figure 7 there are many states in the mountain region, such as Wyoming, Idaho, Montana, and Utah, with AIDS mortality rates close to zero and AMR values less than 1.00, which means that from 1983 to 1988 the mortality experience of the 25–44 age group in these states has continued to improve. In fact, because the AIDS mortality rate cannot take on negative values, these observations all fall above the line of regression, suggesting that AMR is a better indicator of relative immune deficiency among geographic areas than the official definition of AIDS mortality. This official definition is constantly being expanded to include additional diseases (such as tuberculosis) in the AIDS syndrome, and is dependent to an unknown degree on a problematic positive test to HIV. The present findings therefore support the view of Duesberg (40) that HIV infection may be a symptom rather than a cause of AIDS and that the damage to the immune system is due to some noninfectious agent in the environment, such as recreational drugs.

It appears, however, that the single greatest environmental agent involved in the damage to the immune system is the fallout from weapons testing during early intrauterine development rather than recreational drugs used in later life; the earliest emergence of AIDS occurred in the high-rainfall areas of equatorial Africa, where strontium-90 in human bone was found to be higher than in any of 22 nations studied during the late 1950s (41) and recreational drugs were not significant.

How can we explain the fact that the baby boom generation in the mountain states has little AIDS and a relatively good immune response that actually caused the mortality rates for young adults to continue to decline? This appears to be related to the fact that breast cancer mortality rates in these states are also among the lowest in the nation (9). Residents of these states were the least exposed to strontium-90 in the milk and diet from worldwide atmospheric testing during early life, since 90 percent of all fallout is brought down by rain and snow (42). Moreover, they also experienced the least exposure to the secondary wave of fission products released from civilian power reactors after 1970, which appear to be strongly associated with the elevation of breast cancer rates in those regions where these reactors are concentrated and where cumulative per capita levels of

exposure to emissions of radioactive iodine and strontium from the reactors since 1970 are far above the levels reported for the dry mountain states (43).

As shown in Figure 8 there is indeed an extremely significant correlation among the 49 contiguous states between recent age-adjusted breast cancer mortality rates (1984–1988) and the AMR that measures the rise in mortality rate due to all causes of death for the generation most exposed to fallout in early infancy. The heavily nuclearized northeastern states occupy the upper right quadrant of Figure 8, with high cancer mortality rates and high overall mortality in the 25–44 age group, while the nonnuclear states of the mountain and west south central regions fall into the lower left quadrant with significantly lower mortality rates.

The data in Figure 8 suggest, as do those in Figure 3, that a high exposure to fallout during intrauterine and early childhood development strongly increases the risk of developing breast cancer as a young adult when later exposure to other carcinogens or cancer-promoting agents such as releases from nuclear reactors or pesticides take place.

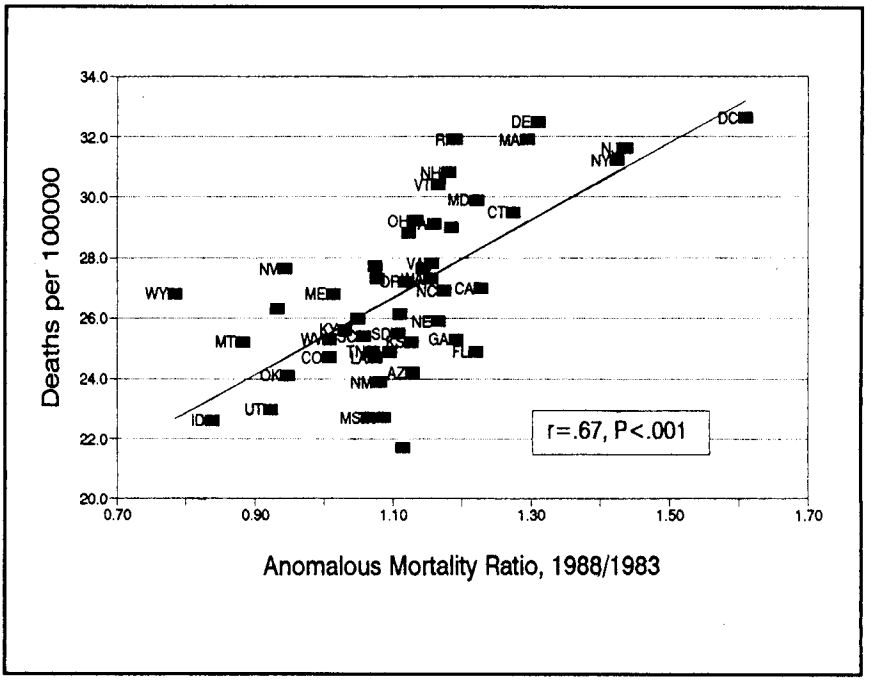

Figure 8. A significant correlation is shown between the age-adjusted breast cancer mortality rates reported for each state by the National Cancer Institute for 1984–1988 and the AMR values calculated for each state.

The adverse impact of radioactive releases into the atmosphere on human health is further supported by Figure 9, which shows a high correlation between the AMR that measures the abnormal rise in mortality between 1983 and 1988 for those most heavily exposed to fission products during infancy, and the more recent exposure to releases from nuclear reactors since 1970 for the nine different census regions of the United States. The plot also shows that for a given amount released, areas of high rainfall, which brings down most of the radioactivity, such as the Mid-Atlantic (MA), New England (NE), Pacific (PAC), and South Atlantic (SA) states, show a greater recent mortality rise than the lower rainfall states such as the western Mountain (MT) and the West and East Central plains states (WSC and ESC), respectively.

We can now restate the Sakharov thesis as follows. Atmospheric fallout constituted a necessary but not sufficient condition for the current emergence of cancer and other immune deficiency diseases among young people. Another

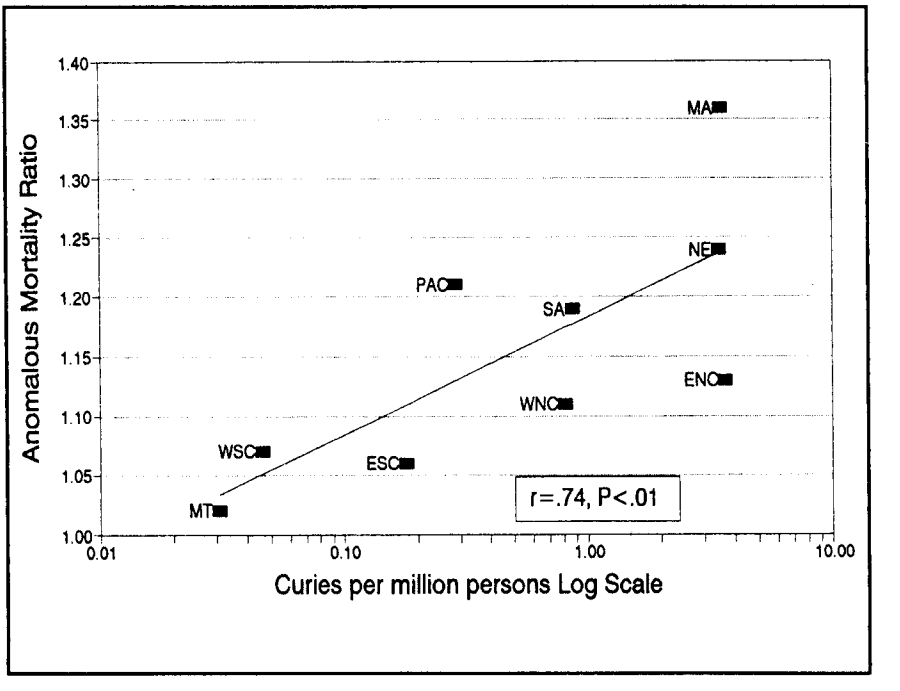

Figure 9. A significant correlation is shown between the AMR values calculated for each of the nine Census regions of the United States and the log values of the cumulated per capita emissions of airborne radioactive iodine and strontium since 1970, as reported by the Nuclear Regulatory Commission. The regions are denoted as MA, Mid-Atlantic; NE, New England; ENC, East North Central; SA, South Atlantic; WNC, West North Central; ESC, East South Central; MT, Mountain; WSC, West South Central; PAC, Pacific.

necessary condition is the secondary insult to previously damaged immune systems by routine and accidental emissions from civilian and military nuclear reactors, especially the reactor meltdowns of Savannah River in 1970, Three Mile Island in 1979, and Chernobyl in 1986. This is supported by the data in Figure 2, which show rises in mortality some one to two years after the 1970–1971 releases from a fuel meltdown at the Savannah River nuclear weapons production plant and one to two years after the Three Mile Island accident in 1979.

In the case of AIDS, a further necessary condition to fulfill the Sakharov prediction is the high-risk behavior of sexual promiscuity and/or drug abuse, which promotes the transmission of mutated microorganisms among individuals with reduced immune competence due to fallout exposure first foreseen by Sakharov.

The Sakharov thesis has the great scientific merit of accurately predicting and explaining past and present epidemiological anomalies. Perhaps the most astonishing is the light it throws on the differences between the mortality trends of the baby boom generations of the major nuclear nations and the inferences that can be drawn concerning their current and future health and economic productivity trends.

Table 1 summarizes mortality data for the 25–44 age group taken from the United Nations Demographic Yearbook, permitting the calculation of the AMR values for the United States, the United Kingdom, France, West Germany, and Japan. The former Soviet Union is missing from this table because it did not submit its annual mortality data broken down by age for the years prior to 1989.

In the aggregate, the AMR for the United States, United Kingdom, and France is 1.18, which means that from 1983 to 1988 the mortality experience of the baby boom generations deteriorated by 18 percent for these nations. On the other hand,

Table 1

International mortality trends, age group 25–44, 1983 and 1988, in thousands[a]

	1983			1988			Anomalous mortality ratio
	All deaths	25–44	Percent of all	All deaths	25–44	Percent of all	
United States	2,019.1	108.1	5.35	2,168.0	136.6	6.30	1.18
United Kingdom	579.6	14.0	2.42	571.4	14.9	2.61	1.08
France	559.7	23.8	4.25	522.0	25.6	4.90	1.15
Total above	3,158.4	145.9	4.62	3,261.4	177.1	5.43	1.18
West Germany	718.3	25.5	3.55	687.8	21.3	3.10	0.87
Japan	740.0	40.6	5.49	793.0	34.8	4.39	0.80
Total above	1,458.3	66.1	4.53	1,480.8	56.1	3.79	0.84

[a]Source: United Nations Demographic Yearbooks, 1983–1990.

the mortality experience of the German and Japanese baby boom generations in the aggregate improved by 16 percent over these years, so that there is a differential of 40 percent in favor of the baby boom mortality experience of these nations. This difference may illuminate one reason for recent economic productivity advantages enjoyed by Germany and Japan over the United States, United Kingdom, and France, because the 25–44 age group constitutes the most productive component of a nation's labor force. This point merits closer examination and can be explained, at least in part, by the Sakharov thesis.

First, wind and rainfall patterns subjected the United States, United Kingdom, and France to more of the massive atmospheric bomb-test fallout from the Nevada, Pacific, and Siberian test-sites than was the case for Germany and Japan. A second reason for the differences may lie in the differential importance of the role played by radioactive iodine in the diet, especially milk and drinking water consumed in the various nations. Highly active fission products such as iodine-131, which concentrates in the fetal and infant thyroid and has a short half-life of 8 days, and strontium-89, which has a half-life of 50 days and seeks out bone, generally reach the consumer of fresh milk within a few days. Unfortunately, in the United States civilian reactors are often located in rural areas close to dairy farms or large rivers and reservoirs that serve as drinking water supply, as discussed in connection with the recent changes in breast cancer rates in the New York Metropolitan area (9). By contrast, the Japanese diet is very low in milk, and the nuclear reactors are located along the coast so that there is a minimal contamination of drinking water when the wastes are discharged in liquid form. Moreover, neither Japan nor Germany has been operating military reactors and reprocessing facilities for plutonium production, whose discharges are much larger than those from normally functioning civilian nuclear plants.

Three examples are pertinent here. In April 1987 the U.S. Nuclear Regulatory Commission temporarily closed down the notorious Peach Bottom reactors on the grounds that the operators "were taking drugs and sleeping on the job." The Peach Bottom nuclear plant borders on Lancaster County, Pennsylvania, one of the largest milk production centers in the United States whose milk is consumed in such cities as New York, Philadelphia, Baltimore, and Washington, D.C. The infant mortality rate in Washington, D.C., rose in the previous two decades of Peach Bottom operation to the extremely high level in April 1987 of 37 per 1000 live births, but following the sudden absence of radioactive iodine in the milk, the infant mortality rate in Washington dropped to the national level of 10 by the summer of 1987 (26, pp. 111–126).

Another example is provided by a recent letter published in *Nature,* endorsed by the World Health Organization and written by Dr. Vasily Kazakov of the Belarus Health Ministry, reporting on the unexpectedly large number of thyroid cancers among young children and specifically identifying milk contaminated by Chernobyl fallout as a vector (44).

Figure 10 illustrates the remarkable similarity between the mortality improvement of Japan's baby boom generation from 1983 to 1988 (shown in Table 1) and that of young Californians of Asian descent, both of whom do not drink much milk or consume dairy products to the same degree as all Californians aged 25–44 combined and whose mortality experience deteriorated significantly during the same period. Milk and dairy products are the most important vectors for both iodine-131 and the bone-seeking isotopes that irradiate the bone marrow, just as in the case of breast cancer (9).

Further support for the hypothesis that great damage to the immune systems of young men and women aged 25–44 is associated in part with emissions from the manufacture and testing of nuclear weapons is given in Table 2, which presents AMR values for 23 nations that reported mortality by age to the United Nations for 1983 and for 1988 or other recent years.

Table 2 reveals the widespread anomalous rise since 1983 in the percentage of all deaths accounted for by this age group, reported by most of the 23 nations.

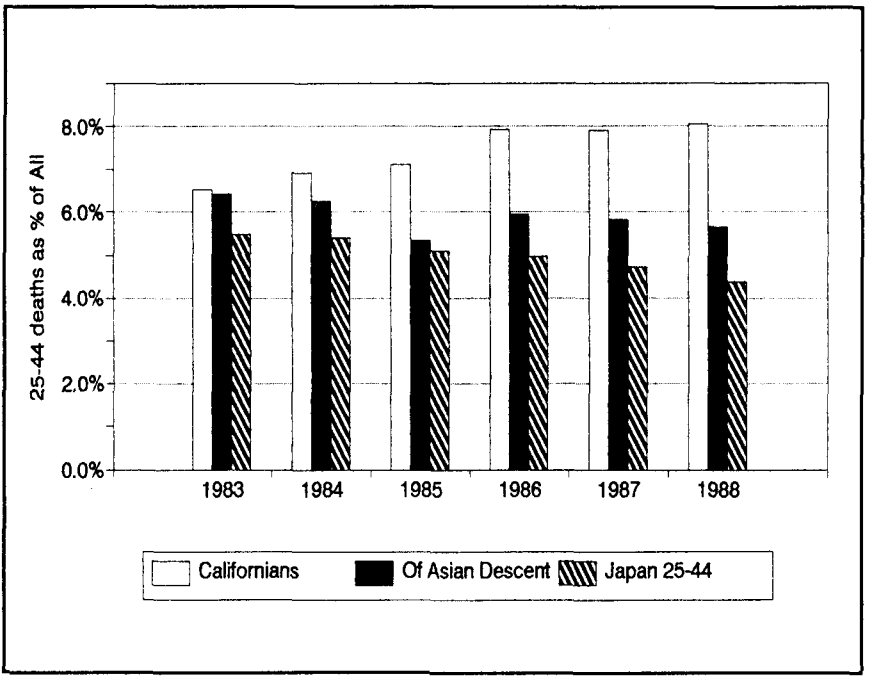

Figure 10. The anomalous mortality deterioration evident from 1983 to 1988 in the percentage share of all deaths of Californians aged 25–44 is contrasted to the corresponding annual movement of the 25–44 age group in Japan and 25–44 year old Californians of Asian descent.

Table 2

Anomalous mortality ratios for nuclear and nonnuclear nations, 1983 and 1988

	Percent of all deaths, age 25–44		Anomalous mortality ratio
	1983	1988	
Nations heavily exposed to nuclear emissions			
Nations making and testing nuclear weapons, including reprocessing			
Soviet Union		7.43 (1989)	
United States	5.35	6.30	1.18
France	4.25	4.90	1.15
United Kingdom	2.42	2.61	1.08
Nations not producing nuclear weapons, less heavily exposed			
Switzerland	3.70	4.10	1.11
Hungary	5.65	6.18	1.09
Bulgaria	4.22	4.56 (1989)	1.09
Norway	2.82	3.12 (1989)	1.08[a]
Poland	5.97	6.46	1.08
Czechoslovakia	4.21	4.57	1.08
Finland	5.18	5.60 (1987)	1.07
Nations least exposed to nuclear emissions			
New Zealand	4.53	4.88 (1989)	1.08[a]
Australia	4.71	5.02 (1989)	1.07[a]
Denmark	3.80	3.97	1.04[a]
Italy	3.00	3.05	1.02
Cuba	7.88	8.03	1.02[a]
Sweden	3.04	3.05	1.00
Singapore	8.93	8.95	1.00[a]
Netherlands	3.53	3.53 (1989)	1.00
Canada	5.30	5.25	0.99
German Democratic Republic	3.40	3.36 (1989)	0.99
Austria	3.95	3.62	0.92[a]
West Germany	3.55	3.10	0.87
Japan	5.49	4.90	0.80

[a]No civilian reactors.

There would, of course, be many more instances if the table included data for the former Soviet Union and all the high-rainfall third world nations in Africa, the Caribbean, and South America that received heavy fallout during the period of atmospheric bomb tests. These nations do not submit annual mortality breakdowns by age because of inadequate records, but we know that their young adults now suffer greatly from immune deficiency diseases such as AIDS and a resurgence of cholera.

In addition to rainfall, proximity to the point source of nuclear emission appears to be a significant factor. Thus, while the absence of an age breakdown for the former Soviet Union for 1983 precludes a calculation of the post-1983 mortality deterioration of its baby boom generation, we can infer that it may be even greater than that of the United States, given that high AMR values of the order of 1.07 to 1.09 prevail for all the neighboring nations from Finland in the north to Bulgaria in the south where nuclear reactors of Soviet design have been operating.

The highest AMR values of 1.18 and 1.15 are observed for the United States and France, both of which produced nuclear weapons and engaged in reprocessing operations on a large scale. Switzerland has a relatively high AMR of 1.11, consistent with the large number of nuclear reactors very close to its major cities and its location downwind of the French plutonium-producing reactors. Switzerland also reported the highest levels of strontium-90 in milk and bone in Europe when radiation clouds from the huge Soviet H-bomb tests of 1961–1962 were captured by the Swiss Alps, which have subsequently been associated with very high rates of cancer and AIDS mortality (26, pp. 198–207).

Although England has been reprocessing spent nuclear fuel to extract plutonium since shortly after World War II, it is an island nation similar to Japan and was able to discharge much of the nuclear wastes into the ocean, thereby reducing the contamination of its milk and drinking water and thus explaining the lower increase in mortality of young adults compared with the United States and France.

In a similar fashion, Norwegian mountains readily capture radiation clouds from the British nuclear reprocessing facility at Sellafield, drifting east with the prevailing winds. For example, very high radioactivity readings were recorded in 1964 in western Norway in contrast to areas along the eastern coast, as reflected in corresponding later differences in scholastic achievement in the seventh and ninth grades (33).

Because of the worldwide distribution of fallout, all nations must be considered exposed to emissions from weapons testing, military nuclear facilities, and civilian reactors to some degree, even if they are located far from the source and have no operating reactors within their own borders, such as New Zealand, whose mountains captured large amounts of fallout from the French atmospheric tests in the South Pacific. The data in Table 2 suggest that Central Europe—including Sweden, Denmark, the Netherlands, the two former German nations, Austria, and Italy—have been sufficiently far removed from emissions from France, the United States, and the United Kingdom in the west and from the Soviets in the east to have been spared some of the worst effects of the manufacture, testing, and reprocessing of nuclear weapons.

Several factors other than geographic location clearly play a role in altering the impact of ingested fission products, especially the type of diet, as illustrated most clearly in the case of Japan and of the Japanese population in California. Thus, the Central European states have highly educated homogeneous populations where an adequate diet, widely available medical care, and lower levels of ordinary

industrial pollutants that act synergistically with radiation reduce the impact of fission products on mortality rates more than in the United States and in the Eastern European countries.

DISCUSSION

In the light of all the accumulated evidence correlating infant mortality, low birthweight, total mortality, and cancer rates with strontium-90 in the diet and human bone, it would be unwise to ignore these widely differing international patterns in the recent mortality experience of young adults, which have enormous implications for the future of these nations. Finally, we can use the Sakharov thesis to make predictions for the United States in the 1990s; if these predictions come to pass, they will constitute even stronger support for his warnings.

Just as the Sakharov thesis explains the anomaly that those aged 25–44 registered a significant deterioration of mortality in the 1980s on the basis of their being born in the 1945–1965 bomb-test period, it permits us to predict that in the 1990s, when this generation reaches the 35–54 age groups, it will continue to register an anomalous degree of mortality deterioration. We can be even more precise: the age group 35–54 has throughout previous decades accounted for a declining share of total deaths, from 18 percent in 1940, for example, to a low of about 9 percent in 1990. But because in the 1990s this age group will be mainly made up of those born between 1945 and 1965, its percentage share will begin to rise for the first time in the 20th century. We have calculated that, just on the basis of the mortality performance of the baby boom generation in the 1980s, and assuming that there will be no additional catastrophes like Three Mile Island or Chernobyl in the 1990s, by the year 2000 the 35–54 age group may account for perhaps 11 percent of all deaths, and perhaps more if this generation is exposed to considerable additional radioactive stress.

The results of the present study support Sakharov's hypothesis that nuclear fission products released into the environment appear to have had a significant effect on the human immune system, both immediately on the newborn and later in life on adults, and most strongly on those adults who were exposed during intrauterine development and early infancy.

Moreover, the high degree of correlation between the measured concentration of strontium-90 in bone and the percentage of underweight births observed for the case of New York strongly supports Whyte's (11) conclusion that the abnormal rise and decline of neonatal deaths in the United States and United Kingdom are most probably due to strontium-90 and other fission products in the diet. Furthermore, the present investigation provides an explanation for the rise in the percentage of underweight births after World War II, resulting from two different biological mechanisms. One involves bone-seeking, high-energy beta-emitting isotopes such as strontium-89 and -90 acting on the immune system of the mother and producing an enhanced risk of rejection of the fetus as a foreign object during

early pregnancy. The other involves radioactive iodine that concentrates in the fetal thyroid in the latter part of intrauterine development, leading to a reduced growth rate and below normal weight at full term, as first observed for the Marshall Islanders accidentally exposed to fallout in 1954 (45).

The evidence for an anomalous upward movement in mortality rates for young adults beginning in the late 1970s, involving infectious diseases as well as increasing cancer incidence rates, supports the hypothesis that the abnormal rise in cancer mortality for young adults previously seen for breast cancer appears to be primarily due to an effect on the immune defenses. This leads to the multiplication of existing cancer cells, rather than to an iniating event involving direct damage to the DNA that dominates at high doses and dose rates. This is consistent with the observed nonlinear, concave downward or logarithmic shape of the dose-response curve evident at very low doses, when the available data cover a wide range of doses characteristic of an indirect, free-radical-mediated biological mechanism.

The same logarithmic form of the dose-response curve was found to apply to immune system damage as seen in the case of AMR values as a function of the known releases of fission products from commercial nuclear reactors by regions in the United States, as well as in the regional AIDS mortality for these releases, similar to the case of breast cancer mortality rates. Since free radicals are now recognized as being involved in many if not most diseases (46), the present findings suggest that the induction of cancer, as well as the production of genetic effects in future generations, appears to make up only a small fraction of the total health effects produced by fission products released into the environment as Sakharov proposed, both for the newborn and the adult. As the present study suggests, the greatest impact on human health seems to result from immature or underweight birth, followed by a greatly increased susceptibility to all forms of chronic and infectious diseases resulting from abnormal functioning of the immune system—such as pneumonia, influenza, hepatitis, tuberculosis, syphilis, gonorrhea, herpes, and generalized loss of immunity to bacteria, viruses, and other organisms, both old and newly evolved such as HIV.

CONCLUSION

All the recent evidence on the crucial role of free radicals in human diseases combined with an increased mutation rate produced by very low dose-rate fission products seems to require a complete reexamination of past estimates of the impact of small amounts of fission products entering the human body. Since the efficiency of free radicals at very low dose rates appears to be hundreds to thousands of times greater than was believed to be the case from our experience with short, high-dose-rate exposures to medical radiation or to the flash of the atomic bomb, it seems to require a complete reexamination of the decision to produce plutonium and tritium for nuclear weapons with the attendant releases of fission products into our air, our water, and our food.

Likewise, as difficult as it may be to accept, the hope of using nuclear fission to generate unlimited amounts of cheap and clean energy may have to be abandoned in the light of the evidence for a logarithmic or concave downward form of the dose-response curve for all environmental releases, no matter how small. Instead of a safe threshold for health effects, or even a direct linear relation that appears to hold for exposures at high dose rates, all the recent evidence points to a risk per unit dose that rises with decreasing releases or exposures down to a small fraction of the exposure due to naturally occurring radiation such as that from radium or cosmic rays. This high risk for doses due to artificial fission products results from the unanticipated ability of high-energy beta rays produced by bone-seeking fission products to reach the bone marrow and impair the function of our immune defenses far more efficiently than do the alpha particles emitted by radium in bone. Unless we are willing to face the evidence, releases from routine emissions and accidents are likely to continue the recent increase in low birthweight and cancer that are driving up the cost of medical care and welfare, reducing human productivity and thereby the ability of western nuclear nations to compete.

The evidence now available strongly suggests that the resurgence of infectious diseases believed to have been brought under control, as well as the appearance of new diseases such as AIDS, were brought about in large part by the nuclear arms race of the cold war. Only now that the cold war has ended will it be possible to carry out the studies needed to examine the free-radical processes produced by fission products inhaled or ingested by humans and all forms of life that depend on some form of immune defenses for their continued existence, and to mitigate the effects of the existing contamination of the earth on which we depend for our food and drinking water.

Acknowledgments — We would like to express our appreciation for valuable assistance in the collection of data by Joseph J. Mangano and important help in the computerized handling, analysis, and graphical presentation of the data by William L. McDonnell, both associated with the Radiation and Public Health Project, sponsored by the Commission for Racial Justice of the United Church of Christ. The article benefited from comments made by Drs. Rosalie Bertell and Alice Stewart.

Note — This article was presented at the Conference on Children and Radiation, Trondheim, Norway, June 10–14, 1993.

REFERENCES

1. Sakharov, A. Radioactive carbon from nuclear explosions and nonthreshold biological effects. *Soviet J. Atomic Energy* 4(6): 757–762, 1958.
2. Sakharov, A. *Memoirs.* Alfred Knopf, New York, 1991.

3. Norris, R. S., Cochran, T., and Arkin, W. *Known U.S. Nuclear Tests.* Natural Resources Defense Council, Washington, D.C., 1988.
4. Natural Resources Defense Council. *Nuclear Weapons Handbook,* Vol. IV, p. 373. Harper & Row, New York, 1989.
5. Cohen, M. Epidemiology of drug resistance: Implications for a post-anti-microbial era. *Science* 257: 1050–1055, 1992.
6. Bloom, B. R., and Murray, C. J. L. Tuberculosis: Commentary on a reemergent killer. *Science* 257: 1055–1064, 1992.
7. Neu, H. C. The crisis in antibiotic resistance. *Science* 257: 1055–1073, 1992.
8. Krause, R. M. The origin of plagues: Old and new. *Science* 257: 1073–1078, 1992.
9. Sternglass, E. J., and Gould, J. M., Breast cancer: Evidence for a relation to fission products in the diet. *Int. J. Health Serv.* 23(4): 783–804, 1993.
10. Pauling, L. *No More War.* Dodd Mead, New York, 1958.
11. Whyte, R. K. First-day neonatal mortality since 1935: A reexamination of the Cross hypothesis. *Br. Med. J.* 304: 343–346, 1992.
12. Sternglass, E. J. Evidence for low-level radiation effects on the human embryo and fetus. In *Proceedings of the 9th Annual Hanford Biology Symposium,* Richland, Washington, May 5–9, 1969, pp. 693–717. U.S. Atomic Energy Commission, Division of Technical Information, Oak Ridge, Tenn., 1969.
13. Sternglass, E. J. Environmental radiation and human health. In *Effects of Pollution on Health, Proceedings of the 6th Berkeley Symposium on Mathematical Statistics and Probability,* edited by L. M. LeCam, J. Neyman, and E. L. Scott, pp. 145–216. University of California Press, Berkeley, 1972.
14. Sternglass, E. J. The implications of Chernobyl for human health. *Int. J. Biosoc. Res.* 8: 7–136, 1986.
15. Coulam, C. B., Moore, B., and O'Fallon, W. M. Association between major histocompatibility antigen and reproductive performance. *Am. J. Reprod. Immunol. Microbiol.* 14: 54–58, 1987.
16. McCormick M. C. The contribution of low birth weight to infant mortality and childhood morbidity. *N. Engl. J. Med.* 312: 82–89, 1985.
17. Lee, K. S., et al. Neonatal mortality: An analysis of the recent improvement in the U.S. *Am. J. Public Health* 70: 15, 1980.
18. Lee, K. S., et al. The very low birth-weight rate: Principal predictor of neonatal mortality in industrialized populations. *J. Pediatr.* 97: 759–764, 1980.
19. New York State Department of Health. *Annual Reports.* Albany, N.Y., 1945–1950.
20. U.S. Public Health Service. *Vital Statistics of the United States,* Natality section. Washington, D.C., 1950–1988.
21. United Nations. *Strontium-90 to Calcium Ratios in Human Adult Vertebrae, Ionizing Radiation Levels and Effects,* Vol. 1, p. 47. New York, 1972.
22. Greer, D. S., and Rifkin, L. S. The immunological impact of nuclear warfare. In *Medical Consequences of Nuclear War.* U.S. Academy of Science, Institute of Medicine, Washington, D.C., 1986.
23. Petkau, A. Radiation carcinogenesis from a membrane perspective. *Acta Physiol. Scand. Suppl.* 492: 81–90, 1980.
24. Graeub, R. F. *The Petkau Effect.* Four Walls Eight Windows, New York, 1992.
25. Segi, M., Kurihara, M., and Matsuyama, T. *Cancer Mortality in Japan, 1892–1962.* Tohoku University School of Medicine, Sendai, 1965.
26. Gould, J. M., and Goldman, B. A. *Deadly Deceit, Low-level Radiation High-Level Cover-up.* Four Walls Eight Windows, New York, 1991.
27. Stewart, A., Webb, J., and Hewitt, D. A survey of childhood malignancies. *Br. Med. J.* 1: 1495–1508, 1958.

28. Knox, E. G., et al. Background radiation and childhood cancers. *J. Radiol. Prot.* 8: 9–18, 1988.
29. Hatch, M. C., and Susser, M. Background radiation and childhood cancers within ten miles of a US nuclear plant. *Int. J. Epidemiol.* 19: 546–552, 1990.
30. Sternglass, E. J., and Bell, S. Fallout and SAT scores: Evidence for cognitive damage during early infancy. *Phi Delta Kappan* 65: 541–545, 1983.
31. Newman, L. and Buka, S. L. *Every Child a Learner: Reducing Risks of Learning Impairment During Pregnancy and Infancy.* Education Commission of the States, Denver, 1990.
32. College Board. *Annual Reports on Scholastic Aptitude.* Princeton, N.J., various years.
33. Oftedal, P. Radioactive fallout in Norway in 1964: Scholastic achievement of the 1965 cohort, and the repair induction lag hypothesis. *Berzelius Symposium XV,* pp. 75–81. Umea, 1988.
34. Diamond, E. L., Schmerler, H., and Lilienfeld, A. M. The relationship of intra-uterine radiation to subsequent mortality and development of leukemia in children. *J. Epidemiol.* 97: 283–293, 1989.
35. Strand, J. A., et al. Permanence of the primary immune response in rainbow trout, *Salmo gardneri,* sublethally exposed to tritiated water during embryogenesis. *Radiation Res.* 91: 533–541, 1982.
36. Buehler, J. W., et al. Impact of the human immunodeficiency virus epidemic on mortality trends in young men, U.S. *Am. J. Public Health* 80: 1080–1085, 1990.
37. National Cancer Institute. *Cancer Statistics Review, 1973–1988.* NIH Publication No. 91-2789. Bethesda, MD., 1991.
38. Connecticut Tumor Registry. Connecticut Department of Health, 1935–1990.
39. Pellegrini, R. J. Nuclear fallout and criminal violence: Preliminary inquiry into a new biogenic predisposition hypothesis. *Int. J. Biosoc. Res.* 9: 125–143, 1987.
40. Duesberg, P. AIDS epidemiology: Inconsistencies with human immunodeficiency virus and with infectious disease. *Proc. Natl. Acad. Sci.* 88: 1573–1579, 1991.
41. Sternglass, E. J., and Scheer, J. Radiation Exposure of Bone Marrow Cells to Strontium-90 During Early Development as a Possible Cofactor in the Etiology of AIDS. Paper presented at the American Association for the Advancement of Science, Annual Meeting, Philadelphia, May 29, 1986.
42. United Nations. *Report of U.N. Committee on the Effects of Atomic Radiation, 17th Session,* Supplement No. 16. New York, 1962.
43. Nuclear Regulatory Commission. *Radioactive Materials Released from Nuclear Power Plants,* Annual report. NUREG/CR-2907. Washington, D.C., 1987.
44. Kazakov, V. S., et al. Thyroid cancer after Chernobyl. *Nature* 359: 21–22, 1992.
45. Sutow, W. W., and Conard, R. A. The effects of fallout radiation on Marshallese children. In *Proceedings of the 9th Hanford Biology Symposium,* Richland, Wash., May 5–9, 1969, pp. 661–673. U.S. Atomic Energy Commission, Springfield, Va., 1969.
46. Waldren, C., et al. Measurement of low levels of X-ray mutagenesis in relation to human disease. *Proc. Natl. Acad. Sci.* 83: 4839–4843, 1986.

Direct reprint requests to:

Dr. Jay M. Gould
Radiation and Public Health Project
302 West 86th Street
Suite 11B
New York, NY 10024