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HEALTH EFFECTS OF ENVIRONMENTAL RADIATION

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When the first commercial nuclear power station in the United States, located at Shippingport on the Ohio River 30 miles below Pittsburgh, started to operate in 1958, there was great hope that the atom could be harnessed safely for peaceful purposes, outweighing the destructive aspects of fission associated with the development of the atomic bomb. Based on the engineering success of this plant, a massive program of nuclear plant construction was launched in the mid-1960's that was to rid the world of its dependence on the rapidly depleting reserves of clean gas and oil, and in the process ending once and for all the pollution of the air and water produced by the burning of coal with its attendant deleterious effects on human health. What has happened in the last ten years that suddenly threatens the end of this dream?

There are actually many factors that have been involved in this development, including economic, engineering, and political problems. However, affecting them all is the fact that we greatly underestimated the biological hazard of small amounts of radioactivity in the environment as compared to what we had learned from over seventy years of experience with medical x-rays and the study of the survivors of Hiroshima and Nagasaki.

Thus, both human experience and laboratory studies of animals exposed to high doses of x-rays at first seemed to indicate that there might be a safe threshold dose below which essentially no observable health effects would exist. There was much evidence that the effects at high doses increased more rapidly than linearly with dose, so that at the very least a linear extrapolation to low doses would conservatively overestimate the likely effects at the much lower doses close to those of natural background radiation. All the data available in the early 1950's indicated that the typical dose needed to double the spontaneous incidence of genetic defects and cancers was of the order of 100,000 millirads (mr), or very large compared with natural background doses of 100 mr per year.

Since it appeared that it would be technically feasible to hold maximum doses to less than 5 mr per reactor [illegible] to much less than one milirad per year, the added risk due to the operation of nuclear plants was expected to be quite negligible compared with those due to the operation of coal burning plants.

The first indication that the risk of small doses of radiation might have been seriously underestimated did not begin to emerge until the large-scale epidemiological studies of Dr. Alice Stewart at Oxford University first published in 1958.(1) Dr. Stewart discovered that children exposed to only a few diagnostic x-rays during intrauterine development had almost twice the risk of developing leukemia and other cancers before age 10 than children not exposed. Since typical pelvic x-rays gave the fetus doses of the order of 300 to 500 mr, this meant that doses as small as 1,000 to 2,000 mr could double the normal rate of childhood cancers when given in the last months of pregnancy. This was some 50 to 100 times smaller than for the doubling of genetic effects and cancer in adults and mature animals on which the development of nuclear technology had originally been based.

However, this was not to be the end of the reasons for the growing concern. By 1970, Dr. Stewart had completed a study of some 16 million children born in England and Wales, and she was able to find enough cases to allow her to study the relative sensitivity of the fetus at different stages of development.(2) She discovered that for those fetuses irradiated in the first three months of pregnancy, the risk was some 15 times greated than for the majority who were irradiated just before birth. Translated into the dose D_0 needed to double the normal rate of this turned out to be only about 80 to 100 mr, or some 1,000 times smaller than the doubling dose for genetic damage and cancer in adults.

If one compares this with the maximum permissible dose of 500 mr to any member of the population of 170 mr average annual dose under existing Federal Radiation guidelines and the 25 mr per year under proposed E.P.A. standards for permissible exposures from nuclear power production one sees that the risk for childhood leukemia and cancer from normal operation of nuclear plants might be increased by

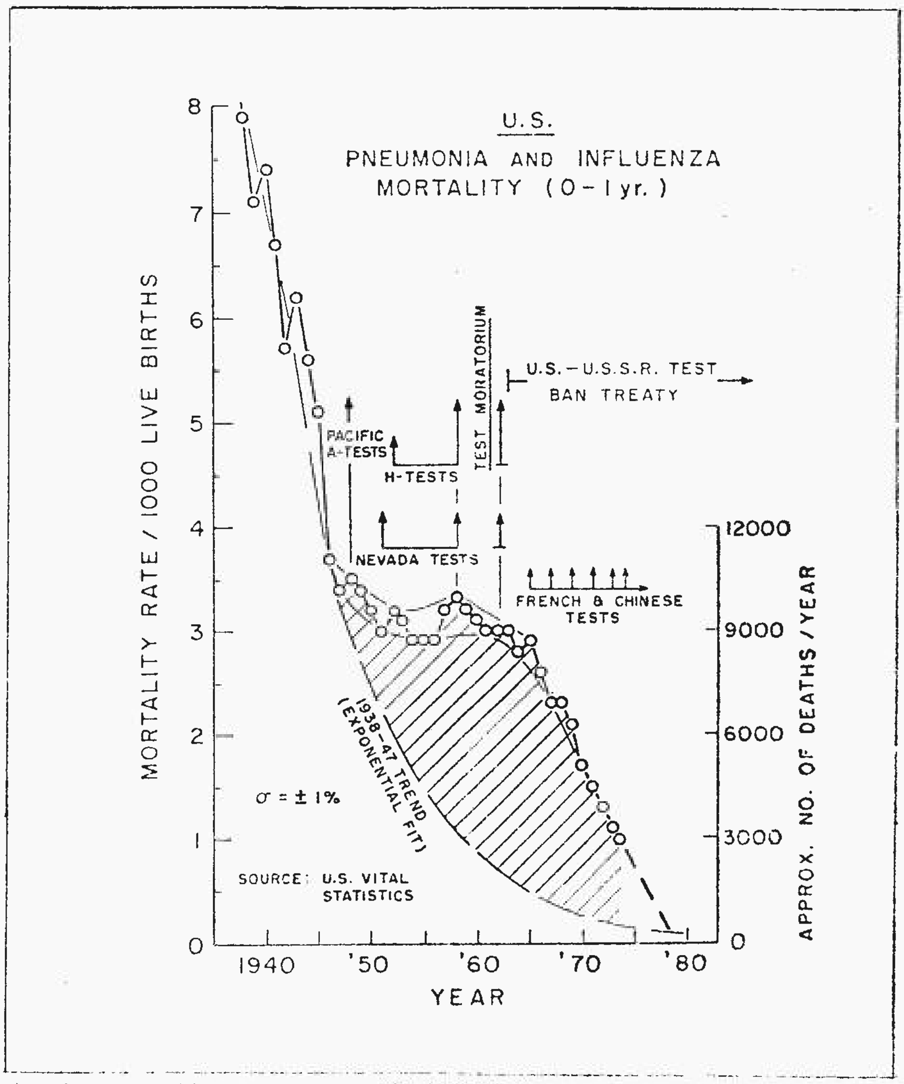

Fig. 1. Mortality rate per 1,000 births (0 - 1 yr. age group) for pneumonia and influenza, U.S., 1938-1974. (U.S. Vital Statistics).

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20% or more for children born near such facilities, drinking the water and the local milk, without the legally permitted doses being exceeded.

However, the recent studies have shown that the risk of cancer and leukemia is actually not the dominant one for exposure during intrauterine development, since only about 1 in 1,000 children develop leukemia or cancer before age 10. A large-scale prospective study of mothers who received abdominal x-rays in the course of necessary diagnostic exposures carried out at Johns Hopkins University by Diamond, Schmerler and Lilienfeld[3] showed that an even greater increase in deaths per 1,000 births took place for diseases of the respiratory and digestive system. Altogether for all causes of deaths combined, this very careful study sponsored by H.E.W. showed that for the exposed group of white children, the mortality rate in the first 10 years of life was 18.3 per 1,000 births, as compared with 9.8 for those who had not been exposed to radiation in utero. And once again, those who had been exposed at an earlier stage of development showed a much greater risk than those x-rayed just before birth.

This indication of increased risk of infectious diseases or reduction in the effectiveness of immune-system defenses following intrauterine exposure to small amounts of radiation is perhaps the most serious potential health effect of environmental radiation. The Johns Hopkins study explains the findings that deaths due to influenza and pneumonia for the age group 0 to 1 year stopped declining in the United States during the early 1950's when very heavy fallout occurred as a result of nuclear weapons tests in Nevada, the Pacific and Siberia, actually beginning to rise again the 1957-58 after decades of rapid decline.[4] (See figure 1). Not until after the end of atmospheric testing by the U.S., the U.S.S.R. and England in the early 1960's did this cause of infant mortality resume its original trend, so that it has by now almost decreased to the level expected if nothing had interrupted the original constant rate of decline. The reason why the immune system seems to be so much more sensitive to radiation than the genes of the adult is suggested by the recent laboratory and animal studies of Dr. Abram Petkau and his associates at the Canadian Atomic Energy Laboratories in Pinawa, Manitoba.[5] In March of 1972, Dr. Petkau reported that cell membranes are damaged by an indirect chemical action of radiation involving the dissolved oxygen in the surrounding fluid, in which the normal oxygen molecules are converted to the excited O_2^- free-radical. This highly active form of oxygen diffuses to the cell membrane and initiates an oxidative chain-reaction which weakens and ultimately destroys normal membrane functions. And since the chance of an O_2^- radical reaching the cell membrane without being deactivated is greater when the instantaneous concentration is less, the action of radiation on cell membranes is more efficient per unit energy absorbed at low doses than at high doses and dose rates.

Thus, the target area for radiation is now the entire cell surface and not just the small nucleus where the DNA is located. Furthermore, the dose D_o needed to damage the cell membrane declines as the radiation dose rate decreases from a rate of about 1 to 10 rads per minute used in medical diagnosis to about 1 microrad per minute for environmental radiation (see figure 2).

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multiply out of control, can also
to increased cancer incidence of th

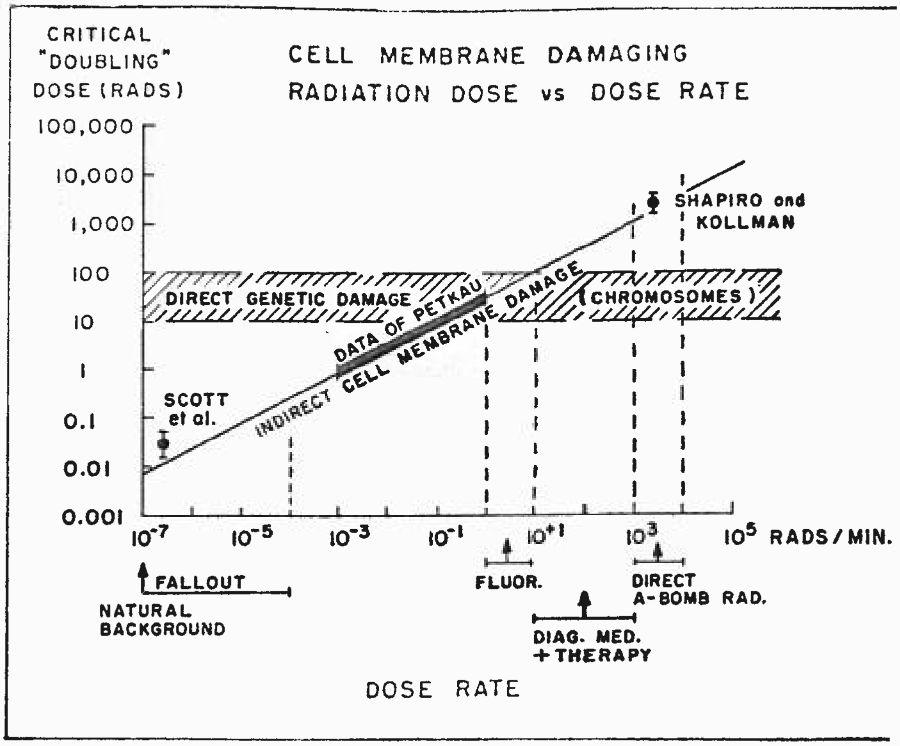

Fig. 2. Critical dose required to produce a given radiation effect a
a function of dose-rate.

This type of indirect radiation damage, which is more damaging at low dose rates, leads to dose-response curve that rises more rapidly at low doses than a linear curve as illustrated in figure 3.

As a result of such indirect chemical damage to membranes, the cells responsible for the immune defenses of the body are impaired, and the normal risk of infectious diseases is increased much more at low doses than had been expected by the "conservative" linear extrapolation from high doses.

type recently found for individual
who use river water[6] with its hi
concentration of short-lived radic
isotopes than old, deep-well water

It therefore follows that especial
in the very young and the very old
where the immune system is not as
effective as in the rest of the pc
lation, one would expect to find i
in cancer rates following the arri
of fresh fallout from nuclear test
even though the annual doses to cr
cal organs are only of the order c
10 to 100 mr, mainly through the n

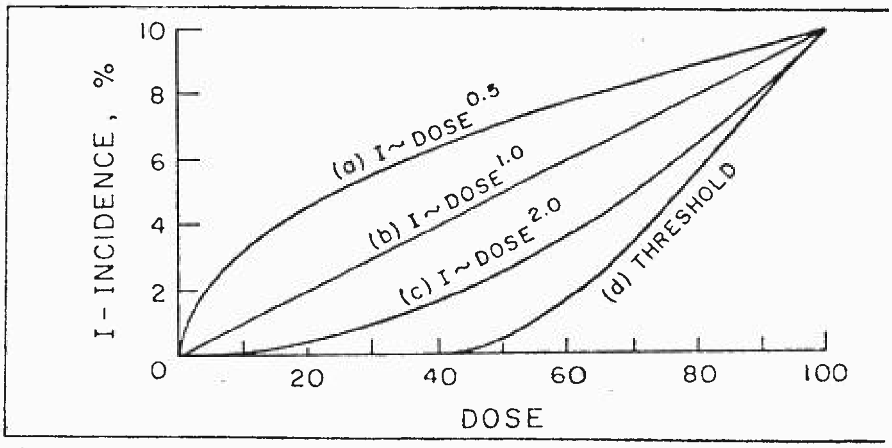

Fig. 3. Various possible forms of the dose-response relationship at low radiation doses. (Ref. 4)

However, not only are viruses and bacteria able to multiply more readily when the body's immune defenses are impaired by small amounts of radioactivity in the food and water. The same has been found to be the case for cancer cells, which are normally destroyed by the action of certain white blood cells or phagocytes. Thus, low-dose radiation, by reducing the

and the food chain, but also throu
river drinking water as a result c
surface run-off.

That this appears to have happenec
be seen from figure 4, which shows
pattern of childhood cancers, incl
leukemia, for male Japanese child
5 to 9 years old, the age group f
which Dr. Stewart had observed th

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greatest rise after intrauterine exposure. It is seen that for 12 years, or between 1935 and 1947, cancer rates were level or even declining despite rising chemical pollution, increased use of coal generated electricity and growing use of medical x-rays in Japan. But within 5 to 7 years after the beginning of fallout from Hiroshima and weapons tests by the U.S. and U.S.S.R., the cancer rates rose 200%, peaking at 600% over the pre-Hiroshima levels five years after the last U.S.-U.S.S.R. H-bomb test series. Furthermore, the recent peaking and decline occurred also for all age groups combined, strongly supporting the likelihood that these dramatic and sudden rises in cancer after the detonation of the first nuclear weapons were indeed due to the action of low dose rate radiation on the cells responsible for the immune defenses of the body (see figure 5).

Similar rises and declines of leukemia and cancer rates as well as infant mortality have been seen around a number of nuclear reactors in the United States[8] where the doses were of the same order of magnitude as from distant nuclear weapons fallout, i.e., annual doses of only about 10 to 50 mr, well below the present permissible doses of 500 mr (max.) or 170 mr (average).

The principal vectors were the local milk and other foods, as well as drinking water contaminated by the run-off of Cs-137, Sr-90, and I-131 deposited on the land by the releases of radioactive materials into the air. Thus, alone from the external gamma radiation produced by the radioactivity in the air and on the ground, the Humbolt Bay reactor in 1967, with a total gaseous release of 896,000 curies, resulted in a dose of 56.7% of the maximum permissible limit, or 283 mr to the most heavily exposed members of the population.[9]

It has therefore become apparent since the recent studies of Stewart, Lilienfeld and Petkau that when the present generation of nuclear plants was designed in the early 1960's, the risk of exposures in the millirad range had been underestimated by anywhere from 100 to 1,000 fold, especially for the developing infant in utero, so that the existing cost benefit calculations are no longer valid. Unless it is possible to reduce emissions of I-131, Cs-137, Sr-89 and Sr 90 by factors of this order, the health effects of nuclear power generation will greatly exceed those produced by fossil fuels. Alternatively, it would be prudent to convert to the nuclear steam generation system of existing nuclear plants such as the Zimmer Station to one using fossil fuel, as has already bee[n] done for a series of nuclear power stations in the U.S. and Sweden.

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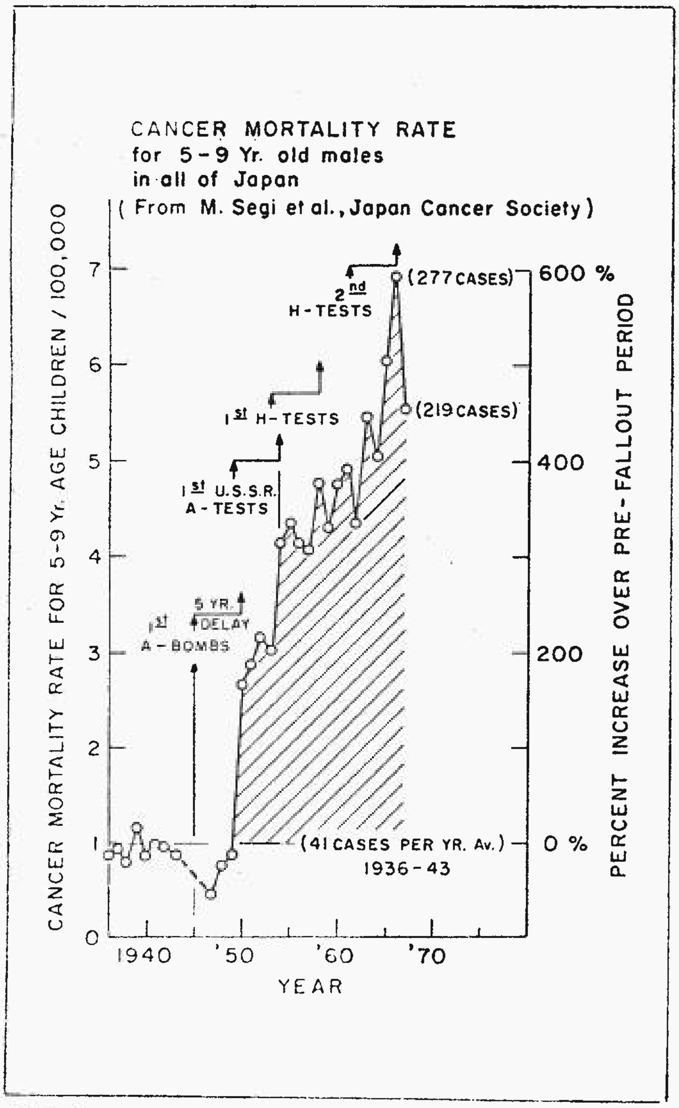

Fig. 4. Cancer mortality rate in Japan, 5-9 yr. old males, for the period 1936-1966. (Data of Segi and Kurihara, Ref. 7).

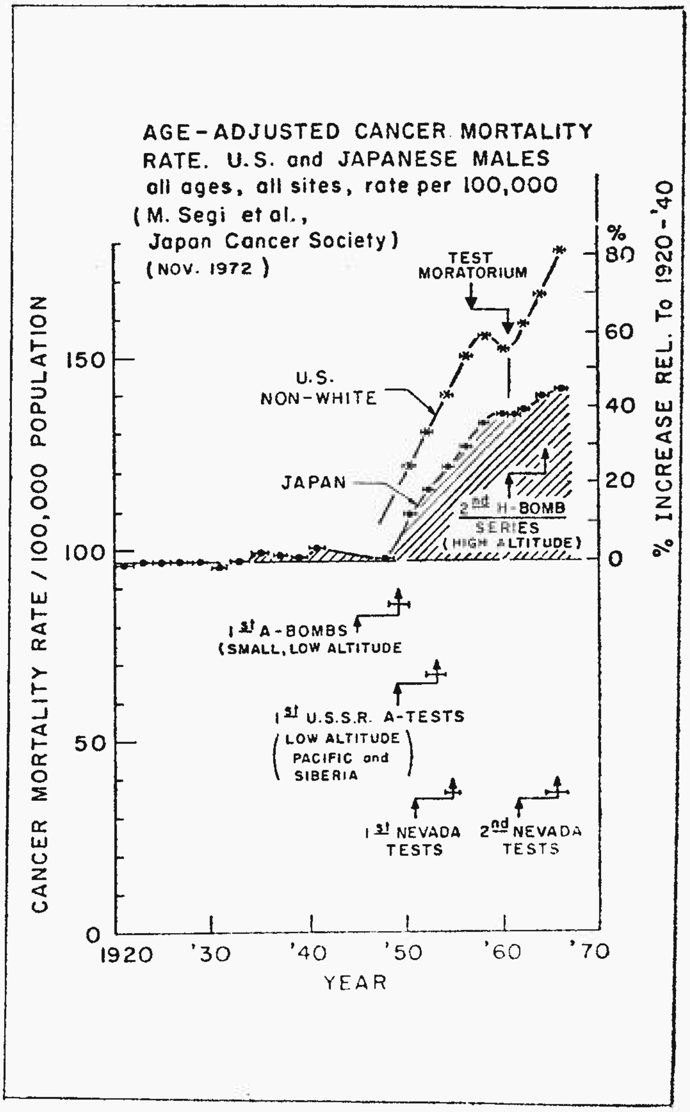

Fig. 5. Age-adjusted cancer mortality rate for Japanese and U.S. non-white males, all sites, 1920-1967. (Data of Segi and Kurihara, Ref. 7).