HEALTH EFFECTS OF LOW-LEVEL RADIATION*

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The widespread concern about radiation, especially by the general public, is understandable in view of the conflicting reports they receive. However, we know more, both qualitatively and quantitatively, about the effects of radiation on humans, animals, and the environment than about any other agent, including those that have been known to be hazardous for decades. The widespread controversy over the low-level effects of radiation is not about what we don't know but, paradoxically, about what we do know. The most extensive early studies of radiation effects on a population large enough to provide statistically valid data were those of Robley Evans on radium dial painters and radium chemists. His data, obtained during the 1930's and 1940's chiefly, are still of great value. These data served as one of the bases for radiation standards and guides until the mid-1950's and to some extent, even later. The apparent threshold at 1000 rads of alpha radiation to bone corresponds to 1 microcurie (or 1 microgram) of radium in the skeleton. The International Commission on Radiological Protection in 1949 agreed on a guideline of 0.1 microgram for occupational workers and 0.01 microgram for non-occupational exposure. This corresponded to 30 or 3 rem/year and has, of course, been slightly modified recently by the weighting factor of 0.12 recommended for bone in ICRP Publication 26. The occupational limit corresponds to 5 rem/year whole body divided by a 0.12 weighting factor for bone or about 44 rem (or 4.4 rem for members of the public).
All reputable scientific groups have endorsed the concept that linear extrapolation of effects at high doses to zero effect at zero dose provides a safe upper limit for predicting health effects. In doing so, they point out that certain effects, when produced by neutrons or other high Linear Energy Transfer (LET) radiations, are closely approximated by such relationship. They also emphasize that all low LET radiations, such as x- and gamma radiations, produce markedly less effects than high LET, when the dose is delivered acutely, and less still when fractionated or protracted at low dose rates. Typically, a quadratic form fits the dose/response relationship for acute doses of low LET radiations. A good example of this is the incidence of leukemia in the Japanese survivors of the nuclear bombings of Hiroshima and Nagasaki. Because the number of cases is zero in Nagasaki below 100 rads (or are not observable because of statistical and epidemiologic uncertainties in choosing the comparison populations) the curve is debatable at low doses until additional data are considered. Keep in mind that, due to the differences in bomb designs, the people in Hiroshima were exposed to both neutrons and gamma rays whereas the Nagasaki bomb produced a field of almost pure gamma rays, especially far out in the low dose zone.

Using the Japanese data, T. D. Jones used Katz's model for cell-killing of red marrow cells as a function of radiation type and dose, to construct a human effects model for acute radiation doses. His model fits the data well and makes clear that the relationship of dose and leukemia is not linear, especially for low LET radiations. Further, it is clear that leukemia induction as a function of the number of cells killed is a linear relationship. When extended to other forms of cancer
the model still holds well. Finally, the model has been applied to other forms of radiation and other species of animals and still describes the responses accurately for acute exposures.

Many substances are known to kill cells in the body and to be carcinogenic. Good examples of such are benzine and cigarette smoke. Dose and effect relationships are generally not known well with the exception of cigarettes. It is clear that the quantitative relationships that have been established in radiation protection are far better known than those for other substances.