

**A Radiation Primer:****LAURISTON TAYLOR REVIEWS RADIATION RISKS**

**F**oremost among the principal sources of radiation to which humans are exposed is "background radiation," which occurs naturally. It irradiates the entire globe—man and beast—to varying degrees related to time and location. Averaged over the whole U.S. population, everyone is exposed each year to one-tenth *roentgen* (or *rad* or *rem*) of radiation, primarily gamma rays. Very

This type of information has been misused in various ways by some nuclear objectors. Since body burdens of over about 0.1  $\mu\text{g}$  of radium are regarded as being potentially cancerous, these objectors might claim that one whole gram of radium is just too dangerous to leave lying around—that it is enough to kill more than a million people. If one gram of radium were divided equally among

mans from environmental sources. For example, people in Denver, CO get double the national average. Because of its altitude, Denver has less atmosphere to absorb cosmic rays from the sun. That city also lies in a region containing above-average amounts of radioactivity in its soil.

In some sections of Brazil and India, the natural background is ten to 20 times higher than the U.S. average, and as much as double the average exposure of radiation workers. No deleterious effects have been found in either country, but the numbers of persons exposed may be too small to permit adequate statistical sampling.

In discussing natural background radiation, it is assumed that it offers no particular harm or benefit to man. If there are indeed such risks as cancers or genetic effects from background radiation, they must be considered a part of the normal risks of living, and there is virtually nothing to be done about them.

To outline some facts about the actual or possible deleterious effects

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roughly, three sources contribute fairly equally to this exposure: a) cosmic rays from the sun; b) gamma rays from radioactive material in the earth; and c) more gamma rays, mainly from radioactive potassium that is in all our bodies.

Where does the earth's radiation come from? The principal sources are radium, uranium, and thorium, each having roughly the same radioactivity per pound of the soil in which they are contained. If one were to refine a layer of soil one-foot deep and one-mile square (1.7 million tons), one could extract roughly three tons of uranium, six tons of thorium, and one gram of radium. These elements produce radioactive gases, radon and thoron, which continuously breathe out of the soil and are responsible for the major portions of atmospheric environmental radioactivity.

a million people, each individual would have 1  $\mu\text{g}$  of radium. In order to get 1  $\mu\text{g}$  into the system, one would have to ingest about two tons of soil!

Other factors influence the amounts of radiation exposure to hu-

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of radiation, let me say that radiation—among more than a thousand other agents, *can* cause cancer. But exposure to radiation does not necessarily—or even often—*result* in cancer.

Our best and most detailed knowledge about radiation-produced cancer is derived from large acute exposures of 100 to 400 rads to the whole body, such as resulted from the Japanese bombings, and from the much larger

therapeutic exposures to limited portions of the body. An exposure of 100 rads is 1,000 times greater than the annual exposure from natural radiation which we all receive.

Below 100 rads, injurious effects are rarely detectable when received in one short exposure, and even more rarely detectable if spread over a year. Ill-defined exceptions may be leukemia, cancer of the thyroid, or breast cancer. Only sophisticated statistical

studies of large numbers of people not exposed (other than to natural radiation), can allow for detection of injurious effects caused by low exposure.

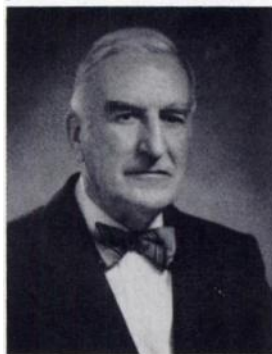
In a large group of people exposed acutely, that is about 450 rads all at once, half will die within a month. Acute exposures of 800 rads are lethal. Some people use the results of these high exposures to try to deter-

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## COMMENTARY:

# EXPERTS MUST EDUCATE THE PUBLIC

**E**ver since the nuclear weapons testing programs in the mid-1950s, there has been an acute public concern over the hazards of ionizing radiation. The concern has been enhanced by a variety of causes, mostly self-serving to those who wish to exploit some position of their own or of some larger group of which they are a part. Some of these exploitations are aimed at acceptable purposes, but are carried out under a cloud of ignorance or



misunderstanding of the fundamental facts about ionizing radiation and its potential hazards. Other exploitations are clearly carried out with malicious intent and justified by whatever "righteous" cause the promoter may be supporting. Still other exploitations are through individuals seeking personal financial gain, publicity or public approbation, or votes. Whatever the reason, the end result is a public fear where there is no valid reason for one. The main purveyors of this "disease of fear" are the news media.

On the other hand, advocates of education and of understanding the radiation problem are found today, as they have been in the United States for the past five decades, in such public, nongovernmental groups as the National Council on Radiation Protection and Measurements (55 years) or

the National Academy of Sciences (25 years). At the international level there are the International Commission on Radiological Protection (55 years) and the United Nations Scientific Committee on the Effects of Atomic Radiation (25 years). Collectively these bodies are made up of thousands of the world's leaders involved in matters of protection against ionizing radiation, yet collectively they are not succeeding in overcoming the pernicious influence of the world's news media.

The reason is not hard to find. Their studies, findings, and recommendations are fully available, but not without a small cost to the user. Although they are as scientifically flawless as scientists know how to make them, as far as the general public is concerned, these studies, findings, and recommendations make for very dull reading, as only scientists know how to make them. The problem is that the facts are primarily technical and, hence, are difficult to explain to the nonscientifically trained general public. Some of the efforts of the NCRP are an attempt to promote a public understanding of ionizing radiation and protection from it. It is the only one of the above organizations that has seriously tried to educate the public. And so far it has not fully succeeded. It is high time that people be given information that enables them to judge for themselves the hazards of radiation—without fears engendered by the news media.

—Lauriston S. Taylor

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mine the effects of low dosages of radiation. (Although there is no precise definition of what is "low," 5 to 10 rads, delivered acutely or spread over a year, is the proper magnitude. Some experts even consider 50 rads a low dosage.) However, we have been unable to establish any causal relationship, based on individual observation, between such low radiation doses and a specific deleterious effect.

One exception could be in-utero exposure, which may cause an injurious effect later in life. This one fact has led to the common feeling among the uninformed and the media that "here is a mysterious region of exposure to which we are all subject, and even the scientists don't know what is happening there." That is true, but the thinking is backwards. The reason scientists don't know is that if anything is happening, it is so minor and so infrequent as to be undetectable by the whole armamentarium of scientific research over the past 40 years. Stated differently, we know that the number of effects is very small; what we do not know is how small the number is. The fact that it cannot be found should fully tell the story of its relative unimportance.

One way around the dilemma has been to assume possible relationships between high-dose effects, which we can observe and measure, and low dose effects, which we cannot even find. If we assume that the number of effects is exactly proportional to dose at all levels, we can calculate the theoretical number of effects for low doses.

We do indeed know enough about the dose-effect relationship to believe that this theoretical number will be conservative—that is, the margin of error will be in the direction of five or ten times fewer effects. Nevertheless, sticking with an assumption of

**TABLE 1**  
**Sources of Radiation**

Radiation source	Average exposure (millirems per year)	National exposure index
Natural background		
average (U.S.)	100	100
average at 5,000 ft.	300	20
average at 500 ft.	103.5	1.7
average for 10-story bldg.	100.7	0.4
Medical	200	100
genetically significant dose	20	10
Nuclear power	1	1
TV receivers	1	0.5
Radiation workers		
maximum allowed	5,000	2.25 max.
normal average	1,000	0.45
Weapons fallout	2	1
Wristwatches	0.6	0.3
Highway material	4	0.1
Smoke detectors	1	0.05
Air travel	0.5	0.015
Airport inspection	0.002	0.0001

Source: NCRP Report No. 56, "Radiation Exposure from Consumer Products and Miscellaneous Sources."

exact proportionality, fatal cancers *may* develop in 100 out of a million people, each exposed to 1 rad, at some time during the next 50 years of their lives. *In other words, each person exposed to this much radiation stands only a one in 10,000 chance of dying from radiation-caused cancer, as compared with a one in six chance of dying from cancer arising from all other causes.* The percentage increase, due to that 1 rad of radiation, would be only 0.06 percent of all other cancer deaths. In addition, we don't *really* know that *any* cancers will result from such low radiation. Breast cancer may be a possible, but uncertain, exception.

Table 1 gives comparative data about the public's exposure to a variety of radiation sources. Starting with natural background information, we use 100 as the national exposure index. At least half the U.S. population is exposed to the first four sources listed—natural, medical, nuclear power, and television—at all times.

As an example, assume that someone living in San Francisco was exposed to 80 mrems per year. Then, supposing that one-third of the day was spent on the tenth floor of an office building, the exposure would be increased by 0.7 mrems per year, or nearly 1 percent. If half the population were to do this, it would add nearly 0.5 percent to the national exposure index, our total risk indicator. Living on one of the surrounding hills at a 500-foot altitude, the annual exposure would be further increased by at least 3.5 mrems per year. Again, if half the population lived in these hills, the exposure index would be increased by nearly 2 percent. These values are double the exposure that might be expected from television receivers today or from nuclear power in the year 2000.

The public's exposure from medical diagnostic procedures provides by far the largest exposure from any single identifiable source. It is estimated that the *average* medical exposure of

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half of the individuals in the United States would be double that due to background radiation. In other words, half the population would be exposed to an average of 200 mrem per year, which, incidentally, means that the exposure index would be 100, as shown in the third column. As far as future populations are concerned, only about 20 percent of all medical exposures, or 20 mrem per year, contribute to genetic effects. A 20-mrem exposure to half the population results in an exposure index of 10.

A projected exposure level from nuclear power by the year 2000 is of the order of 1 mrem per year, or less. If it is assumed that the entire population is exposed to this level, on the average, the index is only 1 percent of that for natural background radiation. Exposure from television equipment is also about 1 mrem or less per year, and assuming that half the population would be exposed to this source, the exposure index is 0.5, or only 0.5 percent of the total.

Looking at the other radiation sources in Table 1, we see that exposure from past weapons testing fallout is comparable to that from television or from nuclear power and, again, the overall radiation exposure index is 1 percent or less of the natural background base. The contribution of radiation workers' exposure to the overall risk to the nation is less than 0.5 percent of the risk from natural radiation.

It must be emphasized that all of these numbers are very crude and are used primarily to give some idea of how average exposures may run and how they may influence the national exposure index, or, let us say, the relative radiation risk to the population as a whole. As already emphasized, the medical exposure is the largest single source and is comparable to

that from natural background. However, it must be further emphasized that of all the radiation exposure situations we have, the medical procedures most assuredly have an overall positive benefit, although we cannot evaluate it quantitatively. Any medi-

acute effects (not cancer) within minutes or hours; low doses, below 50 rads, will not show any acute effects. Even for large doses, cancer will not likely appear for many years, if ever, depending on the type of cancer and the person's age at exposure.

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cal radiation exposure to an individual may *theoretically* subject that individual to some small but indeterminable risk. At the same time, however, it is that individual who receives the net positive benefits.

Let us now turn to some established facts, which the public should learn, about possible hazards from radiation exposure.

- Three units—roentgen, rad and rem—are the measures of radiation, and for x-rays and gamma rays they are numerically the same. A common subterm is the millirem (mrem), which is 0.001 rem. In radiology, a rad is the unit of absorbed dose, or 100 ergs per gram. (An erg is a unit to measure the amount of work done.)

- Although large amounts of radiation do cause determinable injuries to any biological system, radiation is not necessarily the causative agent every time these specific injuries are found. Practically any effect caused by radiation can also result from more than a thousand nonradiation causes.

- There may be long latent periods between exposure and effect. Large doses, 400 to 500 rads, can show

- Man has always lived in a radiation environment which, except for a very small increment due to weapons testing, has been very slowly decreasing.

- There is believed to be no threshold of exposure below which cancer will not be induced, and above which cancer will be induced. There does exist a few such thresholds for non-cancerous effects, such as cataracts.

- The effects of radiation are not necessarily cumulative. There is some process, genetic and/or somatic, of repair or recovery or replacement of cells. If this process did not occur, I and many of my radiation colleagues would have died a couple of times in the last 50 or 60 years.

Before concluding this review, it is important to state that none of the comments and comparisons should, in any way, be construed as playing down the real or theoretical hazards of ionizing radiation. We should indeed devote reasonable efforts and funds to an orderly, sensible endeavor to hold down unnecessary radiation exposures wherever feasible.

—Lauriston S. Taylor