Low-Level Radiation: Just How Bad Is It?

The controversy over the effects of low-level radiation has been sparked by several recent—but highly disputed—studies

If a number of recent reports are right, the harmful effects of low doses of radiation may be substantially—perhaps 10 times—greater than previously estimated. These reports, which fly in the face of the conventional view of the dangers of low-level radiation, have added new fuel to the ongoing controversy over the adequacy of the standards set by the U.S. government to regulate medical, occupational, and environmental exposures to radiation.

The radiation hazard most people are concerned about is cancer, although other untoward effects, such as genetic damage that may produce birth defects in future generations, are also possible. The current radiation standards are based on estimates of cancer risk derived from studies of some 82,000 survivors of the atom-bomb attacks on Hiroshima and Nagasaki and of groups of people who received therapeutic x-ray treatments for a variety of conditions.

Many of these individuals, especially those treated with the medical x-rays, received relatively high doses of radiation usually delivered in one or a few exposures. This situation is very different from that of most environmental and occupational exposures where low doses are received gradually over an extended period of time. Consequently, there has been a long-standing debate about how best to extrapolate data on risk estimates obtained at high doses to the lower doses likely to be encountered in the normal course of life.

This kind of low-level radiation is not precisely defined but is usually taken to mean exposures of less than 5 to 10 rems annually. The rem, or roentgen equivalent man, is a common unit for measuring radiation dose. It refers to the amount of radiation required to produce a particular amount of biological damage in tissue. The rad is another unit of radiation measurement; it specifies the amount of energy absorbed by tissue. For the type of radiation designated low LET (for linear energy transfer), including x- and γ-rays, the rad and rem are roughly equivalent. High LET radiation, such as the α-particles released by plutonium-239 and fast neutrons, is more effective than low LET radiation at causing tissue damage. Thus, for high LET radiation, 1 rad may be equivalent to as many as 20 rems.

The data on radiation risks obtained from the atom-bomb survivor study suggested two possible ways in which the data on cancer incidence at high radiation doses might be extrapolated to low doses. For high LET radiation, the risk seemed to decline with dose in a linear fashion with zero risk at zero dose (the solid line in Fig. 1). For low LET radiation, the risk seemed to fall off more quickly at low doses, as illustrated by the dashed line in Fig. 1. Thus, the assumption was made that the linear extrapolation would be conservative because it would overestimate the risk of low levels of some kinds of radiation. Maximum permissible exposures set according to these risk estimates would then be, if anything, lower than they have to be to safeguard the public health.

What some researchers are now saying, however, is that the linear extrapolation is not conservative after all. Rather, the risks at low levels of radiation are much greater than linear extrapolations would indicate.

The new data come from epidemiological studies of human beings exposed to low doses of radiation from medical x-rays, on-the-job exposures, and the fallout from nuclear weapons testing. For the most part the doses are well within those permitted by current standards.

In fact, the investigators calculate doubling doses for some forms of cancer to be as low as 5 to 15 rems. (The doubling dose is the amount of radiation that will double the cancer incidence.) These values are only about one-tenth or less of those predicted by the atom-bomb survivor study. Moreover, they are in the same range as the maximum occupational exposure now permitted by government standards. This is 5 rems per year for external radiation, an adequate standard according to the earlier risk estimates—but far too high if the newer estimates are correct.

Not everyone is convinced that the new estimates are valid, however. Some epidemiologists have severely criticized the design and data analyses of the studies producing them. The question of who is right is not going to be easy to resolve.

The experts are certainly having trouble agreeing on the magnitude of the hazards of low-level radiation. The dilemma has been plaguing the Committee on the Biological Effects of Ionizing Radiation of the National Academy of Sciences.* The BEIR committee has been reviewing the data to determine whether revision of the risk estimates the committee produced in its 1972 report is required. The committee is reported to have had trouble agreeing on a recommendation, although there are rumors that it will propose a reduction in permissible occupational exposures. Edward Radford of the University of Pittsburgh, committee chairman, is already on record in congressional testimony as being in favor of a tenfold reduction. The BEIR committee report, which was due in December of 1978, is expected to be released soon.

In May 1978, the White House commissioned an Interagency Task Force,† under the leadership of the Department of Health, Education, and Welfare, to

*The members of the BEIR committee are: Edward Radford (chairman), University of Pittsburgh; Seymour Abrahamson, University of Wisconsin; Gilbert Beebe, National Cancer Institue; Michael Bender, Brookhaven National Laboratory; Bertrand Brill, Vanderbilt University School of Medicine; Reynold Brown, University of California; Stephen Cleary, Medical College of Virginia; Cyril Comar, Electric Power Research Institute; Carter Denniston, University of Wisconsin; Jacob Fabrikant, University of California School of Medicine, San Francisco; Marylou Ingram, University of Miami School of Medicine; Charles Land, National Cancer Institute; Charles Mays, University of Utah Medical Center; Dade Moeller, Harvard School of Public Health; Dean Parker, Austin, Texas; Harald Rossi, Columbia University College of Physicians and Surgeons; Liane Russell, William Russell, and Paul Selby, Oak Ridge National Laboratory; Margaret Sloan, National Cancer Institue; Edward Webster, Massachusetts General Hospital; Henry Wellman, Indiana University School of Medicine.

†The members of the Interagency Task Force on the Health Effects of Ionizing Radiation are: F. Peter Libassi (chairman), Department of Health, Education, and Welfare; Donald Fredrickson, Director, National Institutes of Health; William Foege, Director, Center for Disease Control; Arthur Upton, Director, National Cancer Institute; Donald Kennedy, Commissioner, Food and Drug Administration; Linda Donaldson and June Zeitlin, HEW; Gilbert Beebe and Charles Land, National Cancer Institute; Clark Heath, CDC; John Villforth, FDA; Vice Admiral Robert Monroe, Department of Defense; Ruth Clusen and James Liverman, Department of Energy; Robert Copeland, Department of Labor; David Hawkins and William Mills, Environmental Protection Agency; Robert Minogue and Karl Goller, Nuclear Regulatory Commission.

formulate a program for addressing the questions raised about the effects of low-level radiation and the protection of the people who are exposed to it. The "working papers" of the Task Force released for public and scientific comment on 27 February serve to illustrate the problems faced by the BEIR committee. One conclusion of the Task Force states: "Current data are obviously insufficient to settle the question of human low-dose effects." Nevertheless the group points out that data from some recent studies are suggestive of higher than expected risks. The Task Force recommends further study but does not now see a need to reduce the occupational radiation exposures permitted by governmental standards.

One of the studies suggesting that low-level radiation entails a high risk of cancer is being carried out by Thomas Mancuso of the University of Pittsburgh and Alice Stewart and George Kneale of the University of Birmingham (England). To say that their conclusions are controversial is an understatement.

These investigators have been analyzing the causes of death of people who had worked at the U.S. government's nuclear facilities in Hanford, Washington. The workers were exposed to radiation delivered at very low dose rates over an extended period of time.

According to Mancuso, Stewart, and Kneale, 6 percent of the cancer deaths of the Hanford workers were caused by the radiation to which they were exposed. Moreover, these deaths were mostly due to cancers of tissues, such as the bone marrow, pharynx, lung, pancreas, and large intestine, which have been classified as being very sensitive to radiation by the International Commission on Radiation Protection.

Mancuso, Stewart, and Kneale estimate that the dose of radiation required to double the incidence of multiple myeloma (a cancer of the bone marrow) is only about 4 rads. For cancers of the lung, large intestine, and pancreas, they calculated the doubling dose to be about 14 to 15 rads.

Mancuso first began to study the Hanford workers in 1964. At that time the Atomic Energy Commission, whose research-related activities have since been incorporated into the Department of Energy, funded the work. But DOE withdrew its financial support in 1977 on the grounds that Mancuso's execution of the study was defective. Many people, including Mancuso, viewed DOE's action as an attempt to suppress findings unfavorable to the department's policies that encourage the development of nuclear

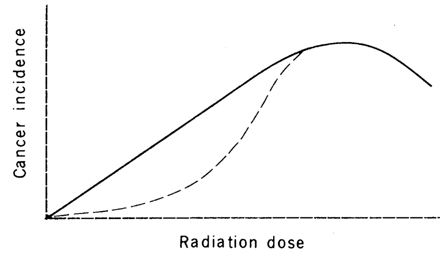

Fig. 1. Graph showing two possible ways in which the incidence of cancer might increase as the radiation dose increases. Both curves eventually level off and then decrease at high doses of radiation that kill cells rather than causing them to become cancerous.

power plants. The Environmental Policy Center, a privately funded environmental action group in Washington, D.C., now provides much of the support for the joint efforts of Mancuso, Stewart, and Kneale.

Researchers in England and this country have lodged vigorous criticisms of the conclusions reached by these three investigators. The critics question the low doses at which they are finding adverse effects of radiation and the lack of an increased incidence of leukemia in their study. Most other investigations have linked radiation to the development of leukemia, a finding not duplicated in the questioned study at the present stage of analysis.

The critics think the conclusions of Mancuso, Stewart, and Kneale are wrong because the statistical methods they used to analyze the Hanford data are defective. For example, Charles Land of the National Cancer Institute (NCI) with George Hutchison and Brian MacMahon of the Harvard School of Public Health and Seymour Jablon of the National Academy of Sciences have reanalyzed the Hanford data with a conventional method for doing studies of this type; they found only an increased incidence of multiple myeloma and pancreatic cancer. Another analysis of the Hanford data by Sidney Marks and Ethyl Gilbert of DOE's Battelle Pacific Northwest Laboratory and B. Breitenstein of the Hanford Environmental Health Foundation, also a part of DOE, produced similar results.

Although Mancuso cites these findings as confirming at least part of the conclusions reached by him and his collaborators, Land has another opinion. He says the size of the Hanford population is too small to give reliable results on cancer incidences. In other words, the apparent increases in multiple myeloma and pancreatic cancer might merely be statistical flukes that would disappear if a large enough population were studied. By Land's estimate, a population of 1 to 10 million would be needed. The total Hanford population includes about 35,000 workers.

Even if the increases in the cancers are real, they may not be radiation effects, according to Land, who says there may be alternative explanations for the excess cancers. Multiple myeloma and pancreatic cancer are known to be caused by other industrial pollutants to which the Hanford workers may have been exposed. Mancuso maintains, however, that the Hanford workers' environment is relatively free of occupational carcinogens other than radiation.

If the criticisms of the conclusions of Mancuso, Stewart, and Kneale have been vigorous, so have their replies to that criticism. According to Mancuso, the issue is not so much the size of the sample but rather whether the appropriate statistical method was used to analyze what is happening to the population. The method used by statistician Kneale to determine the effects of radiation on the Hanford workers is capable of doing the job, at least in the view of his colleagues in that study. Kneale originally thought that he had developed a new method for the Hanford study, but when he submitted it for publication to the journal *Nature*, he learned that his procedure was a variation of one previously developed by B. D. Cox of Oxford University for measuring the beneficial effects of drugs. As Kneale told a reporter for *Nucleonics Week* (15 February 1979, pp. 12–13), "We have simply reversed the process to see how much harm is caused by a dose of radiation instead of calculating how much good a drug might do."

Stewart says they have now reanalyzed the Hanford data, taking into account the criticisms of their earlier work, and have found the same results. She thinks that the critics have been concentrating their attacks on that earlier analysis, which was somewhat preliminary in nature, but that the more recent analyses have answered all the questions the critics raised.

Stewart herself is highly critical of the atom-bomb survivors study, which she maintains has underestimated the incidence of radiation-induced cancers. She points out that the study did not begin until 1950, 5 years after the bombs were dropped. Immediately after the blast, conditions would have been such as to cause the selective deaths of the weaker members of the population, who are usually concentrated in the cancer-prone age groups. Therefore, Stewart concludes, following an atomic explosion, many of these cancer-prone individuals may have died of causes other than cancer before their malignancies became apparent. Other work has shown that people who are developing cancer, especially leukemia, which was the first cancer to develop in excess among the atom-bomb survivors, are more susceptible to other causes of death. No evidence suggesting an increased death rate from causes other than cancer in the atom-bomb survivors has turned up, however.

Stewart also suggests a reason why leukemias were so prominent among the atom-bomb survivors and not among the Hanford workers. Atom-bomb blasts produce a lot of radioactive dust that may be inhaled and ingested. Thus, Stewart thinks that the leukemias, which developed early in the survivors, may have resulted from such internal radiation, whereas the solid tumors, which developed later, may have resulted from the external radiation. The Hanford workers have not been exposed to radioactive dust the way the atom-bomb survivors were.

Another indication that low-level radiation encountered on the job may cause cancer comes from a preliminary study of the causes of death of men who worked at the Portsmouth Naval Shipyard where nuclear submarines have been repaired and refueled since 1959. The study, which was carried out by Thomas Najarian, a physician who was then at the Boston University School of Medicine, Theodore Colton of Dartmouth Medical School, and a group of reporters from the Boston *Globe*, suggested that there was an excess of cancer deaths among shipyard workers who had contact

The Sources of Ionizing Radiation

Natural sources account for much—about 50 percent—of the radiation to which the general population of the United States is exposed, according to the Environmental Protection Agency. Little or nothing can be done to minimize exposure to this natural background radiation, roughly one-third of which is in the form of cosmic rays coming in from outer space. The remainder originates in sources such as deposits of minerals, including uranium and phosphate ores, that contain radioactive components. Some of the radioactivity may turn up in common building materials, granite and brick, for example, or may make its way into our air, water, and food supplies. But the average exposure to an individual from natural radiation sources is very low, a total dose of about 0.1 to 0.2 rem per year.

Medical and dental procedures constitute the next largest radiation source; they contribute about 40 percent of the total exposure of the general population. Most of this comes from the use of diagnostic and therapeutic x-rays, with the remainder attributed to the use of radiopharmaceuticals. Radiopharmaceuticals concentrate in specific organs and give physicians information about the clinical condition of those organs.

Medical and dental radiation is the largest block of radiation subject to human control. Although its use is generally considered to provide benefits that outweigh the risks, Health, Education, and Welfare Secretary Joseph A. Califano has recently directed the Food and Drug Administration to accelerate its program to reduce unnecessary exposures to medical and dental radiation in order to minimize the risks as much as possible.

1978 Estimates of the radiation exposures of the U.S. general population. [Data on radiation exposures as summarized by the Interagency Task Force on Ionizing Radiation]

Source	Person-rems* per year (in thousands)
Natural background	20,000
Healing arts	17,000
Technologically enhanced	1,000
Nuclear weapons	
Fallout	1,000 to 1,600
Development, testing, and production	0.165
Nuclear energy	56
Consumer products	6

*"Person-rems" are calculated by multiplying the total number of people exposed by their average individual doses in rems.

Radioactive fallout from nuclear weapons tests is the third largest source of radiation exposures, but it represents only about 3 percent of the total. Most of the fallout produced by U.S. weapons occurred between 1945 and 1962 when the testing was carried out in the atmosphere. Since the Atmospheric Test Ban Treaty of 1963 went into effect, the United States and the Soviet Union have tested their weapons underground. These tests have released little fallout into the atmosphere. But some of the radioactive materials in fallout, including strontium-90 and plutonium isotopes, are extremely long-lived. Materials released from the atmospheric tests are still present in the environment and in our bodies. Moreover, some countries, notably China and India, still occasionally conduct weapons tests in the atmosphere. The doses of radiation received from fallout vary with geographical location. People living immediately downwind from the test sites usually get the largest doses, but weather patterns can carry the radioactive materials for long distances and they are now spread over the entire globe.

Although the average exposures of the general U.S. population from natural radiation sources are very small, human activities can greatly increase the exposures of specific groups of people. The activities include the mining and processing of ores, uranium oxide, for example. Miners and other workers carrying out these activities and people living near the mines and processing plants are exposed to higher radiation doses than the general population. This "technologically enhanced natural radiation" accounts for about 2.5 percent of the total human exposure in this country.

Another source of radiation exposure is the use of nuclear energy to produce electricity. Most of this exposure is concentrated in the workers producing the nuclear fuels and running the power plants. People living near such facilities are exposed to lesser doses.

Finally, some consumer products emit very low levels of radiation. They include luminescent clock or watch dials containing radium, some kinds of smoke detectors, color televisions, and the glass used for making eyeglasses.

—J.L.M.

with nuclear materials. The investigators did not have reliable estimates of radiation doses for the shipyard workers, however. In fact, they determined whether the dead workers had been exposed to radiation by asking the next-of-kin.

In a move that is itself the subject of some controversy because of the conflict-of-interest allegations lodged against DOE by Mancuso and others, the department has recently announced a large-scale follow-up study of workers in seven shipyards where nuclear work has been done. The investigation, which is being contracted out to researchers at Johns Hopkins University, will take 5 years and cost almost $10 million.

But Mancuso says that 5 years and $10 million will not be adequate to do the job. Since most nuclear shipyards are relatively young, and the latent period for cancers may be 15 to 20 years or more, an adequate study could take 20 years to accomplish. A shorter study might give false negative results if it were stopped before an increase in cancer incidence became apparent.

Occupational exposures are currently a potential problem for perhaps a few hundred thousand workers, a substantial number, but still a small fraction of the population exposed to the most important source of man-made radiation, that of medical and dental x-rays. According to a survey performed by HEW, 60 percent of the U.S. population had at least one such x-ray in 1970. The use of medical and dental x-rays has probably increased since then.

Recently, Irwin Bross and his colleagues at Roswell Park Memorial Institute published results implicating diagnostic x-rays as a significant cause of cancer and even heart disease. Bross's study is also controversial. The editor of the *American Journal of Public Health*, which published the study in the February issue, took the unusual step of running a disclaimer to the effect that "Dr. Bross stands virtually alone in defense of his data and the interpretations he places on them." The journal published the report because "Dr. Bross has been a respected investigator whose statements are frequently quoted by the press, and because published critiques of his analysis have been rare. . . ." Accompanying the Bross article is a critical review by Land and John Boice, also of NCI.

According to Bross, his study is the first to show directly how the incidence of leukemia increases as the radiation dose increases from 0.1 to 10 rads. The men studied had been exposed to ordinary diagnostic radiation in this dose range. Other studies of the effects of medical x-rays have involved much higher doses and the data had to be extrapolated to the lower dose levels.

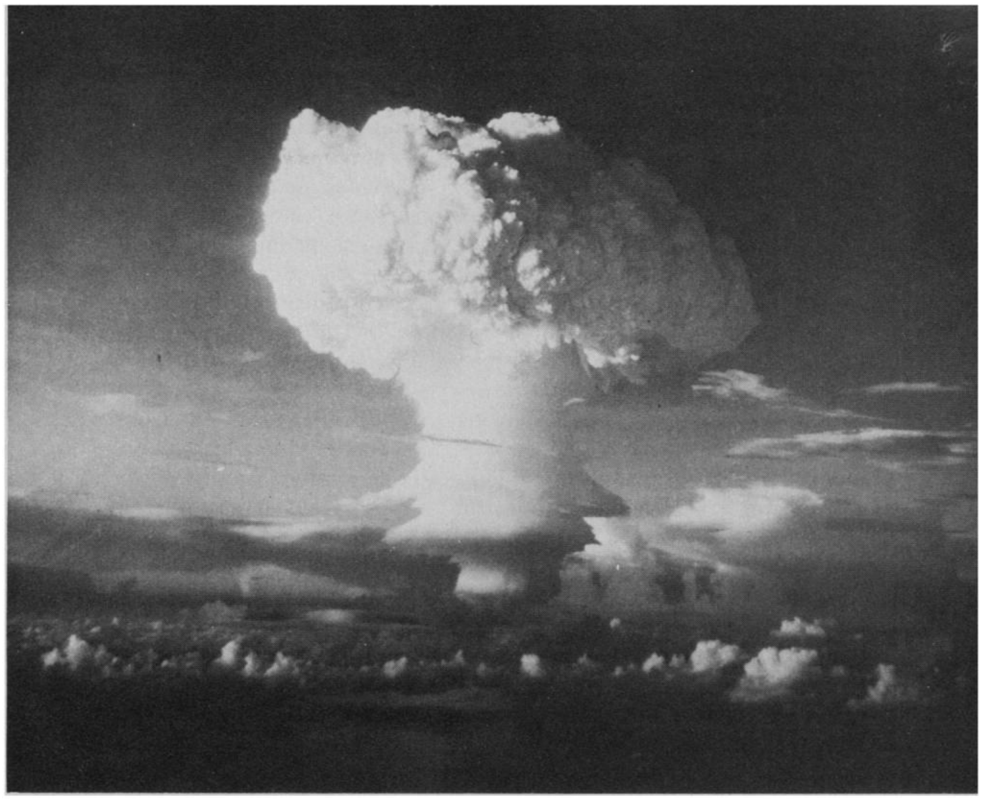

Fig. 2. Photograph of a mushroom cloud produced by an atmospheric nuclear bomb test. The cloud extended well into the stratosphere, with the mushroom cap spreading about 100 miles. (Source: United States Air Force)

Bross now estimates that the risk of the low-level radiation is some ten times greater than the previous studies predicted. In particular, he believes that some portions of the population are especially sensitive to radiation effects.

The source of Bross's data is the Tri-State Survey, a survey of leukemia cases in sample areas of New York, Maryland, and Minnesota. Bross says that even the large population included in the Tri-State Survey is too small for detection of radiation hazards by standard statistical methods. For this reason, he and his colleagues developed a new technique for analyzing the data.

According to Boice and Land, however, this new statistical method is not a valid way of analyzing the data. They detail their objections to it in their article in the *American Journal of Health Physics*.

One of their many criticisms concerns the increased susceptibility of individuals who are developing leukemia to infections and other health problems. Such individuals come under increased medical surveillance, including the use of medical x-rays. Thus, even though the x-rays may precede the diagnosis of leukemia they do not necessarily cause the blood cancer. In reply to this criticism Bross says that most of the x-ray exposures occurred at least 3 years before the onset of leukemia, a time when the early effects of the condition would not yet be developing.

A third source of low-level radiation exposure, in addition to occupational and medical sources, is contamination of the environment with radioactive materials. Among the sources of the contamination are fallout from nuclear weapons tests (Fig. 2) and various nuclear facilities such as plants for processing reactor and weapon fuels.

According to Carl Johnson of the Jefferson County Health Department in Lakewood, Colorado, a large area of land in Jefferson County has been contaminated with radioactive plutonium, which was released from the Rocky Flats Nuclear Weapons Plant. The contaminated region, which is near Denver, is highly populated. Almost 150,000 people live within 10 miles downwind of the Rocky Flats plant.

Some of the release was the result of emissions of permissible quantities of plutonium, but most of it occurred as a result of a fire at the plant in 1957 and because of leakage from barrels of contaminated oil stored by the plant. Johnson says the plutonium concentrations in some parts of Jefferson County are more than 3000 times higher than the background plutonium concentrations produced by nuclear fallout. Some plutonium isotopes are extremely long-lived; plutonium-239, for example, has a half-life of 24,000 years.

Johnson now finds higher incidences

of cancer among people living in the contaminated areas. He obtained his cancer incidence data from the Third National Cancer Survey conducted between 1969 and 1971 under the aegis of NCI. Johnson says there appears to be a direct association between the plutonium concentrations in the soil and the increased risk of cancer. The increases in cancer incidences ranged from 6 percent in the areas with the least contamination to 16 percent in the area with the most contamination. Among the cancers showing increases were leukemia, lung cancer, and cancer of the nasal passages and larynx. Johnson thinks that inhalation and ingestion of plutonium in dust are the most likely routes by which the material enters the body. Jefferson County is a dusty, arid region having only about 8 inches of rainfall per year.

Johnson points out that the plutonium concentrations in most of the contaminated regions are still only about one-hundredth of the maximum permissible concentration proposed by the Environmental Protection Agency for limiting plutonium contamination in residential areas. Johnson has written EPA Administrator Douglas M. Costle to request a public hearing on the adequacy of the proposed standard. The EPA has declined this request on the basis of its having held a public meeting on the issue last year in Colorado.

Two studies have now implicated radioactive fallout as a cause of an increased risk of cancer, primarily leukemia. One study was carried out by investigators at the Center for Disease Control in Atlanta. It includes more than 3100 men who participated in 1957 in a nuclear weapons test code-named "Smoky." Most of the men at the Smoky test were exposed to less than 5 rads of external radiation, according to the exposures monitored by their film badges.

Analysis of the data is not yet complete but so far eight cases of leukemia have been found. Fewer than four would be expected in a group of men of that size and age range. Glyn Caldwell of the CDC, who is in charge of the study, considers this finding to be suspicious, but he cannot be sure about its significance until all the data are analyzed.

The second study includes children living in Utah who were exposed to the nuclear fallout from weapons tests conducted in the Nevada desert between 1951 and 1958. Joseph Lyon and his colleagues at the University of Utah College of Medicine compared the leukemia death rates in the parts of Utah that received high fallout doses with the rates in areas of the state subjected to little fallout. The rate did not change in the low-fallout regions between 1944 and 1975 but it more than doubled in the high-fallout areas between 1959 and 1967. After that it declined to about the same value it had been before the weapons tests began. The findings imply that the radioactive fallout caused a temporary rise in leukemia deaths in the high-fallout counties of Utah.

According to Land, who has been spending a lot of time recently in commenting on epidemiological studies linking cancer to low-level radiation, the interpretation of Lyon's data may not be as simple as it seems. Lyon's results show that the death rate from childhood leukemia in the high-fallout counties was much lower both before the weapons tests and in the period from 1968 to 1975 than it was in the low-fallout regions. Moreover, the death rate from childhood cancers other than leukemia declined after the nuclear tests at a time the leukemia death rate was rising, so that the death rate from all forms of childhood cancer was unchanged. All this implies that the high leukemia death rate observed by Lyon between 1959 and 1967 might be a statistical fluke, although Lyon points out that, at its peak, the rate was still some 50 percent higher than the rate in the low-fallout counties and in the United States as a whole.

Some necessary information is also missing from this study. No one really knows how much radiation the children were exposed to. Thus Lyon says it is impossible to tell whether the increased leukemia death rate was an unusually large response to low-level radiation or whether the exposures were actually high. At least one test resulted in heavy fallout in the area of St. George, Utah, which is in Lyon's high-fallout area, when the wind shifted unexpectedly at the time of the test. Lyon hopes that newly released information on the nuclear tests will provide the data needed to assess the doses of radiation to which the people of Utah were exposed.

Investigators have known for some time that radiation, usually in relatively high doses, can cause chromosome abnormalities. Now there are indications that workers exposed to low-level radiation within the limits set by government standards can also experience the abnormalities. A group of researchers at Western General Hospital in Edinburgh, consisting of H. J. Evans, K. E. Buckton, G. E. Hamilton, and A. Carothers, identified an increased number of chromosome aberrations in nuclear-dockyard workers. Most of the dockyard workers were exposed to less than 5 rems per year over a period of 10 years.

In addition, William Brandom of the University of Denver and his colleagues found increased numbers of abnormal chromosomes in workers at Rocky Flats, even in men whose bodies contained concentrations of plutonium well within the amounts permitted.

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The biological consequences of the abnormalities found in the two studies is unclear. There is general agreement, however, that damage to the genetic material carried in the chromosomes is undesirable even if the exact effects of that damage are not understood.

Because of the results of the studies linking cancer and chromosome damage to low-level radiation, some researchers and members of environmental groups are now recommending an immediate reduction in permissible levels of radiation exposures. However, many investigators, in and out of government, maintain that, because of their flaws, these studies are not conclusive, either separately or in combination. As Arthur Upton, Director of the NCI, puts it, "Fragmentary and incomplete data do not by sheer numbers make a case." Not surprisingly, Mancuso has a different view: "When a series of independent studies point in the same direction, the evidence should not be ignored."

Or, as one might say, where there is smoke there is fire. If nothing else, the new data are forcing a reexamination of the risk estimates on which radiation standards are based. Since every man, woman, and child in the country is exposed to some kind of man-made radiation at some time in their lives, a reevaluation of those risk estimates, however messy it may be in execution, certainly appears to be in order.—JEAN L. MARX