WM DOCKET CONTROL CENTER

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David G. Scott
Acting Director
Office of State Planning
2-1/2 Beacon Street
Concord, NH 03301

Dear Mr. Scott:

During the August 18, 1985 meeting of the High-Level Waste Task Force, it was suggested that the Task Force be provided with information about natural background radiation, plans for transportation of HLW and information about NRC meetings and technical positions established in the HLW area.

I have enclosed several background papers that provide information about the sources of, variation in and exposures from natural radiation. I hope these will be of help to you. Cathy Russell has also placed Cris Simmers' name on our distribution list to receive copies of meeting notices and documents distributed by the HLW program. We also have a toll free number you may call for a recording of upcoming HLW program meetings; 1-800-368-5642, extension 79002. With respect to information about plans for HLW transportation, I suggest you contact Robert E. Philpott of DOE on (202) 252-9620 directly for information on their Transportation Business and Transportation Institutional plans.

We appreciated the opportunity to meet with the Task Force and to discuss NRC's HLW program. If we may be of further assistance, please let me know.

Sincerely,

Original Signed By
Paul H. Lohaus

Paul H. Lohaus
State Liaison Officer

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Radiation Exposures from Various Sources

The radiation dose from natural background radiation and the variations in background radiation are discussed in two other fact sheets.

Medical and dental diagnostic x-rays are the second highest source (after natural background radiation) of radiation exposure for most people in the U.S. Table 1 shows the radiation dose to the bone marrow for different common x-ray examinations.

Other minor sources of radiation exposure to the average person are fallout from previous nuclear weapons tests in the atmosphere, radiopharmaceuticals, occupational exposure to radiation, nuclear power and miscellaneous sources, such as radioactivity in consumer products. The average whole-body doses from all sources are summarized in Table 2. A more detailed comparison of exposures to the whole body, and to different parts of the body is given in Table 3.

Table 1. DIAGNOSTIC MEDICAL AND DENTAL RADIATION EXPOSURE --MEAN ACTIVE BONE MARROW DOSES, U. S. ADULT POPULATION, 1970*

Type of Examination	Millirems per Examination**
Dental X-ray	9
Chest radiographic x-ray	10
Chest photofluorographic x-ray	40
Skull x-ray	80
Gallbladder x-ray	170
Lumbar spine x-ray	350
Upper GI Series x-ray	540
Barium Enema x-ray	880

*Schleien, B., et al., The Mean Active Bone Marrow Dose to the Adult Population of the United States from Diagnostic Radiology. U. S. Department of Health, Education and Welfare, Public Health Service, Food and Drug Administration, HEW Publicaion (FDA) 77-8013, January 1977; excerpted from Table 4-3 in HEW Publication (FDA) 80-8104, The Selection of Patients for X-ray Examinations, January 1980.

**Values in the table have been rounded. The units in the original table are millirads; however, for practical purposes, 1 millirad = 1 millirem in this table.

ANSWERS TO FREQUENTLY ASKED QUESTIONS

1. What is meant by risk?

   Risk can be defined in general as the probability (chance) of injury, illness, or death resulting from some activity. More precisely, risk is a combination of the probability of an event and the severity of the consdequence of that event, or "probability times consequence."

2. What are the possible health effects of exposure to radiation?

   Some of the health effects that exposure to radiation may cause are cancer (including leukemia), birth defects in the children of exposed parents, and cataracts. These effects (with the exception of genetic effects) have been demonstrated in studies of medical radiologists, uranium miners, radium workers, and radiotherapy patients who received excessive doses in the early part of the century. Studies of people exposed to radiation from atomic weapons have also provided data on radiation effects. In addition, radiation effects studies with laboratory animals have provided a large body of data.

   The studies mentioned, however, involve levels of radiation exposure that are much higher than those permitted by regulatory agencies today. Studies have not shown a clear cause-effect relationship between health effects and current levels of occupational radiation exposure or (the much lower) levels of radiation exposure to the general public.

3. What is meant by prompt effects, delayed effects, and genetic effects?

   Prompt effects are observable shortly after receiving a very large dose in a short period of time. For example, a dose of 450 rems to an average adult will cause vomiting and diarrhea within a few hours; loss of hair, fever, and weight loss within a few weeks; and about a 50 percent chance of death within 1 month without medical treatment. Delayed effects such as cancer and cataracts may occur years after exposure to radiation. Genetic effects occur when there is radiation damage to the genetic material. These effects may show up as birth defects or other conditions in the offspring of the exposed individual and succeeding generations, as demonstrated in animal experiments, although this effect has not been observed in human populations.

4. What is the difference between acute and chronic exposure?

   Acute radiation exposure, which causes prompt effects and may cause delayed effects, refers to a large dose of radiation received in a short period of time; for example, 450 rems received within a few hours or less. The effects of acute exposures are well known from studies of radiotherapy patients, atomic bomb victims, and accidents that have occurred in nuclear

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fuel processing. Chronic exposure, which may cause delayed effects but not prompt effects, refers to small doses received repeatedly over long periods, for example, 20-100 mrems (mrem is one-thousandth of a rem) per week every week for several years.

5. How does radiation cause cancer?

How radiation causes cancer is not well understood. It is impossible to tell whether a given cancer was caused by radiation or by some other of the many apparent causes. However, most diseases are caused by the interaction of several factors. General physical condition, inherited traits, age, sex, and exposure to other cancer-causing agents such as cigarette smoke are a few possible interacting factors. One theory is that radiation activates an existing virus in the body which then attacks normal cells causing them to grow rapidly. Another is that radiation reduces the body's normal resistance to existing viruses which can then multiply and damage cells. Radiation can also damage chromosomes in a cell, and the cell is then directed along abnormal growth patterns.

What is known is that, in groups of highly exposed people, a higher than normal incidence of cancer is observed. An increased incident of cancer has not yet been observed at low radiation levels, although human studies are still incomplete. Higher incidence rates of cancer can be produced in laboratory animals by high levels of radiation.

6. If I receive a radiation dose, does that mean I am certain to get cancer?

Not at all. Everyone gets a radiation dose every day but most people do not get cancer. Even with doses of radiation far above legal limits, most individuals will experience no delayed consequences. There is evidence that the human body will repair some of the damage. The danger from radiation is much like the danger from cigarette smoke. Only a fraction of the people who breathe cigarette smoke get lung cancer, but there is good evidence that smoking increases a person's changes of getting lung cancer. Similarly, there is evidence that large radiation doses increase a person's chance of geeting cancer.

Radiation is like most substances that cause cancer in that the effects can be seen clearly only at high doses. Still, it is prudent to assume that smaller doses also have some chance of causing cancer. This is as true for natural cancer-causers such as sunlight and natural radiation as it is for those that are man-made such as cigarette smoke, smog, and man-made radiation. As even very small doses may entail some small risk, it follows that no dose sould be taken without a reason. Thus, a time-honored principle of radiation protection is to do more than merely meet the allowed regulatory limits; doses should be kept as low as is reasonably achievable (ALARA).

We don't know exactly what the chances are of getting cancer from a radiation dose, but we do have good estimates. The estimates of radiation risks are at least as reliable as estimates for the effect from any other important hazard.

7. What are the estimates of the risk of cancer from radiation exposure?

The most recent risk estimates (developed by the groups of scientific experts identified in Question 8) are:

Risk Estimates for Cancer Death from Exposure to Low-Level Radiation

Source	Number of Addition Cancer Deaths Estimated to Occur in 1 Million People After Exposure of Each to 1 Rem (1000 mrem) of Radiation
ICRP 1977	100
UNSCEAR 1977	100
BEIR-III 1979 (Draft)	150-353 Relative Risk Model 68-124 Absolute Risk Model

All three groups indicate that these estimates may be high for low doses of most types of radiation (that is "low-LET" radiation such as x-rays and gamma-rays rather than "high-LET" radiation such as neutrons and alpha radiation). While the rate per rem is unlikely to be higher than the values given, it may be substantially lower, and, indeed, may be zero.

In particular at low doses (of x- and gamma-rays) in the region of those received annually from natural sources (about 100 mrem, or 0.1 rem, per year), it is unknown whether there is any effect, the values given in the Table are likely to be overestimates, and, in any case, any effect is very likely to be undetectable.

There is no evidence that the risk per rem is different for "internal" and "external" exposures; i.e., there is no evidence that the rates of cancer induction from radionuclides inside the body ("internal radiation") are different from those from "external radiation" when account is taken of the dose (rem) to the body from the "internal radiation."

For exposure to "high LET" radiation (such as neutrons and alpha particles), the risk estimates for low dose are likely to be overestimates of risk and may, in fact, be underestimates.

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To put these estimates into perspective, we use the value of 100 excess cancer deaths per million people, each exposed to 1 rem (1,000 mrem) of ionizing radiation. This means that if in a group of 10,000 people each receives 1 rem, one would be predicted to develop cancer because of that exposure, although the actual number could be more or less than one (including none).

The American Cancer Society has reported that approximately 20 percent of the deaths in the U.S. in 1977 were from cancer. These cancer deaths result from all possible causes such as smoking, food, alcohol, drugs, air pollutants, and natural background radiation. Thus in a group of 10,000 people not exposed to radiation other than background radiation, we can expect about 2,000 to die of cancer. In this entire group of 10,000 people were to receive an additional radiation dose of 1 rem (1000 mrem) each, we could estimate that one additional death might occur which would give a total of about 2001 cancer deaths this means that a 1-rem (1000 mrem) dose to each of 10,000 persons might increase the cancer death rate from 20 percent to 20.01 percent, an increase of about 1 hundredth of one percent.

Since cancer resulting from exposure to radiation usually occurs 5 to 25 years after the exposure and since not all cancers are fatal, another useful measure of risk is years of life expectancy lost from a radiation-induced cancer. Several independent studies have indicated that the average loss of life expectancy from exposure to radiation is about 1 day per rem (1000 mrem) of exposure. In other words, an individual in a population exposed to 1 rem of radiation may on the average lose 1 day of life. The words "on the average" are important, however, because the individual who gets cancer from radiation may lose several years of life expectancy while his more fortunate coworkers suffer no loss. The International Commission on Radiological Protection (ICRP) estimated that the average number of years of life lost from a fatal industrial accident is 30 while the average number of years of life lost from a fatal radiation-induced cancer is 10.

It is important to realize that these risk numbers are only estimates. Many difficulties are involved in designing research studies that can accurately measure the small increases in cancer indicence due to low exposures to radiation as compared to the normal incidence of cancer. There is still uncertainty and a great deal of controversy with regard to estimates of radiation risk. The numbers used here result from studies involving high doses and high dose rates, and they may not apply to (the lower) doses that radiation workers are exposed to or the still lower doses that the general public is exposed to. At low dose levels, it is possible that the risk is zero. The NRC and other agencies both in the United States and abroad are continuing extensive long-range research programs on radiation risk.

8. What groups of expert scientists have studied the risk from exposure to radiation?

Since 1956, the National Academy of Sciences established two advisory committees to consider radiation risks. The first of these was the Advisory Committee on Biological Effects of Atomic Radiation (BEAR) and more recently it was renamed the Advisory Committee on the Biological Effects of Ionizing Radiation (BEIR). These committees have periodically reviewed the extensive research being done on the health effects of ionizing radiation and have published estimates of the risk of cancer from exposure to radiation (1972 and 1979* BEIR reports). The International Commission on Radiological Protection (ICRP) is an international group of renowned scientists who have studied radiation effects and published risk estimates (ICRP Publication 26, 1977). In addition, the United Nations established an independent study group that published an extensive report in 1977, including estimates of cancer risk from ionizing radiation (UNSCEAR 1977).

9. Can someone become sterile or impotent from radiation exposure?

Observation of radiation therapy patients who receive localized exposures, usually spread over a few weeks, has shown that a dose of 500-800 rems to the gonads can produce permanent sterility in males or females (an acute whole-body dose of this magnitude would probably result in death within 30 days). An acute dose of 20 rems to the testes can result in a measurable but temporary reduction in sperm count. Such high exposures could result only from serious and unlikely radiation accidents. The whole-body dose required to make someone impotent is also greather than the lethal dose. Thus, exposure to permitted levels of radiation has no observed effect on fertility and should have no physical effect on the ability to function sexually.

10. How are radiation dose limits established?

The NRC establishes occupational radiation dose limits based on guidance to Federal agencies from the Enviromental Protection Agency (EPA) and on National Council on Radiation Protection and Measurements (NCRP) and International Commission on Radiological Protection (ICRP) recommendations. Scientific reviews of research data on biological effects such as the BEIR reports and UNSCEAR reports are also considered. (BEIR is the Advisory Committee on the Biological Effects of Ionizing Radiation of the National Academy of Sciences; UNSCEAR is the United Nations Scientific Committee on the Effects of Atomic Radiation.

11. Several scientists have recently suggested that NRC limits are too high and should be lowered. What are the arguments for lowering the limits?

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*The draft publication of the 1979 BEIR report is currently under revision. However, the risk estimates are not expected to change significantly.

In general, those critical of present dose limits say that the individual risk is higher than estimated by the BEIR Committee and the ICRP. A few studies have indicated that a given dose of radiation may be more likely to cause biological effects than previously thought. Opinions differ on the validity of the research methods used and the methods of statistical analysis. The chief problem is that, with small groups, the incidence of effects such as leukemia is small. It cannot be shown without question that these effects were more frequent in the exposed study group than in the unexposed group used for comparison or that any observed effects were caused by the exposure to radiation.

The current BEIR committee concluded that claims of higher risk had "no substance," and nearly one-half of the committee members were convinced that the BEIR risk estimates were actually to high.

The NRC staff is committed to a continuing review of research on radiation risk and is funding a study to design new research on human effects from exposure to radiation.

12. The "Heidelberg Report" gives extimates of doses to people from routine releases from nuclear power plants that are 10 to 10,000 times higher than NRC values. What is NRC's response to this report?

The "Heidelberg Report" is the report entitled "Radiological Assessment of the Wyhl Nuclear Power Plant" by the "Department of Environmental Protection of the University of Heidelberg, Germany." The NRC staff has had this report translated from German to English and has reviewed it carefully.

Although the Heidelberg Report assessment is based largely on environmental models described in the NRC Regulatory Guides, the authors of the Heidelberg Report use values for some model parameters that are much higher than the values NRC uses. As a result, the estimates in the Heidelberg Report of doses to humans through some pathways are from 10 to 10,000 times higher than the doses calculation using NRC parameter values. Large fractions of the total dose estimates in the Heidelberg Report are due to Cs-137 and Sr-90. Based on an in-depth review, the NRC staff has concluded the following: (1) Although the source term varies from plant to plant, the average measured release of the two nuclides (i.e., Cs-137 and Sr-90) from pressurized water reactors operating in the United States that account for most of the doses estimated in the Heidelberg Report was less than 1 percent of the corresponding source terms used in the Heidelberg Report. (2) The Heidelberg Report values for the following parameters are unrealistically large: (a) soil-to-plant transfer factors for cesium and strontium; (b) the kidney dose conversion factor from ingestion of Cs-137, and (c) the bone dose conversion factor from ingestion of Sr-90.

There is positive evidence that the doses around nuclear power reactors sited in the United States are less than the values estimated in the Heidelberg Report. This statement is based on measured environmental concentrations of Cs-137, the most crucial nuclide to the Heidelberg Report analysis, in vegetation, meat and milk, and I-131 in milk around reactors in the United States. The NRC staff reviewed the environmental monitoring data of 18 nuclear power plants, arbitrarily selected out of about 50 plants sited within the United States. In all cases, the average measured environmental concentrations near U.S. reactors lead to dose estimates that are less than those estimated in the Heidelberg Report analysis of the Wyhl nuclear reactor. The Heidelberg Report offered no environmental monitoring data in support of its unrealistic estimates.

The NRC staff has published a report (NUREG-0668) on its review of the Heidelberg report.

References

1. "Instruction Concerning Risk from Occupational, Exposure, "Draft Regulatory Guide and Value-Impact Statement, May 1980, Division 8, Task OH 902-1.

2. "Staff Review of Radiological Assessment of the Wyhl Nuclear Power Plant", NUREG-0668, June 1980.

Average Background Radiation Exposure

Radiation in the environment from natural sources is the major source of radiation exposures to people. All natural background exposures, except those from direct cosmic radiation, are produced by radiation coming from the natural radioactive materials (natural radionuclides) in the environment.

Background radiation exposure is both external (from radioactive materials outside the body) and internal (from radioactive materials inside the body).

Most of the terrestrial backgound radiation and external radiation exposure comes from the radioactive decay of unstable potassium, thorium, uranium, and other radioactive elements in the soil or other materials from the earth.

Internal radiation exposure results primarily from alpha and beta particles emitted by these same radioactive elements inside the body. These elements are taken into the body with the air we breath, the food we eat, and the water we drink.

Another major source of external exposure is cosmic rays that fall on the earth at all times from all directions in space.

A minor source of (non-natural) background radiation is the man-made world-wide fallout from previous tests of nuclear weapons in the atmosphere.

The average annual background whole body radiation exposures in the U.S. are:

	mrem/ yr
External	
Cosmic radiation	28
Natural terrestrial radiation	32
Fallout	3
Subtotal	63
Internal	
Natural Radionuclides in the body	34
Fallout Radionuclides in the body	1
Subtotal	35
TOTAL	About 100

A more detailed breakdown of exposures for different parts of the body is given in Table 1.

Table 2 gives a detailed breakdown of the exposure from radionuclides inside the body.

Table 1. ANNUAL PER CAPITA DOSES FROM NORMAL EXPOSURE TO NATURAL SOURCES OF RADIATION*

(in mrem)**

	Gonads	Whole Lung	Bone-Lining cells	Red bone marrow
External irradiation				
Cosmic rays	28	28	28	28
Terrestrial Radiation	32	32	32	32
Internal Radiation				
Potassium-40	15	17	15	27
Radon-222 (with daughters)	0.2	30	0.3	0.3
Other nuclides	2	5.5	9.1	4
Total	78	110	84	92

* Sources and Effects of Ionizing Radiation, United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) - 1977 Report (Table 1)

** The units in the original table are mrad; however, for practical purposes, 1 mrad = 1 mrem in this table.

Table 2. Estimated Radiation Doses from Radionuclides Inside The Body*

Nuclide	Total activity (pCi)	Dose equivalent** mrem/yr
^{3}H	700	0.001
^{3}H†	27000	0.06
^{14}C	80000	1.0
^{40}K	110000	15.7 + 1.2(γ)
^{87}Rb	29000	0.6
^{90}Sr†	1300	0.4
^{137}Cs†	2800	0.14 + 0.13(γ)
^{210}Pb(^{210}Bi, ^{210}Po)	600	9
^{226}Ra (series)	75	2
^{228}Ra (series)	50	3
U (natural)††	90	2
	Total	35

*Richard B. Holtzman, "Comments on 'Estimate of Natural Internal Radiation Doses to Man'" Health Physics 32, 324-325 (April 1977).
**From alpha and beta particles; unless otherwise noted, QF_α = 10
†Man-made nuclides.
††Natural uranium is defined as ^{234}U in radioactive equibrium with ^{238}U and containing 0.72% ^{235}U (isotopic abundance).