MIT News
ON CAMPUS AND AROUND THE WORLD

Radiation, how much is considered safe for humans?

January 5, 1994

Editor's Note: The information below compares 1. the radiation exposures to the whole body which are the established federal standard for various activities (Note: The first federal standard for fetuses of pregnant radiation workers went into effect Jan. 1.); 2. amounts of natural background radiation; 3. common sources of additional radiation; 4. amounts from medical treatment (very high radiation to a limited part of the body), and 5. amounts from diagnostic research (low levels from radioactive tracer elements). The source of this information is Francis Masse, director of the MIT Radiation Protection Office. Dr. Masse is a past president of the Health Physics Society and served in 1987-89 as chairman of the National Academy of Sciences panel which reviewed the exposure of soldiers to radiation from atmospheric testing in the 1940s and 1950s.

Astronauts: 25,000 Millirems
The highest recommended limit for radiation exposures is for astronauts-25,000 millirems per Space Shuttle mission, principally from cosmic rays. This amount is beyond the average 300+ millirems of natural sources of radiation and any medical radiation a person has received.

25,000 millirems per year level was the federal occupational limit during World War II and until about 1950 for radiation workers and soldiers exposed to radiation. The occupational limit became 15,000 millirems per year around 1950. In 1957, the occupational limit was lowered to a maximum of 5,000 millirems per year.

Average Natural Background: 300 Millirems
The average exposure in the United States, from natural sources of radiation (mostly cosmic radiation and radon), is 300 millirems per year at sea level. Radiation exposure is slightly higher at higher elevations-thus the exposure in Denver averages 400 millirems per year.

(A milliRem is 1/1000th of a Rem. According to McGraw-Hill's Dictionary of Scientific and Technical Terms, a Rem is a unit of ionizing radiation equal to the amount that produces the same damage to humans as one roentgen of high-voltage x-rays. The name is derived from "Roentgen equivalent man." Wilhelm Roentgen discovered ionizing radiation in 1895 at about the same time that Pierre and Marie Curie discovered radium.)

All of these limits are for the amount of radiation exposure in addition to background radiation and medical radiation.

Adult: 5,000 Millirems
The current federal occupational limit of exposure per year for an adult (the limit for a worker

using radiation) is "as low as reasonably achievable; however, not to exceed 5,000 millirems" above the 300+ millirems of natural sources of radiation and any medical radiation. Radiation workers wear badges made of photographic film which indicate the exposure to radiation. Readings typically are taken monthly. A federal advisory committee recommends that the lifetime exposure be limited to a person's age multiplied by 1,000 millirems (example: for a 65-year-old person, 65,000 millirems).

Minor: 500 Millirems

The maximum permissible exposure for a person under 18 working with radiation is one-tenth the adult limit or not to exceed 500 millirems per year above the 300+ millirems of natural sources, plus medical radiation. This was established in 1957 and reviewed as recently as 1990.

Fetus: 500 Millirems Or 50 Per Month (New Rule Jan. 1, 1994)

New federal regulations went into effect New Year's Day, establishing for the first time an exposure limit for the embryo or fetus of a pregnant woman exposed to radiation at work. The limit for the gestation period is 500 millirems, with a recommendation that the exposure of a fetus be no more than 50 millirems per month.

Weight Variables

Like alcohol intoxication levels, levels of exposure to radioactivity (due to radioactivity deposited in the body) depend on a person's weight. A diagnostic tracer of one microcurie of radioactive calcium 45, given orally, would result in an exposure of 3.7 millirems for a 100-pound person, and half of that, 1.85 millirems, for a 200-pound person.

Therapeutic Radiation

Therapeutic radiation treatment that is delivered by administering radioactive material via the mouth or by injection usually results in high, very localized doses to a small part of the body, which absorbs most of the radioactivity. The radioactivity concentrates and remains in the target organ (for example, the thyroid) for a longer period of time than does the radioactivity that is distributed to the rest of the body. The radiation exposure for other parts of the body is a function of the amount of radioactivity per pound and the time the radioactivity is present in the tissue.

George Bush's Hyperthyroid Problem

For example, a hyperthyroid problem such as that experienced by former President George Bush is typically treated with a radioactive iodine drink designed to deliver about 10,000,000 millirems of radioactive iodine to the thyroid. It would coincidentally deliver a dose to the rest of the body of about 20,000 millirems. A slightly lower dose of radioactivity is used for cancerous tumors. Radiation to kill a cancerous tumor often involves a beam delivering 6,000,000 millirems to the cancerous tissue, but the whole-body equivalent dose is much less, as it was in the thyroid example cited above.

What is a lethal dose from a single instance of radiation? According to studies made after the atomic bomb explosions in 1945 at Hiroshima and Nagasaki, half of the people died whose entire bodies were exposed to 450,000 millirems of radiation from the atomic bomb. All persons died whose bodies were exposed to 600,000 millirems of radiation.

Federal Standards, Permissible Levels Of Radiation Exposure to Whole Body (1994 unless noted otherwise)

Millirems above natural background levels (average 300) and medical radiation:

25,000-Astronauts, per Space Shuttle mission. This also was the annual occupational limit for adults from World War II through 1950.

15,000-1950 to 1957 occupational limit per year for adults, including radiation workers and soldiers. Limit changed in 1957 to 5,000 millirems.

5,000-(Since 1957) Occupational limit per year for adult radiation workers, including soldiers exposed to radiation. It is "as low as reasonably achievable; however, not to exceed 5,000 millirems." It is recommended that lifetime cumulative exposure is not to exceed the age multiplied by 1,000 millirems.

500-Occupational limit per year for a minor under 18 exposed to radiation. An embryo or a fetus of a pregnant worker exposed to radiation (a new regulation as of Jan. 1, 1994) is not to exceed more than 500 cumulated total millirems before birth, and it is recommended that the exposure of a fetus be limited to no more than about 50 millirems above background levels per month.

Sources of Naturally Occurring Radiation (Whole Body Equivalents)

25 to 35-Human body's own radiation dose per year from radioactive elements and minerals in the body.

300-Average annual natural background radiation, sea level (includes your own body radiation, cosmic radiation and radon).

400-The city of Denver's average annual natural background radiation (altitude 5,000 feet).

Common Additional Sources of Radiation (Whole Body Equivalents per year in millirems above background levels)

12-Coast-to-coast US round trip flight in airplane at 35,000 feet of altitude.

10-Annual increase due to daily use of salt substitute (potassium chloride) or eating a diet heavy in such potassium-rich foods as bananas and Brazil nuts. Potassium is an essential dietary element that is present mostly in the muscles.

2-Annual exposure due to watching four hours of television every day.

Therapeutic Doses of Radiation to A Part of the Body (Whole Body Equivalents in millirems above background levels)

20,000-Therapeutic radioactive iodine treatment of thyroid gland. A localized dose delivers 10,000,000 millirems to the thyroid and about 20,000 millirems to the rest of the body. A radiation dose to kill a cancerous tumor often sends a beam delivering 6,000,000 millirems to the cancerous tissue, but the whole body equivalent dose is much less, as in the thyroid case.

Doses of Radiation for Medical Diagnosis or Research Purposes (Whole Body Equivalents in millirems above background levels)

500 to 200-Cardiac stress test.

245-Exposure of one 70-pound youth in federal research at the Fernald School by MIT in the 1940s, using trace elements to track iron absorption through eating cereal. The research showed iron supplements are more effective if not be taken with meals.

172-Average exposure of 17 youths, ages 12 to 17, avgerage weight 100 pounds, in the above research.

127-Exposure of heaviest youth, 135 pounds, in the above research.

4 to 11-Exposure received by 45 youths, ages 10 to 16, in federal research in the 1950s by the Fernald School, with the assistance of MIT. The study used radioactive calcium 45 to track calcium absorption. One adult (age 21) was also in the study and received a higher dose, resulting in an exposure equal to 11 millirems for the whole body.

2-One chest X-ray (the whole body equivalent). A typical X-ray exposes the chest to a dose equal to 20 millirems at the entrance and 1 milliRem at the exit. Averaging this exposure over the whole body yields a whole body equivalent of about 2 millirems.

———

The US Food and Drug Administration's current regulations state, "The amount of radioactive material to be administered shall be such that the subject receives the smallest radiation dose with which it is practical to perform the study without jeopardizing the benefits to be obtained by the study. Under no circumstances may the radiation dose to any adult research subject from a single study, or cumulatively from a number of studies conducted within one year, be generally recognized as safe if such doses exceed the following:

Single dose for an adult-3,000 millirems;

Annual total dose-5,000 millirems.

For a research subject under 18 years of age at the last birthday, the radiation dose shall not exceed 10 percent of that set forth above."

Therefore, the single exposure limit for a child is 300 millirems (whole body equivalent) and the annual total exposure cannot exceed 500 millirems.

Since 1968, medical researchers at institutions doing the research have been required to follow informed-consent procedures. These procedures require the assent (if feasible) of a child 7 years of age or older, and the consent of both parents if there is any perceived risk involved in the research. For research involving any perceived risk, there also has to be a relationship between the study and a child's disorder or disease.

If there is direct benefit that is likely to accrue from participation in the study, then a researcher needs the assent of the child (age 7 or older) and the consent of at least one of the parents. In such direct benefit research situations, the permitted levels of radiation can be exceeded.

A version of this
article appeared in the
January 5, 1994

issue of MIT Tech Talk (Volume
38, Number
18).

Topics: Physics

About This Website

This Website is maintained by the MIT News Office, part of the Office of Communications.

MIT News Office • Building 11-400
Massachusetts Institute of Technology • Cambridge, MA 02139-4307