Biological Effects of Ionizing Radiation

Radiation

Radiation is all around us. It is naturally present in our environment and has been since the birth of this planet. It comes from outer space (cosmic), the ground (terrestrial), and even within our own bodies (internal). It is present in the air we breathe, food we eat, water we drink, and construction materials we use to build our homes. Certain foods (such as bananas and brazil nuts) naturally contain higher levels of radiation than others. Similarly, homes constructed of brick and stone have higher natural radiation levels than homes made of wood and other building materials. Our Nation's Capitol, which is largely constructed of granite, contains higher levels of natural radiation than most homes.

Levels of natural (or background) radiation also vary greatly from one location to another. For example, people residing in Colorado are exposed to higher levels of natural radiation than residents of the east or west coasts. This is because Colorado has more cosmic radiation (given its higher altitude) and more terrestrial radiation (from soils enriched with naturally occurring uranium). Furthermore, much of our natural exposure is attributable to radon, a gas from the earth's crust that is present in the air we breathe.

Individuals in the United States receive an average annual radiation exposure of about 0.3 rem (3 millisieverts, mSv)[1] from natural sources. Radon gas accounts for two-thirds of this exposure, while cosmic, terrestrial, and internal radiation account for the remainder. No adverse health effects have been discerned from doses arising from these levels of natural radiation exposure.

In addition, man-made sources of radiation from medical, commercial, and industrial activities contribute another 0.06 rem to our annual radiation exposure. One of the largest sources of exposure is medical x-rays. Diagnostic medical procedures account for about 0.04 rem each year. In addition, some consumer products (such as tobacco, fertilizer, welding rods, gas mantles, luminous watch dials, and smoke detectors) contribute another 0.01 rem to our annual radiation exposure.

Natural radiation contributes about 82% of the annual dose to the population, while medical procedures contribute most of the remaining 18%, for a total annual average radiation exposure of 0.36 rem. Both natural and artificial radiation affect us in the same way.

The U.S. Nuclear Regulatory Commission (NRC) requires its licensees to limit the maximum radiation exposure to individual members of the public to 0.1 rem per year above background levels, and occupational radiation exposure to adults working with radioactive material to 5 rem per year.

---

1. Effects of radiation on matter are characterized by radiation dose, or absorbed energy per unit mass. Dose is measure in units Gray (1 Gy = 1 J/Kg) or rad (1 Gy = 100 rad). In order to evaluate biological effects of different types of radiation (α,β, γ, or neutrons), the absorbed dose is multiplied by a Relative Biological Effectiveness (RBE) factor. The resulting quantity is called dose equivalent and it is measured in units Sievert or rem (1 Sv = 100 rem).

Enclosure

The NRC's regulations and radiation exposure limits (in Title 10, Part 20, of the *Code of Federal Regulations*) are consistent with the recommendations of national and international scientific organizations, as well as practices in other developed nations.

Biological Effects

There is a threshold of radiation exposure below which no harmful effect is observed. In other words, if only a few cells are killed by radiation exposure, a person would notice few discernable health effects. However, exposures above that threshold would cause a noticeable effect (e.g., radiation sickness) and the severity of the effect would increase for higher radiation doses. As radiation exposure increases, more cells may be killed and, if enough cells are killed, organ function may be adversely affected. A large radiation exposure (e.g., 1,000 rads or 1,000 rems from gamma radiation) can kill more than 99% of the precursor cells in the bone marrow and small and large intestines, resulting in diarrhea, intestinal bleeding, and increased susceptibility to infection. Death may occur within 2 months, depending on the medical treatment received. Several radiation protection standards were designed to prevent such effects in workers, particularly with regard to exposures of the skin of the whole body or the extremities, or the lens of the eye.

Because radiation affects different people in different ways, it is impossible to indicate the dose needed to prove fatal. However, it is believed that 50% of a population would die within 30 days after receiving an exposure to the whole body of 350 to 500 rads (350 to 500 rems from gamma radiation), in a very short period of time (ranging from a few minutes to a few hours). This would vary depending on the health of the individuals before exposure and the medical care they received after exposure. Similar exposure of only parts of the body would likely lead to more localized effects, such as skin burns.

Conversely, low exposures — less than 10 rads (or 10 rems from gamma radiation) — spread over long periods of time (years to decades) do not cause an immediate problem to any bodily organ. The effects of such low doses of radiation, if any, would occur at the cellular level and, as a result, changes may not be observed for many years (usually 5 to 20 years) after exposure. The development of cancer is the primary health concern attributed to radiation exposure. Unlike radiation sickness, radiation exposure need not exceed a minimum level to result in the development of cancer. Nonetheless, the likelihood or probability of developing cancer increases with each incremental exposure to ionizing radiation. Fortunately, however, ionizing radiation is a weak carcinogen. This means that small exposures to ionizing radiation most likely will not induce cancer. For example, of the 52,000 Japanese atomic bomb survivors monitored since 1950 who received at least 0.5 rem of acute radiation exposure, 420 excess cancer deaths have been blamed on radiation exposure, while about 7,600 other cancer deaths were attributed to other causes. Similarly, no cancer deaths have been associated with radiation exposure from the Chernobyl nuclear power plant accident, even though 30 emergency workers died within the first 4 months of the accident (most due to acute radiation sickness).

Radiation Protection

The radiation protection community conservatively assumes that any amount of radiation may pose some risk of causing cancer and hereditary effects, and the risk is higher for higher radiation exposures. A linear, no-threshold (LNT) dose response relationship is used to describe the relationship between radiation dose and the occurrence of cancer. This dose-response model suggests that any increase in dose, no matter how small, results in an incremental increase in risk. The NRC accepts the LNT hypothesis as a conservative model for estimating radiation risk, recognizing that the model also may significantly overestimate radiation risk.

So, why are Federal regulations concerning radiation exposure so stringent? Radiation exposure limits for members of the public are established to adequately protect public health and safety and the environment without unduly limiting the desirable human activities that may give rise to or increase radiation exposure. The NRC's public dose limit of 0.1 rem per year from all man-made sources is designed to limit exposure of all members of the public (including both genders and all ages) to reasonable levels of risk comparable with risks from other sources. In addition to the public dose limit, all entities licensed to possess source or byproduct materials are required to keep radiation exposures to workers and the public as low as reasonably achievable (ALARA). Finally, any activity that results in radiation exposure of a member of the public must be justifiable in that the expected benefits to society exceed the overall societal cost (e.g., illness).