Some comparative whole-body radiation doses and their effects

2.4 mSv/yr: Typical background radiation experienced by everyone, but varies largely depending on location.

1.5 to 2.5 mSv/yr: Average dose to uranium miners and US nuclear industry employees, in addition to background and medical.

Up to 5 mSv/yr: Typical incremental dose for aircrew in middle latitudes.

9 mSv/yr: Exposure by airline crew flying the New York to Tokyo via polar route.

10 mSv/yr: Maximum actual dose to a few Australian uranium miners.

10 mSv: Effective dose from abdomen & pelvis CT scan.

20 mSv/yr: Current limit (averaged) for nuclear industry employees and uranium miners during normal operation.

50 mSv/yr: The dose that should not be exceeded in a single year by workers carrying out their normal tasks. Also the dose rate which arises from natural background levels in several places in Iran, India and Europe.

50 mSv: Allowable short-term dose for emergency workers (IAEA).

100 mSv: Lowest level at which increase in cancer risk has been detected (UNSCEAR). Above this, the probability of cancer occurrence (rather than the severity) is assumed to increase with dose. Allowable short-term dose for emergency workers taking vital remedial actions (IAEA).

250 mSv: Allowable short-term dose for emergency workers controlling the 2011 Fukushima accident.

250 mSv/yr: Natural background level at Ramsar in Iran, with no identified health effects (some exposures reach 700 mSv/yr).

800 mSv/yr: Highest level of natural background radiation recorded, on a Brazilian beach.

1000 mSv short-term: Assumed likely to cause a fatal cancer many years later in about 5 of every 100 persons exposed to it (*i.e.* if the normal incidence of fatal cancer were 25%, this dose would increase it to 30%).

1000 mSv short-term: Causes (temporary) radiation sickness (Acute Radiation Syndrome) such as nausea and decreased white blood cell count, but not death. Above this, severity of illness increases with dose.

5000 mSv short-term: Would kill about half those receiving it as whole body dose within a month. (It is twice a typical daily therapeutic dose applied to a very small area of the body over 4 to 6 weeks or so).

10,000 mSv short-term: Fatal within a few weeks.

Protection against radiation

Time: Dose is reduced by limiting exposure time.

Distance: The intensity of radiation decreases with distance from its source.

Shielding: Barriers of lead, concrete or water give good protection from penetrating radiation such as gamma rays.

Containment: Radioactive materials are confined to keep them isolated from the environment.

The International Commission for Radiological Protection (ICRP) has developed a system for protection with three basic principles:

Justification: No practice involving exposure to radiation should be adopted unless it produces a net benefit to those exposed or to society generally.

Optimization: Radiation doses and risks should be kept "as low as reasonably achievable" (ALARA), economic and social factors being taken into account.

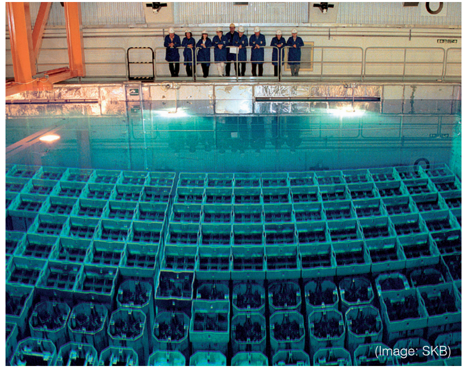
Limitation: The exposure of individuals should be subject to dose or risk limits, above which the radiation risk would be deemed unacceptable.

These principles apply to the potential for accidental exposures as well as predictable normal exposures.

Underlying these principles is the application of the 'linear hypothesis' based on the idea that any level of radiation dose, no matter how low, involves the possibility of risk to human health. However, the weight of scientific evidence does not prove any cancer risk or other health effects at doses below 50 mSv in a short time or at about 100 mSv/yr.

Nuclear accidents and radiation release

- The March 1979 accident at the Three Mile Island nuclear power plant in the USA caused some people near the plant to receive very low doses of radiation, well below the internationally recommended level. There was no evidence of any harm resulting from those exposures.
- Immediately after the Chernobyl accident in Ukraine in 1986, much larger doses were experienced. Apart from the residents of nearby Pripyat, who were evacuated within two days, some 24,000 people living within 15km of the plant received an average of 450 mSv before they were evacuated.
- About 200,000 workers ('liquidators') from all over the Soviet Union were involved in the recovery and clean-up during 1986 and 1987. Some 20,000 of them received about 250 mSv and a few received 500 mSv. Later, the number of liquidators swelled to over 600,000 but most of these received only low radiation doses.
- The highest doses were received by about 1000 emergency workers and on-site personnel during the first days of the accident, estimated to range up to 20,000 mSv. Twenty eight of those workers died from acute radiation syndrome within a few weeks. A further 19 died between 1987 and 2004 from different causes other than radiation.
- A 2008 report from the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) concluded that apart from increased thyroid cancers in children, "there is no evidence of a major public health impact attributable to radiation exposure 20 years after the accident."
- The March 2011 accident at the Fukushima Daiichi nuclear power plant in Japan, in which three reactors were severely damaged, released radioactive material, mostly on days 4 to 6 after the tsunami.
- In May 2013 UNSCEAR reported that "Radiation exposure following the nuclear accident at Fukushima Daiichi did not cause any immediate health effects. It is unlikely to be able to attribute any health effects in the future among the general public and the vast majority of workers."
- A group of 173 emergency workers received doses of over 100 mSv during the crisis and will be monitored closely for "potential late radiation-related health effects at an individual level." Six of them had received over 250 mSv - the limit set for emergency workers within Japan, apparently due to inhaling iodine-131 fumes early on.
- Some 160,000 people were evacuated as a pre-cautionary measure, and prolonging the evacuation resulted in the deaths of about 1100 of them due to stress, and some due to disruption of medical and social welfare facilities.
- Timely evacuation ensured that thyroid doses in children were significantly lower than from the Chernobyl accident.



(Image: SKB)

These people looking at the highly radioactive used nuclear fuel stored in a pool at Sweden's Clab facility receive no dose from it as the water acts as a very good radiation shield.

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Pocket Guide

Radiation

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What is radiation?

Radiation is energy being transmitted through space. Visible light, ultra-violet light and transmission signals for TV and radio communications are all forms of radiation that are common in our daily lives. There are two types of radiation: 'ionizing' and 'non-ionizing'. Ionizing radiation is electromagnetic rays or particles with sufficient energy to remove tightly bound electrons from atoms, thereby creating ions capable of breaking chemical bonds, thus causing ionization of the matter through which it passes. Non-ionizing radiation has sufficient energy to move atoms but not create ions.

Types of ionizing radiation

Alpha (α) particles

- Particles (helium nuclei) consisting of two protons and two neutrons.
- Emitted from naturally-occurring heavy elements such as uranium and radium, as well as from some man-made unstable elements (formed artificially by neutron capture and possibly subsequent beta decay).
- Intensely ionizing but can be readily stopped by a few centimetres of air, a sheet of paper, or human skin.
- Only dangerous if alpha-emitter is inhaled or ingested and released inside the body at high exposures.
- Alpha-emitters can be safely stored in a sealed container.
- Measurement of exposures by alpha particles requires special detector systems like surface contamination counters.

Beta (β) particles

- Either electrons or positrons emitted by many radioactive elements.
- Can be stopped by wood, aluminium or glass of a few millimetres thickness.
- Can penetrate into human skin but generally less so than gamma radiation.
- High exposure produces an effect like sunburn, but which is slower to heal.
- Also can be safely stored in appropriate sealed containers.
- Measurement of exposures by beta particles requires special detector systems like surface contamination counters.

Gamma (γ) rays

- High-energy beams almost identical to X-rays and of shorter wavelength than ultraviolet radiation.
- Emitted during many radioactive alpha and beta decays.
- Very penetrating so need mass of heavy materials such as water, glass, lead, steel or concrete to shield them.
- Poses the main hazard to people when a container holding radioactive materials becomes unsealed.
- Gamma activity can be measured with a scintillometer or Geiger counter.
- Doses can be detected by the small badges worn by workers handling radioactive materials.

Neutrons

- Mostly released by nuclear fission and seldom encountered outside the core of a nuclear reactor.
- Very penetrating so need mass of heavy material for shielding.
- Strongly ionizing and hence can be destructive to human tissue.
- Can be slowed down (or 'moderated') by graphite or water.
- Measurement of exposures by neutrons requires special detector systems like surface contamination counters.

Measuring radiation

The amount of ionizing radiation absorbed in tissue can be expressed in grays (Gy): 1 Gy = 1 joule per kilogram. Since neutrons and alpha particles cause more damage per gray than gamma or beta radiation, another unit, the sievert (Sv), is used in setting radiological protection standards. Total dose is measured in sieverts, millisieverts (mSv) or microsieverts (μSv). One gray of beta or gamma radiation has one sievert of biological effect; one gray of alpha particles has a 20 Sv effect; and one gray of neutrons is equivalent to around 10 Sv (depending on their energy).

The rate of ambient dose levels is measured in milli- or micro-sieverts per hour or year. The global average natural dose for humans is around 2.4 mSv/yr from natural sources of radiation. In the nuclear industry, the maximum annual dose allowed for radiation workers is as low as 20 mSv/yr above natural levels, averaged over five years; in practice, doses are usually kept well below this level.

The becquerel (Bq) is a unit or measure of actual radioactivity in material, as distinct from the radiation it emits, or the human dose from that. It indicates the number of atoms that have a nuclear disintegration per second (1 Bq = 1 disintegration/second). A kilogram of granite might have 1000 Bq of activity.

Background radiation

Everyone is exposed to low levels of ionizing radiation. Naturally-occurring background radiation resulting from radioactive materials in the ground (mainly radon gas), cosmic rays and natural radioactivity in our bodies - is the main source of exposure for most people. Levels typically range from about 1.5 to 3.5 mSv/yr, but can be more than 50 mSv/yr.

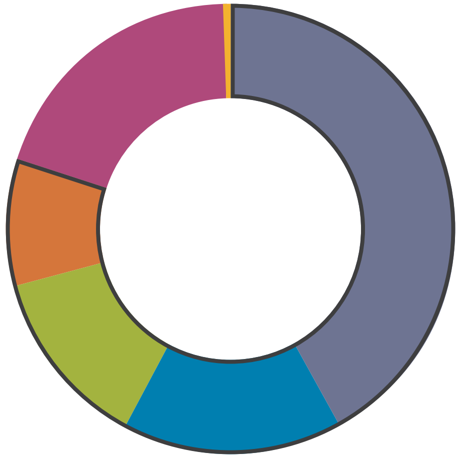
Natural radiation contributes about 80% of the annual dose to the population. The remaining 20% come from a range of medical, commercial and industrial activities. The most familiar of these sources of exposure is medical X-rays.

Radiation resulting from the use of nuclear energy accounts for less than 0.1% of background radiation.

Key points

- Radiation exists naturally everywhere at widely varying levels. Places exist where people live with over 10 times higher than average background from the ground.
- Mankind has evolved in a world with strongly differing background radiation without developing a sense to detect it.
- Radiation has always been around and is now well understood. It has been used and studied for more than 100 years.

Sources of exposure to background radiation



- 20% Medicine
- <0.1% Nuclear Industry
- 42% Radon
- 16% Buildings/Soil
- 13% Cosmic
- 9% Food/Drinking Water
- 80% Natural Radiation

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