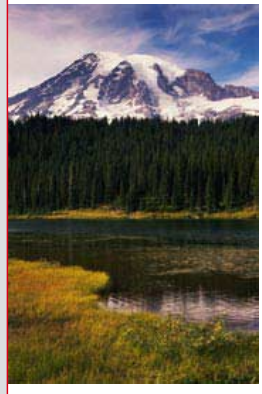
Chapter 7 Natural radiation

Natural ionizing radiation pervades the whole environment. Cosmic rays reach the Earth from outer space. The Earth itself is radioactive. Natural activity is present in food and drink and in the air. We are all exposed to natural radiation to a greater or lesser extent, and for most people it is the major source of radiation exposure. Nevertheless, humans, animals and plants have evolved in this background of natural radiation, and the general view is that it is not a significant risk to health — but there are exceptions.

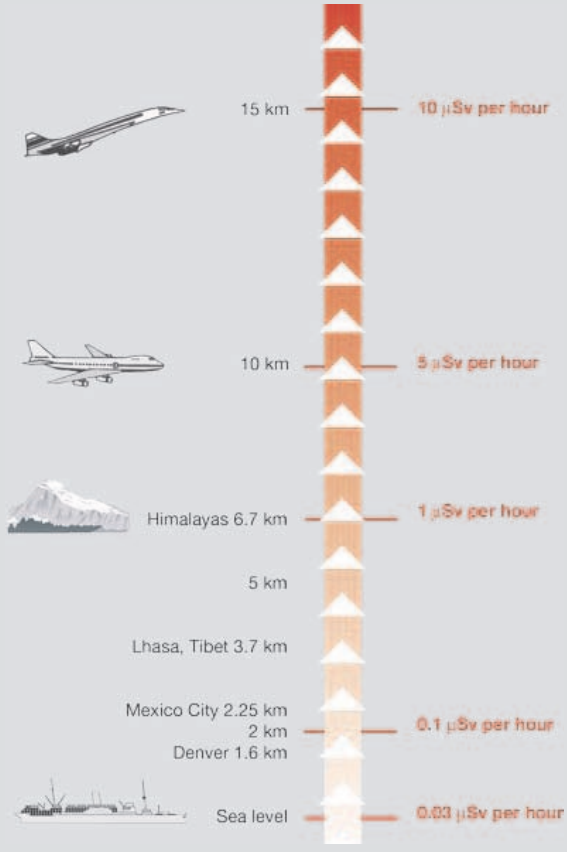
Cosmic radiation

Cosmic rays are mainly protons of uncertain origin in space and very high energies that reach our atmosphere in fairly constant numbers. It is known, however, that some protons with lower energies come from the sun and are given off in bursts during solar flares. Protons are charged particles, so the number entering the atmosphere is affected by the Earth's magnetic field — more come in near the poles than the equator — so the dose rate increases with latitude. As they penetrate the atmosphere, the cosmic rays initiate complex reactions and are gradually absorbed so that the dose rate decreases as altitude decreases. Cosmic radiation is a mixture of many different types of radiation, including protons, alpha particles, electrons and other various exotic (high energy) particles. At ground level, cosmic radiation is primarily muons, neutrons, electrons, positrons and photons, and most of the dose comes from muons and electrons. UNSCEAR has calculated that the annual effective dose from cosmic rays at ground level is about 0.4 mSv, on average, allowing for variations in altitude and latitude.

Most people live at low altitudes, and so experience similar annual doses from cosmic radiation (apart from some variation with latitude). However, there are some significant population centres at considerable altitude (for example, Quito and La Paz in the Andes, Denver in the Rocky Mountains, Lhasa in the Himalayas), where residents may receive annual doses several times higher than those people living at sea level. The annual value for La Paz, for example, is five times the global average. The type of building in which a person lives may also affect the dose from cosmic rays to a slight degree. The intensity of cosmic rays at altitudes where aircraft fly is much greater than on the ground. At cruising altitude on an intercontinental flight, the dose rate can reach 100 times that on the ground. General air travel gives rise to a further annual dose of 0.01 mSv on average to some populations (the doses to some individual 'frequent



fliers' will be much higher than this average), but this does not affect the world average of 0.4 mSv.



Gamma radiation

All materials in the Earth's crust contain radionuclides. Indeed, energy from natural activity deep in the Earth contributes to the shaping of the crust and the maintenance of internal temperatures. This energy comes mainly from the decay of the radioactive isotopes of uranium, thorium and potassium.

Uranium is dispersed throughout rocks and soils in low concentrations of a few parts per million (ppm). Where it exceeds 1000 ppm or so in an ore, it may be economical to mine it for use in nuclear reactors. Uranium-238 is the parent of a long series of radionuclides of several elements, which decay in succession until the stable nuclide lead-206 is reached. Among the decay products in the series is an isotope of the radioactive gas radon, namely radon-222, which can reach the atmosphere, where it continues to decay. Thorium is similarly dispersed in the ground. Thorium-232 is the parent of another radioactive series, which gives rise to radon-220, another isotope of radon, sometimes called thoron. Potassium is far more common than either uranium or thorium and makes up 2.4 per cent by weight of the Earth's crust. The radionuclide potassium-40, however, constitutes only 120 ppm of stable potassium.

Annual effective doses from natural radiation

Based on Table 1 of UNSCEAR 2000 Report to UN General Assembly

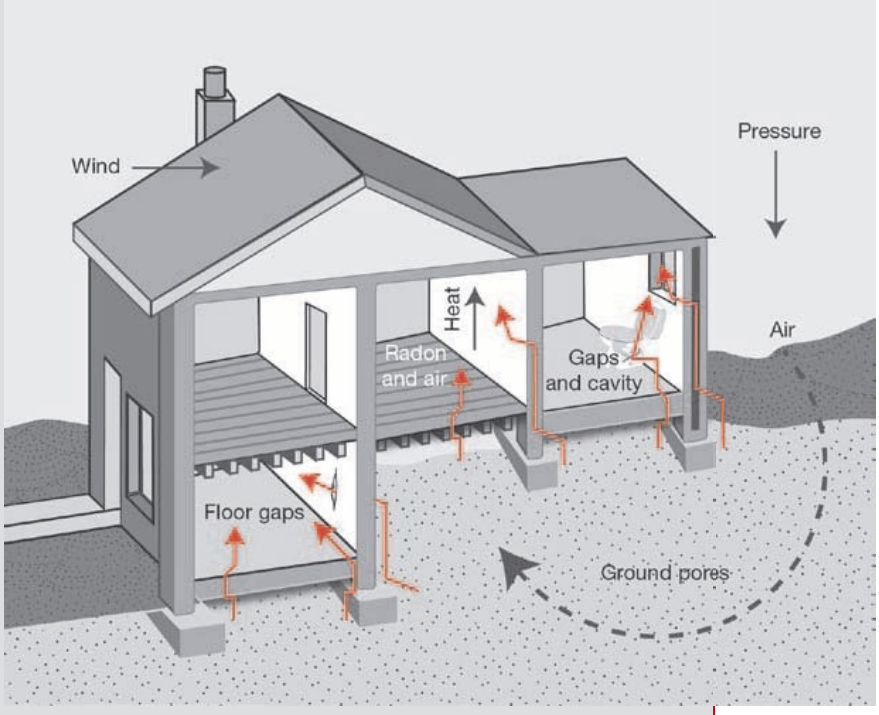
Source	*Worldwide average Dose (mSv)*	*Typical range Dose (mSv)*
Cosmic radiation	*0.4*	*0.3–1.0*
Gamma radiation	*0.5*	*0.3–0.6*
Radon inhalation	*1.2*	*0.2-10*
Internal irradiation	*0.3*	*0.2–0.8*
Total (rounded)	*2.4*	*1.0–10*

The radionuclides in the ground emit penetrating gamma rays that irradiate us more or less uniformly. Since most building materials are extracted from the Earth, they too are mildly radioactive, and people are irradiated indoors as well as out of doors. The doses they receive are affected both by the geology of the area where they live and the structure of the buildings in which they live, but the average effective dose from natural gamma rays is about 0.5 mSv in a year. Actual values vary appreciably. Some people may receive doses a few times higher or lower than the average. In a few places where the ground naturally contains relatively high concentrations of radionuclides, such as Kerala in India and parts of France and Brazil, the dose can be up to 20 times the global average. Although in general there is little that can be done to affect this dose, it would be sensible where possible to avoid building in locations or with materials with unusually high activity.

Radon inhalation

Radon gas is a particularly significant source of exposure to natural radiation. This is because the immediate decay products of radon-222 are radionuclides with short half-lives, which attach themselves to fine particles in the air, are inhaled, irradiate the tissues of the lung with alpha particles, and increase the risk of lung cancer. The same is true of radon-220 (thoron), but the degree of exposure of the lung is much less. When radon gas enters the atmosphere from the ground, it disperses in the air, so concentrations out of doors are low. When the gas enters a building, predominantly through the floor from the ground, the concentration of activity builds up within the enclosed space.

If buildings are well ventilated this accumulation of radon will not be marked. However, in many — generally colder — countries, buildings are constructed with more emphasis on retaining heat and preventing draughts. They are, therefore, often poorly ventilated, and radon concentrations indoors can be many times higher than those outdoors. Radon concentrations in buildings are also very dependent on the local geology and can vary a great deal between different parts of a country and even from building to building in the same area.



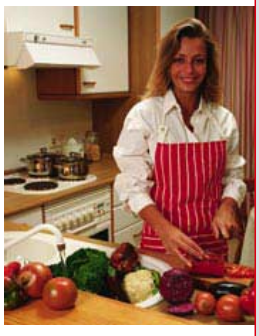
How radon enters a home

The worldwide average annual effective dose from the decay products of radon is estimated to be about 1.2 mSv. There are, however, pronounced variations about this value. In some countries (e.g. Finland) the national average is several times higher, and in particular homes in many countries occupants have received effective doses of the order of hundreds of mSv in a year. Given this, ICRP and IAEA have recommended the use of Action Levels (expressed in Bq m^{-3}) above which householders are advised to reduce radon levels in their homes. Typically these Action Levels should be in the range 200–600 Bq m^{-3}, which is about ten times the average value for the radon concentration in homes.

Anyone finding high radon levels in their homes can reduce it by preventing air from the ground entering the building. The most effective way to do so is to reduce the air pressure under the house with a small fan. As mentioned in Chapter 5, this circumstance is an example of intervention, in the ICRP sense, to reduce human exposure to ionizing radiation.

Internal irradiation

Radionuclides are found naturally in the diet



Other radionuclides from the uranium and thorium series, in particular lead-210 and polonium-210, are present in air, food, and water, and so irradiate the body internally. Potassium-40 also comes into the body with the normal diet. It is the main source of internal irradiation apart from the radon decay products. In addition, the interactions of cosmic rays with the atmosphere create a number of radionuclides, such as carbon-14, which also contribute to internal irradiation.

The average effective dose from these sources of internal irradiation is estimated to be 0.3 mSv in a year, with potassium-40 contributing about half. Information on how the total varies from one person to another is limited, although it is known that the potassium content of the human body is controlled by biological processes. The amount of potassium, and hence potassium-40, varies with the amount of muscle in the body, and is about twice as high in young men as in older women. There is little anyone could do to affect internal irradiation from the other radionuclides except by avoiding any food and water with a high radioactive content.

Total doses

The total average effective dose from natural radiation is about 2.4 mSv in a year, but doses can vary a great deal. Some national averages exceed 10 mSv in a year, and in some regions individual doses may exceed 100 mSv in a year, usually because of homes with particularly high levels of radon and its decay products.

Average doses are useful measures for comparing the health significance of radiation from natural and artificial sources, but they may need to be supplemented by additional data when there are, as with indoor radon, large variations about the average. The most helpful step might be to describe the frequency with which doses of a certain magnitude occur in the circumstances of interest.