

UK atmospheric nuclear weapons tests

Factsheet 4: Radiation and health

Radiation dose

The first definition of a unit of radiation dose was made in 1928 by the International Congress of Radiology. The roentgen (R) was defined as that quantity of radiation which produces in 1 cm of air one unit of charge of either sign, thus defining a unit of exposure. Units of **absorbed dose**, the actual energy absorbed in the tissue being irradiated, are now used. The radiation absorbed dose or **rad** is now cited in SI (System Internationale) units - joules per kg of absorbing material. The fundamental unit - 1 joule/kg - is 1 gray (1 Gy), equivalent to 100 rads (R).

Different radiation types have greater or lesser effect per unit dose, so they are all expressed relative to the effects of X-rays, i.e. a unit equivalent dose is used. To calculate the roentgen equivalent in man (**rem**), the absorbed radiation dose is multiplied by a radiation weighting factor that is dependent on type and energy of the radiation. The current SI unit of equivalent dose is the **sievert**. For X-rays and gamma rays the equivalent dose in sieverts and the absorbed radiation dose in grays are the same. The relationship between the different dose units is:

1 gray (Gy) = 1 joule/kg = 100 rads (R) = 100 rems (r) = 1 sievert (Sv) = 1,000 millisieverts (mSv) = 1,000,000 microsieverts (microSv)

Typical doses of radiation include:

Chest X-ray	0.02	mSv
Brain scan	7	mSv
Bone scan	4	mSv
Average annual UK dose from cosmic rays	0.26	mSv
Average annual UK dose from gamma rays	0.35	mSv
Average annual UK dose natural background radiation	2.2	mSv

Radiological protection

Since the days of Marie Curie, it has been appreciated that ionising radiation exposure may be hazardous to health. Radiation dose limits were first recommended for ionising radiation exposure in 1928. The statutory limit on the amount of radiation to which the general public may be exposed in excess of natural background radiation and excluding medical exposure is set, from 1 January 2000, at 1 mSv per annum.

The most important source of man-made exposure is medical investigation, which accounts for 90 per cent of it. Average natural background radiation is raised to 2.6 mSv by all man-made exposure. UK estimated experience excluding medical investigation is 0.04 mSv. Other statutory limits include occupational dose limits. From 1 January 2000 these are 20 mSv per annum for classified workers and 6 mSv per annum for unclassified workers.

Health effects of ionising radiation

Adverse health effects of ionising radiation are independent of the source of radiation and are of two types, early and late:

Early effects (also called deterministic)

- These effects usually arise shortly after exposure, usually within hours or weeks.
- There is a threshold dose, beneath which no effects are seen.

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- This threshold is relatively high, exceeding natural background radiation levels at all parts of the planet by several hundred-fold.
- The severity of the effect varies directly with dose.
- Duration of exposure is also important, and for a given total dose, acute exposure is more harmful than a protracted dose.
- The tissues affected are those whose cells have a high turnover rate, i.e. bone marrow, skin, gastro-intestinal tract.

Late effects (also called stochastic/probabilistic)

- These effects arise years (2-40 or more) after exposure and the probability depends on the level of the dose.
- There appears to be no threshold and the severity of the effects is not dose-dependent.
- This means that there is a finite risk even from low-level natural background radiation. At the same time, persons exposed to high dose may suffer no ill effects.
- The two main late effects are induction of cancer and hereditary disease in subsequent generations.
- All diseases which can be radiation-induced can also occur naturally or in relation to other exposures - cigarette smoke, alcohol, diet (both excesses and deficiencies), occupational exposures - and are not distinguishable on the basis of cause.
- Current best evidence is that radiation of all types gives rise to less than 2% of all cancers worldwide. The most important carcinogenic type of radiation is in fact ultra-violet light (UVB), not ionising radiation.
- Not all types of cancer have been shown by evidence to be caused by ionising radiation.
- Hereditary effects have not been demonstrated in humans, but there is such evidence in some types of animal.

Effects of total body irradiation

Equivalent dose (Sv)	Effect
Sublethal to man	
0.0001 (0.1 mSv)	Around 2 weeks' natural background radiation, no detectable effect
0.001 (1 mSv)	Around 6 months' natural background radiation, no detectable effect
0.01 (10 mSv)	No detectable effect
0.1 (100 mSv)	Minimal decrease in peripheral lymphocyte count, no clinical effect
1 (1000 mSv)	Mild acute radiation sickness in some individuals (nausea, possible vomiting), no acute deaths, early decrease in peripheral lymphocyte count, decrease in all WBC and platelets at 2-3 weeks, increase in late risk of leukaemia, solid tumours
Equivalent dose (Sv)	Effect
Lethal to man	
10 (10,000 mSv)	Severe acute radiation sickness, severe vomiting, diarrhoea, death within 30 days of all exposed individuals. Severe depression of blood cell and platelet production, damage to gastrointestinal mucosa

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100 (100,000 mSv)	Immediate severe vomiting, disorientation, coma, death within hours
1000 (1,000,000 mSv)	Death of some micro-organisms, some insects within hours
10,000 (10,000,000 mSv)	Death of most bacteria, some viruses
100,000 (100,000,000 mSv)	Death of all living organisms, denaturation of proteins

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Glossary

Absorbed dose See dose.

Acute radiation syndrome (ARS) The onset, within hours of high **dose** whole body **irradiation**, of nausea and vomiting followed by destruction and diminished (or absent) replacement of essential blood cells resulting in vulnerability to serious infection and bleeding; recovery is possible but with increasing **doses** these effects are more severe and death is more likely.

Alpha particle A particle consisting of two protons plus two neutrons; emitted by a radionuclide.

Background radiation **Ionising radiation** from naturally occurring **radionuclides** both in the environment (from soil, rock and building materials and from space – cosmic radiation) and in the body.

Beta particle An electron emitted by the nucleus of a radionuclide. The electric charge may be positive, in which case the beta particle is called a positron.

Contamination The suspension in air or deposition of **radionuclides** upon, or in, the ground, water and other surfaces, and personnel and equipment

- **External contamination** Of a person or equipment - deposition, general or localised, of **radionuclides** upon all or any of clothing, hair, skin and/or equipment
- **Internal contamination** Of a person - deposition within the body, usually by inspiration, by ingestion or sometimes through penetration of (usually broken) skin by **radionuclides** which will then **irradiate** the cells of surrounding body tissues.

Cosmic rays High-energy ionising radiation from outer space.

Decay The process of spontaneous transformation of a radionuclide; the decrease in the activity of a radioactive substance.

Dose The amount of **ionising radiation** received, as deduced from the energy absorbed from an external radiation source

- **Absorbed dose** Quantity of energy imparted by ionising radiation to unit mass of matter such as tissue. Unit is the gray, symbol Gy. $1\text{Gy} = 1 \text{ joule per kilogram}$
- **Equivalent dose** The quantity obtained by multiplying the absorbed dose by a factor to allow for the different effectiveness of the various ionising radiations in causing harm to tissue. Unit is the sievert, symbol Sv
- **Effective dose** The quantity obtained by multiplying the equivalent dose to various tissues and organs by a weighting factor appropriate to each and summing the products. Unit is the sievert, symbol Sv.

Dosimeter A small device worn on the person to measure absorbed energy and from which a record of **Absorbed Dose** may be obtained.

Dosimetry The estimating, recording and maintaining of records of **dose**.

Emitter A **radionuclide** decays by emission of certain radioactive particles and/or electromagnetic radiation. A particular **radionuclide** may be described as an **alpha** or **beta** or **beta/gamma** emitter.

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Fallout The transfer of radionuclides produced by nuclear weapons from the atmosphere to earth; the material transferred.

Fission products The two, invariably radioactive, fragments remaining after an atom has been split (undergone fission).

Gamma ray A discrete quantity of electromagnetic energy without mass or charge, emitted by a radionuclide; similar to an X-ray but with higher energy.

Ionising radiation Radiation that produces ionisation in matter; examples include alpha particles, gamma rays, X-rays and neutrons. When these radiations pass through the tissues of the body, they have sufficient energy to damage the DNA.

Ionisation The process by which a neutral atom or molecule acquires or loses an electric charge; the production of ions.

Monitoring The process of searching for the presence of radiation and then measuring, reporting and recording radiation **dose rates** found within a given area or on a person.

Neutron A nuclear particle (similar to a proton but without electrical charge); emitted during fission and fusion by only a few **radionuclides**; long range (kilometres) in air and highly penetrating; an external **hazard** only at detonation; densely **ionising**.

Non-ionising radiation Radiation that does not produce ionisation in matter; examples include ultraviolet radiation, light, infrared radiation and radiofrequency radiation. When these radiations pass through the tissues of the body they do not have sufficient energy to damage the DNA directly.

Radiation weighting factor (RWF) A factor intended to take account of the relative biological effectiveness of different types of radiation according to both their energies and how densely ionising they are.

Radionuclide An unstable nuclide (atomic nucleus) that emits ionising radiation.

X-ray A discrete quantity of electromagnetic energy without mass or charge, emitted by an X-ray machine; similar to a gamma ray but with lower energy.