Fact Sheet 17

Ionising Radiation and Health

Like all other living organisms, you are exposed to ionising radiation every day. This exposure comes from background radiation.

You can have additional exposure from other sources; for example having an X-ray or flying in a commercial aeroplane results in additional exposure to ionising radiation. It is best to limit your exposure because there is a possibility of adverse health effects. The first publication in ARPANSA's Radiation Protection Series[1], provides recommended ionising radiation dose limits for the public and for people exposed to ionising radiation as a result of their occupations

What is Ionising Radiation?

All matter is made up of atoms consisting of a nucleus surrounded by negatively charged electrons, similar to the sun surrounded by the planets. The nucleus consists of neutrons and positively charged protons. Atoms containing the same number of protons have identical chemical properties and are known as elements. Elements with a different number of neutrons are known as isotopes. There are 88 naturally occurring elements some examples of which are oxygen, iron, sulphur, uranium and radon gas etc. Some atoms are radioactive (they are called radionuclides) and the nucleus of such atoms can change structure (lose energy); in so doing the energy is emitted as radiation in three main forms: alpha particles (helium nuclei), beta particles (electrons) and gamma rays. This process is termed radioactive decay and the resulting daughter product, a new element, is formed as a result. These radiations can interact with surrounding matter to produce positively and negatively charged particles (a type of electricity). This process is called ionisation, hence the term *ionising radiation*. X-rays are also known as ionising radiation and they are identical to gamma rays except they are emitted by the passage of electrons through the electric field of a nucleus, not by the nucleus itself.

What are the Properties of Ionising Radiation?

Beta particles are sub-atomic particles that can travel at close to the speed of light (300,000,000 metres per second). Alpha particles travel relatively slowly and can be stopped (energy absorbed) by a piece of paper, while beta particles can be stopped by one or two centimetres of human tissue. Gamma

rays and X-rays are waves of energy similar to visible light, the stuff that comes out of the domestic lamp; except they have more energy and are invisible. They travel at the speed of light and penetrate matter more easily than the particulate radiations. High atomic number metals such as lead are normally required to absorb their energy.

What Units are Used to Measure Radioactivity?

Radiation is measured in decays (disintegrations) per second which corresponds to the number of nuclei losing energy each second. One becquerel (abbreviation Bq) is equal to one decay per second: one megabequerel is equal to one million disintegrations per second. The human body is naturally radioactive due to the presence of radioactive potassium: A 70 kilogram person would contain about 3500 Bq.

How Does Radiation Interact with Matter?

When the energy from radiation is absorbed by matter, chemical changes occur at the atomic level. If the exposure is large enough these changes can be readily observed. For example, if glass is heavily irradiated it changes colour. Some precious stones are coloured for commercial purposes using this method. When the body is subjected to a medical X-ray the bones absorb most of the energy and a photographic film can then give an image of the skeleton. The amount of radiation absorbed per gram of matter is called the *absorbed dose*.

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What Units Are Used To Measure Absorbed Dose?

Absorbed dose is measured in grays (abbreviation Gy). One gray corresponds to one joule of radiation energy deposited in one kilogram of matter. (Note: It would require 320,000 joules of energy to boil one kilogram [one litre] of water). A uniform dose of 3 to 5 Gy to the whole body will kill fifty percent of people exposed in one to two months. This is a large unit and the milligray (mGy), which is one thousandth of a gray, is more commonly used.

When radiation interacts with living tissue the effect it has varies with the type of radiation. Alpha rays are 20 times more effective than beta, gamma or X-rays at causing tissue damage. To allow for this, the dose in grays is multiplied by an effectiveness factor and the new units are called sieverts (abbreviation Sv) and the dose is called the *equivalent dose*. A one milligray dose of alpha rays is equal to 20 mSv (millisieverts) of equivalent dose. A one milligray dose of beta rays is equal to 1 mSv equivalent dose because the effectiveness factor is 1 for beta rays. In most cases the effectiveness factor is unity and the dose in grays is equal to the dose in sieverts.

How Does Radiation Interact with the Human Body?

When radiation is absorbed in the body it causes chemical reactions to occur which can alter the normal functions of the body. At high doses (above 1 sievert) this can result in massive cell death, organ damage and possibly death to the individual. At low doses (less than 50 mSv) the situation is more complex.

The body is made up of different cells. For example we have brain cells, muscle cells, blood cells etc. It is the genes within a cell that determine how a cell functions. If damage occurs to the genes then it is possible for a cancer to occur. This means the cell has lost the ability to control the rate at which it reproduces. Radiation can cause this effect and at low doses it is the only known deleterious health effect. This type of event is very unlikely to occur, and an estimate of its frequency can only be obtained by measuring the effect at higher doses and calculating the probability at low doses. A dose of one millisievert corresponds to a chance of 6 in 100,000 of contracting a cancer. This figure can be compared with the normal incidence of cancer which is 25,000 cases per 100,000 over a lifetime[2].

If the damage occurs in the testes or ovaries then hereditary effects in descendents may become apparent. No first generation hereditary effects were observed amongst Hiroshima survivors. Based on other studies the ICRP recommended a risk factor of 2 per thousand per sievert effective dose. A dose of one millisievert to a large population will produce two cases of severe hereditary effects per million births[3]. This figure can be compared with the normal incidence of severe congenital abnormalities which is 23,000 per million births[4].

The Natural Background

The effect of radiation on health must be discussed within the context of the natural background. Background radiation consists of cosmic rays from space and radiation present in the earth from when it was formed. Cosmic radiation increases with altitude and so airline pilots receive a high exposure from this source; the dose rate at 12,000 metres being about 150 times the sea level dose. The terrestrial radiation comes from naturally occurring radiosiotopes of potassium and rubidium and from decay products of uranium and thorium. On average two thirds of the dose people receive comes from terrestrial sources. Much of this dose can come from the gas, radon, which is a decay product of uranium and thorium. Radon emanates from the soil and tends to concentrate in buildings. Overseas radon contributes a high proportion of background dose. However in Australia studies have shown that radon contributes a smaller proportion to background dose.

Exposure Limits

The International Commission on Radiological Protection (ICRP) has set the following limits on exposure to ionising radiation[5]:

- The general public shall not be exposed to more than 1 mSv per annum (over and above natural background).
- Occupational exposure shall not exceed 20 mSv per annum.

These limits exclude exposure due to background and medical radiation.

Monitoring of Radiation Exposure

People who are occupationally exposed to ionising radiation can be monitored with a dosemeter which is worn as a badge attached to clothing. At monthly intervals the dosemeter is sent to a laboratory where the radiation exposure can be read. In Australia the average radiation worker receives a dose of 0.12 mSv per annum.

Man's Exposure To Ionising Radiation	
Source of Exposure	**Exposure**
Natural Radiation (Terrestrial and Airborne)	1.2 mSv per year
Natural Radiation (Cosmic radiation at sea level)	0.3 mSv per year
Total Natural Radiation	**1.5 mSv per year**
Seven Hour Aeroplane Flight	0.05 mSv
Chest X-ray	0.04 mSv
Nuclear Fallout (From atmospheric tests in 50's & 60's)	0.02 mSv per Year
Chernobyl (People living in Control Zones near Chernobyl)	10 mSv per year
Cosmic Radiation Exposure of Domestic Airline Pilot	2 mSv per year

Health Risks Arising from Low Doses of Ionising Radiation		
Effect	**Risk**	**Normal Incidence**
Risk of cancer from 1 mSv of radiation	1 in 17,000*	57 in 17,000**
Risk of severe hereditary effect from 1 mSv of radiation	1 in 77,000	1,770 in 77,000

* Age standardised lifetime probability for whole population
**Age standardised incidence rate for whole population (not necessarily fatal)

The risk of obtaining cancer from 1 mSv of radiation exposure is equivalent to the risk of getting cancer from smoking approximately 100 cigarettes[6].

References

1. Recommendations for Limiting Exposure to Ionizing Radiation (1995) and National Standard for Limiting Occupational Exposure to Ionizing Radiation (republished 2002). Radiation Protection Series No. 1.
2. P. Jelfs et al, Cancer in Australia 1983 - 85, Australian Institute of Health and Welfare Cancer Series 1, p101 (Australian Government Printing Service, 1992).
3. Radiation: Doses, Effects, Risks. United Nations Environment Programme (Nairobe, 1985).
4. Czeizel et al, in Multiple Congenital Abnormalities, p27 (Akademia Kiado, Budapest, 1988)
5. Recommendations of the International Commission on Radiological Protection, ICRP Publication **60**. Annals of the ICRP **21**, p22 (ICRP 1990)
6. Cohen, B.L. Catalog of risks extended and updated, Health Physics 61/3:317-333 (1991).