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This Leaflet was written by
Dr. William Reville, University College, Cork.

IONISING RADIATION

Briefing Sheet 7

Trefoil symbol for ionising radiation

RADIOACTIVITY has become a matter of serious public concern. Radioactive substances emit ionising radiation. The world is naturally radioactive and this background radiation is by far the biggest source of exposure of the general public to ionising radiation. Ionising radiation cannot be detected by any of the senses but excess exposure to it can cause serious health problems. It can cause cancer in the person exposed to the radiation and can also cause acute affects if dose is large enough, and it can cause genetic defects that are not seen until future generations. Nevertheless, ionising radiation is used in the service of man in nuclear power generation, in medicine, in scientific research, in industrial radiography, etc. In this leaflet ionising radiation, background radiation, man-made radiation, and the risks to which we are all subject are explained and discussed.

WHAT IS RADIOACTIVITY?

Matter is composed of elements and the smallest part of an element that can exist independently is the atom. Atoms of certain elements are unstable and they disintegrate spontaneously. These elements are said to be **radioactive**. Each disintegration is accompanied by the emission of high energy waves or particles. These emissions are called **ionising radiation**. As the radiation is emitted, the atoms change their nature from one element to a 'daughter' element. This daughter may also be radioactive leading to a second generation radioactive daughter and so the process will continue until eventually a stable atom is reached. This process is called a **radioactive decay series**. Each radioactive element has its own characteristic rate of disintegration and this is quantified as the **half-life** - the time taken for half of the radioactive atoms to decay. Half-life can vary from fractions of a second to thousands of millions of years. Radioactivity is measured in terms of the number of disintegrations that occur per second. The unit of radioactivity is the **Becquerel** (Bq) which corresponds to one disintegration per second. The universally recognised symbol for radioactivity and ionising radiation is the trefoil symbol.

The main forms of ionising radiation are alpha (α) particles, beta (β) particles, gamma (γ) rays, X-rays and neutrons. α particles have very little penetration power and can be stopped by a sheet of paper. β particles also have poor penetration and, on average, can travel only a few millimetres through biological tissue. γ and X-rays and neutrons are very penetrating and can readily pass through the body.

WHAT IS THE EFFECT OF IONISING RADIATION ON MATTER?

Ionising radiation differs from other forms of radiation, e.g. visible light, in that it has sufficiently high energy to cause ionisation when it interacts with matter. Atoms in matter consist of a central positively charged nucleus surrounded by a cloud of negatively charged electrons. Normal matter has no net electrical charge, i.e. the positive and negative charges are balanced. Ionisation is the removal of electrons from the atom, producing an ion pair, i.e. a positive ion (the atom) and a negative ion (the electron). These ionisations are damaging to the orderly structure of matter and, in human tissue, may initiate a cancer or the possibility of a hereditary defect in future generations.

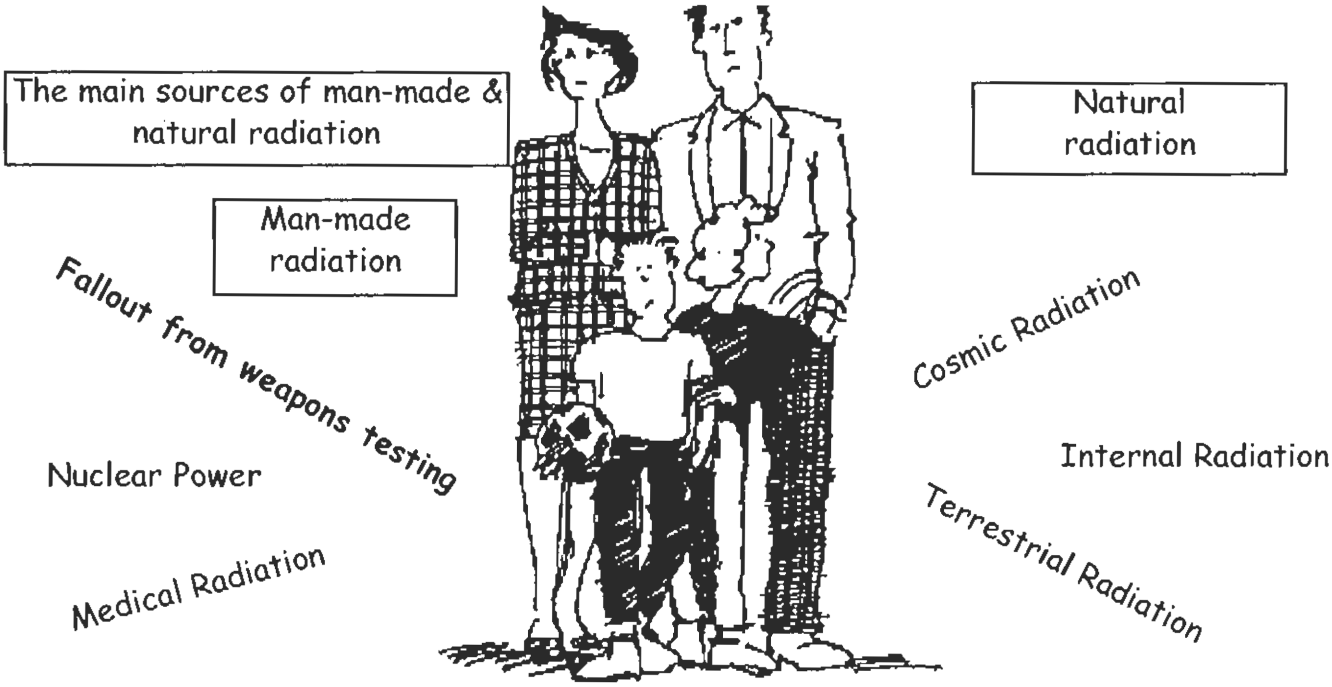
WHAT IS RADIATION DOSE?

Energy is required to cause ionisation and, so, when ionising radiation interacts with matter, energy is deposited in the matter. The amount of energy deposited per unit mass of matter is called the radiation dose. For biological tissue, dose is measured in units called sieverts (Sv). A millisievert (mSv) is one thousandth of a Sv, and a microsievert (μSv) is one millionth of a Sv. The Sv is the modern unit of dose and has replaced an older unit called the Rem.

WHAT ARE THE BIOLOGICAL EFFECTS OF RADIATION?

Human tissue is composed of cells. There are basically two types of cell in the body (a) germ cells used in reproduction of the species and (b) 'somatic' or 'body cells' that form the various organs. Any problems from radiation damage to a somatic cell will affect only the irradiated individual. Damage to a germ cell (mutation), however, can also be passed onto future generations - genetic damage.

The risk that exposure to ionising radiation will cause a problem is proportional to the dose received. For the low doses that we encounter in our everyday lives, the risk is very low indeed. However, there is no good reason to believe that there is any threshold level of dose below which risk is reduced to zero. It is presently estimated that if one million people each



receive one mSv of whole body radiation, 50 will develop a fatal cancer. The cancer will not express itself fully until after a latent period of somewhere between several years and 45 years. Approximately 13 serious hereditary defects will also be caused over all future generations descended from the one million exposed persons. To put these figures in perspective however it should be noted that in any population of one million there will be about 2,100 deaths a year from cancer induced by all causes (i.e. not only by radiation) and about 200 births per year with hereditary defects attributed to mutations from all causes.

The International Commission on Radiological Protection (ICRP) is responsible for recommending values of maximum permissible exposure to radiation. The latest ICRP recommendation for annual dose limit to members of the public is **1 mSv additional to background.** (The average annual dose received by each of us from natural background sources is approximately 2.6 mSv - see below). Legislation in most countries is based on ICRP guidelines. In this country the Radiological Protection Institute of Ireland (RPII) is responsible for advising the Government on radiation protection and for administering a system of control and monitoring to protect the public.

A large whole body dose of radiation (greater than 1,500 mSv) received over a few hours will result in early, acute effects and possibly lead to death within a few days or weeks. The only way in which Irish people could receive such doses would be in the event of nuclear war, or exposure to a massive release of radioactivity from a catastrophic accident in the nuclear industry, or a serious accident exposing a small number of people in an industrial or medical irradiating facility. Such events are outside the scope of this leaflet, which deals mainly with the types of exposure we encounter in our normal lives.

HOW MUCH IONISING RADIATION DO WE RECEIVE AND FROM WHERE?

The earth we live on, the atmosphere we breathe, and even our own bodies are naturally radioactive. Until the turn of the 20th century no other source of ionising radiation existed except the natural background form. In 1895, X-rays were discovered and quickly put to use in medicine. As the 20th century progressed, more and more uses were found for man-made sources of ionising radiation.

NATURAL BACKGROUND RADIATION

We are exposed to natural background radiation from three different sources: (a) cosmic radiation, (b) terrestrial radiation, and (c) internal radiation

Cosmic radiation The earth is continuously under bombardment from outer space by this complex mixture of very penetrating ionising radiations. The atmosphere has a partial shielding effect and, therefore, the dose received increases with altitude. On average we each receive an annual dose of about 0.3mSv from cosmic radiation and there is no sensible way that we can shield ourselves from this.

Terrestrial radiation Certain radioactive elements were incorporated into the earth's structure when it was formed five billion years ago. Because of their long half-lives (i.e. very slow rate of disintegration) these elements and their daughters are still present in the earth emitting α, β and γ radiations.

The dose that we receive from external γ irradiation from these sources will vary depending on local geology. Igneous rocks, e.g. granite, have a greater concentration of radioactive elements than sedimentary rocks, e.g. limestone. The average annual dose that we each receive in this way in Ireland is about 0.3 mSv.

A further source of terrestrial radiation, and by far the single biggest source of natural radiation, is the gas **radon.** This is a radioactive daughter in the uranium decay series. (A similar gas, thoron, in the thorium decay series, makes a minor but important contribution to annual dose - estimated 0.12 mSv). As a gas it can escape into the atmosphere from the rock or soil where it is continuously being formed. Radon concentration in outdoor air varies from about 4 to 15 becquerel per cubic metre (Bq/m^3). When radon is breathed into the lungs and disintegrates, the daughter radioactive particles can lodge there and continue to irradiate the lung for some years. Radon may cause 10% to 20% of all lung cancers. The risk from radon is greater for smokers than for non-smokers.

Radon in outdoor air is unavoidable and causes little problem. Radon enters houses mainly from the soil beneath the house. It can also enter the house from building materials in the house fabric itself. The concentration of radon within houses builds up because of restricted ventilation and this can cause problems. A national survey carried out by University College Dublin found an average concentration of radon of 60 Bq/m^3 in indoor air in Ireland. 40 Bq/m^3 of indoor radon will give an annual dose of 1mSv. The average annual dose from indoor radon in Ireland is therefore 1.5 mSv.

Some areas have higher indoor radon concentrations than others - e.g. parts of the West and South-East of Ireland. The Irish Government advises that remedial action to reduce indoor radon concentration should be considered when it exceeds 200 Bq/m^3. The national radon survey to date shows that 4% of houses in Ireland have radon levels in excess of 200 Bq/m^3. You can arrange to have the radon level in your house measured by contacting the Radiological Protection Institute of Ireland, 3 Clonskeagh Square, Clonskeagh Road, Dublin 14 (Tel: 01 2697766. Fax: 2697437). The RPII also operates a Radon Free-Phone (1800 300600) to answer enquiries about radon. Information on how to reduce indoor radon levels is contained in the booklet Radon in Buildings by N.M. Ryan and M. Finn (published by the Department of the Environment and Local Government and available from the Government Publications Sale Office, Dublin, Tel. 01 6613111 - price £5).

Various radioactive elements are taken up by plants and other organisms and incorporated into their structures. We, subsequently, eat the plants, or the animals that ate the plants, and in this way the radiation enters our bodies. It is estimated that on average we each receive an annual dose of 0.30 mSv from these various internal sources.

The average annual dose received by each of us from the natural background sources is approximately 2.6 mSv and the approximate health implications of this dose for the Irish population can be calculated using the risk estimates quoted before.

MAN-MADE RADIATION

We are exposed to artificial ionising radiations in various ways. By far the commonest way is through the use of ionising radiation in medicine. Other sources of exposure include emissions from the nuclear industry, fallout from nuclear weapons tests, and radiation from miscellaneous sources used in modern society.

Ionising radiation in medicine Ionising radiation is very important in modern medicine where the commonest use is the diagnostic X-ray examination. There is scarcely an adult in Ireland who has not had several diagnostic X-ray examinations. X-rays and γ-rays are also used therapeutically to kill cancer cells. Various radioactive compounds are also administered internally either to assist the imaging of internal organs or for therapeutic reasons.

The use of ionising radiation in medicine carries a risk, just as radiation encountered anywhere else does. However, the situation is always monitored to ensure that the benefit to the patient outweighs the risk involved. The doses received in most forms of diagnostic X-rays are very low, e.g. the dose to the patient from a chest X-ray may be as low as 0.02 mSv, posing less risk to health than smoking one cigarette.

Emissions from the nuclear industry Ireland has no nuclear industry but we are exposed to low level radioactive waste from the British nuclear reprocessing plant at Sellafield, on the Cumbrian coast only 100 miles from the Irish coast. Low-level waste is discharged into the Irish Sea. The main route by which people in Ireland are exposed to this radioactivity is by eating fish from the Irish Sea. Soluble forms of radioactive elements, (mainly caesium), are taken up by fish. The level of radiation in Irish Sea fish is monitored by the RPII and others. The most recent report estimates that the average annual dose to consumers of Irish Sea fish is 0.32 µSV, which is 0.032% of the ICRP recommended annual limit. The annual dose received by a heavy consumer of Irish Sea fish is about 1.43 µSV, representing only 0.06% of the average annual dose of 2.6 mSv received from natural background radiation by a person living in Ireland.

Emissions from Sellafield have been greatly reduced since the mid 1970s and early 1980s. However it is generally felt in Ireland that emissions over the years were not kept as low as reasonably achievable. Since 1986 the Irish Government has been calling for the closure of the Sellafield plant. The UK Government agreed at the OSPAR Convention (1998) to reduce emissions from Sellafield by the year 2020 to as close to zero as is technically achievable.

On 26th April, 1986 a nuclear reactor at Chernobyl, near Kiev, suffered a massive accident resulting in the release of large amounts of radioactivity into the atmosphere. About a week later some of this radioactivity reached Ireland and was deposited here by fallout (explained in next section) over a period of several days.

The RPII estimates that the average extra radiation dose per person received in Ireland from Chernobyl fallout during the first year following the incident was 0.105 mSv. This may result in about 18 extra deaths from cancer in Ireland over the next 70 years. Over this same period there will be 525,000 cancer deaths caused by agents other than radiation.

Radioactive fallout Nuclear weapons derive their explosive power from the uncontrolled break-up of radioactive plutonium and uranium. This releases a large number of radioactive daughter products that are blown high into the atmosphere and are carried around the earth. These radioactive elements gradually fall back (fall-out) to earth over a period of many years. During the 1950s and early 1960s, many test explosions were carried out in the atmosphere as nuclear weapons were developed. In 1963 an Atmospheric Test Ban Treaty was signed and most subsequent tests have been conducted underground. The peak year for radioactive fallout was 1963 and levels have been declining since then. Levels of fallout are now less than ten per cent of what they were at peak. We each receive approximately 0.005 mSv from this source each year.

Miscellaneous sources Modern society employs radioactive substances for a variety of purposes and only a few examples can be given here. Small amounts of radioactive substances are used in scientific research. Properly handled, this work poses no hazard either to the workers involved or to the general public.

Because cosmic radiation increases with altitude, air travel increases exposure to radiation. For example, a return Dublin to New York flight would give a dose of 0.05 mSv.
Most of us travel so little by air that the overall doses received are negligible. However, a weekly return Dublin - New York flight would give an annual dose comparable to that received from natural sources otherwise.

There was widespread concern several years ago that visual display units (VDU's) may emit ionising radiation and, thereby, cause a health hazard. Extensive testing of these devices has shown that no significant amounts of ionising radiation are emitted. Of course the VDU may still pose a problem for other reasons. Early colour television sets might leak some X-rays when improperly adjusted but this is most unlikely with sets manufactured after 1970. The average annual dose from these miscellaneous sources is 1.0 µSv.

The mean relative contribution made by the various sources of ionising radiation to the Irish public is illustrated in the pie chart.

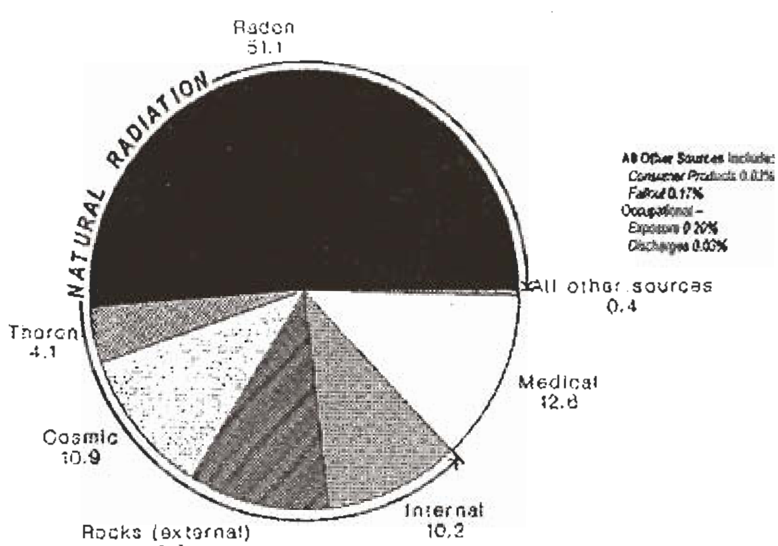
FURTHER READING

Exposure: Living with Radiation in Ireland, John O Dea, Irish Reporter Publications, 1997.

Nuclear Radiation, Risks and Benefits, Edward Pochin, Oxford University Press, 1985.

Radiation Protection in the European Union (poster, available from The European Commission Office, 18 Dawson Street, Dublin 2, Tel. (01) 6625113).

Radioactivity Monitoring of the Irish Marine Environment 1996 and 1997. S. Long, D. Pollard, E. Hayden, V. Smith, M. Fegan, T.P. Ryan, A. Dowdall, J.D. Cunningham, Radiological Protection Institute of Ireland, 119 Clonskeagh Road, Dublin 12. Tel. (01) 2697766 (1998).



This leaflet was written by Dr. William Reville, University College, Cork and issued by
ENFO - The Environmental Information Service, 17 St. Andrew Street, Dublin 2, Ireland.
Tel 1890 200191 Fax 01-8883946 email: info@enfo.ie Web: www.enfo.ie
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