PART 2 IMPORTANT CONCEPTS IN RADIATION PROTECTION

1 RADIATION QUANTITIES

The effects of ionizing radiation are largely dependent on the radiation dose, or the amount of energy absorbed from the radiation.

The **absorbed dose** measures the energy **absorbed** per unit mass of the absorbing material from the radiation field. The absorbed **dose rate** is the **absorbed dose per unit time,** usually **per hour.**

The word **dose** is often used instead of the more correct **absorbed dose**.

A more detailed account of radiation quantities and units is contained in Part 6.

2 BIOLOGICAL EFFECTS OF IONIZING RADIATION

Ionizing radiation is harmful to life because it acts at the molecular level on cells and their constituents. Absorption of energy from ionizing radiation may result in changes to the molecules, destruction of cellular elements, and altered function or death of the cell.

At low doses ionizing radiation may cause cancers and induce genetic defects.

At high doses it can kill cells, damage organs, and cause rapid death.

2.1 SOMATIC AND GENETIC EFFECTS

The biological effects are

- **somatic** if they appear in the exposed individuals or
- **genetic** (**hereditary**) if they affect their offspring.

2.1.1 Somatic effects

These are the result of direct cell damage, such as the death of a brain cell. They are

- **acute** if they appear within a short time of the exposure (hours or days) or
- **delayed** if they appear after months or years.

The damage done by high doses normally becomes evident within hours or days. Cancers take many years to emerge.

2.1.2 Genetic effects

These are the result of damage to the DNA of germ cells and may occur at low doses. The effects are only apparent in offspring and are difficult to observe even in large populations.

Hereditary malformations and diseases caused by genetic damage may take generations to show in the descendants of those irradiated.

2.2 MEDICAL EFFECTS

These are divided into

2.2.1 Deterministic effects

where the severity of the effect increases with the dose and there is a threshold dose below which no detrimental effects are seen. These are produced by relatively high doses. The effects vary considerably from one organ to another and the more radiation sensitive tissues or organs are the ovaries, testes, bone marrow and the lens of the eye

and

2.2.2 Stochastic effects

that are statistical or random in nature (stochastic) and occur with a probability that depends on the radiation dose. In general only the probability of an effect can be established. The probability of the effect occurring is very low at low doses and it is assumed to be proportional to the dose. There are two types of stochastic effects. The first may result in the induction of cancer in the exposed person (somatic). The second may result in genetic (hereditary) disorders.

Martin and Harbison (see Part 6 Section 8) give some indication of the deterministic and stochastic effects of radiation doses.

3 SOURCES OF RADIATION EXPOSURE

Everyone is exposed to natural radiation from cosmic rays and radioactive elements in the earth, the atmosphere and our own bodies. The dose from natural radiation background radiation in South Australia is about 2 mSv per year.

People are also exposed to radiation sources in medical and dental procedures, and may be occupationally exposed to ionizing radiation because of their work.

The largest sources of exposure to radiation are the medical and dental uses of X-rays and radioactive substances.

4 CONTROL OF RADIATION DOSE

The radiation protection program is concerned with the control of occupational exposures and radiation doses.

4.1 DOSE LIMITS

Dose limits are like speed limits - they do not necessarily mean there is zero risk for a dose less than the limit. The NHMRC and the State Regulations set down dose limits for occupational exposures. In general the limits are designed to ensure that the risk of death to a radiation worker through exposure to ionizing radiation is no more than the average risk of death in all occupations. This limit is below the levels at which deterministic effects will occur.

Currently the effective dose limits for radiation workers are 20 mSv per year and for the public 1 mSv per year.

The NHMRC recommendations on dose limits are included in Part 7.

4.2 DOSE CONSTRAINTS

Institutions may establish constraints on the dose received by workers limits. It is important to recognise that dose limits do not mean that below these doses there are no biological effects. University policy is that occupational doses should be **As Low As Reasonably Achievable**, economic and social factors being taken into account (ALARA). With this aim in mind it is expected that no individual at the university will receive an occupational dose greater than 1 mSv a year. This 1 mSv per year is a **dose constraint**.

5 CONCEPTS OF RADIATION PROTECTION

The aim of a radiation protection program in an institution is to reduce the radiation doses and the risks of receiving a significant radiation dose to the lowest possible levels that are reasonably achievable for radiation workers and members of the public.

The reduction in dose is achieved by limiting the **exposure** of people to ionizing radiation.

Exposures can be controlled by engineering, training and operational procedures and may involve the source (minimum source strength, shielding and containing the source), work practices and the use of protective clothing and equipment.

The reduction in the risk of receiving a dose is achieved by monitoring radiation doses and by planning so as to reduce the effects of unexpected events.

Radiation protection is based on

- **Justification**

the use of radiation should produce a benefit to the exposed individual or to society to offset the harmful effect it causes

- **Optimisation**

exposures to ionizing radiation should be kept as low as reasonably achievable (ALARA), taking into account economic and social factors

- **Dose limits and constraints**

exposures of individuals to radiation should be subjected to dose limits and dose constraints.

6 GENERAL PRINCIPLES FOR CONTROLLING RADIATION HAZARDS

6.1 ALARA

The primary objective of radiation protection procedures in the University is to ensure that the radiation exposure of radiation workers (those using ionizing radiation in the course of their employment or study) and the general public (all others), from both external and internal radiation sources is kept below the levels required by the Regulations and **A**s **L**ow **A**s **R**easonably **A**chievable, **(ALARA principle).**

6.2 EXPOSURE TO RADIATION

The use of X-ray equipment or sealed radioactive sources may result in radiation exposure from radiation sources **external** to the body. The handling of unsealed radioactive materials may result in radiation exposure from radioactivity both **external** and **internal** to the body (through ingestion).

Exposure to radiation is
acute if it occurs over a short time, e.g. exposure from a medical X-ray or a radiation accident
or
chronic if it occurs over a longer period of time, e.g. occupational exposure.

6.3 CONTROLLING EXPOSURE

The measures required to counter external and internal radiation hazards are different.

For external radiation, exposure ceases:

- when one leaves the radiation area
- the source is removed
- the irradiating apparatus is turned off.

External radiation can be measured with relative accuracy and the magnitude of the hazard can be estimated.

For internal radiation from ingested radioactive material, the contaminated person continues to be exposed to radiation even after the external contamination is removed.

6.4 EXTERNAL EXPOSURE

External radiation may come from

- X-ray generators or sealed radiation sources such as neutron sources
- Unsealed radionuclides used in a laboratory – with nuclides like P-32 the external radiation hazard can be large.

Exposure to **external radiation** is controlled by:

- **maximising the distance** from the radiation source.
- **minimising the time** of exposure.
- **shielding** the radiation source.

6.4.1 Distance

Increasing the distance from the source is the most effective and economical means of reducing radiation exposure.

For point sources the intensity of the radiation varies inversely with the square of the distance from the source. By doubling the distance from the source the radiation intensity falls to a quarter of the original value.

The variation of the radiation intensity with distance is more complex if the source is large compared with the distances involved (non-point source). The intensity decreases with distance but does not follow a simple law. As a rough guide the inverse square law can be applied if the distance from the source is greater than about 5 times the dimensions of the source.

Distance should be used whenever possible to minimise radiation exposure. Use tongs or other long handled tools rather than fingers for handling radioactive materials. Even short forceps provide a large reduction in the radiation dose from that given to the skin by direct contact.

6.4.2 Time

Decreasing the time of exposure decreases the dose proportionally.

Any new procedure should be practised with non-radioactive materials or as dummy procedures so that the final work with ionizing radiation takes the minimum time.

6.4.3 Shielding

Shielding placed between the source and the worker absorbs the ionizing radiation and therefore reduces the dose rate outside the shielding. It should be used whenever maximum distance and minimum time are not sufficient to reduce exposure to an acceptable level.

6.4.4 General

All three concepts (time, distance and shielding) must be taken together. It is useless to add shielding, or use 2 metre tongs, if these increase the difficulties of working, and increase the time. The dose may be greater than it would be without the shielding!

6.5 INTERNAL EXPOSURE

Internal radiation exposure occurs when the body is contaminated internally or externally with a radionuclide through breathing, swallowing or contact with the skin.

6.5.1 Inhalation

Breathing radioactive dust and gas introduces soluble and insoluble air borne radioactive materials not only into the lungs but also into the gastro-intestinal and upper respiratory tracts. Different radionuclides have different long-term fates in the body and present different hazards.

Iodine poses a special problem because of its volatility. Work with materials containing free radioactive iodine requires special precautions.

6.5.2 Ingestion

By drinking contaminated water, eating contaminated food or generally by transferring radioactive material to the mouth, radioactive material may enter the body.

Ingested material is taken up by various organs depending on the chemical nature of the radionuclide, the biochemistry, and the biological pathways.

6.5.3 Absorption through the skin

The absorption of radionuclides through intact skin as well as open wounds is a hazard as is the retention of radionuclides in the skin itself.

6.5.4 Committed Dose

Radioactive material that is absorbed by the body represents a different hazard from external radiation, because in general there is no way to force the elimination of the material by the body. Someone who has ingested radioactive material has a **committed dose** – we can calculate the dose they are committed to receiving over time.

6.6 CONTROL OF INTERNAL RADIATION HAZARD

Internal radiation exposure is controlled by:

- **limiting the dispersal** of the material so that it cannot be breathed or ingested
- **limiting contact** with the material.

Control is achieved by:

- using the radionuclides in properly designed laboratories
- confining the handling of the radionuclide preparations in well-defined and separate areas of the laboratory
- wearing appropriate protective clothing
- following clearly defined procedures and working rules and good housekeeping
- Careful monitoring of workplaces, gloves and protective clothing after use

6.7 ANNUAL LIMIT OF INTAKE, ALI

For the internal radiation hazards produced by ingesting or inhaling radioactive material, the radiation dose received depends on the nature of the radionuclide, the chemical and biochemical properties of the material and its interaction with the organs of the body.

To help in controlling the internal radiation dose, the **Annual Limit of Intake**, **ALI**, is used. This limit on the amount of a radionuclide that can be taken into the body is dependent on the radionuclide and its biological properties. The ALI may depend on the physical or chemical form of the nuclide.

The **ALI**s are designed to ensure that the 20 mSv per year limit on the dose received by a radiation worker is not exceeded.

6.7.1 Derived Limits

The concentrations of radionuclides that can be present in the laboratory air, and the amounts of the radionuclides that can be present as contamination on laboratory surfaces, are limited by the ingestion hazard (the Annual Limit of Intake, ALI), and the dose which might be received by the hands from a contaminated surface. Limits for air concentration and surface contamination are called **Derived Limits**. They are

Derived Air Concentration (DAC) in Becquerel per cubic metre for breathing

Derived Limit for Surface Contamination in Becquerel per square cm for contamination

These are explained more fully in Part 6.