RADIATION PROTECTION

I. External radiation protection

The three basic methods used to reduce the external radiation hazard are time, distance, and shielding.

A. Time

The amount of radiation an individual accumulates will depend on how long the individual stays in the radiation field. How long a person can stay in an area without exceeding a prescribed limit is called the "stay time" and is calculated from the simple relationship:

$$\text{Stay Time} = \frac{\text{Dose Rate (mrem/hr)}}{\text{Limit (mrem)}}$$

Example: How long can a radiation worker stay in a 1.5 rem/hr radiation field if we wish to limit his dose to 100 mrem?

$$\text{Stay Time} = \frac{\text{1500 mrem/hr}}{\text{100 mrem}}$$

$$= 0.067 \text{ hr} = 4 \text{ minutes}$$

B. Distance

The amount of radiation an individual receives will also depend on how close the person is to the source.

C. Shielding

When reducing the time or increasing the distance may not be possible, one can choose shielding material to reduce the external radiation hazard. The proper material to use depends on the type of radiation and its energy.

Alpha particles are easily shielded. A thin piece of paper or several cm of air is usually sufficient to stop them. Thus, alpha particles present no external radiation hazard. Beta particles are more penetrating than alpha particles. Beta shields are usually made of aluminum, brass, plastic, or other materials of low atomic number to reduce the production of bremsstrahlung radiation.

Lead is a common shielding material for x-rays and gamma radiation because it has a high density, is inexpensive, and is relatively easy to work with. When working with a radionuclide that emits multiple types of radiation such as beta particles and gamma radiation, it is sometimes necessary to shield with several materials. The less penetrating beta radiation can first be shielded with a layer of plastic or plexiglas, thereby slowing or stopping the beta particles while reducing the production of bremsstrahlung. The more penetrable gamma radiation would require an additional layer of shielding. Types of shielding and amount of shielding vary depending on photon energy. A good rule of thumb: shield the less penetrable radiation type first then proceed to shield the more penetrable type. This usually decreases both scattering and the total amount of shielding material required.

II. Internal radiation protection

Internal radiation exposure results when the body is contaminated internally with a radionuclide. When radioactive materials enter the body, they are metabolized and distributed to the tissues according to the chemical properties of the elements and compounds in which they are contained. For example, consider a complex molecule which can be equally satisfied with a C-12 (stable) atom or a C-14 (radioactive) atom at its regular carbon position. If the C-14 decays to nitrogen; the molecular structure is affected. If the molecule were DNA, this might be equivalent to a gene mutation. Once radioactive material is in the body, little can be done to speed its removal. Thus, internal radiation protection is concerned with preventing or minimizing the deposition of radioactive substances in personnel.

A. Radioactive Materials in the Body

Radioactive substances, like other toxic agents, may gain entry into the body by four processes:

1. Inhalation - breathing radioactive aerosols or dust
2. Ingestion - drinking contaminated water, or transferring radioactivity to the mouth
3. Absorption – entry through intact skin
4. Injection - puncture of skin with an object bearing radioactive materials

How long a radioactive substance stays in the body is a combination of the radiological half-life of the radionuclide. The biological half-life is defined as the amount of time it takes for half of the substance to be eliminated from the body by biological means. It is completely independent of the radiological half-life, as it depends entirely on bodily processes such as metabolism, and is not specific to radioisotopes (e.g., radioactive C-14 has the same biological half-life as stable C-12).

B. Guidelines

The basic methods to control and prevent radioactive contamination which can lead to internal radiation exposures are:

1. Isolate the contamination at the source: seal samples and change gloves often to avoid cross-contamination.
2. Separate your radioactive and non-radioactive work areas.
3. Establish and maintain the contamination control zone.
4. Follow established laboratory procedures. Proper protective clothing, designated work areas, surface contamination monitoring, personnel monitoring, etc. are required in all laboratories that use radioactive material.

C. Limits

Limits pertaining to internal emitters are set up for particular radionuclides. These limits are called Annual Limits on Intake (ALI’s). A permissible constant ALI of a radionuclide is a quantity which when present continuously in the body will deliver a dose rate not exceeding the maximum permissible dose rate. The constant ALI must not deliver a committed effective dose equivalent of more than 50 rem per year to any individual organ or tissue or more than 5 rem per year to the whole body. The concentrations of radionuclides in the air required to yield an ALI are called Derived Air Concentrations (DAC’s). A DAC is a concentration of a radionuclide (in microcuries per milliliter) which, when taken into the body on an occupational exposure basis, results in an organ burden which produces the maximum permissible committed effective dose equivalent, e.g. one ALI to the organ of interest. Some of the factors which are considered in calculating ALI's and DAC's are:

1. The type and energy of the radiation emitted
2. It's distribution in the body

3. The solubility/volatility of the compound containing the isotope
4. The effective half-life of the isotope

D. Internal Exposure Monitoring

The internally deposited radioactive material can be monitored by measuring the radiation emitted from the body or by measuring the amount of radioactive material contained in the urine or feces. Such monitoring techniques are called bioassays.

III. General precautions and rules of thumb

General Precautions for Working with Radioactive Materials

1. Always keep radioactive and nonradioactive work separated as far as possible, preferably by maintaining rooms and/or areas used solely for radioactive work.
2. Always work over a spill tray and in a ventilated hood (except with compounds in a nonvolatile form).
3. Always use the minimum quantity of radioactivity compatible with the objectives of the experiment.
4. Always wear protective clothing, safety glasses, and gloves when handling radioactivity.
5. Always wash your hands and monitor yourself before leaving a radioactive work area.
6. Always work carefully and monitor the working area regularly with both swipes and a survey meter to avoid ruining experiments by accidental contamination.

7. Always label containers of radioactive material clearly; indicating nuclide, total activity, compound, specific activity, date and the exposure rate at the surface of the container.

8. Never eat, drink, smoke or apply cosmetics in an area where unsealed radioactivity is handled.

9. Never use ordinary handkerchiefs; use paper tissues and dispose of them as radioactive waste as necessary.

10. Never work with cuts or breaks in the skin unprotected, particularly on the hands or forearms.

11. Never pipette radioactive solutions by mouth.

12. In the event of a spill it is essential to minimize the spread of contamination:

a) Cordon off the suspected area of contamination.

b) Ascertain, if possible, the type of contamination, i.e. the nuclide(s) involved (it may be necessary to use breathing apparatus, protective clothing or other equipment).

c) Determine the area of contamination by monitoring with a survey meter after taking the necessary precautions.

d) Starting from the outer edge, decontaminate the area in convenient sectors by wiping or scrubbing, if necessary.

e) Before moving on, ensure that a sector is clean by monitoring with swipes.

13. Dispose of all radioactive waste according to statutory requirements. Short-lived radionuclides.

14. Film badges should be worn for all radioactive work except with the low energy.

15. Federal and State regulations require that occupational exposure should not exceed 5 rem (50 mSv) per year to the whole body. The exposure of the general public should not exceed 100 mrem (1 mSv) per year to the whole body.

16. To minimize the dose to the extremities, tongs or other remote handling equipment should be used where appropriate.

APPLICATIONS OF RADIATION

In medicine

Radiation and radioactive substances are used for diagnosis, treatment, and research. X-rays, for example, pass through muscles and other soft tissue but are stopped by dense materials. This property of X-rays enables doctors to find broken bones and to locate cancers that might be growing in the body. Doctors also find certain diseases by injecting a radioactive substance and monitoring the radiation given off as the substance moves through the body.

Radiation used for cancer treatment is called ionizing radiation because it forms ions in the cells of the tissues it passes through as it dislodges electrons from atoms. This can kill cells or change genes so the cells cannot grow. Other forms of radiation such as radio waves, microwaves, and light waves are called non-ionizing. They don't have as much energy and are not able to ionize cells.

In communication

All modern communication systems use forms of electromagnetic radiation. Variations in the intensity of the radiation represent changes in the sound, pictures, or other information being transmitted. For example, a human voice can be sent as a radio wave or microwave by making the wave vary to corresponding variations in the voice.

In science

Researchers use radioactive atoms to determine the age of materials that were once part of a living organism. The age of such materials can be estimated by measuring the amount of radioactive carbon they contain in a process called radiocarbon dating. Environmental scientists use radioactive atoms known as tracer atoms to identify the pathways taken by pollutants through the environment. Radiation is used to determine the composition of materials in a process called neutron activation analysis. In this process, scientists bombard a sample of a substance with particles called neutrons. Some of the atoms in the sample absorb neutrons and become radioactive. The scientists can identify the elements in the sample by studying the radiation given off.

References

INTERNATIONAL COMMISSION OF RADIATION PROTECTION Publication 103: 2007 recommendations of the ICRP, including Annexes on Quantities used in radiation protection, Biological effects of radiation, and Bases for judging the significance of the effects of radiation. *Ann ICRP* 37: issues 2-4, 1-332 (2008).