10 RADIATION

This chapter provides essential information about the recognition, assessment, and control of radiation.

What is Radiation?

Radiation is energy that travels through space in the form of electromagnetic waves or sub-atomic particles. There are two main types of radiation: IONIZING and NON-IONIZING.

NON-IONIZING						IONIZING	
Low Frequency	Radio-Frequency	Microwave	Infrared	Visible	UV A B	UV C	Alpha Beta Gamma X-ray
Large wavelength Low frequency →				Small wavelength High frequency			

Figure 18.1

IONIZING RADIATION produces electrically charged particles or ions when it interacts with material. Ionization is the result of a collision between ionizing radiation and matter.

NON-IONIZING RADIATION produces changes in the human body mainly through thermal effects.

What is Ionizing Radiation?

Ionizing radiation can be found anywhere in the natural environment. It comes from space, from the sun, and from naturally occurring radioactive elements in the earth.

Ionizing radiation can also come from manmade sources such as nuclear power plants and x-ray machines. The main sources of ionizing radiation are x-rays, gamma rays, alpha particles, beta particles, and neutrons.

X-rays
X-radiation is electromagnetic radiation produced by x-ray machines. X-rays can penetrate deep into the human body.

Gamma Rays
Like x-rays, gamma rays are electromagnetic. They can pass right through the human body, interact with tissue, and cause severe damage.

Alpha Particles
Alpha particles are emitted from the nucleus of atoms. Because of their large size, a piece of paper or the outermost, dead layer of the skin can stop alpha particles. Alpha particles are produced by elements such as uranium and radon gas. Alpha particles are hazardous when taken into the body through inhalation or ingestion. Uranium miners exposed to radon gas have a much higher incidence of lung cancer when compared to the general population.

Beta Particles
Like alpha particles, beta particles are emitted from the nucleus of atoms. However, unlike alpha particles, they are extremely small and move at nearly the speed of light. Beta particles can penetrate up to 2 centimetres of tissue depending on their energy. This type of radiation is used for light-emitting sources, medical procedures, and biological research.

Neutrons
Neutrons can penetrate deep into the body. Neutrons are produced by nuclear reactors and particle accelerators. A thick layer of plastic or water slows neutrons.

Exposure to Ionizing Radiation
Workers can be exposed to radiation in two ways:

1) Internal exposure — radioactive substances are ingested, inhaled, or absorbed through the skin. Some can be eliminated within a few hours via urine and feces while others are stored in the body and eliminated slowly over many years.
2) External exposure — x-rays, gamma rays, and neutrons represent the main health hazard because of their ability to penetrate the human body.

The extent of radiation damage varies with the type of radiation. For a given dose, alpha radiation produces greater damage than beta, gamma, or x-rays. The degree of harm depends on the specific organ or tissue exposed to the radiation. The same dose may result in different damage to various organs. Reproductive organs, for example, are particularly sensitive to radiation.

Two kinds of health effects result from exposure to ionizing radiation:

Immediate effects — High doses of radiation delivered in a short period to the whole body or particular organs can produce various health effects including death within a few weeks after exposure. Death is usually a result of the body's inability to cope with the large quantity of dead cells within various tissues and/or organs. The severity of symptoms depends on

- the total radiation dose
- how quickly the dose was delivered
- the type of radiation and the part of the body exposed.

Delayed effects — Workers exposed to low doses of radiation are at increased risk of developing cancer later in life and of passing on damaged genetic material to their offspring. Cancers observed in populations exposed to low levels of radiation include leukemia, thyroid, breast, lung, and bone.

Sources of Ionizing Radiation
Construction workers can be exposed to ionizing radiation from both natural and manmade souces.

		Job type	***Radiation type***
Natural Sources	Radon in soil	Tunnelling, highway and road construction	Alpha
Manmade Sources	Industrial Radiography		Gamma
	Nuclear Power Plants		Beta, Gamma, Neutrons
	X-ray Machines		X-rays

Figure 18.2

Natural Sources
Radon — Rock and soil rich in uranium decays to radon gas which produces alpha particles. Alpha particles can be inhaled with air and deposited in the lungs, thereby increasing the risk of lung cancer. Radon can accumulate in poorly ventilated areas such as crawlspaces, basements, mines, and tunnels.

Manmade Sources
Industrial Radiography — Industrial radiography is a non-destructive method of inspecting materials or finding objects underground using ionizing radiation to form an image of the object. Industrial radiography employing highly radioactive materials such as cobalt-60 is used commonly on construction sites. Exposure is possible without adequate shielding.

Nuclear Power Plants — Contractors working in a nuclear power plant can potentially be exposed to beta, gamma, and neutron radiation.

Monitors

Various monitors are available to measure radiation. They can be divided into two main types:

1. personal monitoring for measuring a worker's cumulative exposure
2. survey instruments for measuring exposure at a given time and place.

Personal Monitoring
Film Badge — The film badge, worn on the outer layer of clothing, is used for monitoring x-ray, gamma rays, and high-energy beta particles. Radiation interacts with the film causing it to lighten (develop). After a specific period of time the film is compared to a control film to determine the amount of exposure the person has sustained.

Thermoluminescence Detector (TLD) — TLDs are dosimeters widely used to detect x-rays, gamma rays, and beta particles. They are usually pinned to the outer layer of clothing or worn as finger rings. TLDs are most commonly composed of lithium fluoride. Lithium fluoride absorbs radiation and releases it as light when heated. The amount of light emitted is directly related to the individual's radiation exposure.

Pocket Dosimeter — The pocket dosimeter is a direct reading instrument shaped like a pen with a pocket clip. It is used for monitoring x-rays and gamma rays. The barrel contains a quartz fibre and a charged piece of wire. When the wire is exposed to radiation, it causes the fibre to move. The amount of movement is read off a scale and is directly proportional to the amount of radiation present.

Survey Instruments — The most common survey instruments used for detecting radiation are the ionization chamber, Geiger Müeller (GM) counter, and proportional counter.

Ionization Chambers — When radiation interacts with air, ions are produced. Radiation can be accurately quantified to determine the amount of ions produced. This is the principle behind the ionization chamber. These units can measure gamma, x-rays, beta, and alpha radiation but cannot discriminate between them.

Geiger Müeller Counters — The Geiger Müeller Counter is used for gamma, x-ray, and beta radiation survey measurements. This instrument cannot distinguish different types of radiation but is sensitive to small amounts.

Proportional Counters — Proportional counters are similar to ionization chambers except that they are able to differentiate between alpha and beta particles.

Scintillation Counters — Scintillation counters use the principle that when ionizing radiation strikes certain materials, visible light is created. The amount of light generated is directly proportional to the amount of radiation. Scintillators can differentiate between various types of ionizing radiation.

Body Monitoring Instruments

Frisker Monitor
Workers exiting radiation areas should be frisked for contamination. This does not apply to workers exiting areas containing only radionuclides, such as tritium, that cannot be detected using hand-held whole body or automatic frisking equipment.

Frisker monitors are used at nuclear power stations to scan the body and clothing for radioactive contamination (Figure 18.3). The instruments click when they detect radiation. The greater the number of clicks the greater the level of contamination.

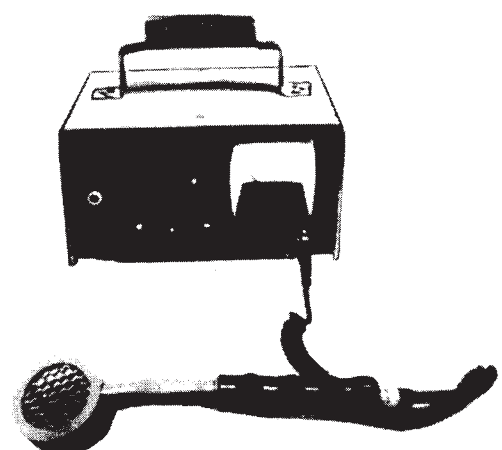

Figure 18.3

Foot and Frisker Monitors
These are used at boundaries where there is a fairly low probability of your hands being contaminated (Figure 18.4). To use the monitor, simply centre your feet on the foot grills and wait for the green "clean" signal on the display panel. If you suspect that hands, clothing, or anything else may be contaminated, survey them with the frisker provided.

Hand, Foot, and Frisker Monitors
These are placed at zone boundaries where traffic flow is highest (Figure 18.5) To check for contamination, centre your feet on the foot grills, insert your hands in the slots, and press the plates at the back. If your hands and feet are not contaminated, the panel will display a green "clean." If you are contaminated, an alarm will sound, the

word “contaminated” will flash in red, and a symbol indicating which extremity is contaminated will light up. If you move off the monitor before it has finished counting, an alarm will sound and the words "removed too soon" will flash. Remonitor and wait for the "clean" signal. If you suspect that hands, clothing, or anything else may be contaminated, survey them with the frisker provided.

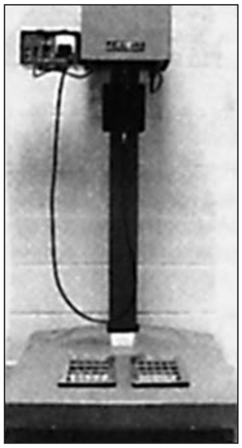

Figure 18.4

Figure 18.5

Portal Monitor
Portal monitors (Figure 18.6) check not only your hands and feet for contamination but also your skin, clothing, and hair.

Figure 18.6

Bioassay Samples
A bioassay program is set up to measure radioactive material within the body so that internal dose may be calculated. The main contributor to internal dose is tritium, a radioactive form of heavy water. Tritium in the body can easily be measured by determining concentration in a urine sample.

Radiation Control Programs

Basic Safety Factors
For external radiation exposure, the basic protection measures are reducing time of exposure, increasing distance from the source, and shielding the source with appropriate material.

Time
The longer a person is exposed to radiation, the greater the chance of injury. Reducing exposure time by one-half reduces exposure by one-half. A common control method is therefore to reduce exposure time and thus exposure.

Distance
Doubling the distance from the source reduces the radiation exposure by one fourth of the original amount. Workers working around radiation-producing machines that are not adequately shielded must maintain a safe distance.

Shielding
Radiation can be blocked by placing a barrier between source and worker. The greater the mass of the barrier the less radiation the worker will receive. Shielding can take many forms depending on type of radiation. The table below outlines the appropriate shielding for various types of radiation.

Radiation type	***Shielding material***
Neutrons	Water
Alpha	Paper
Beta	Plastic
Gamma	Lead, concrete

Figure 18.7

Controlling Radiation Exposure
To minimize exposure, the following measures are recommended.

1. Engineering controls, such as properly enclosing the source, are the primary means of control.
2. Administrative controls, such as restricting access and maintaining a safe distance, should be used as a secondary means of control.
3. Training and educating workers is an essential element in any control program.
4. Personnel should not smoke, eat, drink, or chew in contaminated areas.
5. The selection of personal protective equipment depends on the contamination level in the work area. Workers should inspect protective equipment and clothing before using it.
6. Workers must wear personal monitoring devices where required.
7. Workers must keep track of radiation exposure status.
8. Potentially contaminated clothing should be removed without spreading contamination to the skin and disposed of in the dirty clothes hamper.
9. A shower is required to ensure that contamination is not taken home.

Control for Industrial Radiography Machines
Because of potential high radiation exposure to operators of industrial radiography machines and to workers in adjacent areas, strict controls are necessary during operation.

The following measures are recomended by Health Canada.

1. Portable cameras should be properly shielded to prevent excessive radiation from escaping.
2. The device should be locked to prevent unauthorized use.
3. The camera should be designed so that the radiation source cannot be removed.
4. The camera should be designed so that it cannot be unlocked unless it is fully shielded.

5. The control device should be designed so that it cannot be removed unless the radiation source is in the stored position.
6. A radiation warning sign should be placed in the vicinity of the instrument.
7. The control device should be designed so that the operator can work the device without being exposed to the emergent beam.
8. The camera must be transported in accordance with regulations for transporting dangerous goods.
9. Operators must be certified to operate the machine.
10. Operators should have a yearly medical exam.

What is Non-Ionizing Radiation?

Non-ionizing radiation does not have enough energy to ionize atoms, but it vibrates and rotates molecules, causing heating. Non-ionizing radiation is classified by frequency and stated in units of hertz (Hz).

The following types of non-ionizing radiation may be present in construction; ultraviolet (UV), lasers, radio-frequency, and RF/microwave.

Ultraviolet Light Radiation
Ultraviolet (UV) radiation occupies the range between visible rays and x-rays on the electromagnetic spectrum. UV rays can be divided into three categories according to wavelength:

- UVA 320 nm
- UVB 290-320 nm
- UVC 100-290 nm

Wavelengths are measured in nanometers (nm). A nanometer is one billionth of a metre.

UVC from the sun is usually not a concern because wavelengths below 290nm are filtered out by the earth's atmosphere.

Construction personnel working outdoors are exposed to invisible UV radiation from the sun during spring and summer. Another source of UV radiation is the intense light generated by welding. Overexposure to UV radiation can lead to skin and eye damage.

Skin Damage — Overexposure to UV radiation leads to the painful reddening, blistering, and peeling of skin commonly known as sunburn. The skin may "tan" by producing melanin to protect itself against UV light. Although this dark pigment blocks some of the damaging rays (mostly UVB), the protection is far from adequate. Skin damage still occurs.
Damage done to the skin by excessive exposure to UV rays is cumulative. Chronic or long-term exposure to UV radiation has been related to a number of health effects, including skin cancer, premature aging or wrinkling of the skin, and eye problems.

Note the following points about UV exposure and skin cancer.

- UV exposure from the sun has been established as a major cause of melanoma — a deadly form of skin cancer in people with light skin colour.
- People who experience multiple sunburns early in life are more likely to develop skin cancer than people who experience no sunburns.
- People who work outdoors as teenagers are at an increased risk of developing skin cancers.
- People with chronic exposure to the sun are at an increased risk of developing skin cancer.

Eye Damage — UV radiation can damage the eyes. Conditions include cataracts (clouding of the lens) and corneal injuries (involving the outer membane of the eye).

Welders' flash, also known as *arc eye* and *snow blindness*, is a painful irritation of the cornea and conjunctiva (the membrane connecting the eyeball and the inner eyelid). Symptoms include sensitivity to light and the sensation of sand in the eye.

Control Measures — To protect yourself from UV radiation while working outdoors, take the following precautions.
- If possible, work in the shade when the sun is most intense (late morning and early afternoon).
- Wear sunglasses or safety glasses that protect against UVA and UVB.
- Use sunscreen with a Sun Protection Factor (SPF) of at least 15. Apply sunsreen *generously* to all exposed skin, including lips and nose.
- Wear clothing that covers arms and legs. The tighter the weave the better.

Lasers
Lasers are increasingly used in construction for line guides and levellers. Lasers can cause serious injuries, especially to your eyes and skin. Lasers are identified by class, ranging from Class 1 (low-power lasers incapable of damaging the eye and therefore exempt from control measures) to Class 4 (high-powered lasers capable of causing severe eye damage in less than 0.25 seconds).

Control Measures — The degree of hazard associated with low-power lasers used in construction is relatively low. However, everyone in the work area should be advised of possible laser hazards and the following precautions should be taken.
1. The lasers should have a power output of less than 5 milliwatts (mW) and a power intensity (density) of less than 2.5mW per square centimetre.
2. Operators of laser equipment should be trained in safety procedures, set-up, operation, and maintenance of the specific devices being used.
3. Where possible, the laser beam should be set up well above eye level.
4. The laser device should be shut off when not in use.
5. All employees working near the laser should be advised not to look directly at the laser or its reflection.
6. Lasers should not be pointed at reflective surfaces.
7. A sign should be placed in the vicinity warning people not to stare at the instrument or beam.
8. Each laser should be labelled to indicate maximum output and power intensity.
9. Workers who regularly work in the laser vicinity should have a yearly eye exam.
10. For the safety of the general public, the beam should be confined within the construction area.
11. Optical instruments such as transits and levels should not be pointed at the laser beam or its reflection.

12. The laser instrument should be stored in a locked box when not in use.

Radio-Frequency Heat Sealers

Radio-frequency sealers commonly operate at a frequency of 27.12 megahertz. These devices are also known as heat sealers or welders. Heat sealers generate high-energy radio-frequency (RF) radiation between two conductive plates. When two or more pieces of non-conductive material such as PVC plastic are placed between the energized plates, the material is fused together. RF sealers are used in construction to weld roof tarps and PVC pipe. RF sealers provide a very strong seal and require no toxic solvents.

The National Institute for Occupational Health and Safety (NIOSH) has found that in certain situations the hands of workers operating RF sealers have been exposed to high levels of radiation.

Control Measures

1. The RF sealer should be properly shielded to prevent excessive radiation from escaping.
2. The device should be designed so that it cannot be operated unless it is fully shielded.
3. The control device should be designed so that the operator can work the device without being exposed to RF radiation.
4. Operators of the RF sealer should have a yearly medical exam.

Radio and Television Antennas

Radio and television broadcast stations transmit their signals via radio-frequency (RF) radiation. In urban areas, broadcast antennas are usually located on rooftops where construction workers may unknowingly be exposed to RF radiation as they complete maintenance, repair, and other work.

Control Measures

1. Temporarily lower power levels while work is being performed on or around antennas.
2. Transmit from another antenna while work is being performed.
3. Perform repairs or other work while the antenna is not operational.
4. Maintain a safe distance from the antenna while it is operating.