M E R R T T
Biological Effects

INTRODUCTION

In this module you will learn about the potential health effects of ionizing radiation, acute and chronic radiation exposure, and ways that radioactive material can enter the body. You will learn that the potential for you to receive a significant or damaging amount of radiation during an emergency response situation is extremely low.

PURPOSE

The purpose of this module is to increase your understanding of how ionizing radiation affects the human body. This knowledge will help you, as a responder, function with confidence during incidents that involve radioactive material.

MODULE OBJECTIVES

Upon completion of this module, you will be able to:

1. Define acute and chronic radiation doses.
2. Identify ways that radioactive material can enter the body.
3. Identify the potential health effects of radiation exposure.

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RADIATION: Dose and Dose Rate

We live with radiation every day. We receive radiation exposures from cosmic rays, from outer space, from radon gas, and from other naturally radioactive elements in the earth. This is called natural background radiation. It includes the radiation we get from plants, animals, and from the natural sources within our own bodies.

We are also exposed to man-made sources of radiation, including medical and dental treatments, television sets and emission from coal-fired power plants. Generally, radiation exposures from man-made sources are only a fraction of those received from natural sources.

Radiation dose is the amount of radiation energy deposited in the body. Radiation dose rate is a measure of the rate at which radiation energy is deposited in the body. Radiation dose rate is measured in terms of exposure per unit of time. This is like the speedometer and odometer in your car. The speedometer measures your rate of speed—like dose rate. And, the odometer measures the total distance traveled—like total dose received.

Radiation dose is usually measured in terms of millirem and radiation dose rate is usually measured in terms of millirem per hour. In the United States, the annual average radiation dose per person from all sources is about 360 millirem; however, it isn't uncommon for any of us to receive far more than that in a given year (largely due to medical procedures we may have done). As an example, workers at nuclear facilities are allowed up to 5,000 millirem of radiation exposure each year.

Radiation Risk

Exposure to radiation may cause detrimental effects. Understanding the risks will allow you to evaluate risks and benefits associated with a potential exposure. Understanding the risks will also help you to minimize those risks.

We know that radiation has the ability to damage living cells, causing modification of the cell or cell death. Most organs and tissues of the body are not affected by the loss of even considerable numbers of cells. However, if the number lost is large enough, there will be

observable harm to organs which may lead to outward observable effects and in some cases death. Such harm occurs in individuals who are exposed to large radiation doses in a short period of time. Cells that are damaged but do not die as a result of radiation exposure often repair the damage such that there are no adverse health consequences. If the damage to the cell is not repaired, the resulting modification may be transmitted to future cells and may eventually lead to cancer. These effects may take years to manifest.

BIOLOGICAL EFFECTS OF IONIZING RADIATION

Scientists began to collect and analyze information about the biological effects of ionizing radiation shortly after its discovery. Since that time, scientists have continued studies of radiation effects on cells, plants, animals, and humans. Although we don't have any concrete evidence of the effects from low doses of radiation, scientists have predicted effects based on studies of individuals and groups that received large doses of radiation. Our knowledge of effects from large exposures on humans was obtained from studies of the following:

- Early radiation workers who received large doses of radiation before scientists understood the biological effects and consequences. Exposure standards have since been established to protect workers and the public.
- 80,000 + survivors of the atomic bombs dropped in Hiroshima and Nagasaki. This large group has provided the most information on the effects of radiation.
- Cancer patients. Some patients receive large doses of radiation focused on a specific portion of the body to destroy cancerous cells. Although doctors try to avoid exposing healthy tissues, exposing healthy tissue adjacent to a tumor site is unavoidable.
- Radiation accident victims. Although small in number, we usually have detailed medical records from this group.

Information gained from years of radiation-related research has helped determine more specifically how ionizing radiation can damage the human body and what levels of exposure cause what kinds of damage. Based on these studies, we know more about the biological effects of ionizing radiation than we do about many other environmental hazards.

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How Ionizing Radiation Affects the Body

Scientists have determined that the effects of ionizing radiation occur at the cellular level. The human body is made up of many organs, and each organ of the body is made up of specialized cells. Ionizing radiation can affect the normal operation of these cells.

The way radiation causes damage to any material is by ionizing the atoms in that material—changing the atomic structure of the material. When atoms are ionized, the chemical properties of those atoms are altered. This is how radiation can damage a cell; it ionizes the atoms and changes the resulting chemical behavior of the atoms and/or molecules in the cell. If a person receives a sufficiently high dose of radiation and many cells are damaged, there may be noticeable—observable—health effects.

The amount of the body exposed to radiation is a factor in determining the biological effect. While many cancer patients receive large doses of radiation to destroy tumors, this radiation is concentrated on a specific portion of the body. Exposing the whole body poses more risk because the radiation-induced damage affects a larger area.

Some parts of the body are more sensitive to radiation-induced damage than others. Radiation damage to the cells of the body depends on how sensitive the cells are to ionizing radiation. Generally speaking, the most sensitive cells are those that divide rapidly or those that are in the process of dividing. These cells are most vulnerable because it is difficult or impossible for them to repair any damage that may occur during cell division. Examples of rapidly dividing cells include:

- Blood-forming cells
- Cells lining the intestinal tract
- Cells in an embryo or fetus

Cells that divide more slowly and cells that are more specialized are not as easily damaged by ionizing radiation. Examples include:

- Nerve cells
- Brain cells
- Muscle cells

Biological Effects

A special concern is the sensitivity of the developing embryo or fetus. The system of cells in the developing embryo or fetus is especially sensitive to ionizing radiation because they are unspecialized and rapidly dividing. In general, we become less sensitive to the effects of ionizing radiation with increasing age. The exception is later in life we become more sensitive because of a less effective cellular repair mechanism. People's health and genetics also play a part in determining what effect an exposure has.

Often, the biological effects of ionizing radiation depend on how much and how fast a radiation dose is received. There are two categories of radiation doses: acute radiation doses and chronic radiation doses.

Acute Doses

A large dose of radiation received in a short period of time is called an acute dose. The body can't repair or replace cells fast enough after a large acute dose of radiation, so physical effects may be seen. Some possible health effects from acute doses of radiation include reduced blood count, hair loss, nausea, and fatigue. The physical reaction to an acute dose of radiation is the result of extensive cell damage over a short period of time.

Radiation therapy patients (e.g., patients undergoing cancer treatment) receive high doses of radiation over a short period of time, generally applied to a small portion of the body. Ionizing radiation is used to treat cancer because cancer cells divide rapidly and are sensitive to ionizing radiation.

It takes a large acute dose of radiation before people experience any observable physical effects. Physical effects may take days to manifest themselves and may include nausea, vomiting, and diarrhea. Other than radiation therapy patients, acute doses have only been received by survivors exposed at Hiroshima and Nagasaki and by people at a few radiation incidents at nuclear facilities.

Most radioactive material shipments contain small amounts of radioactivity. Federal packaging regulations require that the level of radiation (measured on the external surface of shipping packages) be low enough that those who handle packages, or those who are potentially exposed to the package, will not experience any adverse

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health effects. When highly radioactive material is shipped, special packages are used that have been designed to withstand severe accident conditions without breaching or releasing their radioactive contents.

The probability that you, as a responder, will receive an acute dose of radiation while responding to a transportation incident is extremely low.

Chronic Doses

A chronic dose of radiation is a small amount of radiation received over a long period of time. The body is better equipped to handle a chronic dose of radiation than it is an acute dose of radiation. The body can repair the damage from chronic doses because fewer cells will need repair at any given time. The body has enough time to replace dead or non-functioning cells with healthy ones.

Chronic doses do not result in the detectable health effects seen with acute doses. Because of cell repair, even a sophisticated blood analysis will not reveal any biological effects. Examples of chronic radiation doses include the everyday doses we receive from natural background radiation and the doses received by workers in nuclear and medical facilities.

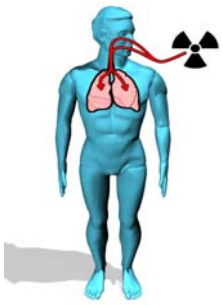
EXPOSURE RISKS

Numerous scientific studies have shown that large non-lethal radiation doses delivered acutely (>10,000 millirem) can increase the risk of cancer. We don't know if this is true for low doses delivered over extended periods of time. The current philosophy of radiation protection is based on the assumption that any radiation dose, no matter how small, may result in human health effects such as cancer and genetic damage. Although this philosophy is simplistic and probably incorrect, it is conservative. The numerous epidemiological studies conducted to date show that health risks at doses below about 10,000 millirem are either zero or so low that they cannot be measured.

If you are interested in learning more, the National Health Physics Society website has a great deal of information on radiation and its biological effects. The web address is http://www.hps.org.

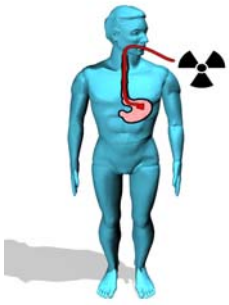
BIOLOGICAL PATHWAYS

Internal radioactive contamination results when radioactive material gets into the body. Your skin, mouth, and nose are the most obvious—and avoidable—routes to internal contamination. Radioactive material can enter the body through the same pathways as any other material.

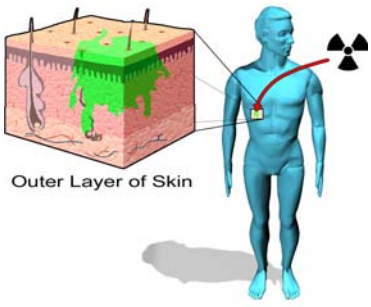


Biological pathways that can introduce internal contamination include:

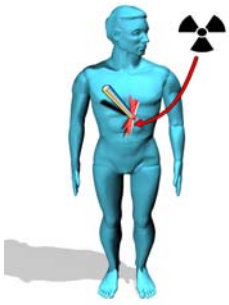
Inhalation - smoke particles or other airborne particulate matter may enter the body through the lungs as you breathe.



Ingestion - eating, drinking, smoking, or chewing contaminated items may cause internal radiological contamination.



Absorption - radioactive material may be absorbed through the skin or mucous membranes the same way other things are absorbed.



Injection - radioactive material can be introduced to the body through cuts, wounds, direct medical injections, or other punctures in the skin.

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Check Your Understanding

1. The way radiation causes damage to any material is by _____ the atoms in that material—changing the atomic structure of the material.

2. If a sufficiently high dose of radiation is received, and a large number of cells are damaged, observable _____ may be seen.

3. A(n) _____ dose is a large dose received in a short period of time.

4. A(n) _____ dose is a small dose received in a continuous or long-term exposure.

5. One possible health effect from a large acute exposure to ionizing radiation is:
   a) Arthritis
   b) Hair loss
   c) Rapid onset of streptococcus
   d) Increased cranial capacity

6. List the pathways by which radioactive material can enter the body:
   _____
   _____
   _____
   _____

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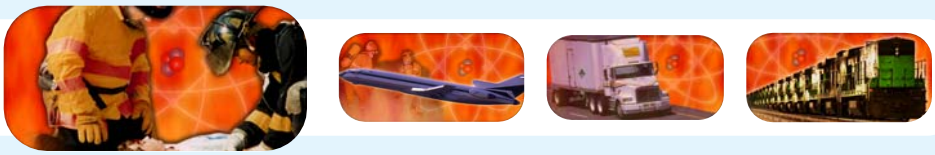

ANSWERS

1. ionizing
2. effects
3. acute
4. chronic
5. b
6. Inhalation
   Ingestion
   Absorption
   Injection