Biological Effects

Radiation Safety Training
Module 2

- This module will discuss the potential for biological effects and risks due to ionizing radiation. These risks will be compared to those of other occupations and daily activities.

Biological Effects Overview

- More is known about the biological effects of ionizing radiation than most other environmental factors. There is a large body of information available regarding exposures to humans.

- There are four major groups of people that have been exposed to significant levels of radiation.

- Group 1 - Early radiation workers, such as radiologists received large doses of radiation before the biological effects were recognized. Since that time, standards have been developed to protect workers.

Introduction

- Group 2 - More than 250,000 survivors of the atomic bombs dropped at Hiroshima and Nagasaki. Some of these survivors received doses estimated to be in excess of 50,000 mrem.

- Group 3 - Individuals who have been involved in radiation accidents.

- Group 4 – The largest group of individuals are patients who have undergone radiation therapy for cancer and other diseases.

Introduction

Sources of Radiation

Radiation can be found almost anywhere. In fact, the majority of us will be exposed to more ionizing radiation from natural background radiation than from our jobs.

- Natural Sources
  - Radiation emitted from natural sources is identical to the radiation that results from manmade sources.
  - The four major sources of naturally occurring radiation exposures are:
    1. Cosmic radiation
    2. Sources in the earth's crust, also referred to as terrestrial radiation
    3. Sources in the human body, also referred to as internal sources
    4. Radon

- Total average dose ~ 28 mrem/yr
- Cosmic radiation comes from the sun and outer space. It consists of positively charged particles and gamma radiation.
- At sea level, the average annual cosmic radiation dose is about 26 mrem.
- At higher elevations, the amount of atmosphere shielding cosmic rays decreases; therefore, the dose increases.

Cosmic Radiation

- Total average dose ~ 28 mrem/yr

- There are natural sources of radiation in the ground (i.e., rocks and soil).
  - Some of the contributors to terrestrial sources are the natural radioactive elements radium, uranium, and thorium.
  - Many areas have elevated levels of terrestrial radiation due to increased concentrations of uranium or thorium in the soil.

Terrestrial Sources

- Total average dose ~40 mrem/yr
- The food we eat and the water we drink contain trace amounts of natural radioactive materials which deposit in our bodies and cause internal exposure to radiation.

Internal Sources

- Total average dose ~ 200 mrem/yr
- Radon comes from the radioactive decay of uranium, which is naturally present in the soil.
- Radon is a gas. It can travel through the soil and enter through building foundation cracks. The greatest concentrations of indoor radon are found in basements.
- Radon emits alpha radiation. It presents a hazard only when taken into the body (e.g., when inhaled).

Radon

- The three top sources of manmade radiation exposures are:
  - Tobacco products (average dose ~1300 mrem/yr for smokers)
  - Medical radiation(total average dose ~ 54 mrem/yr)
    - X rays (total average dose ~ 40mrem/yr)
      - X rays are similar to gamma rays; however, they originate outside the nucleus.
      - A typical radiation dose from a chest X ray is about 10 mrem.
    - Diagnosis and therapy (total average dose ~14 mrem/yr)
      - In addition to X rays, radioactive materials and radioactive sources are used in medicine for diagnosis and therapy.

Manmade Sources

- Building materials (total average dose ~7 mrem/yr)
- Domestic water supply (total average dose ~5 mrem/yr)
- Other minor contributors
  - Other contributors to dose include consumer products, industrial sources, and atmospheric testing of nuclear weapons.

Manmade Sources

- The average annual total effective dose equivalent to the general population (nonsmokers) from naturally occurring and manmade sources is about 360 mrem.

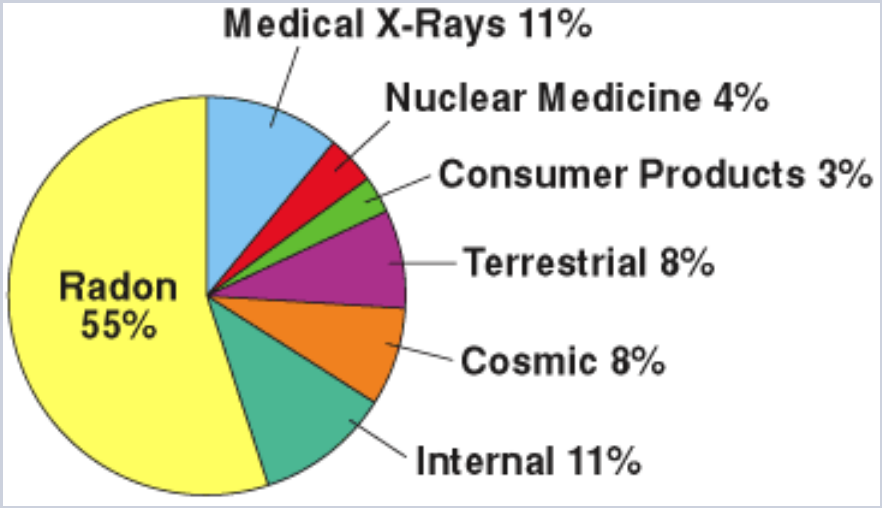

Image from
US Nuclear Regulatory Commission website

Average Annual Dose

- Radiation can cause damage to human cells by the ionization of atoms in the cells. Radiation damage begins with damage to the atoms which make up the cells in the tissues of the body

- When ionizing radiation hits a cell, it may strike a vital part of the cell, like the nucleus, or a less vital part of the cell, like the cytoplasm.

- Some cells are more sensitive than others to environmental factors such as viruses, toxins, and ionizing radiation.

Effects of Radiation on Cells

- The following are possible effects of radiation on cells.
  - There is no damage
  - Cells repair the damage and operate normally
  - Cells are damaged and operate abnormally
  - Cells die as a result of the damage

Effects of Radiation on Cells

- Potential biological effects depend on how much and how fast a radiation dose is received. Radiation doses can be grouped into two categories: acute and chronic dose.

Acute and Chronic Radiation Dose

- Acute radiation doses
  - High doses of radiation received in a short period of time. The body's cell repair mechanisms are not as effective for damage caused by an acute dose.

Acute Radiation Dose

- Acute doses to the whole body
  - Damaged cells will be replaced by new cells and the body will repair itself. This may take a number of months.
  - Only in extreme cases, such as with the Chernobyl firefighters (500 rem), would the dose be so high as to make recovery unlikely
  - It is possible that radiation exposure may be limited to a part of the body.

Acute Radiation Dose

- Probability of a large acute dose
  - It takes a large acute dose of radiation before any physical effect is seen.
  - These acute doses have occurred in Hiroshima/Nagasaki, and in a few radiation accidents, including Chernobyl.
  - The possibility of a radiological worker receiving a large acute dose of ionizing radiation on the job is extremely low.

Acute Radiation Dose

- Chronic radiation doses
  - A radiation exposure received over a long period of time.
  - An example of a chronic dose is the dose we receive from natural background every day of our lives.
  - The body's cell repair mechanisms are better able to repair a chronic dose than an acute dose. It has time to repair or replace damaged cells because a smaller percentage of the cells need repair at any given time.

Chronic Radiation Dose

- Somatic effects refer to the effects radiation has on the individual receiving the dose.

- Genetic effects refer to mutations due to radiation damage to the DNA of a cell. When this change is in the DNA of parental reproductive cells, it is called a heritable effect.

Somatic and Genetic Effects of Radiation Exposure

- A heritable effect is a physical mutation or trait that is passed on to offspring.

- In the case of heritable effects, the parent has experienced damage to some genetic material in the reproductive cells and has passed the damaged genetic material onto offspring.
  - These effects have never been observed in humans.

Genetic (Heritable) Effects

- Total dose
  - In general, the greater the dose, the greater the potential for biological effects.
- Dose rate (how fast)
  - The faster the dose is delivered, the less time the body has to repair itself.
- Type of radiation
  - For example, internally deposited alpha emitters are more damaging than beta or gamma emitters for the same energy deposited.

Factors Affecting Biological Damage

- Area of the body that receives a dose
  - In general, the larger the area of the body that receives a dose, the greater the biological effect.
  - Extremities are less sensitive than blood forming and other critical organs. That is why the annual dose limit for extremities is higher than for a whole body dose that irradiates internal organs.
- Cell sensitivity
  - The most sensitive cells are those that are rapidly dividing. Examples include blood cells, hair follicles, and the cells lining the gastrointestinal tract.
  - The developing embryo/fetus is the most sensitive, and children are more sensitive than adults.

Factors Affecting Biological Damage

- Factors for potential effects associated with prenatal exposures
  - Many chemical and physical (environmental) factors are suspected of causing or known to have caused damage to a fetus, especially early in the pregnancy.
  - Radiation, alcohol consumption, exposure to lead, and heat, such as from hot tubs, are only a few such factors.
- Sensitivity of the fetus
  - Embryo/fetal cells are rapidly dividing, which makes them sensitive to many environmental factors including ionizing radiation. The embryo/fetus is most susceptible to developing adverse health effects if exposed during the time period of 8 - 15 weeks after conception.

Prenatal Radiation Exposure

- Risk estimates that are used to predict health effects in exposed individuals or populations are based on epidemiological studies of well-defined populations (e.g., the Japanese survivors of the atomic bombings in 1945 and medical patients) exposed to relatively high doses delivered at high dose rates.

- It is generally accepted that studies have not demonstrated adverse health effects in individuals exposed to small doses (less than 10 rem) delivered over a period of many years.

Risks in Perspective

- No increases in cancer have been observed in individuals who receive a dose of ionizing radiation at occupational levels.
- The possibility of cancer induction cannot be dismissed even though an increase in cancers has not been observed.
- Risk estimates have been derived from studies of individuals who have been exposed to high levels of radiation. The current rate of cancer death among Americans is about 20 percent regardless of the cause.

Risks in Perspective

- A radiological worker who receives 25,000 mrem over a working life increases his/her risk of cancer by 1 percent, or has about 21 chances in 100 of dying of cancer.
- A 25,000 mrem dose is a fairly large dose over the course of a working lifetime.
- The average annual dose to WKU workers is less than 20 mrem, which leads to a working lifetime dose (40 years assumed) of no more than approximately 800 mrem.

Risks in Perspective

- The estimated risk associated with occupation radiation dose is similar to other routine occupational risks and much less than some risks widely accepted in society.

- The risk of work in a radiation environment is considered within the normal occupational risk tolerance by national and international scientific groups.

- However, acceptance of risk is an individual matter and is best made with accurate information.

Biological Effects Summary

- *Radiological Worker Training*, DOE Handbook, DOE-HDBK-1130-98, October 1998, Reaffirmation with Errata May 2004, Change Notice No. 1, February 2005.
- http://www.nrc.gov/reading-rm/basic-ref/glossary/exposure.html

References