BIOLOGICAL EFFECTS OF IONIZING RADIATION

Purpose:

The lesson presents the current understanding of the biological effects of ionizing radiation. Students will learn what factors are important in determining the biological effects and what the effects can be. They will gain an appreciation of the difficulties involved in ascertaining or documenting the effects of low-level radiation. They will also gain an appreciation of the limitations of our understanding of the biological effects of ionizing radiation.

Concepts:

1. Ionizing radiation produces chemically active charged and uncharged molecular fragments called ions in material it penetrates, including human tissue.
2. The biological effects of ionizing radiation depend principally on the radiation dose or energy absorbed, the type of radiation, and the type and volume of biological cells exposed.
3. There are two general categories of biological effects from ionizing radiation: somatic effects and genetic effects.
4. Biological effects from exposures to low levels of radiation are usually estimated from effects observed from high radiation doses.
5. No level of radiation exposure greater than zero can be considered completely without risk.
6. Shielding protects individuals and the environment from exposure to ionizing radiation from radioactive materials.

Duration of Lesson:

Two 50-minute class periods

Objectives:

As a result of participation in this lesson, the learner will be able to:

1. name principal factors that determine the biological effects of ionizing radiation;
2. explain the difference between somatic and genetic effects;
3. name some effects of acute exposures to high levels of radiation; and
4. state some reasons why it is difficult to say with certainty what the effect of low levels of radiation is.

Skills:

Reading, discussing

Vocabulary:

Absorbed dose, acute exposure, alpha particle, beta particle, DNA (Deoxyribonucleic acid), gamma ray, genetic effect, gonad, ionizing radiation, millirem, molecule, mutation, rad, radiation, radiation sickness, radiologist, rem, somatic effect, sperm, ultraviolet light, X-ray

Materials:

Reading Lesson

Biological Effects of Ionizing Radiation, p. SR-21

Activity Sheet

Biological Effects of Ionizing Radiation, p. 131

Suggested Procedure:

1. The vocabulary introduced in this lesson is extensive. While many words are defined in the text, it may be helpful to preview the vocabulary words before beginning the reading.

   The class may also find it helpful to page through the reading to see the main sections and to read the questions in the margin to help them focus their reading.

2. Assign the reading entitled *Biological Effects of Ionizing Radiation.*
3. When students have completed the paper and have discussed it, they can review the main points by completing the reading review entitled *Biological Effects of Ionizing Radiation.*
4. The following questions can be used for class discussion.

Sample Discussion Questions:

1. What areas of the human body are more sensitive to radiation than others? Besides the type and volume of cells exposed to radiation, what other factors influence the biological effects of radiation?

   (Organs with rapidly dividing cell systems, such as the bone marrow, gonads, and intestines are more sensitive to radiation.)

   (Radiation dose and type of radiation)

2. What terms are used to describe received doses of radiation? What are acute exposures? What symptoms might be experienced in the hours, days, and weeks after an individual receives an acute exposure of radiation?

   (Rad - radiation absorbed dose)

   (Rem - roentgen equivalent man) (usually millirem)

   (Large doses received over short periods of time are acute exposures.)

   (Symptoms: hours - nausea, headache, appetite loss, diarrhea; weeks - changes in blood cell populations, hemorrhaging, hair loss, infertility and/or sterility)

3. How could you reduce your exposure from a known external source of ionizing radiation?

   (Answers may vary but should include the following: Wear protective clothing. Increase your distance from the source. Stand behind a shield or protective barrier. If you must be near the source, minimize the exposure time.)

4. How would exposure to ionizing radiation be reduced by placing spent fuel in underground geologic formations such as the proposed site at Yucca Mountain, Nevada?

   (Answers will vary. Encourage students to consider the concepts they developed in the question about protection, time, distance and shielding. The appropriate geologic formation has not been disturbed for many years and will continue to be undisturbed. The repository should be placed in an area of low population. The repository will be deep underground distancing it from the surface. The rocks and soil under which the waste is buried also work as a protective barrier shielding the surface from ionizing radiation. The waste will be buried in shielded containers.)

5. The main types of ionizing radiation we are concerned with are alpha and beta particles, gamma rays, and X-rays. Use the illustration showing deposition of energy to discuss how these various types of ionizing radiation interact with human tissue. What does the term "per unit path" mean?

   (Alpha particles have the shortest paths in human tissue and deposit the most energy per unit path. Beta particles travel much farther than alpha particles and deposit less energy per unit path. Gamma rays and X-rays, being waves of pure energy and having no mass, travel very long distances in human tissue, and deposit the least energy per unit path.)

6. It is generally accepted among scientists that natural sources of radiation could account for only 1 to 3 percent of the cancer deaths normally expected in the U.S. population. Using the table "Cancer Deaths Attributed to Various Sources" in the reading lesson titled *Biological Effects of Ionizing Radiation,* discuss the contribution of the various sources to cancer deaths in the United States.

   (a.) Is natural radiation a big cause of cancer compared to other causes?

   (b.) Are food additives a big cause of cancer?

   (c.) What are some things we can do in terms of lifestyle to minimize our risk of getting cancer?

   (The two most important things according to this chart would be to watch diet and avoid smoking. Others relate to sexual lifestyle, occupation, exposures related to our natural environment and pollution.)

7. Some risk of a genetic effect is assumed for even low levels of radiation exposure. In light of this, discuss the following:

   (a.) A woman who is 50 years old has two children, ages 17 and 22. Her doctor told her that it is important for her to have a series of X-rays. She is concerned about possible genetic effects of radiation. Discuss whether she should be.

(The woman is past ordinary child-bearing age and her children are already born. She cannot pass on a genetic effect to already born children from an event that occurs after they are born.)

(b.) Suppose the woman is 20 years old and has no children. Discuss whether she should be concerned about genetic effects to her children.

(Scientists generally agree that exposure to ordinary diagnostic X-rays is not likely to be harmful. Nevertheless, it is wise for a young woman and her doctor to discuss risks and to weigh the risks and the benefits to be gained from them.)

8. Discuss the following statement: "It is wise for a woman of child-bearing age to determine whether or not she is pregnant before being exposed to ionizing radiation above background levels."

(Again, scientists generally agree that exposure to ordinary diagnostic X-rays is not likely to be harmful. Rapidly dividing cells are especially sensitive to radiation. So prenatal exposures to the developing infant carry some risk. It is important to balance the benefits of the exposure against the risk.)

9. Discuss the role we think the DNA molecules play in determining the effect of radiation on humans. See *DNA: Mighty Molecules* and the diagram of the molecule in *Biological Effects of Ionizing Radiation*.

(There is some indication that ionizing radiation causes cancer or a genetic disorder by radiation damage to the DNA that is passed on to a great many cells when the cell containing the damaged DNA divides. However, exactly how radiation or other agents cause such effects is not completely understood.)

10. Some effects of exposure to ionizing radiation are delayed and don't show up for many years. Why does this make it difficult to determine exactly what the effects of exposures to low levels of ionizing radiation are?

(The negative health effects of low exposures to ionizing radiation, if there are any, take decades to develop. There are also no observable differences between the negative health effects from radiation and those from many other agents. Therefore, a causal relation between low radiation exposures and a delayed health effect in humans is hard to establish definitively.)

11. There is little data on the effects of exposures to low levels of radiation to examine. Instead scientists rely on information gained from data about high exposures or on data from studies with animals, chiefly mice. Discuss how these two facts affect uncertainty about effects of low exposures.

(There is also disagreement among scientists about whether the data from low-exposure studies with animals can be applied to humans. As in Question 10 above, for humans the many years delay between exposures and effects leads to uncertainties as to a causal relationship.

Scientists agree, however, that low exposures spread over weeks or months have a much lower effect than the total exposure given all at once.)

12. The human species has always been exposed to natural radiation. Some scientists speculate that this may mean there may be some beneficial effects of ionizing radiation. What do you think about this idea?

    (Answers will vary.)

The section of the reading lesson entitled *Ionizing Radiation and Cancer* describes the relationship between radiation exposure and cancer. Generally, this section suggests that the risk of cancer increases as exposure to radiation increases. A study supporting results to the contrary may be interesting for your students to read. The article entitled, "A search for latent radiation effect among men who served as x-ray technologists in the U.S. Army during World War II", can be found in Radiology (1970), Volume 96, pages 269-274. In this study, cause of death for men trained as radiological technologists by the U.S. Army during W.W. II were compared to men trained as pharmacy or medical laboratory technologists. No significant differences in leukemia rate existed.

Teacher Evaluation of Learner Performance:

Student participation in class discussion and completion of activity will indicate understanding.