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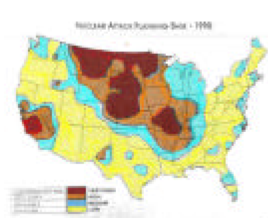

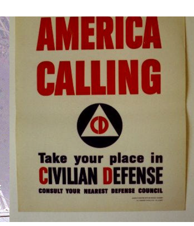

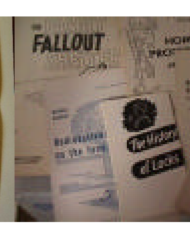

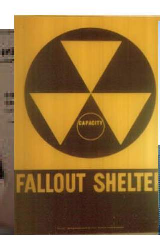

IS 301 January 1998
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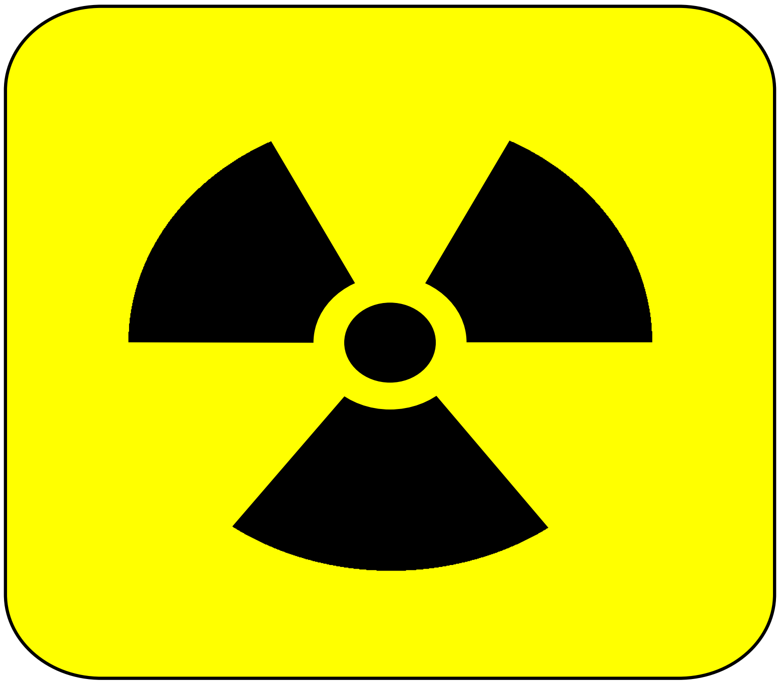
RADIOLOGICAL EMERGENCY RESPONSE INDEPENDENT STUDY



FEDERAL EMERGENCY MANAGEMENT AGENCY

EMERGENCY MANAGEMENT INSTITUTE

(Prerequisite for S302: Radiological Emergency Response Operations Course)

CONTENTS

UNITS OF INSTRUCTION

RATIONALE

FEMA's Radiological Emergency Response Operations (RERO) Course is performance-based training that consists of 4 ½ days of hands-on, evaluated, exercised-based activities. Successful completion of the RERO course requires mastery level of certain knowledge before participation in the course. That knowledge is the focus of the RERO prerequisite courses, the *Fundamentals Course for Radiological Monitors* (FCRM), the *Fundamentals Course for Radiological Response Teams* (FCRRT) and this course, the *Radiological Emergency Response Independent Study*.

This course, deployed through the Emergency Management Institute (EMI) Independent Study Program, is available to RERO candidates and radiological instructors.

COURSE GOAL

The goal of the *Radiological Emergency Response Independent Study (RERIS)* course is to provide a learning experience in which participants demonstrate comprehensive understanding of radiological protection and response principles, guidelines, and regulations through a cycle of text, stimulus, response, and reinforcement. This course of instruction will improve the performance of radiological response team members.

COURSE OBJECTIVES

At the conclusion of this course, learners will be able to do the following:

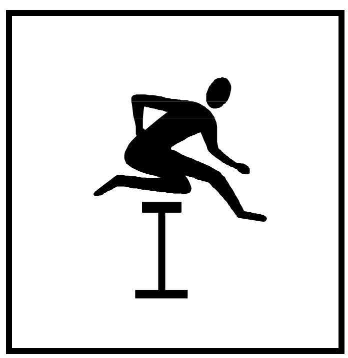
- Differentiate between regulations, standards, law, license conditions, Regulatory Guides, Nuclear Regulatory Commission Regulatory (NUREG) documents, and Radiological Emergency Preparedness (REP) reports that apply to radiological emergency response operations;
- Apply basic concepts of nuclear and health physics appropriate to the needs of radiological emergency response personnel;
- Convert between traditional and SI units of radiation and radiation exposure;
- Convert between “standard notation” and “scientific notation”;
- Associate various biological effects with levels of exposure to ionizing radiation;
- Trace the pathway of radioactive material into, through, and out of the human body;
- Select appropriate external dosimetry for radiological emergency response operations and identify limitations of dosimetry devices;
- Associate radiation protection principles and procedures with characteristics of nuclear radiation;
- Define the Environmental Protection Agency (EPA) Protective Action Guides (PAGs) and the recommendations of the National Council on Radiation Protection and Measurements (NCRP);
- Summarize the Federal/State/local government relationship for different types of radiological emergencies;
- Plan radiological emergency response operations that are consistent with the Incident Command System (ICS)
- Differentiate between the roles of the media, the public information officer, and the radiological response team in radiological emergency response operations;
- Give reasons for and components of environmental monitoring in a radiological emergency;
- Apply knowledge of nuclear power plant structure, operations, and emergency response procedures to the role of the radiological response team member in a related emergency;
- Apply knowledge of radioactive materials transportation regulations to the role of the radiological response team member in responding to a related emergency; and
- Develop a checklist for analysis and control of a radiological hazard area.

HOW TO TAKE THIS COURSE

This independent study course is in a format called "programmed instruction." Programmed instruction has the following characteristics:

- You will work individually on instructional materials at your own pace.
- A relatively small amount of information is presented for you to read. Following this information, you will be asked to complete a statement or answer a question.
- You will be immediately informed whether the response is correct or not. If incorrect, you will be told how the answer is wrong. If your answer is correct, you will be instructed to move on to the next section.

In order to facilitate self-paced course completion, each unit includes a pretest question, also known as a "gate frame." The gate frame question is comprehensive of the unit's overall learning objectives.



If you answer the gate frame question correctly, you may skip to the first of two summary test questions for the unit. If the first summary question is answered correctly, you will be directed to move on to the next summary question. If you answer the second summary question correctly, you will be instructed to move on to the next unit. If you are an advanced learner, you could review the entire course through pretest and summary questions and complete the final examination. However, if you answer the summary questions incorrectly, you will be directed to go back and complete the unit's programmed instruction.

If you answer a gate frame question incorrectly, you should proceed with the unit's programmed instruction. Most learners will complete some or all of the programmed instruction before attempting the final examination.

This course includes a final examination that directly reflects the learning objectives of each unit. Because the course is intended to assure a mastery level of accomplishment of these objectives, a minimum examination score of 85 percent will be the criteria for successful completion.

REFERENCES

Department of Transportation, Code of Federal Regulations (CFR) Part 49, Regulations for Transportation of Radioactive Materials.

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Eckerman, K.F., and A.W. Carricker, *Response of Radiation Monitoring Instruments to Normalized Risk Quantities of Radionuclides*, Sandia National Laboratories, Albuquerque, NM, March 1992.

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Federal Emergency Management Agency, *Basic Public Information Course*, G290.

Federal Emergency Management Agency, *Fundamentals Course for Radiological Response Teams*, G326.

Federal Emergency Management Agency, *Guidance for Developing State, Tribal and Local Radiation Emergency Response Planning and Preparation for Transportation Accidents*, REP-5.

Federal Emergency Management Agency, *Guidance on Offsite Emergency Radiation Measurement Systems Phase 1 - Airborne Release*, FEMA REP-2.REV.2, June 1990; *Phase 2 - The Milk Pathway*, FEMA REP-12, September 1987; *Phase 3 - Water and Non-Dairy Food Pathway*, FEMA REP-13, May 1990.

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Federal Radiological Emergency Response Plan, May 1996.

Hall, Eric J., *Radiation and Life*, Pergamon Press, 1980.

International Commission on Radiological Protection (ICRP) Reports No. 17, 26, 28, 39, and 40.

National Council on Radiation Protection and Measurements (NCRP) Report No. 54 and 91

Occupational Safety and Health Administration, *Hazardous Waste Operations and Emergency Response*, OSHA 1910.120.

Title 10 Code of Federal regulations Part 171, "Hazardous Materials, Transportation Regulations; Compatibility with Regulations of the Internal Atomic Energy Agency," September, 1995

Title 10 Code of Federal Regulations (CFR) Part 20, "Standards for Protection Against Radiation," effective January 1994.

Title 10 Code of Federal Regulations (CFR) Part 19 "Notices, Instruments, and Reports to Workers: Inspection and Investigations."

U.S. Department of Energy, *Overview of Federal Radiological Monitoring and Assessment Center (FRMAC) Operations*, September 1992.

U.S. Department of Energy, *Radioactive Material Transportation Emergency Response Orientation,* attendee workbook.

U.S. Nuclear Regulatory Commission and Federal Emergency Management Agency, *Criteria for Preparedness and Evaluation of Radiological Emergency Response Plans and Preparedness in Support of Nuclear Power Plants*, NUREG-0654/FEMA-REP-1.

UNIT ONE

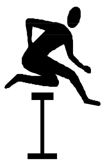
REGULATIONS AND GUIDES FOR RADIATION PROTECTION AND RESPONSE

This unit introduces the major radiation protection regulations, standards, laws and guidance that apply to radiological emergency response. These regulations and guides are produced by two groups.

- Regulatory groups with radiation protection responsibilities are agencies or departments of government, charged with developing and enforcing regulations. The Environmental Protection Agency, the Nuclear Regulatory Commission and the Department of Transportation are examples of regulatory groups.
- *Advisory* groups with radiation protection responsibilities are generally made up of national and international experts in biology, medicine, genetics, health physics, and other related scientific disciplines. The National Council on Radiation Protection (NCRP) is an example of an advisory group.
  - They publish specific recommendations on radiation protection matters.
  - Their recommendations have been widely adopted and form the basis for radiation protection standards throughout the world.

In radiological emergency response operations, you need to know, or know where to find, the standards for radiation protection, the recommended methods for radiation protection, and the regulations being followed by licensees and carriers of radioactive materials. By completing the programmed instruction in this unit, you will develop a base level of knowledge about the contents and purpose of several important documents.

GATE FRAME QUESTION



Based upon your knowledge of and experience with standards and guides on radiation protection and response, differentiate between and provide examples of regulations, standards, and regulatory guides related to radiological protection or response.

ANSWER

Your answer should include the adjacent information.

Regulations are published by Federal agencies and have the effect of law. An example of a regulation is 10 CFR 20, *Standards for Protection Against Radiation*.

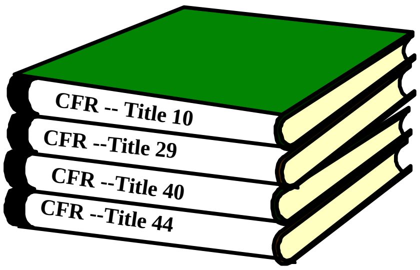
Standards are criteria established by radiation authorities as a rule for the measure of quality programs. An example of a standard is the *Standard for Professional Competence of Responders to Hazardous Materials Incidents.*

Regulatory guides provide the methodology for carrying out the requirements of a regulation. An example of a regulatory guide is NUREG-0654, FEMA REP-1, *Criteria for Preparation and Evaluation of Radiological Emergency Response Plans and Preparedness in Support of Nuclear Power Plants*.

If your answer included all or most of the above points, you should be ready for the Summary Questions at the end of this unit. *Turn to page 1-16.*

If your answer did not include these points, it would be advisable for you to complete the programmed instruction for this unit. *Turn to page 1-4.*

CODE OF FEDERAL REGULATIONS



Regulations have the effect of law. Proposed regulations, final regulations, and notices about regulations are published in a daily government publication called the *Federal Register*. Final regulations published in the *Federal Register* become part of the *Code of Federal Regulations (CFR)*.

The *CFR* is the legal basis for administering any given program. For example, it sets permissible exposure limits for occupationally exposed radiation workers, defines criteria for licensees of radioactive material, and defines for nuclear reactor utilities their responsibilities relating to public welfare.

The *CFR* is divided into 50 *Titles*. Each Title is divided into *Chapters*, and each Chapter is divided into *Parts*. For example, Title 10, Energy, includes regulations of the Nuclear Regulatory Commission (NRC). CFR references are usually denoted by the title (e.g. 10) CFR and the part (e.g. 20). Part 20 of Title 10 sets out the general NRC requirements for radiation protection applicable to all NRC licensees. The NRC's *Occupational Limits for External Exposure* are included in this part of the CFR.

Another important title to remember is Title 29, which includes the OSHA regulation, *Hazardous Waste Operations and Emergency Response* (29 CFR 17).

Title 40 includes the Environmental Protection Agency's (EPA) regulations on radiation protection.

Title 44 includes the radiation planning and protection responsibilities of the Federal Emergency Management Agency (FEMA). 44 CFR 351 assigns to FEMA Federal agency responsibility for assisting State and local government in radiological emergency planning and preparedness activities.

Title 49 covers the U.S. Department of Transportation (USDOT) regulations, including transportation of radioactive materials (49 CFR Parts 171-178).

QUESTION

If someone asked you where in the Code of Federal Regulations to find occupational limits for whole body exposure to radiation, where would you direct him?

Circle the correct answer.

a. Title 40.

b. Title 10.

Turn the page to check your answer.

ANSWERS

a. No. These limits are not located in the EPA regulations.

Review page 1-4 and try the next question.

b. Right. Title 10 includes the NRC's limits for radiation exposure.

Proceed to the next section.

QUESTION

Circle the correct answer.

If you wanted to know the regulations for hazardous waste and emergency response operations, you would refer to

a. 10 CFR 20.

b. 29 CFR 17.

Turn the page to check your answer.

ANSWERS

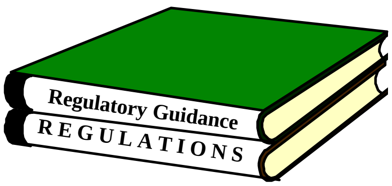
a. No. 10 CFR 20 covers limits for protection against radiation.

Review page 1-4 before you move on.

b. That’s right. Regulations related to emergency response operations for releases of hazardous substances are included in 29 CFR 17.

Go on to page 1-8.

REGULATORY GUIDES AND GUIDANCE DOCUMENTS



The *Code of Federal Regulations* does not always provide the methodology for carrying out the requirements of its regulations. The section of the *CFR* you reference may cite a regulatory guide for doing so. While regulatory guides are not the law, if referenced in a *CFR* as the way to do something, they then carry the force of the law.

NUREG-0654 FEMA REP-1, *Criteria for Preparation and Evaluation of Radiological Emergency Response Plans and Preparedness in Support of Nuclear Power Plants*, is an example of such a regulatory guide. Intended for use by NRC licensees and operators of commercial nuclear power reactors and by State and local governments, it is concerned with accidents at fixed commercial nuclear power reactors that might have an impact on public health and safety. It contains 16 planning standards and evaluation criteria, many of which affect the role of the radiological emergency responder.

Other guidance published by the Federal government does not represent a Federal regulatory requirement. Its use by organizations and governments is voluntary. An example of such a guidance document with relevance to radiological emergency response is FEMA-REP-5, *Guidance for Developing State, Tribal, and Local Radiological Emergency Response Planning and Preparedness for Transportation Accidents*. It is intended for use by Federal, State, Tribal, and local officials responsible for radiological emergency planning and preparedness for transportation accidents. It provides information to use in developing and enhancing emergency capabilities for responding to transportation accidents involving radioactive materials. Its 14 planning objectives cover all aspects of preparedness including post-accident operations.

Under a set of regulations governing radiological emergency planning and preparedness published by the

Federal Emergency Management Agency in March 1982 (47 CFR 10758), the Environmental Protection Agency (EPA) was given the responsibility for establishing Protective Action Guides (PAGs) and preparing guidance for implementing the PAGs. The resulting document, EPA 400-R-92-001, *Manual of Protective Action Guides and Protective Actions for Nuclear Incidents*, presents these guides for specific exposure pathways and associated time periods and guidance for the implementation of the PAGs. A detailed discussion of the PAGs is included in Unit Five of this course.

The *1996 North American Emergency Response Guidebook*, published by the USDOT, Transport Canada, and the Mexican Secretariat of Transport and Communications, provides basic information for first responders on hazardous materials, including radioactive material.

To check your comprehension of these points, complete the following question.

QUESTION

Circle the correct answer.

If you are looking for information on enhancing your emergency plans for responding to transportation accidents involving radioactive materials, you would refer to

a. FEMA-REP-5.

b. FEMA-REP-1.

Turn the page to check your answer.

ANSWERS

a. That's correct. FEMA REP-5 is *Guidance for Developing State, Tribal, and Local Radiological Emergency Response Planning and Preparedness for Transportation Accidents.*

Turn to page 1-12.

b. No. FEMA-REP-1, also referred to as NUREG-0654, deals with preparedness and plans for nuclear power plant incidents.

Review page 1-8 and try the next question.

QUESTION

Circle the correct answer.

At a radiation accident scene, if you are asked whether the projected release of radioactive material will result in implementation of PAGs, where will you go for information about the PAGs?

a. *Code of Federal Regulations.*

b. EPA-400-92-R-001.

Turn the page to check your answer.

ANSWERS

a. You will not find the information you need in the *Code of Federal Regulations* because the PAGs are guidance, not a regulation.

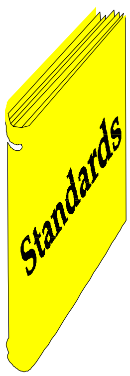
Review page 1-8 before continuing on to the next section.

b. That's right. You are familiar with the purpose and content of *Manual of Protective Action Guides and Protective Actions for Nuclear Incidents.*

Go on to page 1-12.

STANDARDS PUBLISHED BY ADVISORY GROUPS

As mentioned earlier, advisory groups provide recommendations for radiation protection and standards. Standards are criteria established by radiation authorities as a rule for the measure of quality programs. The publications of these organizations can provide useful references for the radiological emergency responder who wishes to learn more about radiation protection and emergency response.



The *International Commission on Radiological Protection (ICRP)* was the first international body concerned with radiation protection standards. ICRP reports often provide the basis for Federal regulation and guidelines. The following ICRP reports have relevance to radiological emergency response:

- ICRP 17: *Protection of the Patient in Radionuclide Investigations.*
- ICRP 26: *Radiological Protection.*
- ICRP 28: *Principals and General Procedures for Handling Emergency And Accidental Exposure Of Workers.*
- ICRP 39: *Principals for Limiting Exposure Of The Public To Natural Sources Of Radiation*.
- ICRP 40: *Protection of the Public In Major Radiation Accidents.*

The National Council on Radiation Protection and Measurements (NCRP) collects, develops, analyzes, and disseminates information about protection against radiation and radiation measurements, quantities and units. The NCRP works closely with the ICRP.

- NCRP 39, *Basic Radiation Protection Criteria*, provides basic information on radiation exposure types and biological effects and outlines various radiation protection standards.

- NCRP 42: *Radiological Factors Affecting Decision Making in a Nuclear Attack* describes effects of nuclear detonations and high level radiation exposure.

The American National Standards Institute (ANSI) and the National Institute of Occupational Safety and Health (NIOSH) are two more advisory organizations that have made a contribution to the radiation protection and preparedness fields through the establishment of standards or the development of suggested means of carrying out standards. In conjunction with the National Fire Protection Association (NFPA), ANSI has published a *Standard for Professional Competence of Responders to Hazardous Materials Incidents*, *ANSI/NFPA 472*. This standard applies to response to radiological materials incidents.

To check your understanding of these concepts, answer the following question.

QUESTION

Circle the correct answer.

Advisory groups in radiation protection and response publish standards that

a. have the force of law.

b. are intended to provide standards and procedures that may be, but are not required to be, adopted by affected organizations.

Turn the page to check your answer.

ANSWERS

a. No. Advisory groups are not associated with the government, and their findings and recommendations are not legally binding.

Complete the next question.

b. That's correct. Advisory groups can provide useful references for the radiological emergency responder who wishes to learn more about radiation protection and response.

Turn to page 1-16.

QUESTION

A reference for developing radiological emergency response operations competencies is

Circle the correct answer.

a. NCRP 39, *Basic Radiation Protection Criteria*.

b. ANSI/NFPA 472, *Standard for Professional Competence of Responders to Hazardous Materials Incidents.*

Turn the page to check your answer.

ANSWERS

a. NCRP 39 is focused on radiation protection principles rather than operational standards.

Review page 1-12 before proceeding to the Summary Questions.

b. That's right. ANSI/NFPA 472 specifies minimum competencies for those who will respond to hazardous (including radioactive) materials incidents.

You are now ready for the Summary Questions on page 1-16.

SUMMARY QUESTIONS

QUESTION

Circle the correct answer.

An example of a regulatory guide referenced in the *Code of Federal Regulations* is

a. NUREG 0654/FEMA-REP-1.

b. FEMA-REP-5.

Turn the page to check your answer.

ANSWERS

a. That is correct. NUREG 0654 is authorized by 10 CFR 20.

Move on to the next Summary Question.

b. No, this document is used by affected organizations and governments on a voluntary basis.

Go back and review this unit.

QUESTION

Circle the correct answer.

An example of guidance published by an advisory group is

a. *Guidance for Developing State, Tribal, and Local Radiological Emergency Response Planning and Preparedness for Transportation Accidents.*

b. *Basic Radiation Protection Criteria*.

Turn the page to check your answer.

ANSWERS

a. No. This guidance document is published by the Federal Emergency Management Agency.

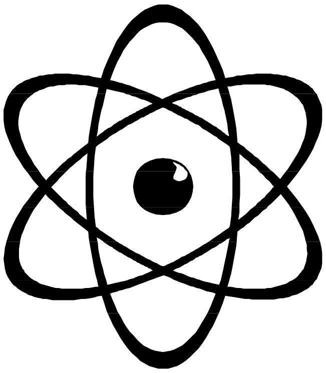
Review this unit before moving to Unit Two.

b. Right. This guidance is published by the NCRP.

You are now ready to turn to Unit Two on page 2-1.

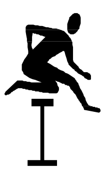
UNIT TWO

NUCLEAR PHYSICS FOR RADIOLOGICAL EMERGENCY RESPONSE



You have had the opportunity to study basic nuclear physics in at least two prerequisite courses, the *Fundamentals Course for Radiological Monitors* and the *Fundamentals Course for Radiological Response Teams.* For that reason, this unit will review concepts, with emphasis on application by the radiological emergency responder.

GATE FRAME QUESTION



You have responded to an accident involving a truck containing radiopharmaceuticals. The Incident Commander tells you that a package found on the ground indicates that it contains 0.2 Ci or 7.4×10^9 Bq of Cs-137. He wants to know exactly what that means in terms of risk to responders. What will you tell him?

ANSWER

Your answer should include the adjacent information

This package contains two-tenths of a curie, or 200 millicuries, of cesium (Cs). A curie is a unit of radioactivity. (Two-tenths of a curie is equal to 7,400,000,000 becquerels. A becquerel (Bq) is an international unit of radioactivity.)

Cesium has a half-life of 30 years, which means that the 0.2 Ci of Cs-137 will decay down to one-tenth of a curie in about 30 years.

Cs-137 is a cesium isotope that emits beta and gamma radiation. Beta radiation cannot travel very far in air and has little penetrating power. It can damage the outer layer of skin, but it is mainly an internal hazard. Gamma radiation can penetrate through the body, travels long distances in air, and is considered an external as well as an internal hazard.

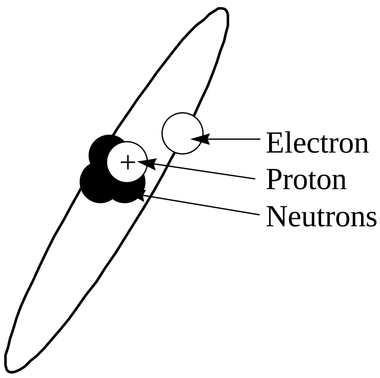
Practical steps that can be taken to reduce your internal risk to Cs-137 would include wearing anti-contamination clothing complete with face mask or respirator (if the responder is trained and respirator fitted.) Your exposure to the gamma emitter in Cs-137 can be reduced by relying on the exposure control methods of time, distance, and shielding. Time spent in the radiation field may be lessened by rotating the crew. Unless you have a designated function, stay out of the radiation field. Put as much shielding between you and the radiation source as possible. The denser the material the better the shielding. For example, a fire truck may provide better shielding than a concrete block wall.

If your answer included all or most of the above points, you should be ready for the Summary Questions at the end of this unit. *Turn to page 2-38.*

If your answer did not include these points, it would be advisable for you to complete the programmed instruction for this unit. *Turn to page 2-3.*

ATOMIC STRUCTURE

Why should knowledge of atomic structure be vital to a radiological emergency responder? Because all radiation originates inside atoms and radiation may be harmful to living cells.



Atoms are basic building blocks of matter. In the center of the atom is the *nucleus*, which contains most of the "weight" of the atom. The nucleus is composed of *protons* that are large and positively charged and *neutrons* that are about the same weight as the protons and have no charge. The collective term for neutrons and protons is *nucleons* because they reside in the nucleus.

Orbiting around the nucleus are *electrons* that carry a negative charge and weigh about 1/2000 of a proton or neutron. The electrons in the outermost orbit determine the chemical properties of the atom. The area between the electrons of the atom is just empty space.

Although the proton is so much heavier than the electron, their opposite charges are equal. The attraction between these forces is what keeps the electrons in their orbits and keeps the atom electrically neutral.

Let's check to see if you can visualize the structure of the minuscule atom. Answer the following question.

QUESTION

Circle the correct answer.

The structure of an atom is most similar to

a. the solar system.

b. children dancing around a maypole.

Turn the page to check your answer.

ANSWERS

a. That's right. Electrons orbit around the nucleus in much the same way as the planets revolve around the sun. Both electrons and planets are held in their orbits by an attractive force—electrons by the attraction between opposite electrical charges and planets by the force of gravity.

Proceed to page 2-6.

b. No, the maypole does not work as well as an analogy. The children that dance around a maypole are attached to the pole or "nucleus" by streamers. Electrons are not connected to the nucleus by a physical bond but rather an attractive force. Another problem with this analogy is that the children may weigh as much or more than the pole, whereas electrons are much lighter than the nucleus of an atom.

Try the next question.

QUESTION

The nucleus of an atom is composed of

Circle the correct answer.

a. protons and neutrons.

b. protons and electrons.

Turn the page to check your answer.

ANSWERS

a. Correct. You understood that the nucleus is composed of the positively charged protons and neutrons, which carry no charge. Negatively charged electrons orbit around the nucleus.

Proceed to the next section.

b. Wrong answer. You have half the answer right. Protons do reside in the nucleus, along with neutrons. Electrons, on the other hand, orbit around the nucleus.

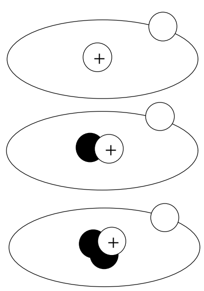
Reread page 2-3 before moving to the next section.

ISOTOPES

Atoms that have an equal number of protons have the same number of electrons and therefore the same chemical properties. As a group they are called an *element* and have one or two letters assigned to them as a symbol. If you know that an atom has one proton in its nucleus, then you know it is an atom of the element hydrogen and that it has one electron orbiting around its nucleus. There are 92 naturally occurring elements, from hydrogen (H) with 1 proton to uranium (U) with 92. There are also artificially created elements, called transuranic elements, used in research and industry.

When atoms have the same number of protons but different numbers of neutrons, they are still the same element, but they are called *isotopes.* That is why elements are further identified with numbers as well as symbols.

Isotopes of the element Hydrogen



For example, ${}^{1}_{1}H$ identifies a form of hydrogen that has 1 proton in the nucleus. ${}^{2}_{1}H$ indicates deuterium, a hydrogen that has 1 proton and 1 neutron in the nucleus, because the upper number, called the mass number, always gives the number of protons *plus* the number of neutrons (as a group called nucleons), and the lower number, called the atomic number, indicates only the number of protons. ${}^{3}_{1}H$, tritium, is a hydrogen that has 1 proton and 2 neutrons.

These three forms of hydrogen are isotopes. Isotopes are important because many of them are radioactive and give off ionizing radiation. In the case of the hydrogen isotopes, ${}^{3}_{1}H$ is radioactive.

It is important to be able to read the symbols associated with the radioisotopes you may be dealing with in an accident. Turn the page to practice.

QUESTION

Circle the correct answer.

What is the composition of $^{238}_{92}U$?

a. 238 protons, 146 electrons, and 92 neutrons. It is a nucleon of uranium.

b. 92 protons, 92 electrons, and 146 neutrons. It is an isotope of uranium.

Turn the page to check your answer.

ANSWERS

a. You read the symbol incorrectly, so let's review using $^{238}_{92}U$ as an example. The 92 is the atomic number and tells the number of protons. Therefore, we know that uranium has 92 protons and an equal number of electrons. The mass number gives the sum of the number of protons plus neutrons; to find the number of neutrons, simply subtract the atomic number (92) from the mass number (238) to get 146.

Finally, *nucleon* is the incorrect term for this atom. U-238 has nucleons in its nucleus, but "nucleon" is not the correct term for the entire atom. U-238 is more correctly called an isotope of uranium because it is one of several forms of the element uranium.

Try the next question.

b. You are right on track. You know that the atomic number (92)indicates the number of protons in the nucleus, the mass number (238) indicates the total number of protons and neutrons, and that the number of electrons equals the number of protons. $^{238}_{92}U$ is one of many forms of uranium and therefore correctly described as an isotope.

Proceed to the next section.

QUESTION

Circle the correct answer.

What is the atomic composition of $^{137}_{55}Cs$?

a. 55 protons, 55 electrons, 82 neutrons. It is an isotope of cesium.

b. 137 protons, 137 electrons, 82 neutrons. It is an isotope of uranium.

Turn the page to check your answer.

ANSWERS

a. Correct! From the atomic symbols you interpreted that this isotope of cesium has 55 protons and an equal number of electrons. With a mass number of 137, you subtracted the 55 protons and correctly calculated that there are 82 neutrons.

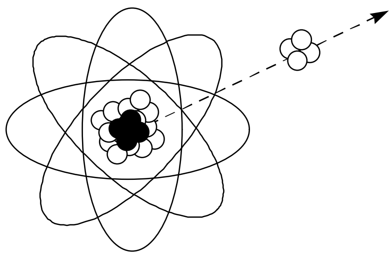
Proceed to the next section.

b. No, you have the atomic number and the mass number mixed up. The atomic number, 55, indicates the number of protons. You correctly assumed that there are an equal number of electrons. The mass number is 137, which is the total of protons plus neutrons, so you were on the right track when you subtracted 55 from 137 to get 82 neutrons. By the way, this is not uranium. Cs is the symbol for cesium. (If you are interested in becoming more familiar with the symbols, there is a Periodic Table of the Elements in most physical science books.)

Return to page 2-6 and reread this sequence.

RADIOACTIVE DECAY

Any of the whole group of elements and their isotopes may be referred to as *nuclides*. Nuclides with high mass numbers have excessive energy in the nucleus, causing them to be unstable and radioactive. In general, the lighter nuclides tend to be more stable, which means they are less likely to transform into another configuration. There are exceptions, however, such as H-3 and C-14.



An unstable atom will attempt to reach stability by ejecting alpha or beta particles and/or releasing energy in the form of gamma radiation. This process is radioactive decay, or "radioactivity."

To assess your understanding of radioactive decay, answer the following question.

QUESTION

Circle the correct answer.

Radiological emergency response personnel are called upon to deal with accidents that involve radioactive nuclides or "radionuclides." The nuclei of these atoms contain excessive energy that makes them

a. more stable and unlikely to transform into another nuclide.

b. more unstable and likely to eject alpha or beta particles and energy.

Turn the page to check your answer.

ANSWERS

a. No, nuclides are radioactive when they have unstable nuclei. This often is a result of a large number of neutrons and protons in the nucleus. These "heavy" nuclei tend to want to get rid of some of these energetic particles to become stable.

Try the next question.

b. That's right. Unstable atoms emit protons or neutrons and energy in an effort to reach a stable form in the process known as radioactive decay.

Move on to the next section.

QUESTION

Circle the correct answer.

When unstable nuclei eject neutrons or protons and release energy, the process is known as

a. radioactive decay.

b. ionization.

Turn the page to check your answer.

ANSWERS

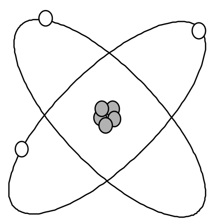
a. That is correct. Radioactive decay, or radioactivity, is the process that results in the ionizing radiations that create a hazard to living things.

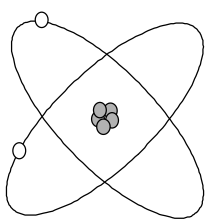
Proceed to the next section.

b. No, the result of radiation may be ionization, but the process of releasing the nucleons is radioactive decay.

You should reread the sections on radioactive decay.

IONIZATION





The orbits in which electrons travel around the nucleus are also called shells. Each shell holds a maximum number of electrons, and the closest shells to the nucleus are full before any electrons will be found in outer shells. The outermost shell will not always be full, leaving space for one or more additional electrons. Atoms tend to seek to fill the outermost shell by sharing electrons with other atoms. When a single electron fills a place in the outer shell of two atoms, the atoms pair together and become a molecule of an element or compound.

Any atom that has lost an electron and thus becomes positively charged is an *ion*. The removed electron also is considered to be an ion because it is a loose, negatively charged particle. Ions tend to be chemically active and try to unite with other atoms or ions. The process of removing an electron, leaving two charged particles (the atom with a net positive charge and the free electron with a negative charge), is called *ionization.*

One of the important characteristics of ionizing radiation is its ability to split atoms on molecules into positively and negatively charged fragments that may realign and form new chemical compounds. When ionizing radiation penetrates living tissue it may cause a disruption of the chemical organization and function of the cells, thus causing a biological effect. Ionizing radiation can be detected and measured as an electrical charge by radiation detection instruments. Ionizing radiations include x-rays, gamma rays, neutrons, beta particles, and alpha particles.

Non-ionizing radiation includes visible light, radio waves, radiant heat, and microwaves. These low-energy radiations do not remove electrons from atoms. They occur when electrons are excited by some external energy source and give off heat and light.

QUESTION

Circle the correct answer.

Ionization is an important concept for the radiological emergency responder to understand because

a. it is the basis for the biological effect caused by radiation and it provides the evidence that radiation is present.

b. it describes how protons are removed from the nucleus of an atom, causing biological damage to a cell.

Turn the page to check your answer.

ANSWERS

a. You are right. Ionizing radiation can knock electrons out of their shells and create ions that may pair together and create new molecules of different compounds. You also understand that the elimination or addition of an electron creates charged particles that are measurable with specially designed equipment.

Move on to the next section.

b. No, ionization is when electrons are knocked out of their shells, not protons out of the nucleus.

Try the next question.

QUESTION

Circle the correct answer.

An ion is any atom that has lost ____.

a. a proton.

b. an electron.

Turn the page to check your answer.

ANSWERS

a. No, ions and ionization are related to losing electrons, not protons. The protons are bundled up in the nucleus of the atom, whereas the electrons travel in orbits around the nucleus. It is the electrons in the shells that may be knocked loose, creating charged particles that eventually partner with other oppositely charged ions.

You should go back and reread this section again.

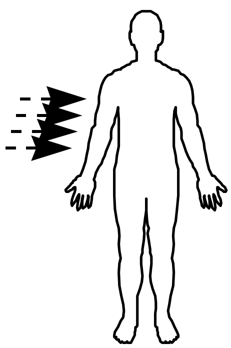
b. Now you've got it. When these atoms are missing electrons they tend to combine with other atoms and/or ions, often forming new compounds. Ionizing radiation can cause biological effects in living cells by disrupting (breaking up) molecules of essential cell structures, consequently affecting cell function and organization. Ions are charged particles and therefore measurable evidence of the presence of the radiation causing the ionization.

Proceed to the next section.

IONIZING RADIATIONS

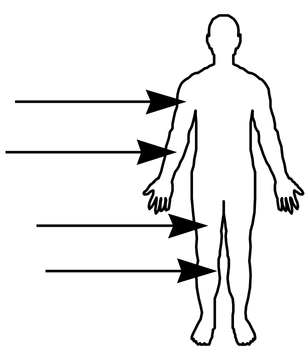
There are several types of ionizing radiation. Because radiological emergency response personnel are most likely to encounter alpha, beta, and gamma radiation, we will concern ourselves with those three types. You have studied the characteristics of ionizing radiation in other courses; this section will consist of a brief review.

ALPHA



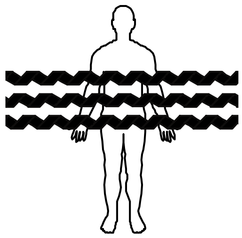
When large, unstable nuclides such as uranium or radium decay and break down, they may give off radiation that is identical to the nuclei of helium atoms (two protons and two neutrons). This type of radiation is called *alpha*. Because these radiations are relatively heavy and carry a positive charge, alpha travels only a few centimeters in air and has little penetrating power. In fact, alpha cannot even penetrate the outer layer of dead skin on the body. For that reason alpha is an internal hazard only—it must get inside the body to cause biological damage.

BETA



Another form of radiation, *beta,* is emitted when a neutron breaks down into a proton and an electron. The electron is ejected from the nucleus at high energy as a beta particle and the atom is transformed into a different nuclide because the number of protons increased. At high exposures beta-emitting radionuclides can cause injury to the skin and superficial body tissues. Otherwise they present mostly an internal hazard.

GAMMA



Gamma rays, which are emitted during most radioactive decay events, have no mass and no charge; they are pure electromagnetic energy. Gamma rays travel great distances in air—a few thousand yards to miles, at the speed of light. They have great penetrating power and are considered to be an external hazard to living things.

To test your knowledge, answer the following question.

QUESTION

Circle the correct answer.

If you identified the radionuclides involved in a transportation accident and found that they emit alpha, beta, and gamma radiation, you would conclude that

a. the radiation presents an internal hazard only.

b. the radiation presents an external as well as an internal hazard.

Turn the page to check your answer.

ANSWERS

a. No. While all three types of radiation present would become a hazard if inside the body, because of its penetrating power gamma radiation constitutes an external hazard.

Try another question.

b. Correct. All three ionizing radiations can affect the internal organs. Alpha and beta must be ingested or inhaled whereas gamma radiation has the ability to penetrate the body and cause biological effects.

Move on to the next section.

QUESTION

Circle the correct answer.

Your radiation detection instrument indicates the presence of gamma radiation. Gamma radiation _____by protective clothing.

a. can be stopped

b. cannot be stopped

Turn the page to check your answer.

ANSWERS

a. You should never rely upon protective clothing to protect you from gamma radiation because gamma has great penetrating power and can pass through material much thicker and denser than protective clothing.

Return to page 2-17 and reread this section.

b. Right. While protective clothing safeguards against radioactive contamination, it cannot stop gamma radiation from penetrating the body.

Proceed to the next section.

RADIOACTIVE HALF-LIFE

As you read a few pages ago, radioactive nuclei give off radiation and transform into stable, other unstable, or nonradioactive nuclei. The number of atoms undergoing this decay during a given time depends not only on the total number of atoms present, but also on a characteristic called *half-life*. The radioactive half-life of a nuclide is the time it takes for half of the radioactive nuclei to decay. Radioactive decay is measured in terms of half-life.

Day 1	8 Days Later	8 More Days Later
100 Ci I-131	50 Ci I-131	25 Ci I-31

Some materials decay at a slower rate and will be radioactive for a long time. Californium-249 (Cf 249) has a half-life of 351 years. Plutonium-239 (Pu 239) has a half life of approximately 24,100 years. Conversely, some radioactive materials decay very quickly. Iodine-131 (I-131) has an 8-day half-life, and carbon-11 (C-11) has a half-life of only 20 minutes.

The concept of half-life is particularly significant when considered in terms of internal deposition in the human body. Nuclides that have short radioactive half-lives give up their energy quickly; inside the body this can cause serious problems because of the damage caused by the resulting ionization. I-131 tends to settle in the thyroid and has a short half-life. Protection of the thyroid is a serious consideration if an accidental release contains radioactive iodine. Strontium-90 (Sr-90) tends to collect in the bones. Because Sr-90 has a longer half-life—29 years—it decays less quickly, but it can cause ongoing damage if it stays in the body for a long time.

Let's pause now and apply this concept by answering the question on the next page.

QUESTION

Circle the correct answer.

An accident involving a radiopharmaceutical shipment includes chromium-51 (Cr-51), which has a half-life of about 27 days. If 800 curies of the Cr-51 spilled and were not diminished by any natural effects, at the end of 27 days __________________ due to radioactive decay processes.

a. there would be no Cr-51 left

b. only 400 curies of Cr-51 would remain

Turn the page to check your answer.

ANSWERS

a. No, the Cr-51 would not be completely transformed to a stable material. The half-life refers to the time it takes for one-half of the radioactive material to decay to a stable nuclide.

Try the next question.

b. That's right. You have correctly applied the concept of half-life.

Move on to the next section.

QUESTION

If a material has a half-life of 1 minute, how long will it take for 100 curies of that material to decay to 25 curies?

Circle the correct answer.

a. one minute.

b. two minutes.

Turn the page to check your answer.

ANSWERS

a. No, one minute is one half-life for this material, and 50 curies would be remaining after one half-life. The material would decay to 25 curies in another half-life. Therefore, it would take two minutes for this transformation to occur.

Return to page 2-21 and reread this section.

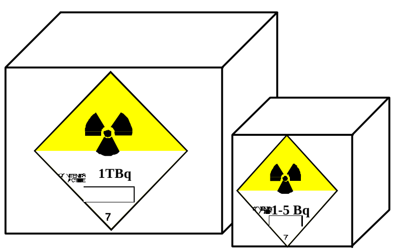
b. Correct. You calculated that it took one half-life to decrease to 50 curies of the material and another half-life to decrease the amount of radioactive material to 25 curies.

Proceed to the next section.

MEASURING PROPERTIES OF RADIATION

There are three important properties of radioactive materials that must be measured. Members of radiological emergency response teams should be able to interpret units in which these properties are measured because they must be able to read meters, packages, shipping papers, labels and placards, in order to analyze the radiological hazard.

The strength or radioactivity of a material is defined by how fast it is decaying or disintegrating and emitting radiation. The *curie* is the traditional unit used to measure this activity. One curie equals 37 billion disintegrations per second.. Because of the great differences in activity of radionuclides, an ounce of one material could be more radioactive, or have more curies, than a pound of another material.



- For smaller amounts of radiation, the millicurie (mCi), which is one one-thousandth of a curie (.001 or 1/1000 Ci), is used.

The international (SI) unit for radioactivity is the *becquerel* (Bq). One becquerel is equal to one disintegration per second.

- One terabecquerel (TBq) equals one trillion becquerels (1,000,000,000,000 Bq).
- One gigabecquerel (GBq) equals one billion becquerels (1,000,000,000 Bq). One curie (Ci) equals 37 GBq (37,000,000,000 Bq).

When regulatory agencies describe how much radioactive material is allowable in a shipping package, that amount is described in curies and in terabecquerels. Package labels describe the activity contained in the package in terms of the appropriate SI units (becquerels and terabecquerels) or in SI units followed by customary units (curies, millicuries, etc.)

Property	Tradi-tional Units	SI Units
Radioactivity	curie	becquerel
Ionization in Air	roentgen	coulombs /Kg
Radiation Absorbed Dose	rad	gray
Dose Equivalence	rem	sievert

Another property of radiation that needs to be measured is how much ionization it is causing.

- The *roentgen* (R) is a unit that indicates the amount of x or gamma radiation that produces a given amount of ionization in each unit of air, or the intensity of the radiation. The roentgen is the unit of radiation exposure.

- A milliroentgen (mR) is one one-thousandth of a roentgen and is often used to indicate exposure. Frequently it is important to describe a rate of exposure over a period of time. This is indicated by roentgens or milliroentgens per hour.

Since the roentgen applies only to x and gamma radiation exposure in air, a different unit is needed to deal with radiation energy absorbed in materials.

- One unit is the *rad*, which stands for radiation absorbed dose. It describes the amount of any radiation absorption occurring in any material. For example, if a person is exposed to beta and gamma radiations, both may interact with and cause ionization in the body. In this case, the actual dose in rads may be greater than the exposure in roentgens because the beta is taken into consideration. The SI unit of radiation absorbed dose is the *gray* (Gy). 1 Gy =100 rad.

- When the dose is a great deal smaller than one rad, the term millirad (mrad), meaning one one-thousandth of a rad, is used.

Biological effect upon tissue is not the same for all types of radiation. Therefore, a different unit, called the *rem*, is used to account for biological damage or risk.

- The rem is known as a unit of dose equivalence. Rem is an acronym for *roentgen equivalent man*. One rem involves the same risk regardless of the type of radiation, but the dose required to produce one rem may vary depending upon the type of radiation. The SI unit of dose equivalence is the Sievert (Sv). 1 Sv = 100 rem.
    - The unit millirem (mrem or .001 rem) is often used for smaller dose equivalents.

The units just described may be encountered on the scene in many places. Here are a few examples.

- Radiation detection instruments such as survey meters and pocket ionization chambers or dosimeters measuring the amount of radiation ionized in air use the measurements of roentgens (R) and milliroentgens (mR). Other instruments that measure dose equivalents read in rems.

- Radiation packages should be labeled and placarded. You will find the international units of becquerel (Bq), terabecquerel (TBq), or gigabecquerel (GBq) on labels or placards, and you may find the radiation described in the traditional units such as curie or millicurie. The radioactivity level whether displayed in traditional units or international units should correspond between the package labels and the shipping papers necessary in the transport of any radioactive material.

The following question is intended to test your grasp of the concepts and units used to measure properties of radiation.

QUESTION

Circle the correct answer

If you were exposed to a beta-gamma source such as iodine-131 (I-131), which term would be used to describe the radiation energy absorbed by your body?

a. roentgen.
b. rad.

Turn the page to check your answer.

ANSWERS

a. No, roentgen describes only the intensity of gamma radiation in air. In this situation we want to know how much beta and gamma radiation energy was absorbed in the body. This amount is better represented by the rad, which describes the radiation absorbed in the body.

Try the next problem.

b. Good. You realize that the term roentgen only indicates the intensity of the gamma radiation in air, while the term rad refers to the dose received from both types of radiation.

Move on to the next section.

QUESTION

Circle the correct answer.

Which quantity or term accounts for the difference in biological risk resulting from equal doses of different types of radiation?

a. rem.

b. rad.

Turn the page to check your answer.

ANSWERS

a. Good. You know the difference between the rad, which is a unit of dose absorbed in any material, and the rem, which deals with the difference in biological effect upon tissue of different types of radiation.

Proceed to the next section.

b. While the term rad is used to describe radiation energy absorbed by the body, it does not indicate the relative effectiveness of the particular radiation involved. The purpose of using the term rem is to reduce the measurement of effects of all types of radiation to a common scale.

Review this section before continuing.

EXPOSURE AND CONTAMINATION

Alpha, beta, and gamma radiations are emitted from a radioactive source. You do not necessarily have to touch the source to be exposed to its radiation, in much the same way you feel the warmth of the campfire and the aroma from cooking without touching the fire or the food. The reason you do not have to touch a source to be exposed is because the radiations from the source can travel in air.

- Gamma travels a long way, so you do not even have to be close to the source to be affected by it.
- Alpha radiation travels approximately 3 cm in air and beta travels up to 10 meters. You have to be a lot closer to the source to be exposed to those types of radiation. In fact, you would actually have to inhale or ingest some of the radioactive source to be affected by the alpha radiation emitting from it.

When you have radioactive material on or in your body, then you are contaminated.

Exposed only

Contaminated and exposed

- For example, if you moved some damaged boxes of radiopharmaceuticals and one of the small vials broke open, spilling the contents on your hand, your hand would be contaminated. If nothing got on or in your body, and the substance was a gamma emitter, you would be exposed to radiation but not contaminated.
- If you tramped through a patch of spilled radioactive material and got it on your person, you would be contaminated as well as exposed.
- If you inhaled or ingested radioactive particles airborne from a burning source, you would be internally contaminated until the particles are eliminated from the body or lose their radioactivity through decay processes.

The good news is that in most cases of external contamination, the radioactive material can be washed off the body or removed when outer contaminated garments are removed. Internal contamination problems are dealt with by medical professionals.

Test your understanding of these concepts by answering the following question.

QUESTION

Circle the correct answer.

To illustrate that you can apply this concept to your radiological emergency response role, read the following statements and select the one which is accurate.

a. You can be contaminated without being exposed.

b. You can be exposed without being contaminated.

Turn the page to check your answer.

ANSWERS

a. No, that would be a very dangerous premise to live by. If radioactive material is on or in your body or on your clothing, you are being exposed to the radioactive source that is contaminating you. The type and amount of radioactive material will determine how much exposure and effect occurs.

Try another question.

b. Certainly. A radioactive source emits radiation. Depending on the type and intensity of the radiation, you can be exposed to radiation without even being near the source.

Move on to the next section.

QUESTION

Circle the correct answer.

Due to a sudden change in wind direction, you find yourself standing in the middle of a radioactive plume from an accident involving burning radioactive material. You would incur

a. contamination only.

b. contamination and exposure to radiation.

Turn the page to check your answer.

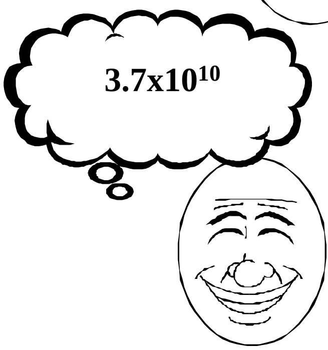
ANSWERS

a. No, if there is radioactive contamination, that means there is radioactive material that is decaying and emitting radiation, from which you could become exposed.

You should go back and review beginning on page 2-30.

b. That's right. The airborne radioactive material that lands on you in the form of ash is a type of contamination. That radioactive material undergoes decay processes and produces the ionizing radiation to which you are being exposed. Inhalation (breathing in) of the radioactive material is more dangerous because the ionizing radiation is on the inside of the body affecting organs and tissue.

Proceed to the next section.



SCIENTIFIC NOTATION

If you are not regularly involved with mathematics, this section is included to briefly explain the type of shorthand used to indicate very large and very small numbers. That shorthand is called *scientific notation.*

Consider two of the numbers mentioned earlier in this unit. An atom has an average diameter of one ten-trillionth of a centimeter. Written in decimal form, that number is 0.0000000000001 cm. The curie equals 37 billion disintegrations per second (dps). In decimal form that is 37,000,000,000 dps.

There is an easier way to write these numbers. When converting numbers to that easier system, the decimal point is the starting point. Most of the zeroes in these long numbers can be eliminated by using "powers" of 10, or exponents, written above and to the right of the number 10.

When a number is smaller than 1, it has integers (digits) to the right of the decimal point and the exponent of 10 has a minus sign. For example, the diameter of the atom may be written as 1×10^{-13} centimeters because there are 13 powers of 10 between 1 and 10 trillion.

When a number is 1 or greater the exponent of 10 has a positive sign, but the + is generally not written. For example, the equivalent of the curie may be written as 3.7×10^{10} dps, which means that you have to multiply 3.7 by 10 ten times to get 37 billion. Or, simply count the number of places you would need to move the decimal point to the left to get to 3.7.

Scientific notation usually operates under the following "rules of thumb." The number by which you multiply the powers of 10 has one integer left of the decimal point and usually is rounded off to 2 numbers to the right of the decimal. For example, 2.34×10^2 rather than 23.4×10^1 or $.23 \times 10^3$. If the number by which you want to multiply the exponent is 1, it is usually written as 10^5 or 10^6 rather than

1.00×10^5 or 1.00×10^6.
Some of the units used to describe radiation characteristics can be translated into scientific notation.

.001	milli	10^{-3}
.000001	micro	10^{-6}
.000000001	nana	10^{-9}
.000000000001	pico	10^{-12}
1,000,000,000,000	tera	10^{12}

Let's see how well you can convert from standard to scientific notation. It will be helpful to you in reading about radioactive material amounts and quantities. Answer the following question.

QUESTION

The curie represents ___ disintegrations per *minute* (37,000,000,000 dps x 60 sec/min = 2,220,000,000,000 dpm).

Circle the correct answer.

a. 2.22×10^{12}

b. 2.22×10^{-12}

Turn the page to check your answer.

ANSWERS

a. Correct. You indicated by the exponent of 12 that the decimal point was moved 12 places to the left in order to leave 1 integer to the left of the decimal point.

Move on to the Summary Questions.

b. No, a negative exponent indicates that the decimal point has been moved to the right and that the number is less than zero. When the decimal point is moved to the left (the number is greater than one) the exponent is positive. In this case the number is much larger than one.

Try another question.

QUESTION

Circle the correct answer.

The approximate diameter of the nucleus of the atom is 0.0000000000001 cm. In scientific notation that can be written

a. 10^{13} cm.

b. 10^{-13} cm.

Turn the page to check your answer.

ANSWERS

a. This time the decimal was moved 13 places to the right because the number is much smaller than one. Instead of .0000000000001, 10^{13} is 10,000,000,000,000.

You should go back and review this section.

b. Right! 10^{-13} indicates that you moved the decimal 13 places to the right.

Proceed to the Summary Questions.

QUESTION

Circle the correct answer.

SUMMARY QUESTIONS

1. A radioactive material that emits beta and gamma radiation has a half life of six hours. Another beta-gamma emitter has a half life of 30 years. If an equal number of curies of each material were involved, which material presents a longer-term problem.

a. The radionuclide with a six hour half-life.

b. The radionuclide with a 30 year half-life.

Turn the page to check your answer.

ANSWERS

a. Incorrect. A short half-lived material is decaying at a more rapid rate than a long half-lived material. The radiation levels may be higher initially, but the material will decay to less than 1% of the original amount in two days.

Move on to the next Summary Question.

b. Correct. It will take 210 years for this material to decay to less than 1% of the original amount.

Go back to page 2-21 and review.

QUESTION

Circle the correct answer.

2. The number 0.00000000000040517 is equal to

a. 4.05×10^{-13}

b. 40.517×10^{14}

Turn the page to check your answer.

ANSWERS

a. Correct.

Move on to the next unit.

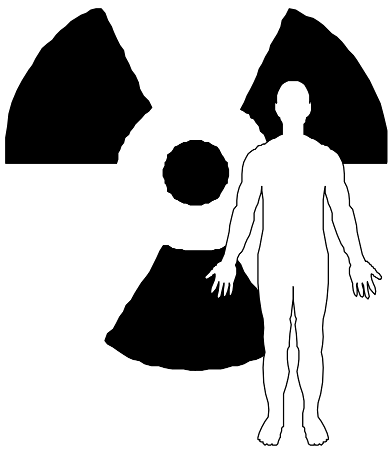
b. Incorrect.

- When moving the decimal to the right, the exponent in scientific notation is always negative.
- The decimal point should be located after the four rather than the zero.
- The integers to the right of the decimal point in scientific notation should be limited to two.

Go back to page 2-34 and review.

UNIT THREE

BIOLOGICAL EFFECTS AND INTERNAL HAZARDS OF RADIATION EXPOSURE



Unit Two reviewed the mechanism by which ionizing radiation may cause biological damage. That mechanism can be summarized by saying that ions created by radiation, as well as new compounds formed by the pairing up of the ions, disrupt cell organization and function. For radiological emergency responders, the potential biological effects of radiation exposure are important considerations.

You have studied biological effects and internal hazards of radiation in other courses. This unit will incorporate a review of some important basic concepts and introduce a few new terms and details that will better prepare you for radiological emergency response operations.

GATE FRAME QUESTION

You have responded to an accident involving a truck containing radionuclides destined for a research facility. The Incident Commander tells you that a package found on the ground indicates that it contains 0.2 Ci of iodine-131 (I-131). I-131 is a beta emitter, with a radioactive half-life of 8 days.

What potential biological effects are associated with radiation exposure to this type of material, and what factors determine the extent of potential biological damage by this material? (Use another sheet if needed.)

ANSWER

Your answer should include the adjacent information.

The radiation health effects from beta-emitting radionuclides such as I-131 may be early (acute) or late (chronic). Early affects, which occur within two or three months after exposure, include skin damage (such as "beta burns"), loss of appetite, nausea, fatigue, and diarrhea. Late effects, which can occur years after exposure, include cancer, cataracts, and genetic effects.

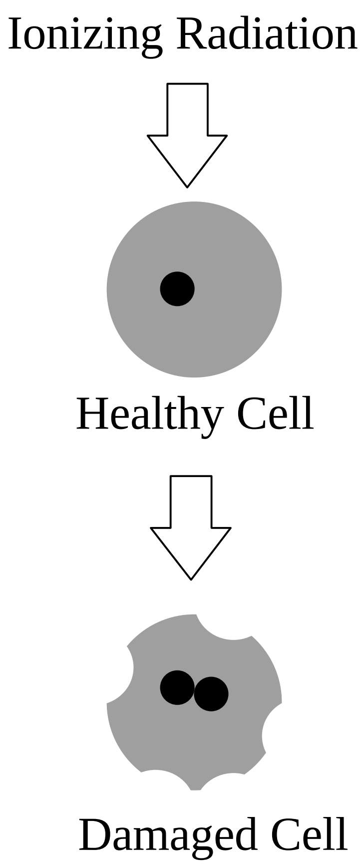
While I-131 is highly radioactive, the amount contained in the intact package would not elicit early effects unless it was ingested. If the package of I-131 were broken, exposure to 0.2 Ci could lead to late effects on health.

The factors that determine the level of biological damage include the following:

- Amount of exposure (measured in rads or rems);
- Duration of exposure (or how long it takes to receive the dose);
- Type of radiation (in this case, beta);
- Exposed person's age, sex, general health, rate of metabolism, size, and weight (collectively referred to as the biological variability factors); and
- Portion of the body exposed (the volume and type of tissue irradiated will influence the response).

If your answer included all or most of the above points, you should be ready for the Summary Questions at the end of this unit. *Turn to page 3-40.*

If your answer did not include these points, it would be advisable for you to complete the programmed instruction for this unit. *Turn to page 3-3.*



RADIATION DAMAGE

Radiation damage affects the vital structure of cells. The effects on these cell structures lead to a wide variety of changes within the cell, which can result in death of the cell or the entire organ, and changes in the genetic makeup of an individual that can lead to delayed effects. These effects cannot be distinguished from damage caused by various chemicals and viruses.

There are two general mechanisms of radiation damage in biological systems: direct action and indirect action mechanisms.

The *direct action mechanism* occurs because of direct insult to a molecule by the ionizing radiation and the consequent breakup of the molecule. In this way, radiation can damage cells by changing the structure of various organic molecules such as enzymes, DNA, and RNA. For example, the molecular structure of enzyme X, which is essential to the formation of energy used by the cell, is changed by radiation. Consequently, energy for the cell can no longer be produced and cell metabolism is disrupted. This disruption causes the cell to die.

The *indirect action mechanism* occurs when water in the body is irradiated. The water molecule is split. The resulting *free radicals* can then damage the cell. A free radical is an atom or molecule that has a single unpaired electron in one orbit (as compared to most electron orbits, which have pairs of electrons). The splitting of water occurs when radiation strikes a water molecule.

The following general formulas outline the processes involved in the breaking down of water. H^o symbolizes the hydrogen radical. OH^o symbolizes the hydroxyl radical.

Radiation

$\downarrow$

$H_2O \rightarrow H^o + OH^o$	Free Radicals
$H^o + H^o \rightarrow H_2$	Hydrogen Gas
$H^o + OH^o \rightarrow H_2O$	Water
$OH^o + OH^o \rightarrow H_2O_2$	Hydrogen Peroxide (poison)
$H^o + O_2 \rightarrow HO_2^o$	Peroxyl Radical

Free radicals, hydrogen peroxide, and the peroxyl radical are extremely harmful to a living cell. The formation of the highly poisonous hydrogen peroxide from recombined free radicals is referred to as the "Poison Water Theory."

To test whether you can distinguish between the direct and indirect mechanisms of radiation damage, answer the following question.

QUESTION

Circle the correct answer.

When radiation damages cells by changing the structure of various organic molecules such as enzymes, DNA, and RNA, which mechanism occurs?

a. direct action mechanism.

b. indirect action mechanism.

Turn the page to check your answer.

ANSWERS

a. Correct. Recall that the direct action mechanism occurs because of direct insult to a molecule by ionizing radiation. This may cause harmful effects within the cell because the radiation changes the structure of the molecule, which in turn changes its function.

Proceed to the next section.

b. Wrong answer. As its name implies, the indirect action mechanism affects cells indirectly by eliciting a series of events (or processes) that lead to the formation of highly reactive molecules and ions that are poisonous to the cell.

Try another question.

QUESTION

Circle the correct answer.

In the "Poison Water Theory," the extremely harmful hydrogen peroxide is formed from the free radicals generated after water is hit by radiation. These free radicals, along with hydrogen peroxide and peroxyl radicals, damage cells via the

a. direct action mechanism.

b. indirect action mechanism.

Turn the page to check your answer.

ANSWERS

a. No, in the given example, radiation harms cells indirectly by breaking up water molecules into extremely harmful molecules and atoms. In contrast, the direct action mechanism occurs because of a *direct* insult to a molecule by the ionizing radiation.

Return to page 3-3 and review this section.

b. Exactly. You were able to recognize the culprits of radiation damage (free radicals, hydrogen peroxide, and peroxyl radicals), as well as the mechanism by which this damage occurs. In the indirect action mechanism, the radiation itself does not damage the cells; it instead causes the formation of highly reactive molecules and ions that are very harmful to the cell.

Move on to the next section.

RADIATION EFFECTS

Radiation effects are generally classified as *early* (or *acute*) and *late* (or *chronic*). The terms early and late refer to the length of the latent period after the exposure. The *latent period* is the time interval between dose and detection of symptoms.

Type of Effect	**Manifested**
Early (Acute)	2-3 Months
Late (Chronic)	Up to years after exposure

Early (acute) radiation health effects are those clinically observable effects on health that are manifested within two or three months after exposure. Their severity depends on the amount of radiation dose that is received. Examples of acute radiation effects include skin damage, loss of appetite, nausea, fatigue, and diarrhea. Late effects can occur years after exposure; examples are cancer, leukemia, cataracts, and genetic effects.

Radiation damage can be repaired if the dose received is not too high and if the dose is received over a long period of time. The time period after the appearance of symptoms and during which repair occurs is called the *recovery period*.

To check your understanding of these concepts, answer the following question.

QUESTION

Circle the correct answer.

In the 1950s, people accidentally contaminated by radioactive fallout from nuclear weapons testing developed beta burns and hair loss. The victims recovered from these effects within approximately six months.

These radiation effects would be classified as

a. early (acute) effects.

b. late (chronic) effects.

Turn the page to check your answer.

ANSWERS

a. Right! You seem to grasp the difference between early and late radiation effects. "Beta burns" occur within hours to days after exposure, and this constitutes an acute radiation effect. However, if years after exposure this individual develops cataracts, it is a *possibility* that the beta exposure is the cause, in which case the effect would be considered a late effect.

Move on to the next section.

b. No, "beta burns" occur within hours to days after exposure. Late, or chronic, effects do not appear until years after radiation exposure. For example, late effects such as cancer and leukemia develop many years after the individual's exposure to radiation.

Try another question.

QUESTION

Circle the correct answer.

The latent period for acute effects is _________ than that for chronic effects.

a. shorter.

b. longer.

Turn the page to check your answer.

ANSWERS

a. Very good. You remembered that the terms "early" and "late" refer to the length of the latent period after radiation exposure. Since early (acute) effects occur within two or three months after exposure, the latent period also would be within that time period. On the other hand, late (chronic) effects occur years after exposure, therefore the latent period may be many years.

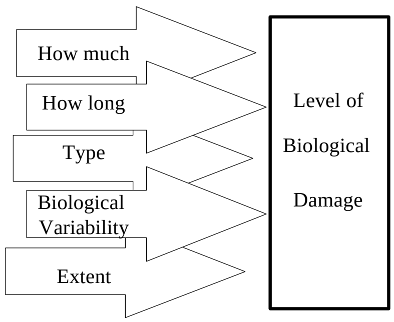
Proceed to the next section.

b. Incorrect. There are actually three concepts presented in this question, and it requires knowledge about all of them to get the answer right. First, the latent period is defined as the period of time when no symptoms or effects are manifested after radiation exposure. Second, you need to know that the terms used to define radiation effects—"early" and "late"—refer to the length of the latent period after radiation exposure. Finally, you should know that early (acute) effects occur within a few months after exposure, so the latent period would be of similar duration. Late (chronic) effects occur years after exposure, so the latent period would also be long.

Return to page 3-7 and review this section.

FACTORS AFFECTING RADIATION DAMAGE

The following factors determine the level of biological damage.



- *Amount of exposure* (or size of the dose received).
- *Duration of exposure* (or how long it takes to receive the dose). This significantly affects the biological result since the body can repair most of the damage (even throughout the duration of exposure).
- *Type of radiation*. Is it gamma, beta, or alpha?
- *Biological variability factors*. These include the exposed person's age, gender, general health, rate of metabolism, size, and weight.
- *Portion of the body exposed*. The extent (volume) of tissue irradiated will influence the response. Most risk estimates, unless otherwise specified, are based on *whole body* exposures or doses. Different tissues have varying sensitivities to radiation.

The following question is intended to test your understanding of these concepts.

QUESTION

Circle the correct answer.

Of the five factors that influence radiation damage, the one that takes into account the varying sensitivities of different organs or tissues to radiation is

a. the general health of the individual.

b. the portion of the body receiving the dose.

Turn the page to check your answer.

ANSWERS

a. No, the general health of the individual is a biological variability factor and does not determine how much or which tissue is damaged by radiation. The portion of the body exposed, however, does influence the level of biological damage. Some tissues or organs are more sensitive to radiation than others.

Try another question.

b. Correct answer! Since different organs or tissues respond to radiation differently, the portion of the body exposed to radiation greatly influences the extent of radiation-induced biological damage.

Move on to the next section.

QUESTION

Circle the correct answer.

If you were conducting an assessment of the potential for radiation-induced biological effects of a radiation accident, which of the following could be determined with radiation detection instruments?

a. biological variability factors.

b. type of radiation.

Turn the page to check your answer.

ANSWERS

a. No, biological variability factors include the exposed individual's age, sex, general health, rate of metabolism, size, and weight. These factors are not measurable using radiation detection instruments. The type of radiation, on the other hand, can be measured using appropriate radiation detection methods.

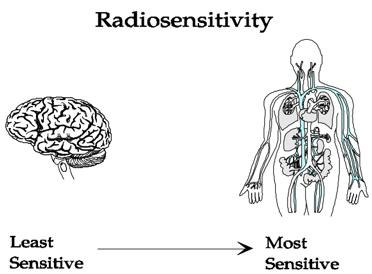
You should return to page 3-10 and reread that section.

b. That is correct. Special radiation detection methods can determine whether gamma, beta, or alpha radiation is present. This type of information, along with the other factors discussed in this section, is useful in determining the extent of biological damage due to radiation.

Proceed to the next section.

RADIOSENSITIVITY

The sensitivity of various cell types can differ markedly, and many organs in the human body have different cell types. In the mature adult, some organs consist of cells that are designed to perform a special function, but essentially no cell division takes place.



- For example, the brain which contains a vast number of special functioning cells, is less radiosensitive than other organs. However, if the brain or any other part of the central nervous system is damaged during adult life, no repair can take place because there are no dividing cells.

Many other tissues, even in the mature adult, contain dividing cells because they have to be replaced continually throughout life.

- For example, the skin, the lining of the stomach and intestines, and the blood system are subject to so much wear and tear that they must be replaced continually by cell division.

Between these extremes lie the vast majority of the tissues of the body, in which cells seldom divide under normal circumstances, but are able to do so if and when the need arises in order to repair damage.

- For example, in the liver there is essentially no cell division under ordinary circumstances. However, if part of the liver is removed by surgery, the remaining cells are triggered into rapid division to make up the loss.

In 1906, Bergonié and Tribondeau examined the cells that were sensitive to radiation. The Bergonié and Tribondeau Law states that cells are radiosensitive if they have a high division rate, have a long dividing future, and are of an unspecialized type.

The *most* radiosensitive cells in humans are mature lymphocytes (white blood cells), erythroblasts (premature red blood cells), and spermatogonia cells (premature sperm cells).

The *least* radiosensitive cells are muscle cells, bone cells, and nerve cells. Both muscle and nerve cells are highly specialized (that is, designed to perform a special function), and when mature are incapable of cell division.

Let's pause now and apply this concept. Answer the following question.

QUESTION

Circle the correct answer.

Given the same amount, duration, and type of radiation exposure, every tissue in the body will be affected to the same degree.

a. true.

b. false.

Turn the page to check your answer.

ANSWERS

a. Wrong answer. The sensitivity of various cell types can differ markedly, and many organs in the human body have different cell types. So, each cell type and each organ within the body will respond differently to radiation, depending upon whether it is has a high cell division rate, a long dividing future, and is of an unspecialized type (Bergonié and Tribondeau Law).

Try another question.

b. You are correct, this statement is false because sensitivity to radiation of various cell types can differ drastically. In fact, there are some organs in the body that consist of different cell types with differing degrees of radiosensitivity. The biological response to radiation even by one organ can be very complex.

Move on to the next section.

QUESTION

Circle the correct answer.

Muscle cells, which are highly specialized and incapable of cell division, are ________ sensitive to radiation than are lymphocytes (white blood cells), which are unspecialized and capable of cell division.

a. more.

b. less.

Turn the page to check your answer.

ANSWERS

a. No, recall that the Bergonié and Tribondeau Law states that cells that are of an unspecialized type and capable of cell division are more sensitive to radiation (are more radiosensitive) than are cells that perform a special function and are incapable of cell division. Muscle cells are highly specialized and do not divide (reproduce), whereas lymphocytes are replaced continually by cell division and are unspecialized.

Return to page 3-13 and review this section.

b. Correct answer. You clearly understand that cells that perform a special function and are incapable of cell division are less sensitive to radiation (less radiosensitive) than are cells that are of an unspecialized type and capable of cell division.

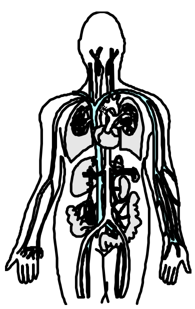
Proceed to the next section.

ACUTE RADIATION SYNDROME

The *acute radiation syndrome* is a set of symptoms that result from short-term radiation overexposures. Symptoms become more severe as radiation doses to the body increase. This syndrome has several forms but all manifest themselves within the first 30 days following exposure and are related to the magnitude of the absorbed dose.

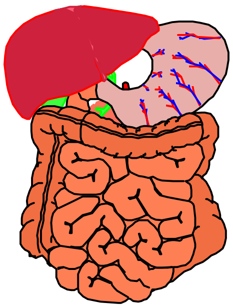
The acute radiation syndrome is divided into three classes: the *hemopoietic syndrome*, the *gastrointestinal syndrome*, and the *central nervous system syndrome*. Some symptoms are common to all three classes; these include nausea and vomiting, malaise (a feeling of lack of health) and fatigue, increased body temperature, and blood chemistry changes. As mentioned earlier, manifestation of illness is a function of dose. No noticeable physical effects result from doses of less than 100 rem. However, some changes in the blood are observable through laboratory testing at about 25 rem.

HEMOPOIETIC SYNDROME



At 100-1,000 rem, the *hemopoietic syndrome* occurs. Symptoms are most usually seen after exposures of 200 rem or more. The degree of severity depends on the dose. Physiological symptoms are destruction or depression of bone marrow, which produces the red blood cells that carry oxygen to every cell in the body and carry away the waste material of the cells. The bone marrow also produces platelets, which contain the blood-clotting factors. Physical symptoms of this syndrome include nausea and vomiting within hours, malaise and fatigue, epilation (hair loss) between the second and third week after exposure, and death, which may occur within one to two months.

GASTROINTESTINAL SYNDROME



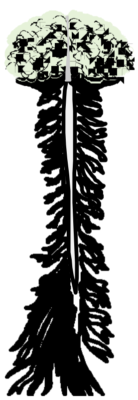
At 1,000 - 2,000 rem, the *gastrointestinal syndrome* occurs. Initial symptoms are they same as the hemopioetic syndrome. Usually severe nausea, vomiting and diarrhea occur within hours. Death usually occurs within one to two weeks.

Physical symptoms are destruction of the lining of the intestines and internal bleeding.

CENTRAL NERVOUS SYSTEM SYNDROME

Above 2,000 rem, *central nervous system syndrome* occurs. Damage to the nervous system occurs in addition to symptoms of the hemopoietic and gastrointestinal syndromes. Unconsciousness occurs within minutes. Death occurs within hours to days.

As a radiological emergency responder, it is important that you understand the different phases of the acute radiation syndrome. Answer the following question to test your knowledge.



QUESTION

Circle the correct answer.

Physiological symptoms of the acute radiation syndrome become

a. more severe as radiation doses to the body increase.

b. less severe as radiation doses to the body increase.

Turn the page to check your answer.

ANSWERS

a. Yes, you understand that the manifestation of illness in the acute radiation syndrome is a function of dose. This syndrome can be described by three separate syndromes: hemopoietic, gastrointestinal, and central nervous system; each occurring at different and increasing levels of radiation exposure.

Proceed to the next section.

b. No, as radiation doses to the body increase, physiological symptoms become *more* severe. Manifestation of illness is a function of dose; as the radiation dose (or the rem) increases, the radiation-induced health effects and symptoms become more life-threatening. Recall that the acute radiation syndrome is divided into three classes: the hemopoietic syndrome, the gastrointestinal syndrome, and the central nervous system syndrome.

Try another question.

QUESTION

At 1 to 99 rem of radiation exposure, which syndrome occurs first?

Circle the correct answer.

a. The hemopoietic syndrome.

b. No noticeable effects result

Turn the page to check your answer.

ANSWERS

a. Incorrect. The hemopoietic syndrome occurs at higher rem levels (100-1,000 rem).

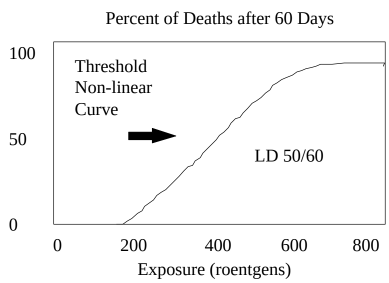
You should return to page 3-17 and reread that section.

b. Correct. At these radiation doses, no physical effect is detected. The majority of field radiological incident responses will involve doses that fall into this lower range. The EPA recommended dose limit for emergency workers is 25 rem.

Proceed to the next section.

$LD_{50/60}$

The whole body dose is the dose resulting from uniform exposure of the entire body to either internal or external sources of radiation. The whole body absorbed dose required to cause death is characterized generally by a median lethal dose (LD_{50}). LD_{50} refers to a dose required to kill 50 percent of the persons irradiated, and it assumes no medical intervention.



It is usually necessary to establish a *rate* with regard to the mortality, which typically is referred to as the $LD_{50/60}$. These are doses that might be expected to result in death in half of the individuals within 60 days.

For humans, the $LD_{50/60}$ from radiation is about 300 rad. This does not account for people who die after 60 days. (Source: EPA 400-R-92-001, May 1992)

Let's pause now and review this concept. Read the following statement and determine whether it is true or false.

QUESTION

The median dose for lethality (LD_{50}) is the radiation dose required to kill a person in 50 days.

Circle the correct answer.

a. true.

b. false.

Turn the page to check your answer.

ANSWERS

a. Incorrect answer. The number "50" refers to the percent mortality, or the percentage of people who die from the LD_{50} dose. Recall that the term LD_{50} refers to the dose required to kill *50 percent* of the persons irradiated, assuming no medical intervention. Another example would be the LD_{25}, which would be the radiation dose that would kill 25 percent of the individuals irradiated, assuming no medical intervention.

Try another question.

b. Correct answer. LD_{50} refers to a dose required to kill 50 percent of the persons irradiated, and it assumes no medical intervention. The number "50" in the median lethal dose refers to the percent mortality, or the percentage of people who die from the LD_{50} dose.

Move to the next section.

QUESTION

The $LD_{50/60}$ is the radiation dose that would cause

Circle the correct answer.

a. 60 percent mortality in 50 days.

b. 50 percent mortality in 60 days.

Turn the page to check your answer.

ANSWERS

a. Wrong answer. In the term $LD_{50/60}$, the number "50" refers to the percentage of irradiated persons who die from the dose. The number "60" is the length of time (in days) it would take for those deaths to occur.

Return to page 3-21 and review this section.

b. Correct! You understand the meaning of the two numbers describing the median lethal dose.

Move on to the next section.

LONG-TERM EFFECTS OF RADIATION EXPOSURE

The effects of radiation on human beings may be expressed in different ways, depending upon the size of the dose. They may be categorized as somatic effects, stochastic effects, nonstochastic effects, carcinogenic effects, lifespan-shortening effects, embryologic effects, and genetic effects.

SOMATIC EFFECTS

Somatic effects occur in the body of the individual who has been exposed to ionizing radiation. They cannot be passed to future generations. The term “somatic” pertains to the body. Somatic effects may be either stochastic or nonstochastic.

STOCHASTIC EFFECTS

Stochastic effects occur by chance and among unexposed as well as exposed individuals. These effects are not unequivocally related to exposure. The typical stochastic effect is cancer induction.

NONSTOCHASTIC EFFECTS

Nonstochastic effects are those associated with cellular and functional abnormalities in certain tissues (such as radiation-induced skin ulcer). In contrast to stochastic effects, the magnitude of the nonstochastic effect increases with the size of the dose. There is a clear causal effect between exposure and effect. However, a certain minimum dose must be exceeded before the particular effect is observed.

CARCINOGENIC EFFECTS

Carcinogenic effects, or cancers, are produced when a cell goes berserk, ceasing to obey the controls of the body so that it divides again and again with no regard for the well being of the body as a whole, and forms a single large mass or series of masses. The initial event that causes the cell to behave in this way is probably a change in its genetic apparatus. Mutations in a cell affect only the individual concerned, and cannot be passed on to future generations.

LIFESPAN-SHORTENING EFFECTS

Radiation-related mortality increases from diseases other than cancer. A study between 1928 and 1950 of radiologists versus other medical professionals showed a definite pattern of shorter lifespans in the radiologists. In addition, animal experiments show evidence of premature aging after radiation exposure. It has been estimated that the total expected life span of the individual is shortened by one day for each rem whole body dose received.

EMBRYOLOGICAL EFFECTS

Every effort should be made to avoid exposure of the developing embryo or fetus to radiation. *Embryological effects* are somatic effects on the fetus. They may be especially severe due to the fast-growing nature of the fetus.

Some information on human embryological effect is available from a study of the pregnant Japanese women who were exposed to the enormous doses of radiation when the atomic bombs were dropped on Hiroshima and Nagasaki. As a result of the radiation many of these women had miscarriages. The women who did not miscarry delivered fetuses that showed stunting in size, microencephaly (small head size), and increased incidence of mental retardation.

There also are embryologic risks involved with the very small doses from diagnostic x-rays. However, information from the studies of large doses tells us little about the risks involved with diagnostic x-rays or other even smaller amounts. The only completely satisfactory solution is to make sure than no irradiation of a pregnant woman's abdomen or pelvis occurs

GENETIC EFFECTS

Genetic effects are those that can be passed to future generations. Genetic mutations do occur naturally, but radiation exposure may increase the *number* of mutations observed. The only large group of humans available for study are again the Japanese exposed at Nagasaki and Hiroshima. However, the number of people exposed was small by genetic standards and several generations must elapse before recessive mutations can be expressed. Experiments intended to produce information or genetic effects have been conducted on animals. In the absence of solid data from humans, the best that can be done is to assume that animal results apply to man. Examples of mutations include anemia, asthma, diabetes, and mongolism. It has been estimated that exposing each member of a population to 1 rem dose will result in 20 to 90 additional genetic disorders per million live births, and 250 to 800 additional genetic disorders across all subsequent generations.

Answer the following questions to review the information presented in this section

QUESTION

Circle the correct answer

Which of the following long-term radiation health effects affect only the individual concerned and cannot be passed on to future generations?

a. carcinogenic effects.

b. genetic effects.

Turn the page to check your answer.

ANSWERS

a. Yes, carcinogenic effects, or cancer, occur only in the exposed individual and are not hereditary. Radiation-induced genetic effects, on the other hand, can be passed on to subsequent generations.

Move on to the next section.

b. No, genetic effects are exactly as the term implies—genetic. These effects, which include diabetes, mongolism, and anemia, can be passed on to future generations. Radiation-induced carcinogenic effects cannot be passed on to subsequent generations.

Review another aspect of long-term radiation exposure by answering another question.

QUESTION

An adult receives a high radiation exposure and suffers from temporary hair loss and develops cancer 20 years later. This person suffers from

Circle the correct answer.

a. somatic radiation health effects.

b. embryologic radiation health effects.

Turn the page to check your answer.

ANSWERS

a. Yes, you understand the meaning of somatic effects. Somatic effects occur in the body of the individual who has been exposed to ionizing radiation. These effects cannot be passed to future generations. Temporary hair loss certainly fits into these descriptions. Cancer also is a somatic effect that is stochastic in nature.

Proceed to the next section.

b. No. First of all, the situation described is about an adult, and not an embryo or fetus. Embryologic effects are manifested in the developing embryo or fetus that has been exposed to radiation. Radiation-induced embryologic effects include stunting in size, microencephaly, and mental retardation.

You should go back to page 3-24 and reread that section.

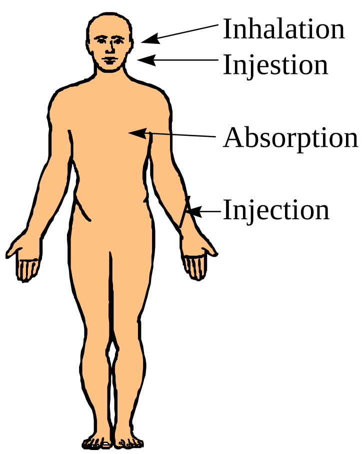
DEPOSITION OF RADIOACTIVE MATERIAL INTO THE BODY

There are four major pathways of deposition of radioactive material into the body.

If an individual is immersed in a radioactive release (such as smoke from a truck fire involving radioactive material), then there is a chance that person will *inhale* some of that radioactive material.

If individuals working, or in contact, with a radioactive substance contaminates their hands and then proceeds to eat without decontaminating, it is likely that they will *ingest* some radioactive material.

There are some radionuclides that can be *absorbed* directly into the body through the skin. For example, tritium (hydrogen-3), as a water vapor, is used frequently in research and can be absorbed by the skin.



The last mode of entry into the body is through breaks in the skin, as might be the case in an accident involving injuries and radioactive material, or intentional *injection* of radioactive material for medical purposes.

Inhalation and ingestion (both of which are also called "in-take") are the most common pathways of radioactive material into the body. Inhalation of radioactive material can be omitted as a common pathway into the body by donning respiratory equipment. You should, however, be trained and personally fitted for your choice of self-contained breathing apparatus (SCBA).

Ingestion can be omitted as a common pathway by use of decontamination and the prohibition of eating or drinking in radiation areas.

QUESTION

Circle the correct answer.

A truck carrying "yellow cake" (uranium-238) in 55-gallon drums has jackknifed on a rural highway. Several of the drums have been crushed and broken open, and the wind is blowing powder over a wide area. Which pathway of deposition of the radioactive powder into the body is most likely to occur?

a. absorption.

b. inhalation.

Turn the page to check your answer.

ANSWERS

a. Incorrect answer. The radioactive powder cannot be absorbed through the skin. Of the four deposition pathways, inhalation and ingestion are the most probable ways that the uranium-238 will enter the exposed individual's body.

Try another question.

b. Correct answer. Individuals exposed to the "yellow cake" powder will most likely inhale, or even ingest, the material. It is unlikely that this radioactive powder will be absorbed through the skin.

Move on to the next section

QUESTION

Circle the correct answer.

Of the four deposition pathways, which two are the most common routes that radioactive material enters the body?

a. absorption and injection.

b. inhalation and ingestion.

Turn the page to check your answer.

ANSWERS

a. Wrong answer. Not many radionuclides can be absorbed directly into the body through the skin. Entry of radioactive substances through breaks in the skin, via wounds or injection, is also not the most common deposition pathway. Inhalation and ingestion (also collectively called “intake”) are the most common pathways of deposition of radioactive material into the body.

Return to page 3-29 and review this section.

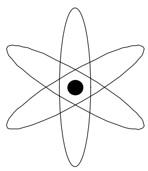
b. Correct! Most incidents involving exposure to radioactive materials (such as via radioactive plumes or spillage) lead to contamination and/or exposure of individuals via inhalation and ingestion. While absorption and injection (or entry through wounds) of radioactive material do occur, they are not as common as the other two pathways.

Proceed to the next section.

DISTRIBUTION OF RADIOACTIVE MATERIAL IN THE BODY

The distribution of radioactive material in the exposed individual depends on the nuclear, physical, and chemical properties of the material.

NUCLEAR PROPERTIES

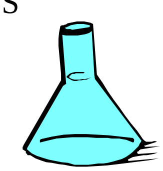


Nuclear properties of radioactive atoms depend on the condition of the nucleus, which can be described by factors such as radioactive half-life, atomic mass (total number of protons and neutrons), and atomic number (number of protons). Radioactive and nonradioactive material are treated the same after internal deposition because the body cannot discern the differences in their nuclear properties.

PHYSICAL PROPERTIES

Physical properties of radioisotopes, including factors such as size and solubility, will determine how the radioactive material will be distributed in the body. For example, how easily does the radionuclide dissolve in the blood? The physical state of the radioactive material also determines the way the material is distributed in the body. For example, is the material a particle or a gas, or a combination of both?

CHEMICAL PROPERTIES



Chemical, or biological, properties of radioactive material determine where in the body the material will most likely concentrate after deposition. The chemical structure of the radionuclide, for instance, determines if it will react specifically with certain molecules within the body. For example, radioactive iodine will concentrate in the thyroid, radioactive lead will build up in the kidney, radioactive strontium will deposit mainly in the bones, and radioactive cesium can spread throughout the whole body.

As a radiological emergency responder, it is important that you understand the factors affecting the distribution of radioactive material in the body.

Test your knowledge by answering the question on the next page.

QUESTION

The body does not differentiate between which properties?

Circle the correct answer.

a. nuclear.

b. physical.

Turn the page to check your answer.

ANSWERS

a. Correct answer. The body cannot distinguish nuclear properties of molecules, and therefore cannot tell whether a substance is radioactive or not.

Move on to the next section.

b. Incorrect answer. Physical properties of radionuclides, such as size and solubility, determine how the material interacts with the body. In other words, radionuclides may be distributed differently throughout the body and may interact with different cells of the body. Nuclear properties, however, do not determine the fate of the nuclide in the body, so both radioactive and non-radioactive substances are treated the same.

Try another question.

QUESTION

Circle the correct answer.

Radioactive iodine will concentrate in the thyroid because of its _________ properties.

a. chemical.

b. nuclear.

Turn the page to check your answer.

ANSWERS

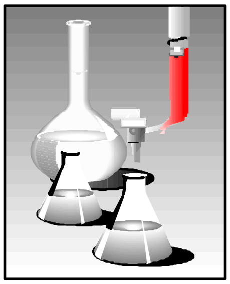
a. Correct answer. Chemical, or biological, properties of radioactive material determine where in the body the material will most likely concentrate after deposition. The chemical structure of the iodine allows it to react specifically with certain molecules of the thyroid. Similarly, radioactive lead will tend to build up in the kidney, but not in the thyroid, because the lead molecule has a greater affinity for certain molecules in the kidney than in the thyroid.

Proceed to the next section.

b. Incorrect answer. Nuclear properties determine whether the nuclide is radioactive or not; the body cannot "recognize" nuclear properties of an atom. So, the fact that radioactive iodine tends to concentrate in the thyroid has nothing to do with the nuclear properties of iodine. Both radioactive and nonradioactive iodine will tend to reside in the thyroid.

Return to page 3-33 and review this section.

DETECTION, MEASUREMENT, AND EVALUATION OF RADIOACTIVE MATERIAL INSIDE THE BODY



After an individual has been exposed to internal contamination it is important to detect, measure, and evaluate the amount of radioactive material that has actually been deposited into the body. Both biological assays and whole body counting are available to perform these tasks.

Biological assays (or bioassays) determine the kind, quantity or concentration, and location of radioactive material in the human body. "Indirect" bioassays may be performed using urine samples (urinalysis), fecal samples, and blood samples. The radioactivity is measured in these samples using special radiation detection instruments, and the results are used to predict the amount of radioactive material deposited in the entire body.

Whole body counting, which is considered a "direct" bioassay, is also used to detect, identify, measure, and locate gamma-emitting radioactive material in the body. A whole-body counting device is used to identify and measure radionuclides in the body of humans (and animals for research purposes). It uses heavy shielding (to keep out background radiation), ultrasensitive gamma radiation detectors, and electronic equipment that will read, evaluate, and store the data generated during a whole body count.

Try the next question to test your knowledge of these concepts.

QUESTION

Circle the correct answer.

Urinalysis is considered a(n) ________ bioassay.

a. direct.

b. indirect.

Turn the page to check your answer.

ANSWERS

a. Incorrect answer. Urinalysis entails measuring the radioactivity in a sample of urine and extrapolating the results to get the whole body exposure. This type of bioassay is considered indirect. A direct bioassay is whole body counting, which does not require sampling of urine, fecal matter, or blood and subsequent extrapolation of the results.

Try another problem.

b. Correct answer. Since urinalysis involves taking a sample of urine, measuring the radioactivity in that sample, and extrapolating the results to determine the whole body exposure, this bioassay would be considered as indirect. Whole body counting, on the other hand, does not require sampling and extrapolation of the results, and is therefore considered as a direct bioassay.

Move on to the Summary Questions.

QUESTION

Circle the correct answer.

Whole body counting measures only the concentration of gamma-emitting radioactive material located in the bone marrow.

a. true.

b. false.

Turn the page to check your answer.

ANSWERS

a. Wrong answer. As its name implies, whole body counting is used to detect, identify, measure, and locate gamma-emitting radioactive material in the entire body. Now, it may be that the radioactive material has concentrated in the bones (such as with strontium), but whole body counting has the capability of measuring radioactivity emanating from all parts of the body.

Return to page 3-37 and review this section.

b. Correct! You understand that whole body counting can detect, identify, measure, and locate gamma-emitting radioactive material in the entire body, and not just in the bones.

Proceed to the Summary Questions.

SUMMARY QUESTIONS

QUESTION

Circle the correct answer.

1. Somatic radiation effects may be either stochastic or nonstochastic. In contrast to nonstochastic effects, stochastic effects

   a. occur by chance and among unexposed as well as exposed individuals.

   b. become more severe as the level of the radiation dose increases.

Turn the page to check your answer.

ANSWERS

a. Very good. You answered this correctly. Stochastic effects occur by chance, occur among unexposed and exposed persons, and are not unequivocally related to exposure. Cancer is a typical stochastic effect.

Move on to the next Summary Question.

b. No, you have the terms stochastic and nonstochastic mixed up.

Stochastic effects occur by chance and among un-exposed as well as exposed individuals. These effects are not related to exposure. In contrast to stochastic effects, the magnitude of the nonstochastic effect increases with the increasing levels of radiation dose. Moreover, there is a causal relationship between exposure and effect.

You should go back to page 3-24 and reread that section.

QUESTION

Circle the correct answer.

2. A serious truck accident has caused a large shipment of Low Specific Activity (LSA) class material to be engulfed in flames. A “radioactive” plume has formed and is beginning to disperse toward a housing development. Which pathway of deposition into the exposed individuals would *most likely* occur?

   a. absorption.

   b. inhalation.

Turn the page to check your answer.

ANSWERS

a. No, it is likely that the radioactive material in this plume would be particulate in nature and unlikely to be absorbed into the body through the skin.

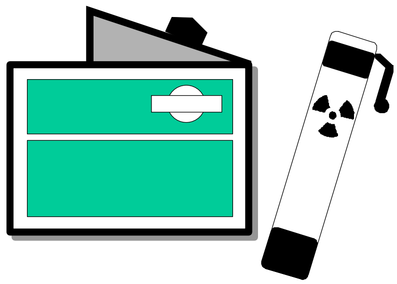
Go back and review page 3-29 before moving on to Unit Four.

b. That is correct. Airborne radioactive material may be inhaled into the body by people in the open when the plume passes.

Continue with Unit Four.

UNIT FOUR

EXTERNAL DOSIMETRY



Unit Three reviewed the biological effects and internal hazards of radiation exposure. You learned about the early and late effects of radiation exposure, the factors affecting radiation damage, the concept of radio-sensitivity, and the pathways of deposition and distribution of radioactive material in the body. Now that you have reviewed the mechanisms of radiation damage and the biological effects of that damage, it is an appropriate time to cover the selection of external dosimetry methods for detecting radiation in emergency response situations.

The radiological emergency responder must monitor his/her total exposure to radiation during the operation. This unit will review the fundamental construction and operation of three commonly used methods of external dosimetry: pocket ionization chambers, film dosimeters, and thermoluminescent dosimeters. The advantages and disadvantages of each dosimeter type will also be covered briefly.

GATE FRAME QUESTION

You have responded to an accident involving a truck containing radiopharmaceuticals packages. The Incident Commander tells you that a package found on the ground indicates that it contains 0.2 Ci of cesium-137 (Cs-137). Cs-137 is a beta and gamma emmitter, with a radioactive half-life of 30 years.

What type(s) of radiation dosimetry device should you be using to monitor your radiation exposure at the site?

ANSWER

Your answer should include the adjacent information.

The pocket ionization chamber, film dosimeter (or film badge) and thermoluminescent dosimeter (TLD) would all be appropriate in this situation. Cs-137 is a beta and gamma emitter, and all three of those methods are capable of measuring gamma radiation exposure. The film dosimeter and TLD could also detect beta radiation.

To determine (i.e. read) the total gamma exposure while at the site, the direct reading pocket ionization should be used. None of these dosimeters will effectively detect exposure from inhaled radioactive material.

If your answer included all or most of the above points, you should be ready for the Summary Questions at the end of this unit. *Turn to page 4-18.*

If your answer did not include these points, it would be advisable for you to complete the instruction for this unit. *Turn to page 4-3.*

RADIATION EXPOSURE RECORD

NAME____
ADDRESS_____________________________________
CITY/STATE/ZIP______________________________

Social Security Number__________Dosimeter Serial No.________

Date	Initial Reading	Final Reading	Dose

Date______________ Total Exposure__________________
Signature ____________________________________

INTRODUCTION TO DOSIMETRY

Dosimetry is the monitoring of individuals to accurately determine their radiation dose equivalent. When radiation interacts with the human body, there are no perceptible sensations and usually no immediate effects. We could therefore receive an amount of radiation that could injure our tissues severely without realizing it at the time. To protect ourselves and others, we must use and rely upon instruments to quantify and qualify radiation measurements.

Radiological emergency responders must be able to keep track of their total exposure to radiation during a radiological emergency operation. To do this, an instrument called a *dosimeter* is used. The dosimeter keeps track of the total charges created due to radiation interactions in it. The very same property of radiation that damages human tissues may be used to detect it - ionization. The concept of ionization was explained in Unit Two.

In order to properly use radiation detection instruments, it is essential to fully understand their method of operation. Only a radiological emergency responder who understands the instrumentation and uses it correctly will attain maximum effectiveness from it. The major dosimetry systems used by those involved in radiation work are pocket ionization chambers, thermoluminescent dosimeters (TLDs), film dosimeters, and combinations of systems (TLD plus pocket ionization chambers.)

To test your understanding of these concepts, answer the question on the following page

QUESTION

Circle the correct answer

_______ is the monitoring of individuals to accurately determine their radiation dose equivalent.

a. radiotherapy

b. dosimetry

Turn the page to check your answer.

ANSWERS

a. No, radiotherapy is the use of radioisotopes for medical purposes. Dosimetry involves special radiation detection instruments that measure radiation exposure of individuals using the device.

Try another question.

b. Exactly. You understand the meaning and purpose of dosimetry. During a radiological emergency, responders keep track of their total exposure to with radiation dosimeters.

Move on to the next section.

QUESTION

Circle the correct answer

What property of radiation is utilized by many dosimeters to detect radiation?

a. ionization

b. radioactive half-life

Turn the page to check your answer.

ANSWERS

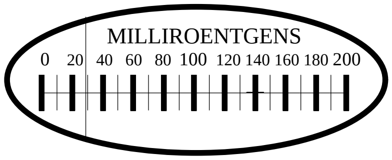
a. Correct. You understand that certain dosimeters keep track of the total charge created due to the ionization created by radiation interactions with matter. Ionization is what also damages human tissue after it has been exposed to radioactive material.

Proceed to the next section.

b. Wrong answer. Recall from Unit Two that radioactive half-life is the time it takes for a radionuclide to decay to one-half of the radioactive atoms that were present at the beginning of the time period. This property is not measured by radiation detection instruments. It is an inherent nuclear property of nuclides. Ionization is the process of removing an electron from an atom, leaving two charged particles. These electrical charges may be detected and measured by the dosimetry system.

Reread page 4-3.

POCKET IONIZATION CHAMBERS



Pocket ionization chambers rely on ionization to detect radiation. A pocket ionization chamber consists of a small, air-filled chamber in which a quartz fiber is suspended. A small microscope and a graduated scale enables one to read the shadow of the quartz fiber. The quartz fiber is displaced by charging it with about 200 volts; at this point, the dosimeter scale reads 0. Exposure to radiation discharges the fiber by creating ions; the dosimeter scale then reads that amount of ionization.

There are various types of pocket ionization chambers. Some are direct, or self-reading, while others are indirect, or nonself-reading. There is also a variety of pocket ionization chambers that read at different rates (0.01-200 mR and 1-500 R). Pocket ionization chambers, *primarily* measure whole body gamma exposure (with some x-radiation).

There are several advantages to using pocket ionization chambers.

- A cumulative exposure can be read at any time or location without ancillary equipment.
- The chambers can be used repeatedly by simply recharging or rezeroing.
- They have a long shelf-life with little to no maintenance requirements.
- The individual can directly read his/her exposure.
- Pocket ionization chambers measure gamma exposure accurately.
- They are sealed at the time of manufacture and are relatively insensitive to environmental conditions.

There are also possible disadvantages to the use of pocket ionization chambers.

- The exposure readings on the devices may be sensitive to a significant mechanical shock (for example, if dropped more than a few feet to a concrete surface).
- The initial cost of a pocket dosimeter is high.

Let's pause now and test your comprehension of how pocket dosimeters operate.

QUESTION

Circle the correct answer

Pocket ionization chambers measure ______ radiation exposure.

a. gamma

b. alpha

Turn the page to check your answer.

ANSWERS

a. Yes, pocket ionization chambers primarily measure whole body gamma exposure.

Move on to the next section.

b. No, pocket ionization chambers primarily measure whole body gamma exposure.

Try the next question.

QUESTION

Circle the correct answer

It is important to closely monitor and document your radiation exposure from responding to a radiological emergency. If you are using a pocket ionization chamber, how would you document your exposures?

a. Manually record the exposure readings.

b. Photocopy and store the computer printouts.

Turn the page to check your answer.

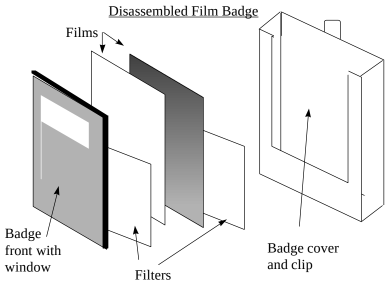
ANSWERS

a. Very good. You remembered that pocket ionization chambers are generally read on site. These exposure readings can and should be recorded on a log. Since there is no printout or film required to get the measurement result, the exposure should be manually recorded at the time of the reading.

You are ready to proceed to the next section.

b. Incorrect answer. There are no computer printouts coming from pocket ionization chambers! Users must manually record the exposure readings.

Review page 4-6.



FILM DOSIMETERS

Film dosimeters, or film badges, consist of layered components. Imagine a sandwich with the following layers starting from the top: the *badge front,* with a window for exposure; *filters* that selectively filter out certain types of radiation; *films* to detect the radiation; more *filters*; then the *badge cover* and *clip* to attach the dosimeter to the individual's clothing.

After a designated period of exposure, the film is taken out of the "sandwich" badge, developed, and read on a *densitometer,* which reads the amount of darkening on the film. The amount of darkening is proportional to the radiation exposure.

There are many advantages to using a film dosimeter for personnel monitoring.

- The dose measurements for various film badges range between 10 mrem to 1500 mrem for gamma and x-radiation, and 50 mrem to 1000 rem for beta radiation.
- Film badges can distinguish between penetrating radiation (high, medium, and low photon energies) and non-penetrating radiation (beta and x-ray radiation less than 20 keV).
- Film dosimeters are practical because they are small, lightweight, and relatively inexpensive.

There are also possible disadvantages associated with the use of film badges to monitor individual radiation exposure.

- The response of the film to radiation is energy dependent; at energies less than 300 keV, the response tends to increase.
- The films cannot be read immediately.
- Environmental conditions such as heat and humidity will affect the film's response to radiation.
- Film badges may be left or lost at the site of the radiation accident
- They may be contaminated with radioactive materials, which will lead to a false higher result.

QUESTION

Circle the correct answer

Exposure to radiation of the film in the dosimetry badge causes the film to darken. The darkening is proportional to the amount of

a. radiation released at the site.

b. radiation exposure of the individual wearing the badge.

Turn the page to check your answer.

ANSWERS

a. No, the film dosimeter, or badge, cannot measure all the radiation released at the site of the radiological response operation. The badge is only useful for the person wearing it.

Try another question.

b. Correct answer! A densitometer measures the amount of darkening of the film. This amount of darkening is proportional to the amount of radiation exposure of the film.

Move on to the next section.

QUESTION

Circle the correct answer

Film dosimeters are capable of detecting beta, gamma, and x-radiation.

a. True

b. False

Turn the page to check your answer.

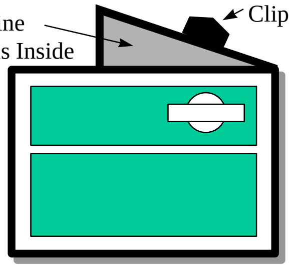
ANSWERS

a. Correct answer. The dose measurements for various film dosimeters range between 10 mrem and 1500 mrem for gamma and x-radiation, and 50 mrem to 1000 rem for beta radiation. Furthermore, film badges can distinguish between penetrating radiation (high, medium, and low photon energies) and non-penetrating radiation (beta and x-ray radiation less than 20 keV).

Proceed to the next section.

b. Wrong answer. The statement is true. Various film dosimeters can measure radiation doses ranging between 10 mrem and 1500 mrem for gamma and x-radiation, and 50 mrem to 1000 rem for beta radiation.

Reread page 4-10.



THERMOLUMINESCENT DOSIMETERS

Thermoluminescence is a property, possessed by certain crystals, of emitting light upon heating after having been exposed to ionizing radiation. The emitted light can be measured. The amount of light is directly proportional to the radiation absorbed dose. Thermoluminescent dosimeter (TLD) badges are issued to radiation workers and emergency responders who have the potential to be exposed to ionizing radiation. The badges are usually issued for use on a monthly or quarterly basis to record the dose received by these personnel from beta, gamma, x-ray , and neutron radiation. Their range of measurement spans anywhere from less than 1 mrem up to as much as 10^5 rem.

There are several advantages to using TLDs for personnel monitoring.

- TLDs can be used with radiation fields of widely varying energy and intensity.
- They can store information for long periods of time without fading.
- TLDs are reusable, and can be used for many applications because of their small size.
- TLDs are less energy dependent than film dosimeters or pocket ion chambers.

There are also some possible disadvantages and problems with TLDs.

- They cannot be analyzed immediately.
- Environmental factors such as humidity and heat may affect the results.

- They may be left or lost at the site of the radiation incident.
- They may be lost, and they may be contaminated with radioactive materials.

To check your understanding of these concepts, answer the following question.

QUESTION

Circle the correct answer

Thermoluminescent dosimeters contain crystals that respond to ionizing radiation and emit ------.

a. radioactive particles.

b. light.

Turn the page to check your answer.

ANSWERS

a. Wrong answer. The crystals *do not* emit ionizing radiation. They measure radiation by emitting light in response to having been exposed to ionizing radiation.

Try another question.

b. Correct. You understand that thermoluminescence is a property possessed by certain crystals. It is the process of emitting light upon heating after exposure to ionizing radiation. The amount of emitted light is directly proportional to the absorbed radiation dose.

Move on to the Summary Question.

QUESTION

Circle the correct answer

One must be cautious with interpreting readings from thermoluminescent dosimeters used during a typical summer day in Florida because

a. of the daily lightning and thunderstorms.

b. the humidity and heat affect the results.

Turn the page to check your answer.

ANSWERS

a. No, unless the thermoluminescent dosimeter is hit directly by lightning, use of this dosimeter should yield relatively reliable readings.

Reread page 4-14.

b. Correct answer. You clearly understand that environmental factors such as humidity and heat may affect the results of thermoluminescent dosimeters.

You may now proceed to the Summary Question.

SUMMARY QUESTION

Complete the following table:

METHOD	TYPE OF RADIATION MEASURED	ONE ADVANTAGE	ONE DISADVANTAGE
Pocket Ionization Chamber			
Film Dosimeter			
Thermoluminescent Dosimeter			

Turn the page to check your answers.

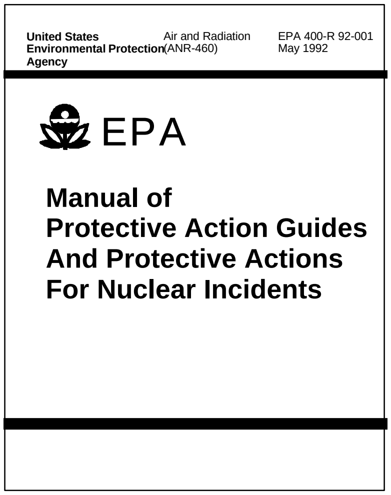
ANSWER

METHOD	TYPE OF RADIATION MEASURED	ONE ADVANTAGE	ONE DISADVANTAGE
Pocket Ionization Chamber	*gamma x-ray*	see page 4-7	see page 4-8
Film Dosimeter	*gamma, x-ray and beta*	see page 4-11	see page 4-12
Thermoluminescent Dosimeter	*gamma, x-ray, beta, and neutron*	see page 4-15	see pages 4-15 and 4-16

Once you are able to complete the chart correctly, move on to Unit 5.

UNIT FIVE

PROTECTIVE ACTIONS AND PROTECTIVE ACTION GUIDES



United States Environmental Protection Agency | Air and Radiation (ANR-460) | EPA 400-R 92-001 May 1992

EPA

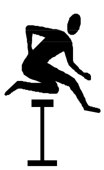
Manual of Protective Action Guides And Protective Actions For Nuclear Incidents

The overall objective of protective actions and protective action guides is to minimize radiation exposure to ourselves and others. Depending on the type of radioactive hazard, different protection guidelines may be set and different protection techniques may be used.

Radiological hazards may be classified as either internal or external. A radioactive material is said to present an internal hazard when it is hazardous inside the body. For example, eating in a radiation controlled zone could allow atoms of a radioisotope to be ingested and lodge within the body. An *external* hazard exists when radiation emanating from a radionuclide located outside the body can affect all or portions of the body.

This section will be limited to methods of and guidelines for radiation protection from external hazards, particularly related to nuclear power plant incidents.

GATE FRAME QUESTION



Suppose you were called to help in the response to a nuclear power plant accident minutes after the accident occurred. Which main protective actions should be taken to protect the public from radiation exposure, and what would you do onsite to minimize exposure to yourself?

ANSWER

Your answer should include the adjacent information

In the case of a nuclear power plant accident, initial public protective actions will be based on plant conditions. In all cases, however, if projected doses exceed the protective action guides (PAGs) then intervention is required by decision makers. The purpose of prompt protective actions is to minimize the health effects to the public. This is generally accomplished by evacuating or sheltering-in-place. In addition, bathing and changes in clothing will help to minimize exposure from contamination. It also may be necessary to initiate protective action for the milk supply during this period.

There are three general guidelines for protecting oneself from exposure to ionizing radiation.

- Decreasing the time spent in the radiation field will decrease exposure.
- Increasing the distance between you and the radiation source will decrease exposure.
- Shielding also will help reduce exposure. Shielding is the placement of a barrier between the individual and the radiation source.

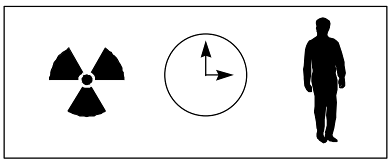
If your answer included all or most of the above points, you should be ready for the Summary Questions at the end of this unit. *Turn to page 5-33.*

If your answer did not include these points, it would be advisable for you to complete the instruction for this unit. *Turn to page 5-3.*

TIME, DISTANCE, AND SHIELDING: PROTECTION FROM IONIZING RADIATION EXPOSURE

There are three general guidelines for controlling exposure to ionizing radiation: minimizing exposure time, maximizing distance from the radiation source, and shielding yourself from the radiation source.

TIME



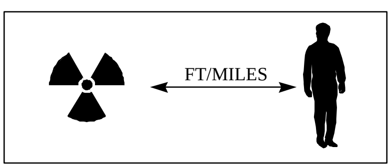
Time is an important factor in limiting exposure to the public and to radiological emergency responders. The shorter the period of time an individual stays in a radiation field, the smaller the dose he or she will receive.

The maximum time to be spent in the radiation environment is defined as the *stay time*. The stay time can be calculated using the following equation:

- Stay Time = Exposure Limit/Dose Rate.

Because of this time factor, it is very important to carefully plan the work to be done prior to entering the radiation environment. Working as quickly as practicable once there, as well as rotating personnel who are in the radiation area, also will help minimize exposure of individuals.

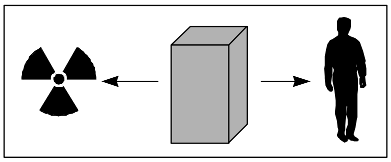
DISTANCE



Distance can be used to reduce exposures. A dramatic reduction in dose equivalent can be obtained by increasing the distance between yourself and the radiation source. The decrease in exposure rate as one moves away from the source is greater than one might expect. Doubling the distance from a point source of radiation decreases the exposure rate to 1/4 the original exposure rate. This relationship is called the *inverse square law*. The word *inverse* implies that the exposure rate *decreases* and the distance from the source *increases*. *Square* suggests that this decrease is more rapid than just a one-to-one proportion.

Radiation exposure levels decrease as distance from a non-point source increases, but not in the same mathematical proportions as the inverse square law suggests.

SHIELD



In radiological emergencies where the radiation exposure rates are very high, some *shielding* may be necessary. Shielding is the placement of an "absorber" between you and the radiation source. An absorber is a material that reduces the number of particles or photons traveling from the radiation source to you. Alpha, beta and neutron radiation can all be stopped by different thickness of absorbers. There is no absorber shield that can stop *all* gamma rays. Instead, introduction of a shield of a specified thickness will reduce the radiation intensity by a certain fraction. Addition of more shielding will reduce the intensity further.

Recommendations for shielding procedures should involve careful comparison of the exposure reduced by the shielding with the exposure added due to increased time required to shield the area.

- Shielding material can include barrels, boards, vehicles, buildings, gravel, water, or whatever else is immediately available.

To test your comprehension of the time, distance, and shielding concepts, answer the following question.

QUESTION

Circle the correct answer

You have responded to a radiological emergency that has a 5 R/hr field. The emergency limit for this activity is 10 R. What is your calculated stay time, or the maximum length of time you can remain in the 5R/hr location?

a. 2 hours.

b. 0.5 hours.

Turn the page to check your answer.

ANSWERS

a. Correct. You applied the stay time equation correctly. Stay Time = Limit/Dose Rate. In this problem, Stay Time = 10 rem/(5 R/hr) = 2 hours.

Proceed to page 5-7.

b. Incorrect. You mixed up the limit and dose rate values. The stay time is calculated by dividing the dose limit, which is 10 rem, by the dose rate, which is 5 R/hr. So, Stay Time = 10 rem/(5 R/hr) = 2 hours.

Try another problem.

QUESTION

Circle the correct answer.

When choosing shielding procedures, you should compare the exposure saved by the shielding with the exposure added due to

a. increased distance from the radiation area.

b. increased time exposed while building shielding.

Turn the page to check your answer.

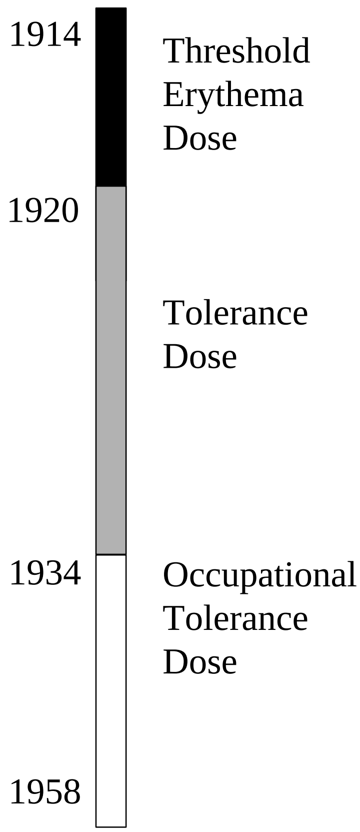
ANSWERS

a. No, first of all, increased distance from the radiation source will *decrease* exposure. The benefits of shielding should outweigh the risks of exposure taken to provide it.

Review this section before moving on to the next section.

b. Correct. There may be a greater risk of exposure associated with the increased time taken to shield an area. Radiological emergency responders should carefully consider whether these risks are worth taking.

Move on to the next section.



EXPOSURE GUIDE HISTORY

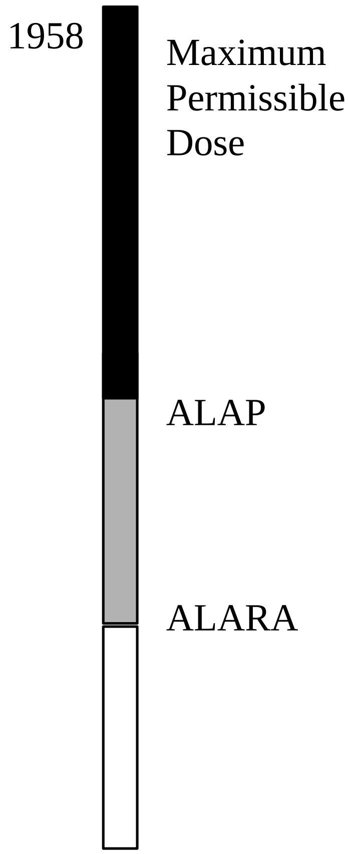
Before 1914, early radiologists determined the quantity of radiation emitted from an x-ray machine by placing a hand in the primary beam until a tingling sensation produced the dose to sufficiently cause reddening of the skin. This was termed “Threshold Erythema Dose” or TED. TED was an inadequate unit of dose because the amount of radiation depended on exposure parameters such as time, wavelength, and size of x-ray field.

Beginning in the 1920s, researchers began developing other methods for quantifying radiation measurements. They also sought to determine the dose that could be “tolerated” without serious harm (called the “tolerance dose”). This was the precursor of current dose limits for workers.

In 1928, at the Second International Congress of Radiology in Stockholm, the International Committee on X-ray and Radium Protection was formed and soon thereafter began the process of developing radiation protection recommendations. This committee become the present International Commission on Radiological Protection (ICRP).

In the United States, a similar development process took place. Beginning in 1929, discussion among the officers of several radiological societies resulted in the consolidation of their radiation protection activities into a single committee, called the Advisory Committee on X-ray and Radium Protection. Following a number of organizational and name changes, this committee has come to be the present National Council on Radiation Protection and Measurements (NCRP).

In 1934, NCRP adopted an occupational tolerance exposure rate of 0.1 roentgen per day (R/d); the ICRP adopted a value of 0.2 R/d. At that time, it was believed that no harmful effects would occur at these levels.



In 1958, ICRP and NCRP developed the concept of a "maximum permissible dose" (MPD). The MPD was defined as the level of exposure that entailed a small risk compared with those posed by other hazards in life.

Over a period of time, ICRP and NCRP moved away from the concept of a "tolerance dose." They concluded that for the purposes of establishing radiation protection standards, the assumption should be made that there is some radiation risk associated with *any* radiation dose, however small, and that the risk decreases with decreasing dose. This concept, known originally as ALAP (as low as practicable), and later as *ALARA (as low as reasonably achievable)*, became a cornerstone of radiation protection philosophy.

The NCRP's most recent dose limit recommendations have been incorporated into the Nuclear Regulatory Commission's Occupational Limits for External Exposure, 10 CFR 20, which was discussed in Unit One of this course. Part 20 states that nothing in the Part shall be construed as limiting actions to protect health and safety.

In 1959, the U.S. Federal Radiation Council (FRC) was formed to provide a Federal policy on human radiation exposure and to advise the President with respect to radiation matters. FRC and its successor agency, the Environmental Protection Agency (EPA), have developed radiation protection guidance for all Federal agencies.

To check your comprehension of exposure guide history, answer the question below.

QUESTION

Circle the correct answer

Which organization plays a major role in developing radiation protection standards worldwide?

a. International Commission on Radiological Protection

b. Federal Radiation Council (FRC).

Turn the page to check your answer.

ANSWERS

a. Right!

Continue to the next section.

b. No, the FRC, which is now defunct, provided Federal policy for radiation matters within the United States. ICRP is a worldwide organization with radiation protection activities, including the development of standards.

Try the next question.

QUESTION

Which of the following standards became a cornerstone for radiation protection philosophy?

a. ALARA (as low as reasonably achievable).

b. TED (threshold erythema dose).

Turn the page to check your answer.

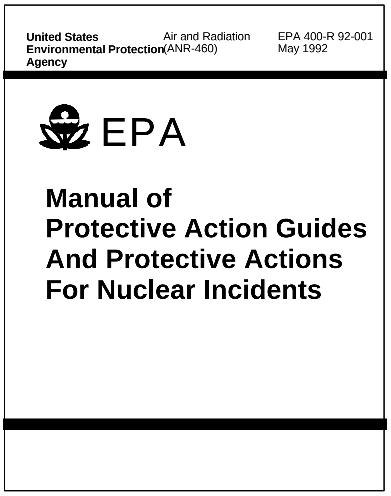
ANSWERS

a. Correct.

Go ahead with the next section.

b. Incorrect. The TED was developed before 1914, and many radiation units and concepts have changed and improved drastically since then. ALARA is the main concept that forms the basis of radiation protection today.

You should reread this section before proceeding.



United States Environmental Protection Agency | Air and Radiation (ANR-460) | EPA 400-R 92-001 May 1992

EPA

Manual of Protective Action Guides And Protective Actions For Nuclear Incidents

INTRODUCTION TO PROTECTIVE ACTION GUIDES

A Protective Action Guide (PAG) is a *decision level* for public officials during a nuclear incident. More specifically, it is the *projected radiation dose* to a standard individual, or other defined individual, from an unplanned release of radioactive material at which a specific protective action to reduce or avoid that dose is warranted. Projected radiation dose is the dose estimated to be received in a specified time in the absence of protective actions or natural shelter.

The Environmental Protection Agency considers four principles when selecting PAGs.

- Avoid *acute* effects on health.

- Keep the risk of delayed effects of health within upper bounds that are adequately protective of public health, under emergency conditions, and reasonably achievable.

- Reduce any risk to public health that is achievable at acceptable cost.

- Regardless of the above principles, risk to health from protective action should *not* exceed risk to health from a dose that would be avoided.

With the *exception* of nuclear detonation, PAGs apply to *all* radiological incidents, including accidents involving a nuclear power plant or other nuclear facility, weapons, transportation, and satellite. The guidance for implementing the PAGs is intended primarily for accidents involving nuclear power facilities.

Let's pause now and apply these concepts. Turn the page to check your understanding.

QUESTION

Circle the correct answer

Protective actions should be implemented if radiation doses to an exposed individual fall below the PAG for that situation.

a. true.

b. false.

Turn the page to check your answer.

ANSWERS

a. Wrong answer. Protective actions are warranted when doses exceed the PAG, *not* fall below the PAG.

Try another problem.

b. Yes, you are right. The statement is false because it states that protective actions are warranted for doses *below* the PAG. The right statement would say "above" the PAG.

Go ahead to the next section.

QUESTION

One of the principles of selecting PAGs is to avoid acute effects on ______________________.

Circle the correct answer

a. property.

b. health.

Turn the page to check your answer.

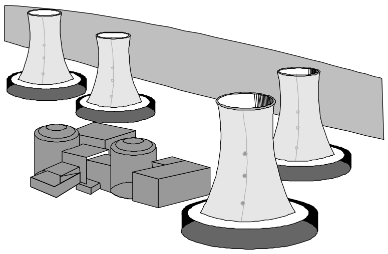
ANSWERS

a. No, acute radiation effects on property is of least importance when selecting PAGs to save human lives.

You should go back and reread that section before proceeding.

b. Correct answer.

Proceed to the next section.



NUCLEAR INCIDENT PHASES

EPA's Manual of Protective Actions and Protective Action Guides defines three time phases that are generally accepted as being common to all nuclear incident sequences. The three phases are termed the *early*, *intermediate*, and *late*.

The *early phase* (also referred to as the identification of the accident) is arbitrarily defined as the period beginning at the initiation of a radioactive release and extending to a few days later, when deposition of airborne materials has ceased. It also is the period when immediate decisions on protective actions are required. Decisions must be based primarily on predictions of radiological conditions in the environment. The early phase may last from hours to days. For purposes of dose projection (or prediction of doses), the time period is assumed to last four days.

The *intermediate phase* is arbitrarily defined as the period beginning after the source and releases have been brought under control and environmental measurements are available for use as a basis for decisions on protective actions. The intermediate phase extends until protective actions are completed. It may overlap with the early and late phases, and may last from weeks to many months. For purposes of dose projection, this phase is assumed to last one year.

The *late phase* (also referred to as the *recovery* phase) is the period beginning when recovery actions are commenced so as to reduce radiation levels in the environment to permit unrestricted, long-term use of property. The late phase ends when all recovery actions have been completed, and it may last from months to years.

To assess your understanding of nuclear incident phases, answer the question on the next page.

QUESTION

Circle the correct answer

What is the name of the period during a nuclear incident when the radiation source and release have been brought under control and environmental measurements are available for use as a basis for decisions on protective actions?

a. early phase.

b. intermediate phase.

Turn the page to check your answer.

ANSWERS

a. Wrong answer. The early phase, or emergency phase, is the period beginning at the *initiation* of a radioactive release and extending a few days later.

Try another problem.

b. Correct.

Proceed to page 5-19.

QUESTION

Circle the correct answer

The ____________________ phase extends until protective actions are completed.

a. intermediate.

b. late.

Turn the page to check your answer.

ANSWERS

a. Correct answer.

Move on to the next section.

b. Incorrect answer. The late phase is when recovery actions begin. If protective actions are still in place, the nuclear incident would still be in the intermediate phase.

You should return to page 5-15 and reread that section before proceeding.

PROTECTIVE ACTIONS FOR A NUCLEAR INCIDENT

The protective actions available to avoid or reduce radiation dose can be categorized according to the exposure pathway (covered in the next section) and incident phase. Evacuation and sheltering-in-place (supplemented by bathing and changes of clothing) are the principal protective actions for use during the *early phase* to protect the public from exposure to direct radiation and inhalation from an airborne plume. It also may be appropriate to initiate protective action for the milk supply during this period.

There are two types of protective actions during the *intermediate phase*. Relocation and decontamination are the principal protective actions for protection of the public from whole body external exposure due to deposited material and from inhalation of any resuspended radioactive particulate material during the intermediate and late phases. The second major type of protective action during the intermediate phase encompasses restrictions on the use of contaminated food and water. This protective action, in particular, may overlap the early and late phases.

Relocation, decontamination, and food and water controls are the protective actions that may be implemented during the *late phase*.

It is necessary to distinguish between evacuation and relocation with regard to the incident phases.

- Evacuation is the urgent removal of people from an area to avoid or reduce high-level, short-term exposure, usually from a plume or deposited radioactivity.

- Relocation, on the other hand, is the removal or continued exclusion of people (households) from contaminated areas to avoid chronic radiation exposure.

Check your comprehension by answering the following question.

QUESTION

Circle the correct answer

What are the two principal protective actions for use during the early phase of a nuclear incident?

a. evacuation and decontamination.

b. evacuation and sheltering.

Turn the page to check your answer.

ANSWERS

a. Wrong answer. While evacuation is a principal action during the early phase, decontamination does not usually begin until the intermediate phase.

Try another problem.

b. Correct answer.

Move on to the next section.

QUESTION

Circle the correct answer

Which form of protective action is the continued exclusion of people (households) from contaminated areas to avoid chronic radiation exposure?

a. evacuation.

b. relocation.

Turn the page to check your answer.

ANSWERS

a. Wrong answer. Evacuation is the *urgent* removal of people from an area to avoid or reduce high-level, short-term exposure, usually from a plume or deposited radioactivity.

You should return to page 5-19 and reread that section.

b. Correct!

Move on to the next section.

PROTECTIVE ACTION GUIDES FOR A NUCLEAR INCIDENT

PAGs for the Early Phase of a Nuclear Incident

Protective Action	PAG (projected dose)	Comments
Evacuation (or sheltering)	1-5 rem	Evacuation or sheltering normally initiated at 1 rem
Admini-stration of stable iodine	25 rem	Requires approval of State medical officials

There are separate PAGs for each nuclear incident phase. In all phases, the PAGs are independent of the previous phase; that is, in applying them, it is not necessary to consider dose received during the previous phase.

For response during the *early phase* of a nuclear incident, the PAG for the evacuation (or sheltering) is 1-5 rem. This means that evacuation of the public will usually be justified when the projected dose to an individual is 1 rem. For the administration of stable iodine, the PAG is 25 rem; this requires approval of State medical officials.

The PAGs for exposure to deposited radioactivity during the *intermediate phase* of a nuclear incident are greater than or equal to ($\geq$) 2 rem for relocation of the general population and less than ($<$) 2 rem for application of simple dose reduction techniques.

- Dose reduction techniques include scrubbing and/or flushing hard surfaces, soaking or plowing soil, minor removal of soil from spots where radioactive materials have concentrated, and spending more time than usual indoors or in other low exposure rate areas.

Answer the following question to test your understanding of PAGs.

QUESTION

Circle the correct answer

During the early phase of a nuclear incident, the radiation dose to an individual is projected to be 0.5 rem. What protective actions should be implemented at this point?

a. no protective actions are required at this point.

b. evacuation and sheltering.

Turn the page to check your answer.

ANSWERS

a. Very good! A projected dose of 0.5 rem is still below the PAG, which is 1-5 rem for this situation. So, protective actions are not warranted.

Move on to the next section.

b. No, a projected dose of 0.5 rem is still below the PAG, which is 1-5 rem for the early phase of nuclear incidents. When projected doses are below the PAG, protective actions are not implemented.

Try another question.

QUESTION

Circle the correct answer

The PAGs for exposure to deposited radioactivity during the intermediate phase of a nuclear incident are greater than or equal to two rem for

a. relocation of the general population.

b. application of simple dose reduction techniques.

Turn the page to check your answer.

ANSWERS

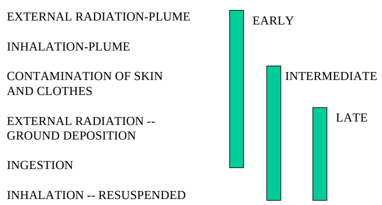
a. You are right.

Move on to the next section.

b. Incorrect answer. Application of simple dose reduction techniques is done when the PAG is less than two rem.

You should return to page 5-23 and reread that section.

POTENTIAL EXPOSURE PATHWAYS
AND INCIDENT PHASES



RADIATION EXPOSURE PATHWAYS IN NUCLEAR INCIDENTS

During the *early phase* of a nuclear incident, exposure may come from external gamma dose and beta dose to the skin from direct exposure to airborne materials and from deposited materials, and the committed dose to internal organs from inhalation of radioactive material. Individuals exposed to a plume also may be exposed to deposited material over longer periods of time via ingestion, direct external exposure, and inhalation pathways.

The principal pathways for exposure of the public during the *intermediate phase* are expected to be exposure of the whole body to external gamma radiation from deposited radioactive materials (groundshine). Exposure may also occur from contamination of skin and clothes and ingestion of radioactively contaminated food and water.

During the *late phase*, exposure may ensue following external radiation from ground deposition, inhalation of radioactive material resuspended in air, and ingestion of radioactively contaminated food and water.

To demonstrate understanding of these concepts, answer the following question.

Individuals exposed to a plume may be exposed to deposited material over longer periods of time via the ___________ pathway.

a. absorption.

b. inhalation.

Turn the page to check your answer.

ANSWERS

a. No, individuals exposed to a plume may be exposed to deposited material over longer periods of time via ingestion, direct external exposure, and inhalation pathways. Absorption is a highly unlikely pathway of exposure in this case.

Try another problem.

b. Correct answer.

Move on to the next section.

QUESTION

Circle the correct answer

During the late phase of a nuclear incident, radiation exposure is no longer occurring.

a. true.

b. false.

Turn the page to check your answer.

ANSWERS

a. Wrong answer. During the late phase, exposure may still be a problem due to external radiation and the inhalation and ingestion exposure pathways.

You should return to page 5-27 and reread that section before proceeding.

b. Correct!

Proceed to the next section.

EPA DOSE LIMITING RECOMMENDATIONS

PAGs consider the risks to individuals from exposure to radiation and the risks and costs associated with a specific protective action. On the other hand, *emergency and occupational workers* may receive exposure under a variety of circumstances in order to assure protection of others. The EPA has published dose limiting recommendations for emergency workers.

EPA GUIDANCE ON DOSE LIMITS FOR EMERGENCY WORKERS

Dose Limit (rem)	Activity
5	All
10	Protecting Valuable Property
25	Life saving or protection of large populations
>25	Life saving or protection of large populations only on a voluntary basis to persons fully aware of the risks involved

Answer the following question to check your comprehension.

QUESTION

Circle the correct answer

EPA's dose limit for radiological emergency responders for lifesaving is

a. 5 rem, total dose (internal & ingested).

b. 25 rem, total dose (internal & ingested).

Turn the page to check your answers.

ANSWERS

a. No, the correct answer is 25 rem; 5 rem is the dose limit recommended where higher exposures are not justified.

Try another problem.

b. Yes, you're right.

Proceed to the Summary Questions.

QUESTION

Circle the correct answer

__________ apply to workers who may receive exposure in order to assure protection of others.

a. Dose limits

b. PAGs

Turn the page to check your answers.

ANSWERS

a. Very good.

You may proceed to page 5-33.

b. No, PAGs consider the risks to individuals themselves from exposure to radiation, whereas dose limits are for those who become exposed to radiation during the protection of others.

You should go back to page 5-30 and reread that section before answering the Summary Questions.

QUESTION

SUMMARY QUESTIONS

Circle the correct answer

1. How does a protective action guide (PAG) relate to projected radiation dose?

   a. PAG's are based on the projected radiation dose and specific protective actions that should be taken to reduce or avoid that dose

   b. No relationship

Turn the page to check your answers.

ANSWERS

a. Correct.

Move on to the next Summary Question.

b. Incorrect. Protective Action Guides (PAGs) are decision levels established for public officials to know when protective actions should be taken to reduce or avoid projected radiation doses to individuals from an unplanned release of radioactive material.

Go back and review the unit before answering the next Summary Question.

QUESTION

Circle the correct answer

2. The early phase of a nuclear incident is the period

   a. when immediate decisions on protective actions are required.

   b. that is assumed to last one year.

Turn the page to check your answers.

ANSWERS

a. Correct.

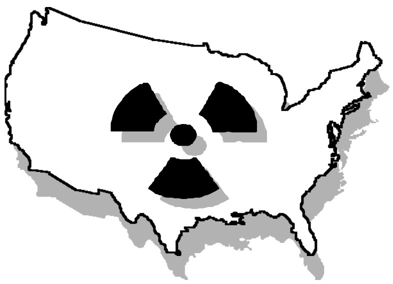
Proceed to Unit Six.

b. Incorrect. It is the intermediate phase of a nuclear incident that is assumed to last one year.

Go back to page 5-27 and review before moving on to Unit Six.

UNIT SIX

FEDERAL RESPONSE SYSTEMS

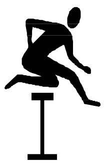


For a radiological emergency at a facility or site not under the control of a Federal agency, State and local governments have primary responsibility for determining and implementing measures to protect life, property and the environment outside the facility boundary. The owner or operator of a nuclear facility has primary responsibility for actions within the boundaries of that facility; for providing notification and advice to off-site officials and for minimizing the radiological hazard to the public.

For radiological emergencies involving an area under Federal control the responsibility for onsite actions belongs to the Federal agency, while off-site actions are the responsibility of the State or local government. In all other radiological emergencies, the State or local government has the responsibility for taking emergency actions both onsite and off-site, with support provided, upon request, by Federal agencies as designated by the Federal Radiological Emergency Response Plan (FRERP).

Each level of government maintains plans for radiological emergency response. In local government the coordination of that function may be assigned to emergency management, public health, or some other agency or department. That role will be identified in the local plan. At the State level, the responsibility for coordinating radiological emergency response lies with the State emergency management agency. At the Federal level, the Lead Federal Agency (LFA) is the coordinating agency for Federal response to radiological emergencies. In this unit you will explore the Federal response to radiological emergencies.

GATE FRAME QUESTION



A severe accident has occurred at the commercial nuclear power plant in your jurisdiction. The facility has issued a site area emergency notification and indicates that unless the problem is brought under control, off-site radiation levels are expected to exceed dose limits for the general public. As a result, the Federal Radiological Emergency Response Plan (FRERP) has been implemented, and Federal agencies are gearing up for immediate deployment to the site. The mayor wants to know what the FRERP is, what agencies will respond, who will be in charge, and what the Federal government can do to help solve the problem.

What will you tell him?

ANSWER

Your answer should include the adjacent information.

The FRERP is an operational strategy by which Federal agencies with various statutory responsibilities in radiological protection and response coordinate their efforts at the accident scene.

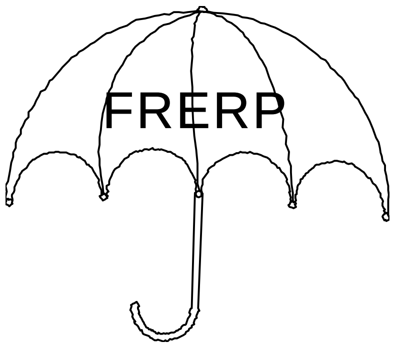
Because this is an accident at a commercial nuclear facility, the Nuclear Regulatory Commission (NRC) is the Lead Federal Agency (LFA). This means the NRC manages the Federal response effort and coordinates among the Federal agencies and their interactions with the State. The Department of Energy (DOE) will set up a Federal Radiological Monitoring and Assessment Center (FRMAC).

The FRMAC provides a wide array of monitoring and assessment data to the State and local governments as well as to the LFA. The LFA will provide advice regarding protective actions to the State and local governments.

The Federal presence does not impact State and local authority or responsibility to assess the situation and to select and implement protective actions.

If your answer included all or most of the above points, you should be ready for the Summary Questions at the end of this unit. Turn to page 6-22.

If your answer did not include these points, complete the instruction for this unit. Turn to page 6-4.



OVERVIEW OF THE FEDERAL RADIOLOGICAL EMERGENCY RESPONSE PLAN

In the event of a radiological accident, Federal agencies with various statutory responsibilities have agreed to coordinate their efforts at the accident scene under the umbrella of the *Federal Radiological Emergency Response Plan (FRERP)*. The FRERP covers any peacetime radiological emergency that has actual, potential, or perceived radiological consequences within the U.S., its Territories, possessions, or territorial waters, and that could require a response by the Federal government. The level of Federal response to a specific emergency will be based on the type and/or amount of radioactive material involved, the location of the emergency, the impact or the potential for impact on the public and the environment, and the size of the affected area. Emergencies occurring at fixed nuclear facilities or during the transportation of radioactive materials, including nuclear weapons, fall within the scope of the Plan regardless of ownership.

The objective of the FRERP is to establish an organized and integrated capability for timely coordinated response by Federal agencies to peacetime radiological emergencies. The agency that is responsible for leading and coordinating all aspects of Federal response is referred to as the *Lead Federal Agency (LFA)* and is determined by the type of emergency.

This cooperative effort is intended to assure the States and the LFA that all Federal technical assistance is fully supporting their efforts and that monitoring results are provided in a working data center for immediate use by the State(s) and LFA decision makers. The Federal agencies do not relinquish their statutory responsibilities. However, this mandated cooperation ensures that each agency can obtain the data critical to its specific responsibility.

The FRERP ensures that emergency response resources are available to respond to any accident scenario. The plan identifies the authorities and responsibilities of each Federal agency that may have a significant role in a radiological emergency. The State is fully recognized as the primary decision maker for any public action outside the boundaries of the facility which experienced the accident (areas considered to be off-site).

Answer the following question to check your understanding of the FRERP.

QUESTION

Circle the correct answer

The _____ describes the responsibilities of each Federal agency with major responsibilities in a radiological emergency.

a. LFA.

b. FRERP.

Turn the page to check your answer.

ANSWERS

a. Incorrect. The Lead Federal Agency is one of the entities whose responsibilities are described within the FRERP.

Try the next question

b. Right! The Federal Radiological Emergency Response Plan is the umbrella under which Federal agencies coordinate response to radiological emergencies.

Turn to page 6-8

QUESTION

Circle the correct answer.

The LFA is the primary decision maker for all public actions outside the boundaries of the facility where the accident occurred.

a. true.

b. false.

Turn the page to check your answer.

ANSWERS

a. No, the State makes the decisions regarding off-site public actions.

You should reread this section before moving on.

b. That's right. The Federal agencies are there to assist the State, not take over the State government.

Turn to page 6-8.

THE FEDERAL RADIOLOGICAL MONITORING AND ASSESSMENT CENTER

The Department of Energy (DOE) may respond to a State or LFA request for assistance by dispatching a Radiological Assistance Program (RAP) team. If the situation requires more assistance than a RAP team can provide, DOE will alert or activate additional resources. These resources may include the establishment of a *Federal Radiological Monitoring and Assessment Center* (FRMAC), to be used as an on-scene coordination center for Federal radiological assessment activities. Federal and State agencies are encouraged to collocate their radiological assessment activities at the FRMAC.

The following radiological information is provided by the FRMAC to the States and the LFA:

- Plume predictions, as appropriate;
- Air and ground concentrations in time and space;
- Deposition patterns of isotopic concentrations & exposure rates;
- Concentrations in environmental media in time and space;
- Assurance of quality of data;
- Retrievable documentation of environmental conditions;
- Dose predictions in time and space;
- Results of data collection, analysis, and evaluation;
- Evaluations, assessments, and interpretation of data, as applicable;
- Technical assistance to State and LFA decision-making officials, as requested; and
- Weather forecasts

Answer the following question to check your understanding of the FRMAC.

QUESTION

Circle the correct answer.

In a major radiological emergency, the State might rely on the FRMAC to provide

a. data on the scope and radiation content of the plume.

b. off-site emergency rescue capability.

Turn to the next page to check your answer.

ANSWERS

a. That's correct. The FRMAC provides technical assistance to the State(s).

Turn to page 6-12.

b. No, the off-site emergency response is provided by local and State agencies with possible assistance from Federal entities other than the FRMAC.

Try the next question.

QUESTION

Circle the correct answer.

How would a local radiological response team access the FRMAC for technical assistance with low level radiation accidents?

a. call the Department of Energy.

b. the FRMAC would not be available.

Turn to the next page to check your answer.

ANSWERS

a. No, a FRMAC is only established in the event of a significant radiological emergency. A local jurisdiction contacts the State Radiation Authority for technical assistance with a localized problem.

Review this section before proceeding.

b. Correct. You realize that the FRMAC is established in the event of significant radiological emergencies.

Turn to page 6-12.

THE LEAD FEDERAL AGENCY

When the State or facility owner requests Federal assistance in a radiological emergency, the FRERP is activated.

Under the FRERP, the LFA will lead and coordinate all Federal response activities from an on-scene location, referred to as the *Joint Operations Center* (JOC).

The LFA will oversee the federal response, monitor and support owner or operator activities (if applicable), and serve as the principal Federal source of information about onsite conditions. The LFA will provide a hazard assessment of onsite conditions that might have significant off-site impact and ensure onsite measures are taken to mitigate off-site consequences.

The LFA will establish a *Joint Information Center (JIC)* for media release coordination and approval. It is the central point of contact for all news media at the scene of the incident. Public information officials from all participating Federal agencies collocate at the JIC.

The assignment of LFA responsibility is determined by the type and location of radiological accident.

TYPE OF RADIOLOGICAL ACCIDENT	LFA
Nuclear Facilities	
Licensed by NRC or an Agreement State	Nuclear Regulatory Commission (NRC)
Owned or operated by DoD or DOE	Department of Defense (DoD) or Department of Energy (DOE)
Material Not Licensed, Owned, or Operated by a Federal Agency or Agreement State	Environmental Protection Agency (EPA)
Transportation of Radioactive Materials	
Shipment of Materials Licensed by NRC or an Agreement State	NRC
Materials shipped by or for DoD or DOE	DoD or DOE
Shipment of Materials Not Licensed or Owned by a Federal Agency or an Agreement State	EPA
Satellite Containing Radioactive Material	NASA or DoD
Impact from Foreign or Unknown Source	EPA
Other Types of Emergencies	LFAs confer

To apply your knowledge, answer the following question.

QUESTION

Circle the correct answer.

The decisions regarding protective actions to be recommended to the public in a radiological emergency are made by

a. the State.

b. the LFA.

Turn to the next page to check your answer.

ANSWER

a. Correct. The FRERP fully recognizes the State as the primary decision maker for any public action outside the boundaries of the facility that experienced the accident.

Turn to page 6-17.

b. No. The LFA will *recommend* protective action measures to the State(s).

Try another question.

QUESTION

Circle the correct answer.

If a vehicle carrying high-level radioactive waste to a DOE facility is involved in a major accident with resulting fire and dispersion of radioactive materials, the LFA would be the

a. NRC.

b. DOE.

Turn to the next page to check your answer.

ANSWERS

a. No. The NRC is the LFA for significant transportation accidents where the radioactive materials are not shipped for DOE or DoD.

Review this section before continuing.

b. That is correct.

Go to page 6-17.

ROLES OF FEDERAL, STATE, AND LOCAL AGENCIES

As defined by the FRERP, FEMA will coordinate provision of non-radiological Federal resources and assistance to affected State and local governments. The Federal non-radiological resource and assistance coordination functions will be performed at a Disaster Field Office (DFO).

The *DOE*, under the FRERP, has the initial responsibility for coordinating off-site Federal radiological monitoring and assessment assistance during response to a radiological emergency. Seven overall responsibilities fall initially to the DOE:

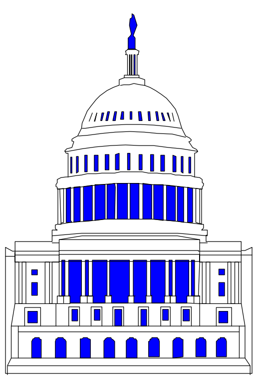
- Provide support to the State through coordination of the off-site Federal radiological monitoring, assessment, and evaluation activities;
- Maintain technical liaison with the State and local agencies having monitoring and assessment responsibilities;
- Maintain a common set of off-site radiological monitoring data;
- Provide monitoring data and any interpretations to the LFA and appropriate Federal, State, and local agencies;
- Provide off-site support, including the FRMAC and the majority of personnel to operate it; and
- Provide various operational assets, including detection and measurement equipment, communications support, and aerial sampling capability, as appropriate.

Following the initial phase of the emergency, the DOE will transfer certain responsibilities to the EPA at a mutually agreeable time. The EPA will assume the Federal agency responsibility for coordinating the intermediate and long-term, off-site radiation monitoring activities. EPA assumes control of the FRMAC with adequate assurances from DOE and the other Federal agencies that they will commit the necessary resources, personnel, and funds for the duration of the Federal response effort.

The U.S. Nuclear Regulatory Commission (NRC) regulates the use of byproduct, source, and special nuclear material, including activities at commercial and research nuclear facilities. The NRC provides assistance in Federal radiological monitoring and assessment activities during incidents. The NRC also provides, where available, continuous measurement of ambient radiation levels around NRC licensed facilities, primarily power reactors, using thermoluminescent dosimeters (TLDs).

STATE AND LOCAL GOVERNMENTS

State and local governments are responsible for the health and welfare of the general public during an emergency. Off-site authority and responsibility at the accident site rests with the State and local officials. State and local officials also assess the situation and issue instructions for necessary protective actions to ensure the health and safety of the general public, making use of the recommendation of the LFA and the data provided by the FRMAC.



Answer the following question to check your understanding.

QUESTION

Circle the correct answer.

The Federal agency that will coordinate the Federal radiological emergency response with the State(s) is

a. FEMA.

b. LFA.

Turn to the next page to check your answer.

ANSWERS

a. No, FEMA coordinates provision of non-radiological Federal resources and assistance.

Try another question.

b. That is correct. The LFA assists State and local governments in determining protective actions and ensures that other Federal agencies assist State and local government in implementing protective actions.

Go to page 6-22.

QUESTION

Circle the correct answer.

The DOE is responsible for all off-site radiological assessment activities.

a. true.

b. false.

Turn to the next page to check your answer.

ANSWERS

a. Incorrect. State and local officials will assess the situation, making use of the recommendation of the LFA and the data provided by the FRMAC.

Review the section before proceeding.

b. Correct. State and local officials also assess the situation and issue instructions for necessary off-site protective actions.

You are ready for the Summary Questions. *Turn to page 6-22.*

SUMMARY QUESTIONS

QUESTION

Circle the correct answer.

As a local member of a State radiological emergency response team, who do you report to in the event of a radiological accident in which Federal response also is involved?

a. the State radiological response team leader.

b. the LFA.

Turn to the next page to check your answer.

ANSWERS

a. Correct. The organizational structures of State response are unaffected by the Federal presence.

Try the next question.

b. No. The LFA manages onsite Federal, not off-site State and local, response actions.

You should go back and review the unit before trying the next question.

QUESTION

Circle the correct answer.

2. One of the benefits to the local and State governments of Federal assistance in a radiological emergency is

a. freedom from decision making.

b. the monitoring and assessment data provided by the FRMAC.

Turn the page to check your answer.

ANSWERS

a. No. The responsibilities of the State and local governments for the health and welfare of their public remain intact.

You should review the unit before continuing on in the course.

b. Yes. The FRMAC provides an excellent resource to the States as well as the LFA and other Federal agencies involved.

Move ahead to Unit Seven.

UNIT SEVEN

INCIDENT COMMAND SYSTEM

The Incident Command System (ICS) was designed by local, State, and Federal fire protection agencies to improve the ability of the fire protection agencies to manage emergencies. It is a generic, all-risk system that enables any company or organization to function in a multi-organization environment. Although the ICS was developed in California, the same management concepts can be used to respond to events of any kind, anywhere. Using ICS, any incident can be managed more efficiently -- from the smallest oil spill to complex national disasters such as earthquakes, floods, and large industrial accidents; or local situations in which several jurisdictions are involved, such as industrial fires and hazardous material accidents.

Today many jurisdictions' emergency-service organizations manage emergencies using the ICS. Radiological emergency response team members must understand and be able to operate within an ICS to provide appropriate advice and assistance to an Incident Commander (IC) at a radiological accident scene.

GATE FRAME QUESTION

How does radiological emergency response fit into the Incident Command System?

____

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ANSWER

Your answer should include the adjacent information.

ICS establishes a command structure that is expanded or contracted as an incident dictates. The command structure identifies the Incident Commander, and command and general staffs that work within five functional areas:

- Command.
- Operations.
- Logistics.
- Planning/Intelligence.
- Finance/Administration.

A radiological emergency response team can support several of these functional areas.

- Monitoring and assessing radiological information and providing advice and guidance to decision makers are tasks that contribute to the planning/intelligence function.
- Supporting tactical operations by providing radiological monitoring, and suggesting contamination control and exposure control measures, contributes to the operations function.
- Identifying needs for and locating radiological survey equipment and contamination control materials assists the logistics section.

If your answer included all of most of the above points, you should be ready for the Summary Questions at the end of this unit. Turn to page 2-27.

If your answer did not include these points, it would be advisable for you to complete the programmed instruction for this unit. Turn to page 7-3.

INTRODUCTION TO THE INCIDENT COMMAND SYSTEM (ICS)

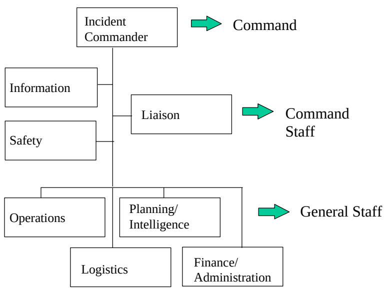
ICS minimizes communications and coordination problems and facilitates the protection of life and property by pre-establishing a command structure for any incident. The command structure identifies the:

- Commander.
- Command staff.
- General staff.

In a simple incident, the Incident Commander may be able to manage all command functions, including working with the media. When an incident becomes large-scale or critical, or if the Incident Commander cannot effectively manage the command functions, a Command Staff is implemented. A "critical incident" is any natural or man-made event, civil disturbance, or any other occurrence of unusual or severe nature which causes or threatens to cause the loss of life or injury to citizens and/or severe damage to property. Critical incidents require extraordinary measures to protect lives, meet human needs, and achieve recovery. For a critical incident to be handled effectively, "economy of resources" must be considered. Economy of resources requires:

- Establishing goals.
- Setting priorities.
- Assigning resources.

In a large-scale or critical incident, the expanded ICS structure includes:



- Command, including Information, Liaison, and Safety.
- Operations.
- Logistics.
- Planning/Intelligence.
- Finance/Administration.

In the ICS Command function, the *Information Officer* works with the media and provides them with accurate and consistent information. The Incident Commander appoints an Information Officer when he or she cannot manage the incident and the media. The *Liaison Officer* acts as a diplomat and a point of contact for assisting and coordinating agencies, providing lines of authority, responsibility, and communication. The *Safety Officer* ensures that safety procedures and safe practices are observed, and identifies unsafe or hazardous conditions that may exist or develop. The Safety Officer also formulates measures to protect the safety of personnel, and takes immediate action to stop or prevent unsafe acts when time or conditions require such action.

The *Operations* function manages tactical operations. The *Planning/Intelligence* section collects, evaluates, disseminates, and uses information about the incident and the status of resources to plan a course of action. The *Logistics* function provides the facilities, services, and materials to carry out the plan, while the *Finance/Administration* function manages all costs and financial considerations of the incident. Each major function may be expanded to allow a large-scale or complex incident to remain manageable and allow information to continue to flow in an organized fashion. ICS is recognized as the foundation for an effective all-risk emergency planning and response capability.

QUESTION

Circle the correct answer

If someone asked you to describe ICS would you say it was:

a. a communications system

b. a management system

Turn the page to check your answer.

ANSWERS

a. Incorrect answer. However, communications are greatly enhanced by the ICS because the system forces agencies to work closely together in the planning as well as the operations. phases.

Review page 7-3.

b. Correct answer. ICS is a management tool that enables any company or organization to function in a multi-organization environment.

QUESTION

Circle the correct answer

The ICS is tailored to the incident by being expanded and contracted.

a. True

b. False

Turn the page to check your answer.

ANSWER

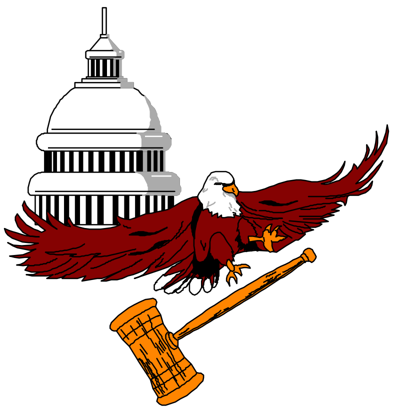
a. Correct. If the incident is too large or complex to be handled by one Incident Commander, the ICS structure may be expanded.

Proceed to page 7-8

b. Incorrect.

Review the information on ICS structure on page 7-3.

LAWS RELATING TO ICS



There is a legal basis for adopting ICS because there are Federal laws that require its use for specific types of incidents.

- SARA, the Super Fund Amendments and Reauthorization Act of 1986, established Federal regulations for handling hazardous materials. SARA directed the Occupational Safety and Health Administration (OSHA) to establish rules for operations at hazardous materials incidents.
- OSHA rule 1910.120, effective March 6, 1990, requires that all organizations that handle hazardous materials use ICS. The regulation states: *The Incident Command System shall be established by those employers for the incidents that will be under their control and shall be interfaced with the other organizations or agencies who may respond to such an incident.*
- The Environmental Protection Agency requires non-OSHA States to use ICS at hazardous materials incidents.

Many incidents require a response from a number of different agencies. For example, a multi-car traffic accident would require medical services, law enforcement, and even public works -- if damage is done to utilities. To coordinate and use all of these resources most efficiently, a system for organizing the resources must be functioning. Such a system lends consistency to the way team members and agencies function in an emergency, and fosters efficiency by eliminating the need to “reinvent the wheel” for each new emergency. To be truly effective, the system also uses an integrated approach to ensure its applicability to all incidents.

Answer the following question to check your understanding of this section.

QUESTION

Circle the correct answer

OSHA 1920.120 requires organizations handling radioactive materials to use ICS.

a. True

b. False

Turn the page to check your answer.

ANSWERS

a. Correct. OSHA requires organizations handling hazardous materials to use ICS, and radioactive materials are classified as hazardous materials.

Move on to page 7-12

b. Incorrect. OSHA regulation states that ICS is required by all organizations that handle hazardous materials incidents..

Review page 7-8.

QUESTION

Circle the correct answer

EPA requires the use of ICS at all hazardous materials incidents.

a. True

b. False

Turn the page to check your answer.

ANSWERS

a. Incorrect. EPA only regulates certain states (see answer below).

Review page 7-8

b. Correct. EPA only requires non-OSHA states to use ICS at hazardous materials incidents. However OSHA requires ICS for hazardous materials incidents in OSHA states therefore all states effectively have this requirement.

Proceed to page 7-12

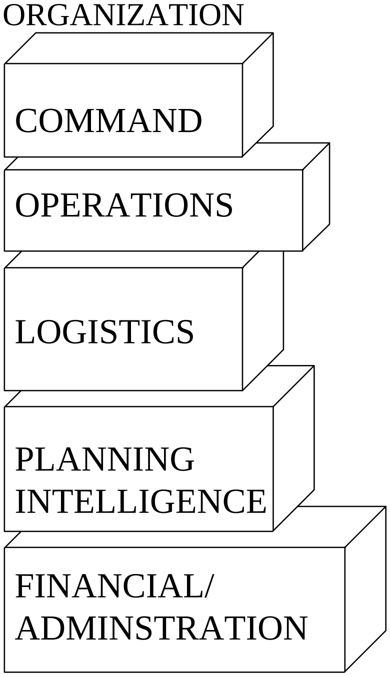
ICS CONCEPTS, PRINCIPLES, AND STRUCTURE

COMMON TERMINOLOGY

The need for common terminology in any emergency management system is essential, especially when used by diverse agencies. In ICS, major organizational functions and units are pre-designated and the system's terminology is standard and consistent.

To prevent confusion when multiple incidents occur within the same jurisdiction or on the same radio frequency, each incident is named. For example, if an incident occurs at 16th and Rivermont, it could be called the "Rivermont Command." An incident that occurs at 16th and Bellingham could be called the "Bellingham Street Command." Common names are established and used for all personnel and equipment as well as for all facilities in and around the incident area.

MODULAR ORGANIZATION



ICS organizational structure develops from the "first in" unit at any incident. The five functional areas are implemented as the need develops at an incident site.

The command function is always established. Specific ICS organizational structure for any incident is based on the incident's management needs. A modular organization can expand or contract, depending on the magnitude of the incident or operational necessity.

INTEGRATED COMMUNICATIONS

Lack of an integrated communications system is one of the biggest problems at major disaster sites. Integrated communications involves managing communications at incidents through the use of a common communications plan. Standard operating guides (SOGs) should be established using common terminology and clear text.

Effective two-way communication is essential to effective incident management. Not only is it important that messages are received, but it is also important that messages are acknowledged properly.

QUESTION

Circle the correct answer

What function is always established under the ICS regardless of the incident magnitude?

a. Operations.

b. Command.

Turn the page to check your answer.

ANSWERS

a. Incorrect. Operations are carried out but sometimes they can be accomplished by the IC.

Try another question

b. Correct. Command is always established regardless of the size of the incident.

Proceed to page 7-16

QUESTION

Circle the correct answer

What is the biggest problem noted at disaster sites?

a. Lack of unified command.

b. Lack of integrated communications.

Turn the page to check your answer

ANSWERS

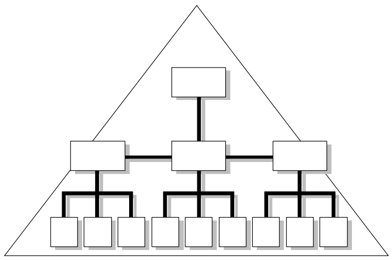
a. No. Although this could prove to be a big problem, it is not the biggest complaint noted at disaster sites.

Review page 7-12 before you continue.

b. Yes. Unless you can communicate the needs and the resources available to meet those needs, your operation is severely hampered.

Proceed to page 7-16.

UNITY OF COMMAND



ICS is built, in part, on the concept of unity of command. Unified command is shared responsibility for overall incident management as a result of a multi-jurisdictional or multi-agency incident. In the event of conflicting priorities or goals-or where resources are scarce-there must be a clear line of authority for decision making.

The command function within ICS may be conducted in two general ways:

- Single command may be applied when there is no overlap of jurisdictional boundaries or when a single Incident Command (IC) is designated by the agency with overall responsibility for managing the incident.
- Unified command may be applied when the incident occurs within one jurisdiction but management responsibility is shared by more than one agency. Unified command also is used when an incident is multi-jurisdictional in nature -- or when more than one individual, designated by his or her jurisdiction or agency, shares overall management responsibility.

The concept of unified command means that all involved agencies contribute to the command process by:

- Determining overall goals and objectives.
- Jointly planning for tactical activities.
- Conducting integrated tactical operations.
- Maximizing the use of all assigned resources.

Selection of participants to work effectively within a unified command structure depends on the location and type of incident.

A unified command structure could consist of one key official from each jurisdiction or representatives of several functional departments within a single political jurisdiction. Implementing action plans under a unified command is the responsibility of the Operations Section Chief. He or she usually represents the agency with the greatest jurisdictional involvement. Under the unified command concept, all agencies involved contribute to the command process.

CONSOLIDATED ACTION PLAN

Every incident needs some sort of consolidated action plan. Action plans can be either written or verbal-but all should cover:

- Strategic goals.
- Tactical objectives.
- Support activities needed during the entire operational period.

THE COMMAND POST

The Command Post (CP) is the location from which all incident operations are directed. There is only *one* CP. The CP is the location from which direction, control, coordination, and resource management are exerted over the incident. Ideally, the CP houses the:

- Incident Commander.
- Planning/Intelligence function.
- Communications Center.
- All agency representatives.

In some incidents, however, housing all of these persons at the CP may not be practical. In this case, *separate areas* must be clearly designated. Sometimes the Emergency Operations Center (EOC) is established. The purpose of the EOC is to provide a central location from which government at any level can provide interagency coordination and executive decision making for managing disaster response and recovery. The important thing to remember is that ICS manages the incident. The EOC should be in place to provide the support of established policy, coordination of multi-government resources, and financial commitment that only elected officials can provide.

QUESTION

Circle the correct answer

Unified command is applied when more than one agency shares management responsibility.

a. True

b. False

Turn the page to check your answer.

ANSWERS

a. Correct. Unified command is necessary in multi-jurisdictional or multi-agency incidents.

b. Incorrect. Unified command is established because of multiple agency involvement. In the event of conflicting priorities or goals, or scarce resources, there must be a clear line of authority for decision making.

Review page 7-16.

QUESTION

Circle the correct answer

The EOC provides

a. Interagency cooperation

b. An alternative to ICS management.

Turn the page to check your answer.

ANSWERS

a. Correct.

Move on to page 7-21

b. Incorrect. The EOC can enhance the ability of operations at the scene by coordinating additional resources and providing the decision making necessary for recovery. However the ICS manages the incident with or without the activation of the EOC.

Review pages 7-17 and 7-18.

RADIOLOGICAL EMERGENCY RESPONSE OPERATIONS WITHIN THE INCIDENT COMMAND SYSTEM

Where does the RRT fit into the Incident Command System? Recall that the *planning/intelligence* function includes the collection, evaluation, dissemination and use of information about the development of the incident and the status of resources. This is one place where radiological emergency response skills and capabilities are used in the ICS. Monitoring and assessing radiological information and providing advice and guidance to the Incident Commander are tasks that come under the planning/intelligence function.

When radiological emergency response teams support tactical operations by providing radiological monitoring in support of emergency operations and establishing contamination control and exposure control measures, they are part of the *operations* function.

When radiological emergency response team members assist in identifying the need for and then locating radiological survey equipment and contamination control materials, they are assisting the *logistics* section. Radiological emergency response teams must be prepared to assist the IC in establishing and carrying out first and second level response priorities.

In larger events, there may be a representative of the State or local radiation authority located at the EOC, receiving radiological data from the incident and providing hazard assessment and response guidance to decision makers.

QUESTION

Circle the correct answer

By providing radiological monitoring in support of emergency operations and establishing contamination control and exposure control measures, radiological emergency response team members support what ICS function?

a. Planning/intelligence

b. Operations

Turn the page to check your answer.

ANSWERS

a. No, these are tactical tasks that are considered part of the operations function.

Review page 7-21.

b. Correct.

QUESTION

Circle the correct answer

When radiological survey teams provide monitoring reports used in assessing the radiological hazard, they are supporting what ICS function?

a. Planning/intelligence.

b. Logistics.

Check your answer on the next page.

ANSWERS

a. Correct. Instrument readings from radiological survey team members provide hard data that can be used by the IC to make planning and tactical decisions.

Proceed to page 7-25.

b. Incorrect.

Review page 7-21 before proceeding.

SUMMARY QUESTIONS

QUESTION

Circle the correct answer

1. The radiological emergency response team leader at a radiological accident scene takes direction only from the State Radiation Authority.

   a. True

   b. False

Check your answer on the next page.

ANSWERS

a. Incorrect. The radiological emergency response team may report to and receive advice from the State Radiation Authority, but the Incident Commander is in charge at the accident scene.

Go back and review this unit.

b. Correct answer.

Move on to the next Summary Question.

QUESTION

Circle the correct answer

2. Which incident is more likely to initiate the activation of the Emergency Operations Center?

   a. Fire and explosion causing the declaration of a Site area emergency at a nuclear power plant.

   b. Three-vehicle accident involving a delivery truck carrying a box of radiopharmaceuticals.

Turn the page to check your answer.

ANSWERS

a. Correct answer. The EOC is activated to provide a central location from which government at any level can provide interagency coordination and executive decision making. A nuclear power plant accident has the potential to require the support of established policy, coordination of multi-government resources, and financial commitment that only elected officials can provide.

Move on to Unit Eight.

b. Incorrect answer. In most cases, radiopharmaceuticals are unlikely to create a major radiation hazard, and automobile accidents are usually managed by an Incident Commander at the scene.

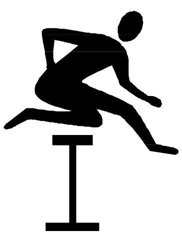
Review this unit before proceeding to Unit Eight.

UNIT EIGHT

PUBLIC INFORMATION AND MEDIA RELATIONS

Public information and media relations were not covered in FEMA's *the Fundamentals Course for Radiological Monitors* nor the *Fundamentals Course for Radiological Response Team* courses. However, you may have studied effective communications in other professional development courses or attended FEMA's *Basic* or *Advanced Public Information Officer* courses. If you have experienced working with the media or have attended these courses, this section will be a review. If not, it will provide valuable new knowledge for you to apply in your radiological response role.

GATE FRAME QUESTION



You are at the scene of a major radiological incident and the Incident Commander calls you to the command van. There you find a group of reporters gathering and see a satellite truck setting up just beyond the site perimeter. The Incident Commander asks you to handle this group until the Public Information Officer (PIO) arrives. What do you do next?

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ANSWER

Your answer should include the adjacent information

First, introduce yourself to the reporters and ask them to stand by for information regarding a briefing. Then contact your agency's Public Information Officer, who will establish a time and place (usually at the Emergency Operations Center, or EOC) for the briefing to be held. The first briefing should be held as soon as possible, perhaps 15 to 30 minutes after your announcement.

Once you have this information, announce to the reporters where information will be available and the time for the first briefing. Because of the shortness of time, many will leave to attend the briefing. Others may stay to capture the event on film and ask for access to get a better shot. You will follow agency guidelines on working with the media at the scene.

Some of the media will try to interview you. Explain that all questions will be answered at the briefing, and that you do not have all the information they will need. Provide directions to the briefing or whatever you can do to encourage them to attend the briefings. If you find yourself speaking to the media despite the agency's guidelines, look directly at the reporter (not the camera), speak in plain English, and do not use jargon.

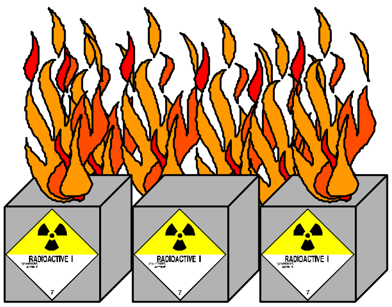
- Do not say "No comment."
- Do not speculate or hypothesize about the situation.

If your answer included all or most of the above points, you should be ready for the Summary Questions at the end of this unit. *Turn to page 8-20.*

If your answer did not include these points, you should read the programmed instruction for this unit. *Turn to page 8-3.*

THE NEED FOR GOOD PUBLIC INFORMATION PROCEDURE

You've seen it . . . a radioactive materials transportation accident was handled correctly by the response agency. Any radiological response expert reviewing the incident report would have seen a flawless response. But the community saw the incident through the eyes of a reporter who arrived on the scene before Incident Command.



Not understanding anything about radioactive materials, the reporter's first live remote caused massive panic in the neighborhoods nearest the industrial loop. The responders worked around calls from the mayor's office and interruptions by a growing number of media. The ambulance, delayed by a traffic jam caused by panicked residents evacuating the area, had to thread through several satellite trucks and mini-cam support vans. The camera's confused view lead the evening news and featured interviews with firefighter, law enforcement, and emergency medical personnel at the scene. None of them had the whole story, and this gave the impression that they were all confused and untrained.

There was an editorial in the morning paper about a "lack of caution" in the department's response to the accident; a front page story registered concerns from the hospital that their emergency room was contaminated when the injured truck driver was brought in for treatment. Despite having only a broken arm and a gash on his forehead, the hospital administrator assures the community that the patient is in "isolation for the protection of the public." One radio station is calling for the Chief's resignation.

Although the event just described is not based upon a real situation, it is realistic. With increasing technology, a small event can be live on national television. CNN and most local stations have the capacity to utilize home videos and often advertise for citizens to join their “news hawk” or “video reporter” team. Wherever you respond to an incident (even in the middle of nowhere), it is important to know that you will not be far from a camera. The event above demonstrates both the power of the media to form opinion and the importance of agencies developing a method to deal with the media in such an incident.

Answer the following question to assess your understanding.

QUESTION

If your radiological response team controls a radiological event successfully and according to procedure, but does not have a single point of contact for public information,

a. the media will see that the public is informed about your success.

b. the media’s version of the events may not accurately reflect the actual events.

Turn the page to check your answer.

ANSWERS

a. Not always. In fact, if the media hears the story in "bits and pieces" they interpret based upon incomplete information.

Try another question.

b. Right. The example in this section showed you how it can happen.

Turn to page 8-7.

QUESTION

As a radiological responder who is not associated with your agency's public information office, you are likely to be approached by the media.

a. true.

b. false.

Turn the page to check your answer.

ANSWERS

a. That is correct. If you are involved in an event that may interest the public, the media will consider you "fair game" for questions.

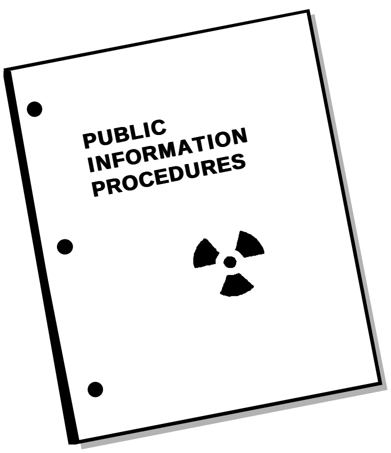
Turn to page 8-7.

b. No. It is not always true. In fact, it is likely to occur.

Review this section before proceeding to page 8-7.

BEFORE AN INCIDENT

Responding correctly to a radiological incident takes knowledge and practice, accomplished through training and exercises. Responding correctly to the needs and concerns of the public and the media also takes knowledge and practice. Although a few people seem to be naturals with public relations, most of us are not. This course is not intended to make you a media expert; rather, its goal is to familiarize you with the best way to work with the public and the media during an incident, a method that will enable you to concentrate on responding appropriately to the event rather than reacting to interruptions and questions of the public and media.



Your agency should have a plan for working with the media during a an incident (whether natural or technological). The plan should outline how information will be disseminated to the media and the public during an emergency. Most plans will describe the Emergency Alert System resources in the area. Most plans also will designate a PIO. This person will probably be the main contact with the media during an emergency. Depending on the size and nature of your agency, you may have a full-time public relations officer who works with the media on a day-to-day basis, writing routine media releases and speaking to the media regarding day-to-day activities. If the local media know that your PIO understands deadlines, knows video reporters need pictures, and knows print journalists need a lot of information, they will prefer to work with the PIO. The local media will feel comfortable with this person during an emergency.

Find out the name of your agency's PIO. Depending on the nature of your agency, the PIO may be very knowledgeable regarding radiological concerns and response. If so, breathe easier. In a real emergency, your PIO is unlikely to call you away from response work to talk with the media. If, however, your agency works with many hazards, the PIO may have little knowledge of radiological hazards and response and so will need more input from you during an incident.

Answer the following question to test your understanding of this section.

QUESTION

Circle the correct answer

If, after responding to a transportation incident involving medical radionuclides, a reporter asks you to do a live remote, you should

a. assume that because you are a member of a radiological emergency response team, you will be able to respond to the reporters questions.

b. refer the reporter to your PIO and explain that you will be glad to answer further questions if the PIO thinks that would be necessary.

Turn the page to check your answer.

ANSWERS

a. No. Even if you have had training in dealing with the media, you should refer the reporter to the PIO. Because the PIO works with the media every day, he/she will be in the best position to provide the media with what they need to tell their story.

Review page 8-7 and try the next question.

b. Correct. The PIO will have most of the information the reporter needs. If some technical data is needed, the PIO may ask you to provide this information to the reporter.

Proceed to page 8-11

QUESTION

Although it is just an exercise, you find a large number of media showing up at the scene. They are trying to get close enough for a good "shot," and one reporter is trying to interview the Incident Commander. You should

a. have someone contact the PIO to assist by coming to the scene, working with the media from the operations center, or giving some suggestions for controlling the situation.

b. threaten to have the media removed from the scene and ask law enforcement to start making arrests.

Turn the page to check your answer.

ANSWERS

a. Right. Although the media should not interfere with the task at hand, you should not try to keep the media from getting a story. In the post-exercise briefing, the problem with the media should be addressed and changes in procedure should be made as necessary.

Turn to page 8-11.

b. Wrong answer. Remember, the public will see you shouting at the camera. They will not see the earlier footage of you doing your job. Your reaction to the media could be a bigger story than the actual event. Overreaction to the media could be perceived as an indication that the situation is very "serious" and that local agencies do not have things under control; this could contribute to panic during an event and complaints after the event.

Return to page 8-7 and reread this section before moving on.

USING THE MEDIA TO DISSEMINATE INFORMATION

After a cyclone devastated a remote portion of Australia, one of the first items distributed by relief flights was transistor radios. No local broadcasting systems had survived the storm, and there was no power and few backup systems. The transistors allowed the response agencies to give information directly to the people who needed the information through broadcast.

After the 1989 San Francisco earthquake, one vacationing firefighter made the national news when he got a free ticket from Chicago to San Francisco by presenting his firefighter's badge to an airline official. He had been watching CNN when his boss held a media conference to say he was canceling all leave and needed all available firefighters. While the firefighter's dedication made news, it is important to note that the media can play a very important role in providing accurate and important information to those who need to know that information.

While these are good examples of the positive approach to working with the media during a crisis, there are plenty of examples of the negative approach. Soviet officials denied the presence of a problem until the radioactive cloud from Chernobyl could no longer be kept secret. At Three Mile Island, the lack of a controlled central point for information lead to misinformation, rumors and panic.

Media often have been used to announce evacuation areas due to threat of natural or manmade disasters. The Emergency Alert System is one resource for disseminating this kind of information. However, sometimes communications are not clear between the responders and the media. In one instance, residents called headquarters to ask why the police were asking them to leave when the media was reporting that the toxic spill at a train derailment was under control. At another incident, persons in an affected area kept evacuating long after the threat to the area had passed; authorities had failed to advise the media that the situation was under control and residents could return to their homes.

Apply the above information to the following scenario.

QUESTION

Circle the correct answer

A fire occurs at a radiopharmaceuticals factory in your jurisdiction. The downwind area is evacuated as a precaution. It is soon apparent that there is no contamination in the area and residents can return to their homes. How do you let them know they can go home?

a. You work with your PIO to develop a media release explaining that the area is safe and announcing that residents should return. The PIO will distribute this information to the media.

b. You pick up the phone and call the local radio station and tell them to announce that residents can go home.

Turn to the next page to check your answer.

ANSWERS

a. This is the correct response. The release should reassure residents that neither the area nor their homes are dangerous. Having the PIO distribute the information to the media will ensure a thorough dissemination of this good news.

Turn to page 8-14.

b. Incorrect answer. By calling one local station directly, you will create a lot of problems for your agency and the PIO. If only one source reports something, some people will not trust the information. Because most people do not understand radiation nor contamination, they may be reluctant to return home without assurances from "authorities" that they are safe. The public realizes that the reporter will know little more than they do about radiological dangers. By reporting to only one source, you also may create problems for your agency in the future. PIOs do not play favorites with the media; neither should you.

Please review page 8-11 before continuing.

INTERACTING WITH THE MEDIA DURING AN INCIDENT

As mentioned earlier, it is important for your agency to have someone to work with the media—someone who understands the needs of the various mediums (print versus broadcast, etc.) and understands the pressures of deadlines. The PIO will work with local media during non-emergency conditions so all members of the media are familiar with your agency and your procedures.

If you have a central point to distribute information during an emergency, the media will probably report there for primary information. The central point is sometimes called a *Joint Information Center* (JIC), especially for multi-agency incidents, or a Public Information Center. From this point, information can be controlled and coordinated to allow all information to flow as quickly and correctly as possible.

In some communities, the sight for the JIC may be located in the Emergency Operations Center. Wherever your agency locates the JIC, most agencies use the briefing as a method to provide information to media during a crisis. Because the media will want to be part of the briefings, they will accept your format and rules. Providing fast, accurate information without playing favorites will get respect and attention from the media. If you give information only at these briefings and all media are treated equally, it is possible to maintain an effective control of the flow of information.

Even though the PIO will be the main contact with the media, it is sometimes necessary to have "experts" present at the briefings. This is often true for technical and manmade disasters, including radiological accidents. Reporters have always been generalists, and recent cost-cutting at the networks has done nothing to change this. It uhms," and "you knows."

- If you normally wear eyeglasses, keep them on. Sunglasses or glasses with self-darkening lenses should be removed. When people cannot see your eyes, you look as if you are trying to hide something.

- Listen to all the questions and all the answers. If you look bored or disinterested, the audience will know.

- Do not look at the camera; instead look at the reporter.

- Speak in plain English and avoid any jargon. If you must use jargon, explain it.

- Do not accuse other responders, agencies, the media, or the public of causing the problem or making matters worse. Talk about solving the problems, not who caused them.

- Do not feel pressured into answering questions for which you are not responsible or prepared to answer. Tell reporters that this is not your area of expertise and either direct them back to the PIO or say that you will find out the answer.

- Remember the answer "No Comment" leaves the wrong impression on the public and may cause the media to dig deeper to see just why you would not comment.

- Ask for clarification of questions you do not understand.

- If you do not know the facts, <u>do not speculate</u> and do not hypothesize. You cannot easily retract statements later.

Check your comprehension by answering the following question.

QUESTION

Circle the correct answer

Suppose while you are attending a briefing a reporter directs a question to you regarding a particular aspect of the response. You suggested a different approach, but after much discussion another method was chosen. You tell the reporter

a. that you believe this approach is more costly and too cautious as well as very time consuming.

b. that this method should accomplish the goals of the response team and explain why it should work.

Turn the page to check your answer.

ANSWERS

a. Telling the reporter that you did not agree with the decision would only cause problems for you and the team even if you are later proven correct. The media and the public will have little faith in anything your team does if they think that even the experts cannot agree.

Please review the suggestions for conduct at a briefing on page 8-15. Then answer the next question.

b. That's right. Even though you may feel that your method would be the best, you are a member of a team and your job is to support and participate in team actions in order to accomplish the overall goal of protecting the population from harmful radiation effects. The public must see a synchronized team effort in order to have confidence in the instructions they receive. An alternative answer would be to tell the reporter that someone else could probably answer the questions better and then refer the reporter to someone who supports and has with knowledge of this particular method.

Turn to page 8-19.

QUESTION

You have been called to participate in the briefing early on in an accident involving a van containing the medical radioisotopes technetium-99m and iodine-131. A reporter asked you to explain what type of danger this material presents to the residents of the new homes along the interstate.

a. You explain that the these amounts and forms of technetium-99m and iodine-131 do not pose hazards to residents along the highway unless they come into direct contact with the material. The perimeter of the accident scene has been cordoned off temporarily until all of the material has been removed.

b. You tell the reporter that these radioisotopes emit penetrating gamma radiation that has the potential to cause internal and external biological damage.

Turn the page to check your answer.

ANSWERS

a. Yes this is the proper response. The reporter may ask a couple of follow-up questions for clarification, but speaking plainly will help get the information to the public in a non-threatening manner.

Turn to page 8-19.

b. If this is your response, you have just caused panic in the streets. The average reporter does not understand most of what you said, and the public just heard the part about penetrating gamma rays. Most of what they know about gamma rays came from watching movies about aliens when they were children. It is very important that you speak clearly and calmly and use plain language.

Reread the section on working with the media on page 8-14 before moving on to the Summary Questions on page 8-19.

SUMMARY QUESTIONS

QUESTION

Circle the correct answer

1. Part of the Incident Commander's responsibilities include working with the media or assigning one of the responders to do so at the scene.

   a. true.

   b. false.

Turn the page to check your response.

ANSWERS

a. Incorrect. Although on a very large scale accident, the media may work with a member of your agency at the scene, all contact with the media should be directed to the Public Information Officer.

Go back to page 8-7 and review before answering the next Summary Question.

b. Correct.

Move to the next Summary Question.

QUESTION

Circle the correct answer

2. The Public Information Officer has asked you to attend a briefing at the Emergency Operations Center later in the day. You review the situation board to update yourself on the accident and feel well prepared for the media. When you are asked to explain a specific, technical concern and how you hope to solve this problem, what do you do?

    a. You should look at the reporter who asked the question and speak clearly, honestly, and in plain language to explain the situation. Go into more detail only if the reporter feels it is necessary.

    b. Look into the camera and explain the situation in minute detail using all the correct scientific terms. This shows that you are very knowledgeable and that the public should not worry.

Turn the page to check your answer.

ANSWERS

a. Correct.

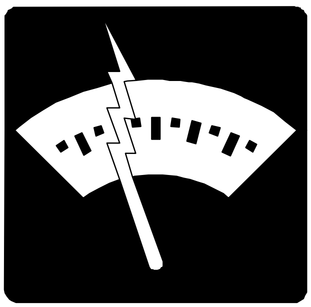
Move on to the next unit.

b. Incorrect. The basic rule for appearing on camera is to look at the reporter who asked the questions rather than into the camera. Looking into the camera will make you look vain. Speaking in scientific jargon also will make you look vain. By using words the public cannot understand, you may increase their anxiety rather than calm them. They may assume the situation is much worse than they feared because you are disguising the information behind jargon.

Before moving on to the next unit, go back to the suggestions for attending a briefing and review.

UNIT NINE

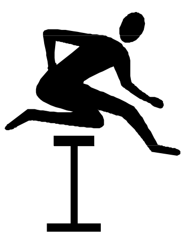
ENVIRONMENTAL MONITORING



Information concerning the characteristics of potential and actual releases of radionuclides are needed to determine emergency action levels (e.g., PAGs), to recommend protective action, and to identify critical exposure pathways. This information can be obtained by environmental monitoring.

This unit will cover the main objectives and purposes for environmental monitoring, as well as the instruments used. This topic is covered in detail in FEMA's *Radiological Accident Assessment* courses. In this course the unit is intended as a review for those participants who have already mastered the competencies involved, and a critical learning objective for those who have not.

GATE FRAME QUESTION



Define "environmental monitoring" and state at least two purposes for environmental monitoring.

ANSWERS

Your answer should include the adjacent information

Environmental monitoring is the assessment of the actual or potential exposure of an individual to radioactive materials which may be present in his or her environment.

Environmental monitoring is the assessment tool which may also confirm the absence of radioactive materials in the environment.

Purposes for environmental monitoring include:

- Verifying that the release has occurred;
- Providing data for input into analytical models;
- Defining affected areas; and
- Estimating hazards to the public.

If your answer included all or most of the above points, you should be ready for the summary questions at the end of this unit. *Turn to page 9-14.*

If your answer did not include these points, it would be advisable for you to complete the programmed instruction for this unit. *Turn to page the next page.*

ENVIRONMENTAL MONITORING

Environmental monitoring is the assessment of the actual or potential exposure of an individual to radioactive materials present in his or her environment. Depending on the nature of the radioactive release, both short-term and long-term environmental monitoring may be necessary.

Short-term measurements, which are performed by emergency personnel during the period of the initial emergency response, are primarily aimed at providing information for analysis and data for determining appropriate action levels and mitigation measures.

Long-term monitoring is generally conducted by supporting or consulting personnel after the release is terminated, and is performed to provide detailed analyses of radiological hazards and accident consequences.

Monitoring results can be used to verify that a release has occurred, provide data for input into analytical models, and define affected areas. Measured data can also be used to estimate hazards to the public.

Conversely, monitoring results may confirm the absence of a radiological hazard.

QUESTION

Circle the correct answer

To test your knowledge of environmental monitoring, answer the following question.
What type of environmental measurements are made to determine appropriate action levels and mitigating measures?

a. short-term.

b. long-term.

Turn the page to check your answer.

ANSWERS

a. Correct answer. Protective actions should be implemented, if warranted, as soon as possible. Short-term measurements would yield results that could provide a basis for decisions leading to a prompt and appropriate emergency response.

Proceed to page 9-6.

b. Incorrect. Long-term measurements are performed to provide detailed analyses of radiological hazards and accident consequences.

Try another problem.

QUESTION

Circle the correct answer

Environmental monitoring results can be used to estimate hazards to the public.

a. true.

b. false.

Turn the page to check your answer.

ANSWERS

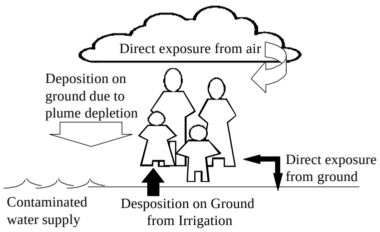
a. You're right.

Move on to the next section.

b. Wrong answer. The statement is true. Radiation data generated by environmental monitoring can help determine whether exposure levels are high enough to create a hazard to the public.

Review this section before moving on to the next section.

ENVIRONMENTAL MONITORING PROGRAMS



EPA's *Manual of Protective Action Guides and Protective Actions for Nuclear Incidents* (EPA 400-R-92-001) identifies three categories of exposure pathways and the dose levels at which protective actions are indicated. Exposure may result from whole body external exposure, inhalation of suspended particulate radioactive materials, or from ingestion of contaminated food and water. An environmental monitoring program must be in place so that in a nuclear incident, potential dose levels in any or all of these potential exposure pathways may be projected.

The function of an environmental monitoring program is to acquire sufficient radiation data to confirm protective action decisions that have been made in time to ensure that radiation exposure to the public will be as low as is reasonably achievable (ALARA). By the same token, it is necessary to consider keeping the cost of the program within reasonable limits, without compromising ALARA exposure, by utilizing existing instrumentation and resources whenever possible. Therefore, planning for the design and implementation of the program must be thorough to assure a rapid and proper response in the event of a radiological accident.

Effective evaluation of gathered information and coordination of environmental monitoring activities require the establishment of a sound environmental monitoring program. This program should be run by a facility staffed by personnel capable of directing field operations and interpreting analytical and measured results. This facility must have reliable communications capability to primary and backup monitoring personnel, emergency directors, laboratory facilities, transportation agencies, and weather services.

Environmental monitoring facilities must be licensed. The license will spell out the extent of the required environmental measurements. Many licenses require that monitoring play a limited role because the radionuclide involved poses little risk to the public. In contrast, facilities such as waste burial grounds, nuclear power stations, and fuel processing plants require extensive monitoring programs.

To check your understanding of these concepts, answer the following question

QUESTION

Circle the correct answer

One reason for maintaining an environmental monitoring program is

a. to acquire sufficient radiation measurement results to confirm protective action decisions.

b. to promote the benefits of radionuclides in modern technology.

Turn the page to check your answer.

ANSWERS

a. Right! The protective action decisions ensure that radiation exposure to the public are at ALARA levels. Such decisions could not be made without knowing the radiation levels at hand.

Continue to the next section.

b. No. Although radionuclides do play an important role in many facets of today's technology (such as radiotherapeutics and research), their benefits are not promoted by environmental monitoring programs. These programs are designed to provide environmental radiation data that aid in the planning, response, and analysis stages of a radiological incident.

Try another question.

QUESTION

Circle the correct answer

All facilities utilizing radiation should maintain extensive environmental monitoring programs.

a. true.

b. false.

Turn the page to check your answer.

ANSWERS

a. Incorrect. Some facilities use radionuclides in amounts that pose very little risk to the public. These places do not require extensive monitoring. Other facilities may use radionuclides in amounts that are hazardous to the public, and therefore require much more extensive environmental monitoring programs.

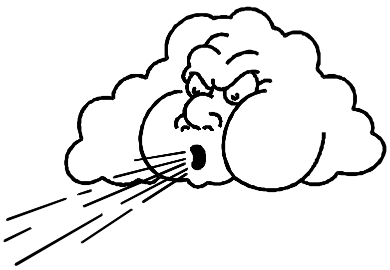
You should reread this section before proceeding.

b. Correct answer. You understand that not all facilities have the same requirements for their environmental monitoring program.

Go ahead with the next section.

ENVIRONMENTAL MONITORING INSTRUMENTATION

AIRBORNE RELEASE



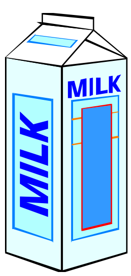
For airborne releases, measurements to be made by initial environmental monitoring teams include dose rate in air, airborne particulate activity, and airborne iodine activity.

Dose rate can be measured using a standard radiation survey detector (movable window ionization detector) held at waist height. This measurement provides an indication of the radiological hazard resulting from whole-body exposure to external gamma rays from immersion in the plume and from ground contamination.

Airborne particulate activity can be measured using high-volume, high-efficiency filtered or impact air samplers. Particulate samples can be evaluated in the field for alpha and beta-gamma activity using standard survey meters.

Fixed instruments used for airborne environmental monitoring include passive dosimeters (thermoluminescent or film), airborne particulate filters, and iodine absorber canisters.

MILK



Iodine-131 is the nuclide of major concern in contaminated milk because it is deposited in the human thyroid and the thyroid is a critical organ. The instrument system currently recommended for field monitoring of milk at the preventive PAG level is a hand-held Sodium Iodide (NaI) detector. This instrument system should be used with the ion exchange method, a filtering and collecting process. However, this system is also sensitive enough to be used with the immersion method for milk sample monitoring. Available information indicates that other types of hand-held instrumentation such as Geiger-Mueller or ion chamber detectors are not sensitive enough for this task.

NON-DAIRY FOOD AND WATER

After emergency monitoring of surface-deposited radioactivity defines the boundaries of contaminated areas, non-dairy food and drinking water within the boundaries should be sampled and analyzed. Laboratory tests on food samples may include strontium analyses or other chemical separations. Field monitoring instrumentation for water should be similar to that recommended for emergency milk monitoring, i.e. immersion counting or ion-exchange resin counting.

Try the following question to apply your knowledge of environmental monitoring instrumentation.

QUESTION

Circle the correct answer

Airborne particulate samples can be collected using

a. column anion resin exchange.

b. high-volume, high-efficiency filtered air samplers.

Turn the page to check your answer.

ANSWERS

a. Wrong answer. Airborne particulate matter is collected using high volume air samplers or fixed particulate filters. The column anion resin exchange method is used for liquids.

Try another problem.

b. Yes, you are right.

Go ahead to the next section.

QUESTION

Ionization detector measurements provide an indication of the radiological hazard resulting from whole-body exposure to external ____________________________ from immersion in the plume and from ground contamination.

a. alpha radiation.

b. gamma radiation.

Turn the page to check your answer.

ANSWERS

a. No. Ionization detectors can only detect gamma radiation.

You should go back and reread that section before proceeding to the Summary Questions.

b. Correct answer.

Proceed to the Summary Questions.

SUMMARY QUESTIONS

QUESTION

1. Facilities such as radioactive waste burial grounds, nuclear power stations, and nuclear fuel processing plants

   a. do not require extensive environmental monitoring programs.

   b. require extensive environmental monitoring programs.

Turn the page to check your answer.

ANSWERS

a. Incorrect. The sources at these facilities may produce high level radiation doses. Their licenses require extensive monitoring programs.

Go back to page 9-3 and review before answering the next Summary Question.

b. Correct.

Move on to the next Summary Question.

QUESTION

2. *Initial* environmental monitoring involves radiation measurements in

   a. air.

   b. food.

Turn the page to check your answer.

ANSWERS

a. Correct.

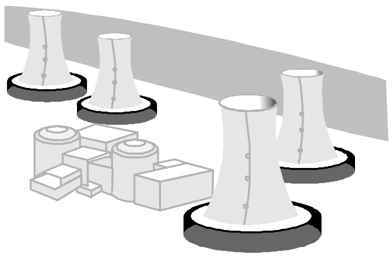
Proceed to Unit Ten.

b. Incorrect. It is unlikely that initial environmental measurements will detect radioactivity in food. Although food contamination does occur, it cannot be measured immediately after the radiological incident.

Go back to page 9-3 and review before proceeding to the next unit.

UNIT TEN

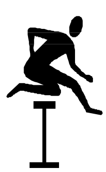
INTRODUCTION TO NUCLEAR REACTORS



The licensees of nuclear facilities have primary responsibility for planning and implementing emergency measures *within* their site boundaries. These emergency measures include corrective actions at the site and protective measures and aid for persons onsite. Since facility licensees cannot do this alone, it is a necessary part of the facility's emergency planning to make advance arrangements with State and local organizations for special emergency assistance such as ambulance, medical, hospital, fire and police services. State and local governments have responsibility for planning and implementing protective actions *outside* the site boundaries. Radiological response team members from State and local emergency services will be better prepared to carry out these responsibilities with some knowledge of nuclear power plant structure, operations and emergency response procedures.

The teaching points included in this unit should be recognized as a review by those who have completed the FEMA radiological series prerequisites or who have experience in the nuclear power industry.

GATE FRAME QUESTION



You are notified of a site area emergency at a nuclear power plant located nine miles from your town. The meteorologist has confirmed that if a release occurs, the town will be directly in the path of the plume. Part of the town is in the plume exposure pathway and the rest is within the ingestion pathway.

How do you interpret this information?

____

____

____

ANSWER

Your answer should include the adjacent information

A site area emergency means that events are in process or have occurred that involve actual major failures of plant functions needed for protection of the public. Any releases are not expected to exceed EPA PAG exposure levels except near the boundary. You will be periodically updated on emergency actions and notified to stand by for further instructions.

If a release occurs, the first 10 miles from the plant is considered to be the plume exposure pathway, or the path for airborne radioactive material in the plume. The plume would commonly contain radioactive noble gases and might also contain radioiodines and radioactive particulate materials. Many of these materials emit gamma radiation and can expose people nearby as the plume passes.

For a 50-mile radius, an ingestion exposure pathway has been defined as the most likely area where radioactive material would settle out from the plume and fall to earth. Principal exposure in this emergency planning zone (EPZ) would come from ingestion of contaminated water, milk, and food.

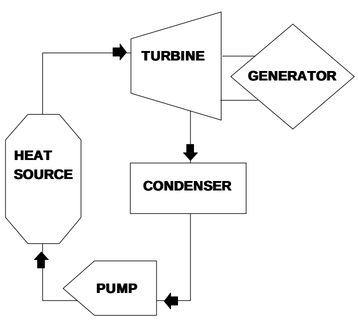
If your answer included all or most of the above points, you should be ready for the Summary Questions at the end of this unit. *Turn to page 10-23.*

If your answer did not include these points, it would be advisable for you to complete the programmed instruction for this unit. *Turn to page 10-3.*

NUCLEAR POWER PLANT STRUCTURE AND OPERATIONS

Virtually all commercial nuclear power reactors in the United States are either *pressurized water reactors* (PWRs) or *boiling water reactors* (BWRs). In both types of reactors the reactor core is covered with water to allow the nuclear reaction to take place and to keep the core cool.

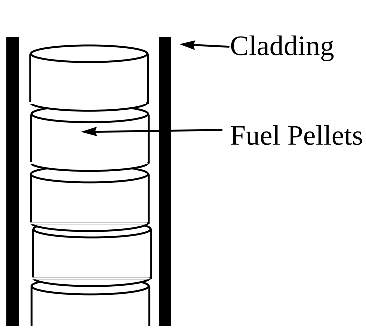
A nuclear power plant is a facility at which energy released by the fissioning of atoms is converted to electrical energy under strictly regulated operating conditions. The major processes are the same as those in non-nuclear (conventional) power plants except that the coal- or oil-fired boiler is replaced by a nuclear reactor.



A *heat source* provides heat to generate steam. In a nuclear power plant, the heat source is the nuclear reactor, often called the reactor core. A *turbine* generator uses the energy of the steam to turn a turbine that generates electricity.

The *condenser* condenses the steam back to water so that it can be returned to the heat source to be heated again. A power plant's condenser uses cool water pumped from a nearby lake, river, or ocean to condense the steam from the turbine. Because the water used to cool the condenser is warmer after use, a cooling tower is sometimes used to prevent a harmful temperature rise in the water supply.

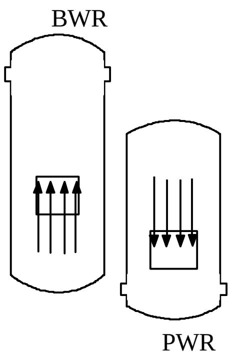
The *pump* provides the force to circulate the water through the system.



Nuclear power plants produce a great deal of heat through a chain reaction of fissions of uranium atoms. The uranium is contained in uranium dioxide *fuel pellets*. These pellets are stacked end-to-end to form a 12 foot long fuel rod that is encased in a metal tube called *fuel cladding*. Fuel cladding prevents radioactive fission products from escaping the fuel pellets into the reactor cooling water.

The nuclear chain reaction may be regulated by *control rods*. Control rods absorb neutrons, the atomic particles needed for the chain reaction to continue. When all of the control rods are inserted into the reactor core, it is called a *reactor shutdown* or *scram*.

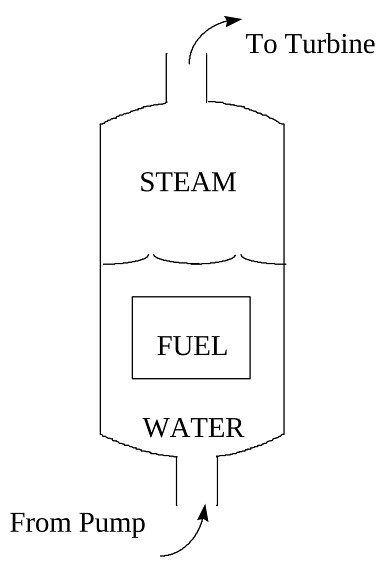
REACTOR SCRAM

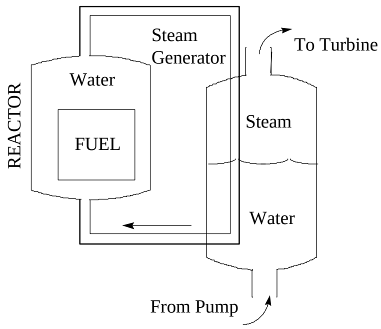


Rapid insertion of control rods to shut down the fission chain reaction

Both BWRs and PWRs require that the reactor core be covered with water for the nuclear chain reaction to continue. This *reactor cooling water* removes the heat generated in the reactor. In an accident resulting in a loss of the water covering the core, the reactor would scram.

The system that contains the reactor cooling water is called the *primary coolant system*. In BWRs, water is allowed to boil directly in the reactor core. The boiling water generates steam, which is drawn away from the reactor and used to rotate the turbine.





In PWRs, the primary coolant is maintained at a much higher pressure. Heat is removed by sending the primary coolant through a series of metal tubes while secondary cooling water flows around the tubes. Heat is thereby transferred from the primary cooling system, which is radioactive, to the nonradioactive secondary system.

The secondary coolant is maintained at a much lower pressure so that as the heat is transferred, the secondary coolant flashes to steam. That steam is used to rotate the turbine which generates electricity.

To check your understanding of these concepts, answer the following question.

QUESTION

Circle the correct answer

A conventional power plant is fueled by

a. a nuclear reactor.

b. fossil fuel.

Turn the page to check your answers.

ANSWERS

a. No, while the major processes in non-nuclear (conventional) and nuclear power plants are the same, a conventional power plant uses a coal- or oil-fired boiler.

Try the next question.

b. Yes. You know the difference between nuclear and fossil fuel power plants.

Proceed to the next section.

QUESTION

Circle the correct answer

The purpose of the fuel cladding around uranium dioxide fuel rods is to

a. prevent radioactive fission products from escaping the fuel rods into the reactor cooling water.

b. remove the heat generated in the reactor.

Turn the page to check your answers.

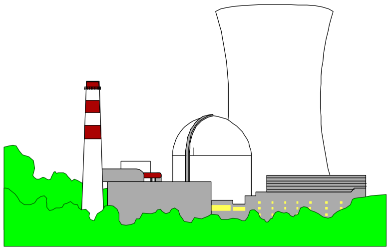
ANSWERS

a. Yes. You are familiar with this structural measure designed to control the radiation generated through a chain reaction of fissions of uranium atoms.

Turn to page 10-8.

b. No, the reactor cooling water removes the heat generated in the reactor and the fuel cladding controls the fission products.

You should review this section before moving on to page 10-8.



DEFINING THE HAZARD

There are two basic sources of safety problems at an operating nuclear power plant. One is the very large amounts of volatile radioactive materials that, if released, could cause offsite health effects. The typical light water reactor has about 4 billion curies in its core 30 minutes after shutdown. Although all of this radioactive material would never escape, even a small fraction of the total inventory would amount to a large release. The other source of safety problems is the heat energy in the core that, if not controlled, could release the fission products by damaging the containment structures.

THREE MILE ISLAND

Despite the many elaborate safety systems designed for plant operation, problems have occurred and undoubtedly will reoccur. The worst commercial accident in the United States occurred at the **Three Mile Island** nuclear station in 1979. As a result of equipment failures and operator error, a valve that was stuck open allowed coolant water that covered the reactor core to escape from the reactor system for over two hours. This radioactive water, nearly a million gallons, ended up on the basement floors of the containment building and auxiliary buildings.

The loss of coolant water in the reactor core continued to the point that the fuel was no longer submerged in water. Without the cooling provided by the water, the cladding and some of the fuel pellets melted. Large quantities of radioactive material were released into the containment building. The containment building performed as designed and radioactive releases to the atmosphere were small. The releases resulted from leakage of the radioactive water that was carried outside the containment building.

CHERNOBYL

Another serious commercial power reactor accident occurred in 1986 at the **Chernobyl** nuclear power plant in the U.S.S.R. That accident released large amounts of radioactive fission products to the environment. It was caused by a variety of factors. Operator error was aggravated by deliberate failure to follow procedures, a circumstance caused by in-progress safety limit testing. In the Chernobyl graphite moderated reactor, loss of coolant increased the chain reaction rather than decreasing it, causing such a buildup of pressure that the reactor was blown apart. This type of accident is not possible in a pressurized water or boiling water reactor in the U.S. because the loss of water would have shut down the reactor.

Answer the following question to check your understanding of these concepts.

QUESTION

Circle the correct answer

One of the major sources of safety problems in a nuclear reactor is

a. the energy in the core.

b. the risk of a nuclear detonation.

Turn the page to check your answers.

ANSWERS

a. That's correct. The other major source is the potential for release of large amounts of radioactive material.

Turn to page 10-12.

b. No. A nuclear power plant could not detonate like a nuclear weapon. The potential problem is a fire or non-nuclear explosion.

Try the next question.

QUESTION

Circle the correct answer

The accident at the Three Mile Island nuclear station was a result of

a. poor reactor design.

b. equipment failures and operator error.

Turn the page to check your answers.

ANSWERS

a. No, the accident occurred when a relief valve stuck open and operators failed to react to signals that coolant water was escaping.

Review this section before moving on.

b. Right. The resulting loss of coolant allowed temperatures to get so hot that some of the uranium fuel melted.

Turn to page 10-12.

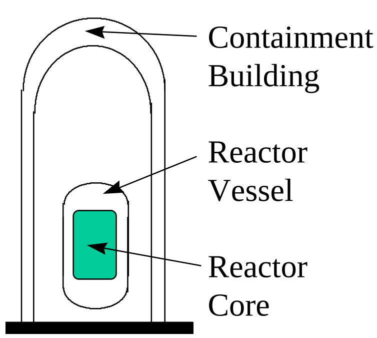
NUCLEAR PLANT SAFETY

Nuclear power plants are designed with two principal safety objectives in mind. One is to contain radioactive fission products to prevent offsite health effects. The other is to ensure that heat generated by the reactor, including heat generated by the decay of fission products after reactor shutdown, is removed.

Three barriers prevent the release of radioactive fission products from the reactor core to the environment: fuel rods, reactor vessel and primary cooling system, and containment.

Fuel rods trap 99 percent of all fission products in the fuel pellets and the remaining 1 percent in the fuel cladding that encases the fuel. If the core is not sufficiently covered with water to provide cooling, it could overheat and cause a breakdown in the fuel cladding. Additional overheating could result in the release of the fission products in the fuel structure. Still more overheating could cause a fuel meltdown.

Even if the fuel cladding were to fail, two more restraints prevent a release to the atmosphere. The reactor core is located within a *reactor vessel* that has walls of steel up to 10 inches thick. The large pipes of the *primary coolant system* also contain the reactor cooling water and any radioactive materials present.



The *containment building* is the third barrier between the fission products and the environment. It is a building that generally is made of high-density, reinforced concrete as much as six feet thick. The containment building is built to withstand severe accidents and natural and technical hazards. Even if the first two barriers are damaged, the containment building should prevent the release of most fission products to the environment.

Turn the page and answer the question.

QUESTION

Circle the correct answer

Nuclear power plants are designed with what two principal safety objects in mind?

a. to contain radioactive fission products to prevent offsite health effects and to ensure that heat generated by the reactor is removed.

b. to contain the reactor cooling water and any radioactive materials present.

Turn the page to check your answers.

ANSWERS

a. Yes. You understand the purpose of onsite safety systems.

Turn to page 10-16.

b. No. These steps are required in order to accomplish the principal safety objectives of preventing offsite releases of radiation and removal of reactor heat.

Try the next question.

QUESTION

Circle the correct answer

The containment building could sustain the effects of a hurricane or tornado.

a. true.

b. false

Turn the page to check your answers.

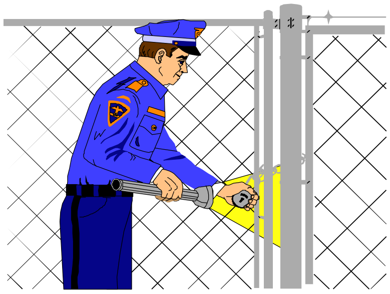
ANSWERS

a. Yes. The design is intended to withstand such hazards.

Turn to page 10-16.

b. Containment buildings are built to withstand severe accidents and natural and manmade hazards.

You should review this section before proceeding to page 10-16.



OFF-SITE PROTECTIVE ACTIONS

In addition to the safety measures designed into nuclear power plants, government emergency preparedness agencies require another degree of protection for the public. Plant operators and all levels of government maintain emergency plans to deal with direct exposure from a plume of airborne radioactive material or from radioactive material deposited on the ground, internal or external contamination caused by direct contact with the plume, and ingestion of radioactive material.

- Guidelines for this planning effort are found in the document *Criteria for Preparation and Evaluation of Radiological Emergency Response Plans and Preparedness in Support of Nuclear Power Plants*, NUREG-0654/FEMA-REP-1.

There are four levels of emergencies covered by these plans. Each level requires specific actions be taken by plant operators and local governments.

Notification of Unusual Event occurs when there is a potential degradation of safety at the plant but no releases requiring offsite monitoring or emergency action have occurred. Fire or security assistance may be required onsite.

An *Alert* is the result of events that involve actual or partial degradation of the level of safety at the plant. Any releases are expected to be limited to small fractions of the EPA Protective Action Guidelines (PAGs), which were reviewed in Unit Five. Resources and emergency personnel are brought to standby status, and offsite monitoring is performed if an actual release occurs. Assistance may be required onsite.

A *Site Area Emergency* means that events are in process or have occurred that involve actual major failures of plant functions needed for protection of the public. Any releases are not expected to exceed EPA PAG exposure levels except near the boundary. The public should be periodically updated on emergency actions and be notified to stand by for further instructions. Monitoring teams and communication personnel are dispatched to assignments.

A *General Emergency* is declared in the event of an actual or imminent substantial core degradation or melting with potential for breech in containment or radioactive releases expected to exceed acceptable levels off-site. Such an event calls for offsite monitoring and immediate protective actions by the public.

Protective actions should be outlined in the jurisdiction's radiological emergency plan or annex to the emergency operations plan. As discussed in Unit Five, protective actions might include such measures as evacuation or shelter. These protective actions are triggered by the EPA Protective Action Guides.

To assess your understanding of these concepts, answer the following question.

QUESTION

Circle the correct answer

Emergency planning for nuclear power plant accidents is undertaken by

a. plant operators only.

b. plant operators and State and local governments.

Turn the page to check your answers.

ANSWERS

a. Partly correct. Plant operators are required to develop radiological emergency response plans *in conjunction with, and in addition to,* State and local government plans.

Try another question.

b. That is correct. NUREG-0654/FEMA-REP-1 provides the guidance for developing these plans.

Turn to page 10-20.

QUESTION

Circle the correct answer

An uncontrolled loss of coolant water would probably be classified by the utility as

a. an Unusual Event.

b. a Site Area Emergency.

Turn the page to check your answers.

ANSWERS

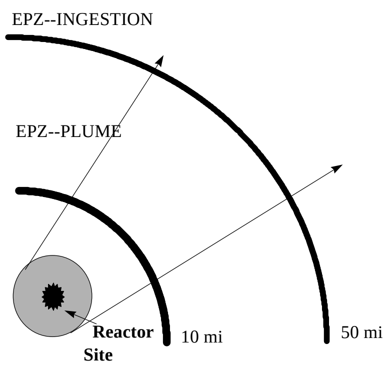
a. No, an uncontrolled loss of coolant water constitutes more than a “potential degradation of safety” at the plant.

You should review this section before beginning the next one on page 10-20.

b. That’s correct. An uncontrolled loss of coolant is an event that involves a major failure of plant function needed for protection of the public. The accident is not reclassified to General Emergency unless there is an actual or imminent substantial core degradation or melting with potential for breech in containment or radioactive releases expected to exceed acceptable levels off-site.

Turn to 10-20.

PLUME EXPOSURE PATHWAY



At every commercial nuclear reactor site in the country there are *emergency planning zones* (EPZ) that have been plotted and carefully investigated to determine who and what within those zones might be affected by an accidental release.
The first EPZ, *plume exposure pathway*, extends 10 miles out from the plant and, for most accidents, would be the path for airborne radioactive material in the plume. The plume would commonly contain radioactive noble gasses (helium, neon, argon, krypton, xenon, and radon), characterized by their stability and extremely low reaction rates. The plume may also contain radioiodines and radioactive particulate materials. Many of these materials emit beta and gamma radiation that can expose people nearby as the plume passes.

The radius from 0-50 miles, the *ingestion exposure pathway,* has been defined as the most likely area where, in a single release, radioactive material settles out from the plume and falls to earth. Principal exposure in this EPZ would come from ingestion of contaminated water, milk, and food.

The size of the EPZs were established at 10 and 50 miles because government and industry calculations have determined that even in the most severe accident a release would generally not exceed the EPA PAGs at these distances.

To check your understanding answer the following question.

QUESTION

Circle the correct answer

The pathway that is limited to a 10 mile EPZ is the plume exposure pathway.

a. False.

b. True.

Turn the page to check your answers.

ANSWERS

a. Wrong. The plume exposure pathway is the pathway limited to the 10 mile EPZ. The ingestion exposure pathway can extend further because radioactive contamination may enter the food supply chain.

Try another question.

b. Correct.

Turn to page 10-23 for the Summary Questions.

QUESTION

Circle the correct answer

The principal exposure hazard from 10-50 miles away from the plant is from

a. contaminated water, milk, and food.

b. contaminated air.

Turn the page to check your answers.

ANSWERS

a. That's right. This is where, in a single release, radioactive material settles out from the plume and falls to earth, creating the potential for contaminated milk, water and food.

Proceed to the Summary Questions on page 10-23.

b. While there is undoubtedly radioactive material settling out at this distance, the plume is much dispersed and the hazard from airborne radiation is much decreased.

Please review this section before turning to page 10-23.

SUMMARY QUESTIONS

QUESTION

Circle the correct answer

1. As a local or State radiological response team (RRT) member, when might your services be requested during a nuclear power plant accident?

   a. only when the radioactive plume passes beyond the boundaries of the plant.

   b. the onsite and offsite radiological emergency response plans describe when local or state radiological response teams are utilized.

Turn the page to check your answers.

ANSWERS

a. This is partially correct but there are other possibilities.

Review your radiological emergency response plan to clarify your potential responsibilities. Also answer the next question.

b. That is a good answer. You should be familiar with what your plan outlines before an emergency occurs.

Move ahead to the next Summary Question.

QUESTION

Circle the correct answer

2. What type of monitoring would be appropriate to determine the offsite radiation level of the plume resulting from an accidental release from a nuclear power plant?

   a. Air sampling.

   b. Area survey.

ANSWERS

a. That's correct. A plume is an airborne release of radioactive material.

Go ahead to Unit Eleven.

b. Incorrect. You might get some reading on a survey meter, but if the reading is not taken in the plume or the plume is far enough overhead, the reading may not correctly characterize the hazard.

Review pages 10-20 before proceeding to the next unit.

UNIT ELEVEN

RADIOACTIVE MATERIALS TRANSPORTATION

Transportation accidents involving radioactive materials are rare. Of the 500 billion total domestic shipments annually, only 3 million contain radioactive materials. However, when accidents do occur, local emergency responders are almost always the first to arrive on the scene. When a radiological response team is called upon, its first responsibility is to assess the scene and determine how to control emergency conditions. In order to do so, radiological responders must be able to recognize and interpret the package types, labels, and placards required by the most recent (September, 1995) Department of Transportation regulations for radioactive materials transport.

This topic is covered to some extent in all of the FEMA radiological series courses. In this course the unit is intended as a review for those participants who have already mastered the competencies involved and a critical learning objective for those who have not.

GATE FRAME QUESTION

Your initial assessment of a transportation accident involving radioactive material reveals that the carrier is not placarded, but some of the packages that have been thrown from the vehicle have yellow radioactive labels and others have white labels. In addition, one of the packages is completely torn apart, and the inner container is broken, revealing small metal capsules.

How do you interpret this situation based only upon the information provided? (Use another sheet if needed)

ANSWER

Your answer should include the adjacent information.

Because the carrier is not placarded, there should not be any Radioactive Yellow III packages or radioactive LSA material in the shipment. Therefore, the yellow radioactive labels should be Radioactive Yellow II. This means that if the package is intact and the contents have not shifted, the exposure rate on the surface of the container exceeds 0.005 mSv/hr (0.5 mrem/hr), but is less than 0.5 mSv/hr (50 mrem/hr) and does not exceed 0.01 mSv/hr (1 mrem/hr) 1 meter away. The white radioactive labels mean that the intact packages have exposure rates under 0.005 mSv/hr (0.5 mrem/hr) on any outer surface of the container and do not present a great exposure risk.

Cardboard packages are either Excepted packages or Type A packages. In either case, the type of packaging indicates small amounts of radioactive material.

The spilled capsules are considered to be in “special form.” Special form is either an indispersable solid of radioactive material or a sealed capsule containing radioactive material. This means that the material has a very high degree of physical integrity so that if the material were released from the package in an accident, while there might be a radiation hazard, it is highly unlikely to be a contamination hazard.

If your answer included all or most of the above points, you should be ready for the Summary Questions at the end of this unit. *Turn to page 11-23.*

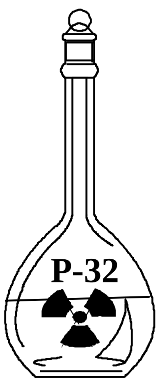
If your answer did not include these points, it would be advisable for you to complete the instruction for this unit. *Turn to page 11-3.*

FORMS OF RADIOACTIVE MATERIAL

For packaging purposes, DOT regulations provide for two forms of radioactive materials, “special form” and “normal form.”

A radioactive material that is shipped as a single solid piece or encapsulated in a very strong metal capsule is in *special form*. A small cylinder containing radioactive cobalt metal for use in industrial radiography is an example of a special form material.

A radioactive material that is shipped as a solid, liquid, or gas is considered to be *normal form*. Radioactive materials shipped in normal form can present a contamination hazard as well as exposure hazard if the package were to fail. Most radioactive material is shipped in normal form.



Radiological response team members can determine what form a radioactive material is in by looking at the shipping papers or the package markings. If a radioactive material is in special form, the words “special form” will be part of the proper shipping name. If those words do not appear in the proper shipping name, the material is in normal form.

If the material is in special form, there should be little or no risk of contamination, even if the capsule is released from its package, but the exposure hazard could be quite high. If the material is in normal form, the packaging requirements will be more stringent; if it is released from the packaging, there may be a contamination hazard and potential external radiation hazard.

The question on the next page will help you assess your understanding of these concepts.

QUESTION

Circle the correct answer.

If you were to see the words "special form" on a smashed package of radioactive material, you would conclude that

a. there is some likelihood of high radiation exposure but little chance of radioactive contamination.

b. there is little likelihood of high exposure rates but some likelihood of a contamination hazard.

Turn the page to check your answer.

ANSWERS

a. That's correct. You understand that the term "special form" means the material is a single solid piece or encapsulated, reducing the probability of contamination.

Proceed to page 11-7.

b. No, that is not correct. Single solid pieces or encapsulated materials have a reduced chance of allowing the radioactive material to be released to the environment.

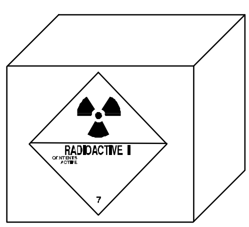
Move on to the next section.

PACKAGING TYPES FOR RADIOACTIVE MATERIALS

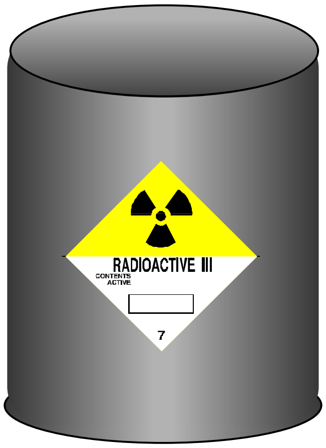
Packaging for radioactive materials falls into four broad categories:

- Excepted packages
- Type A packages
- Type B packages
- Industrial packages

Excepted packages provide radioactive materials the least amount of protection in transit. However, when shipping radioactive materials, this category of packages can only be used when shipping a limited quantity of the material. The relative concentration of radioactive material would be low (typically, there is a small amount of radioactive material mixed with large amounts of non-radioactive material.) Excepted packages are not required to meet specific testing requirements. The only requirement is that they be capable of holding their contents during normal non-accident conditions of transportation. Examples of materials shipped in excepted packages include manufactured items such as watch dials, smoke detectors, and medical test kits.



Type A packages or Type B packages must be used if a shipment of radioactive materials involves more than a limited quantity. A *Type A package* (typically a one-cubic foot cardboard box with interlocking cardboard spacers inside) is generally stronger than an excepted package, but not as strong as a Type B package. Type A packages must pass a series of tests before the design is approved for use. These tests simulate conditions that the packages might be exposed to in normal transportation circumstances or minor mishaps including water spray, free-fall, compression, and penetration. An example of a material shipped in Type A packages is radiopharmaceuticals for medical use.



Type B packages carry the maximum allowable amounts of radioactivity. They must meet the same criteria as Type A packages and pass additional tests designed to simulate accident conditions including water immersion, free drop, fire and puncture tests. Type B packages have never released their contents during transportation accidents. Examples of materials shipped in Type B packages are spent fuel and large cobalt-60 sources.

Industrial packages are used to ship low specific activity (LSA) material or surface contaminated objects (SCO). There are three subcategories of industrial packages, IP-1 IP-2 and IP-3. IP-1 must meet general design criteria for shipment of radioactive materials. IP-2 must also meet free drop and stacking tests. IP-3 must meet all type A tests except for liquid absorbents and gaseous requirements.

Industrial packages are used for such materials as ores, natural or depleted uranium, mill tailings or contaminated debris.

Answer the following question.

QUESTION

Circle the correct answer.

Laboratory chemicals containing “tracer” radionuclides for research have very small amounts of radioactive materials. These laboratory chemicals are likely to be shipped in

a. Type B packages.

b. Type A packages.

Turn the page to check your answer.

ANSWERS

a. No, Type B packaging is designed for shipping large amounts of radioactive materials.

Try another one.

b. Right! Type A packaging is used when the exposure and contamination hazards are minimal.

Continue on to the next section.

QUESTION

Circle the correct answer.

Radiography devices or cameras are used for checking welds at construction sites and other industrial locations. They typically weigh about 50 lbs. and may be transported inside the radiographer's truck in a convenience overpack box. The device or packaging (its overpack) may have either Yellow II or III labels. The device typically contains 3.7 TBq (100Ci) Ir -192. These packages are classified as

a. Type A.

b. Type B.

Turn the page to check your answer.

ANSWERS

a. No, Type A containers are designed for small amounts of radioactive material and only need to be sturdy enough to withstand normal shipping conditions.

Please reread pages 11-6 and 11-7 before moving on to the next section.

b. Correct. Type B containers are substantially stronger and sturdier than the typical cardboard Type A package.

Go ahead with the next section.

LABELS ON RADIOACTIVE MATERIALS PACKAGES

Besides the outward physical appearance of the package itself, the packaging label can be used in hazard assessment of the radiological hazard. The label for a specific container depends on the exposure rates measured outside that package. The purpose of labeling is to inform anyone near or in contact with the package of the external radiation hazard and, in some cases, its contents. In addition to the relative exposure rate limits, these three labels identify the contents of the package and the contained activity in becquerels. Activity may also be listed in curies following becquerels.

Remember that the external exposure rate from any package overpack determines the label used, while the specific contents and quantity determine the package type.

The *Radioactive White I* label is placed on packages of radioactive materials that have exposure rates under 0.005 mSv/hr (0.5 mrem/hr) on any outer surface of the container. Because this is considered a very low hazard, there are no regulations specifying the number of Radioactive White I packages on a conveyance or vehicle.

A *Radioactive Yellow II* label is applied to a package if the exposure rate on the surface of the container exceeds 0.005 mSv/hr (0.5 mrem/hr), but is less than 0.5 mSv/hr (50 mrem/hr) and does not exceed 0.01 mSv/hr (1 mrem/hr) one meter away.

Containers labeled *Radioactive Yellow III* containers may have exposure rates up to 2mSv/hr (200 mrem/hr) on contact and 0.1mSv/hr (10 mrem/hr) at one meter.

Labeling is not required for LSA materials when shipped domestically, and the only required marking is “Radioactive LSA” when shipped exclusive use with placards on the vehicle.

The exact reading at the time of shipping for a specific package can be found from the transport index (TI), which is included only on Yellow II and Yellow III labels. Except in the case of fissile materials, the transport index equals 100 times the highest exposure rate in mSv/hr one meter from the package surface. The transport index is used to limit the total amount of exposure from radioactive materials shipped on one vehicle. The total of all the transport indices on one carrier is not to exceed 50. In other words, if you assembled all the packages containing radioactive material on one shipment and stood 1 meter from them, you would be exposed to no more than 0.5 mSv/hr (50 mrem/hr). For RAM which have “fissile” as part of the shipping name, the TI may not represent the maximum radiation level at 1 meter from the package. In some case the TI may be related to the characteristics of the fissile material. The TI, based on criticality properties, maybe assigned by the shipper so that the maximum of 50 TI per vehicle will be safe for fissile shipments.

Test your knowledge of labeling by answering the following question.

QUESTION

Circle the correct answer.

If you find a Radioactive White I labeled package on the ground, and you measure more than 0.035 mSv/hr (3.5 mrem/hr) on the surface of the box, what would you deduce?

a. The contents have shifted to one side or the package was breached and the outside of the package is contaminated.

b. The reading is appropriate at the surface of a package labeled Radioactive White I.

Turn the page to check your answer.

ANSWERS

a. Yes, these are two feasible possibilities.

Move on to the next section.

b. No, surface readings on Radioactive White I packages cannot exceed 0.005 mSv/hr (0.5 mrem/hr) therefore, a 0.035mSv/hr (3.5 mrem/hr)reading is not within normal limits.

Try another problem.

QUESTION

Circle the correct answer.

If the transport index on a Yellow II package is 1 and you get a reading of 0.65 mSv/hr (65 mrem/hr) on the surface of the package, is the package breached?

a. yes, possibly

b. not necessarily.

Turn the page to check your answer.

ANSWERS

a. Correct. You understand that the transport index is the highest exposure rate *one meter* from the package and a higher reading at the surface would be normal. However, Yellow II has a maximum reading of 0.5 mSv/hr (50 mrem/hr) at the surface. Since the surface reading is now 0.65 mSv/hr (65 mrem/hr) either the contents have shifted or are leaking and the package may be contaminated.

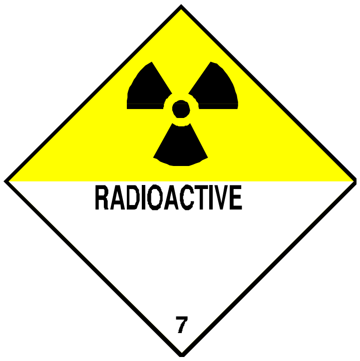
Proceed to the next section.

b. No. It is true that the reading at 1 meter from the package should not exceed 0.01mSv/hr but for yellow II the maximum surface reading is 0.5 mSv/hr. A reading of 65 mrem/hr would indicate a shift in contents or possible a break and leakage.

Reread this section before moving ahead to the next section.

Proceed to the next page.

PLACARDING



The most outward indication of radioactive materials on a truck, freight container, or rail car is a “radioactive” warning placard on all sides. Placards serve as a warning that there may be a need for radiological safety measures in the event of an accident. Vehicles must be placarded if they carry one or more packages with the Radioactive Yellow III label or LSA material (nonradioactive items that may be contaminated in some way).

It is not unusual to detect radiation when monitoring the outside of a vehicle carrying radioactive material. However, certain limits are set to prevent *serious* exposure to persons outside the vehicle. The exact external exposure rate limits depend on whether the vehicle is carrying only radioactive materials, termed *exclusive use*, or contains radioactive as well as nonradioactive materials, termed *non-exclusive* use.

- For a *non-exclusive use* vehicle, the exposure rate limit any package surface is 2 mSv/hr (200 mrem/hr). Individual packages cannot exceed .1mSv/hr (10mR/hr) at 1 meter. At one meter from the actual vehicle, the exposure rate must not exceed .1Sv/hr (10mR/hr).

- For *exclusive use* vehicles the limits are somewhat different. On contact with the outside vehicle surface, the limit is the same (2 mSv/hr or 200 mrem/hr), but 0.1 mSv/hr is allowed as far as 2 meters away. Individual packages may not exceed 10mSv (1000 rem/hr).

- Exposure rates in the driving cab must not exceed 0.02 mSv/hr (2 mrem/hr) with some exceptions for private carriers with radiation protection programs that provide drivers with training and dosimetry.

Answer the question on the next page.

QUESTION

Circle the correct answer.

A tractor trailer involved in a collision has a radioactive placard on the side, but that is all you know about the truck's contents. Your survey meter is reading 10 mSv/hr (1000 mrem/hr) at the surface of a package spilled from the overturned vehicle. You inform the incident commander that

a. this reading is within normal limits according to DOT regulations.

b. you do not have enough information to know if this is a normal reading.

Turn the page to check your answer.

ANSWERS

a. This might be an appropriate response if you knew the vehicle was exclusive use. If it were non-exclusive use the reading is higher than would be expected according to DOT regulations.

Try the next question

b. That's right. You need to know something about the contents of the shipment to provide meaningful advice about the radiation hazard.

Move on to page 11-19.

QUESTION

Circle the correct answer.

The contents of a derailed freight train car have spilled onto the embankment. You see a radioactive placard on the outside of the car but nothing except barrels or drums with spilled contents inside the car. The incident commander asks you about the risk. You state:

a. there must be a Radioactive Yellow III labeled package buried somewhere in the rubble or thrown clear of the area.

b. the barrels may be radioactive LSA, but you can't see the markings.

Turn the page to check your answer.

ANSWERS

a. Incorrect. While a carrier hauling Radioactive Yellow III containers is required to be placarded, radioactive LSA also requires a placard on the carrier.

Review page 11-15.

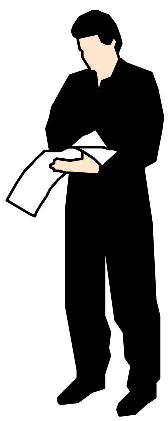
b. Correct. Shipments of radioactive LSA require placarding but not labeling except for the words "Radioactive LSA."

Move to the next section.

SHIPPING PAPERS

In some cases, the shipping vehicle may be badly damaged in the accident. The radioactive placards on the vehicle may not be visible due to the damage, but you still need some indication of the possible hazard. One other clue could be the *shipping papers*. As with the shipment of any other hazardous material through public areas, vehicles transporting radioactive materials must carry papers that properly identify the materials and specify associated quantities and hazards.

The shipping papers, also called *bills of lading*, *air bills*, and *cargo manifests*, contain the following useful information for hazard assessment:



- Proper shipping name;
- Proper hazard classification of the material;
- Four-digit hazardous materials identification number;
- Total quantity by weight, volume, or where appropriate, simply radioactivity;
- Name of radionuclides as listed in DOT regulations;
- Description of chemical form (if not special form);
- Activity in becquerels, terabecquerels, or SI units followed by customary units (curies, etc.);
- Type of labels applied to each package; and
- Transport index assigned to each package bearing Radioactive Yellow II or III labels.

The shipping papers should be located in the cab of a truck, the cockpit of an airplane, the bridge of a ship, or the engine of a train. Unless adverse conditions prohibit, the emergency responder should obtain these papers before calling for assistance since the information about the hazard can be found there.

Answer the next question to check your understanding of these concepts.

QUESTION

Circle the correct answer.

An emergency responder refers to shipping papers to determine

a. the level of radiation coming from the carrier.

b. the amount of radioactivity on the carrier.

Turn the page to check your answer.

ANSWERS

a. No, the actual radiation levels can only be determined using a radiation detection instrument.

Try another problem.

b. That's right. Shipping papers include the activity of the material in becquerels or terabecquerels.

Turn to page 11-24.

QUESTION

Circle the correct answer.

You respond to an accident scene in which steel cylinders bearing yellow radioactive labels have been thrown near and far from a tractor trailer. It is not known whether any of the cylinders have been damaged. One of the cylinders is lying directly next to the cab of the overturned vehicle. The driver walked away from the accident and informs you that the shipping papers are in his lockbox under the seat. Your next move is to

a. obtain from the driver as much information about the load as possible.

b. find a way into the cab and locate the shipping papers.

Turn the page to check your answer.

ANSWERS

a. That is the better choice. Steel cylinders are Type B containers, indicating a potentially high exposure rate if one of the containers were breached.

Proceed to page 11-24.

b. Because of the possibility that the cylinder near the cab may be damaged and causing a radiation hazard, it would be more sensible to attempt to gain necessary information from other sources first.

Reread this section before proceeding to the Summary Questions.

SUMMARY QUESTIONS

QUESTION

Circle the correct answer.

1. Upon arriving at the scene of a cargo plane crash you note that two of the damaged cardboard boxes contain white radiation labels but they are illegible. From this initial assessment, you know that

   a. the radiation hazard from those packages is likely to be substantial.

   b. the radiation hazard from the packages is likely to be relatively low level.

Turn the page to check your answer.

ANSWERS

a. Incorrect. Radioactive White I labels are used when the radiation hazard is small.

Go back and review the unit.

b. Correct.

Move on to the next Summary Question.

QUESTION

Circle the correct answer.

2. A radioactive placard on a carrier means that

   a. the vehicle contains high-level radioactive material called radioactive LSA.

   b. the vehicle carries radioactive LSA or the shipment includes at least one package labeled Radioactive Yellow III.

Turn the page to check your answer.

ANSWERS

a. Incorrect.

Go back to page 11-16 and review.

b. Correct.

Proceed to Unit Twelve.

UNIT TWELVE

RADIOLOGICAL HAZARD AREA CONTROL

Once the radiological responder has collected available information at the incident scene, the problem must be defined in terms of potential harm to people within the affected area. After defining the problem, the radiological responder's next task is to control the problem (reducing or eliminating contamination and/or exposure risk).

This unit will cover the components of radiological problem definition and the methods available for exposure and contamination control. Some of this information has been addressed in prerequisite FEMA courses and will be considered a review. Other concepts are introduced here and should be carefully studied. The sections of the unit are organized into topics that can be developed into a generic checklist for controlling a radiological hazard area.

GATE FRAME QUESTION

What important factors must be considered in defining a radiological problem?

ANSWER

Your answer should include the adjacent information.

- What is the external hazard in terms of exposure rate readings?
- What are the internal hazards—any ways radioactive material might be inhaled, ingested, or absorbed?
- What are the hazards to personnel (victims, on-site public, and emergency workers) in terms of injuries, exposure, contamination, or anticipated risks?

If your answer included all or most of the above points, you should be ready for the Summary Questions at the end of this unit. *Turn to page 12-21.*

If your answer did not include these points, it would be advisable for you to complete the programmed instruction for this unit. *Turn to page 12-3.*

DEFINING THE PROBLEM: EXTERNAL HAZARDS

Using the hazard assessment information available from package types, labels, placards, and shipping papers, the nature of the exposure problem may be identified. However, actual exposure rates can only be determined using radiation detection instruments. In order to provide accurate and timely information, the radiological responder must be able to operate and read the available radiation monitoring instruments.

State response teams have access to a variety of radiation survey instruments. These include scintillation counters, Geiger-Mueller counters, and ionization chambers.

- *Scintillation counters* detect beta, x, and gamma radiation, with typical ranges of 0.02 mR/hr to 20 mR/hr.
- *Geiger-Mueller (GM) counters* detect beta, x, and gamma radiations from 0.2 to 20 mR/hr or 800 to 80,000 counts/minute.
- *Ionization chamber instruments* also detect beta, x, and gamma radiation from 3 mR/hr to 500 R/hr.

These instruments are useful for hazard assessment purposes only if the personnel have some knowledge of the instrument's ability to detect the radionuclides potentially present. A methodology for evaluating the response of survey instruments was developed and applied to the widely available CD V-700 and CD V-715 survey meters distributed by the Federal Emergency Management Agency (FEMA). The results are published in a document titled *Response of Radiation Monitoring Instruments to Normalized Risk Quantities of Radionuclides*, available from the Department of Transportation Research and

Special Programs Administration and reprinted in FEMA's SM 320, *The Fundamentals Course for Radiological Monitors*.

Entry to a scene with both low and high level instruments may be appropriate. The team members assigned to the radiological monitoring task survey first for high-level radiation exposure rates using high-range radiation instruments such as the CD V-715 and maintaining a safe distance from the source. If the high-range instruments do not detect the presence of radiation, a low-range instrument such as the CD V-700 may be used to detect lower radiation levels. The data from these surveys are the basis for determining the external hazards.

The following question will help you assess your understanding of methods used to determine external radiation hazards.

QUESTION

Circle the correct answer

Available information about the cargo of a damaged tractor trailer indicates that it is carrying solid cobalt-60 sources for industrial radiography use in Type B packages. This information is

a. enough to determine the external exposure hazard.

b. a good basis for determining the type of survey instrument to use in the area survey.

Turn the page to check your answer.

ANSWERS

a. No. Unless the area is surveyed to determine radiation levels, the existence of and extent of any problem cannot be determined.

Try the next problem.

b. Correct.

Move on to the next section.

QUESTION

Circle the correct answer

For initial area survey of an accident involving a high-level spent fuel shipment, the radiological responder should select

a. a CD V-715 (ionization chamber).

b. a CD V-700 (GM counter).

Turn the page to check your answer.

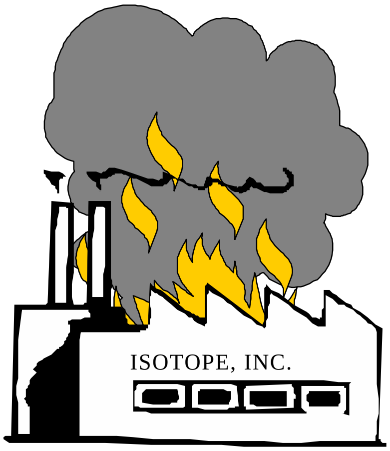
ANSWERS

a. That's correct. You remembered that the CD V-715 is a high-level monitoring instrument appropriate for use with a high-level radiation source.

Proceed to page 12-7.

b. No. The CD V-700 measures radiation levels up to about 50 mR/hr and may malfunction due to saturation of the GM detector under high exposure rates. For an incident with the possibility of higher radiation levels, a higher range instrument, such as the ionization chamber, should be selected where a choice is available.

Reread this section before proceeding to page 11-7.



DEFINING THE PROBLEM: INTERNAL HAZARDS

Radioactive contamination can get inside the body through inhalation, ingestion, absorption, and open wounds. Accidents involving radioactive materials may create conditions where contamination can be breathable—from smoke, gaseous release, or particulate release. It is necessary to take downwind air samples to determine the presence of radioiodine and particulate radiation. Direct radiation measurements can determine the exposure from noble gasses.

If an air sample for radioiodine and particulates was taken and no significant amount of radioactivity was found on either the radioiodine or particulate filter, but measurable amounts above background of gamma radiation were present, it would indicate one of three possible conditions:

- Particulate radioactivity or radioiodines are not present in measurable quantities;
- Measurements are being made just outside or beneath the radioactive smoke or plume; or
- The gamma measurements are being obtained from sources on the ground and there is no airborne radiation at that location.

If subsequent air samples from different locations do indicate measurable amounts of radioactivity, it may be assumed that the first readings were taken near to but not in the radioactive cloud. If survey meter readings taken closer to a source on the ground increase and the airborne readings remain negative, the radiation is probably not airborne.

Spreadable contamination from dispersion of a particulate source such as yellowcake (U_30_8) is determined using radiation survey instruments.

QUESTION

Circle the correct answer

Internal radiation hazards are detected using

a. downwind air-sampling and radiation instruments.

b. high-range gamma detectors.

Turn the page to check your answer.

ANSWERS

a. Correct.

Proceed to page 12-11.

b. No, high range gamma detectors may detect external radiation hazards and contamination hazards, but may not detect airborne radioactive gasses and/or particulates.

Try another problem.

QUESTION

Circle the correct answer

Two Type A packages with Radioactive White I labels containing vials of liquid iodine-131 have failed, spilling the contents on the side and shoulder of a highway. The contaminated area is detected using

a. downwind air sampling equipment.

b. low-range GM counter radiation detection instrument.

Turn the page to check your answer.

ANSWERS

a. No. This radioisotope is in liquid form spilled on the ground. Airborne contamination is unlikely.

Review page 12-7 before moving on to the next section.

b. Yes—the low range survey meter was indicated by the form of the material and the White I labels, indicating a low-level exposure hazard.

Proceed to page 12-11.

DEFINING THE PROBLEM: HAZARDS TO PERSONNEL

The emergency responder's job is to save lives and protect people from injury. Those people include accident victims, onsite public, and emergency workers.

An accident involving radioactive materials may involve hazards other than radiation. These other hazards could include potential bodily injury sustained in the accident itself, exposure to nonradioactive but toxic materials released in the accident, and exposure to radioactive materials that also are chemically toxic.
Radiological response team members identify all possible hazards to people, not just radiation hazards. *Lifesaving first aid is given priority over radiation protection.* Non-radiological hazards can be immediately life threatening and should never be ignored because of radiological hazards. The information about all personnel hazards is collected and recorded on paper and through photos, audio, and videotape. Due to the lack of general knowledge about radiation hazards, it is important to document all actual or potential hazards for legal reasons.

QUESTION

Circle the correct answer.

To check your understanding answer the following question.
Uranium hexaflouride (UF_6) is a hazardous chemical in a gaseous state that requires special handling because it reacts rapidly with water to form the irritating, noxious gas hydrogen fluoride. Because of its low level of radioactivity it is classified as an LSA material. This material would be considered

a. a chemical and radiological hazard.

b. a chemical hazard only.

Turn the page to check your answer.

ANSWERS

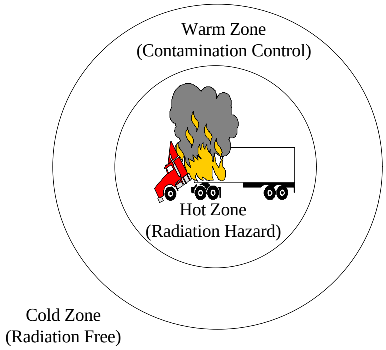
a. Correct.

Proceed to page 12-13.

b. No. While the chemical toxicity may be the more immediate hazard, the low-level radiation presents possible internal exposure and contamination hazards.

Review page 12-11 before moving on to the next section.

CONTROLLING THE PROBLEM: EXTERNAL AND INTERNAL HAZARDS



If it is determined that a radiation hazard exists at an incident site, appropriate exposure control measures should be initiated. Where an external radiation hazard from unshielded radioactive material is indicated, isolate the hazard area, or *hot zone*, and prohibit entry. The physical boundaries of the hot zone are determined by the exposure rate readings taken with radiation survey instruments. Two mR/hour is a generally accepted perimeter. Response actions should be limited to shortest possible entry time into the hot zone. All persons entering the hot zone should wear appropriate dosimetry and protective clothing.

The *warm zone* is a marked area around the *hot zone* where personnel and equipment decontamination and hot-zone support takes place. It includes control points for the access corridor that help reduce the spread of contamination. Other terms for the warm zone are decontamination, contamination reduction, or limited access zones.

The *cold zone* is a marked area around the warm zone that contains the command post and other support functions necessary to control the incident. The zone is also called the clean or support zone.

If exposure rates are very high, some shielding may be necessary if lifesaving or other operations in the hot zone are imperative. Recommendations of shielding procedures should involve careful comparison of the exposure saved by shielding with the exposure added due to increased time needed to shield the area. Shielding material could include barrels, boards, vehicles, or whatever else is immediately available. Because it may take valuable time to fabricate this shield, rotation of response personnel to perform the necessary operations may be a viable alternative for exposure control.

Exposure to breathable internal radiation hazards also may be controlled by remaining at least 150 feet upwind of the hazard and possibly greater distances downwind, or through the use of self-contained breathing apparatus (SCBA). Air sampling procedures should be continued.

Exposure to spreadable contamination is limited by controlling exit and entry to the hot zone. Clothing and equipment with suspected contamination should be isolated and contamination clean-up delayed until the Radiation Authority has been consulted.

Answer the following question.

QUESTION

Circle the correct answer

Brief external exposure to a low-level contained radiation source

a. may be of less concern than an internal exposure hazard.

b. requires the same exposure control methods as an airborne exposure hazard.

Turn the page to check your answer.

ANSWERS

a. Yes. Radiation exposure inside the body is in most cases more hazardous than external exposure to low-level radiation.

Move on to page 12-17.

b. No. Controlling airborne radiation requires air sampling and a larger hot zone.

Try the next problem.

QUESTION

Circle the correct answer.

Building a barrier is an example of controlling

a. internal exposure.

b. external exposure.

Turn the page to check your answer.

ANSWERS

a. No. Internal exposure is controlled by staying upwind of the problem and air sampling.

Review page 12-13 before moving on to the next section.

b. Correct. Shielding will decrease exposure from an ionizing radiation source.

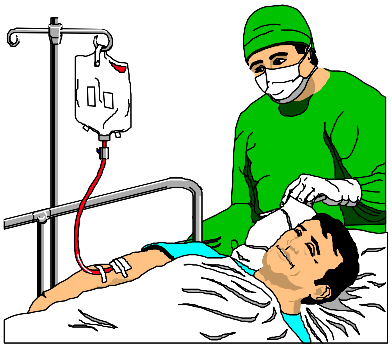
Move on to the next section.

CONTROLLING THE PROBLEM: HAZARDS TO PERSONNEL

The goal of radiological emergency response is to keep radiation exposure to all people as low as possible. The EPA's Protective Action Guides and the NCRP's guides for population exposure provide the radiological emergency responder with information about levels of exposure that should not be exceeded. After finding out what hazards exist, predictions about exposure and contamination risks can be translated into procedures for controlling the problem.

- These procedures are found in the *North American Emergency Response Guidebook* under Guides 161-66. The specific guide to follow is determined by the radioactive material involved.

EMERGENCY ROOM



Accident victims should be treated according to the nature of the injury. If it will not affect the injury, prevent exposure by moving the victim away from the source. If the injury is not affected, remove and isolate suspected contaminated clothing and shoes; wrap the victim in a sheet or blanket before transporting. Advise medical personnel that the victim may be contaminated with radioactive material.

If there is no injury to *onsite public* and they are not contaminated, remove them from the area to prevent radiation exposure and possible contamination. If contamination of uninjured onsite public is suspected, remove and isolate suspected contaminated clothing and shoes. Assist persons to shower with soap and water and notify the Radiation Authority of the action taken.

Emergency workers can reduce exposure and contamination using the *hot-team/cold-team* concept. Perimeters are established as close as practical to victims based on estimated stay times for team members, and equipment is staged accordingly.

- Hot-team members enter the hot zone and treat the patient.
- Cold-team members stand by to receive and transport the patient. This allows the cold-team members to remain free of contamination and maintain some distance from the source of radiation.

A positive pressure SCBA and structural firefighter protective clothing will provide limited protection. In the absence of fire or chemical hazards, disposable coveralls, gloves, and shoe coverings limit contamination of workers and their protective equipment. Before leaving the warm zone, emergency workers remove and isolate suspected contaminated clothing and shoes. If contamination remains, emergency workers shower with soap and water and notify the Radiation Authority of actions taken.

To check your understanding of these concepts, answer the following question.

QUESTION

Circle the correct answer

Protective clothing provides protection from

a. gamma radiation exposure.

b. contamination.

Turn the page to check your answer.

ANSWERS

a. No, gamma radiation penetrates protective clothing.

Try another problem.

b. Correct. Contaminated protective clothing is removed before leaving the warm zone.

Proceed to the Summary Questions.

QUESTION

Circle the correct answer.

For guidance on response actions in a radiological emergency, refer to

a. the *North American Emergency Response Guidebook.*

b. the EPA *Manual of Protective Action Guides*.

Turn the page to check your answer.

ANSWERS

a. Correct.

Proceed to the Summary Questions.

b. No. The *Protective Action Guides* provide exposure guidelines and recommendations on overall protective actions. The *Emergency Response Guidebook* recommends specific emergency response actions.

Review this section before proceeding to the Summary Questions.

SUMMARY QUESTIONS

QUESTION

Circle the correct answer.

1. You are a member of a radiological response team called to an incident on a ship at a busy harbor. A load of pipe being off-loaded was dropped back into the ship's holding area, damaging a Type B container marked radioactive. The shipping papers indicate that it contains three sealed cesium-137 sources. There is no fire and nothing appears to be spilled. In order to define the external radiation hazard, you

    a. survey the area using radiological instruments.

    b. survey the downwind area using an air sampling device.

Turn the page to check your answer.

ANSWERS

a. That's correct. This scenario provides no reason to suspect an airborne radiation hazard

b. No. There is no apparent reason to take air samples in scenario, but it is necessary to survey the area in order to determine the external exposure hazard.

Return to page 12-7 and review before moving on to the next Summary Question.

QUESTION

Circle the correct answer.

2. You are called to assist first responders in handling an incident in which an industrial radiographer was knocked unconscious by falling factory equipment while attempting to radiograph a pipe weld. A radiological survey shows readings of 20 mrem/hr 1 yard from the victim. Your advice to emergency medical personnel is

   a. immediately treat the victim's injuries and move him away from the source if doing so will not affect his injury.

   b. move and decontaminate the victim before treating the head injury.

Turn the page to check your answer.

ANSWERS

a. That is correct. Lifesaving first aid takes precedence over exposure control.

Proceed to the final examination.

b. No. First aid is applied according to the nature of the injury and then exposure control of the patient is initiated.

Review page 12-11 before proceeding to the final examination.

RADIOLOGICAL EMERGENCY RESPONSE OPERATIONS COURSE
FINAL EXAMINATION

This exam is intended to test your mastery of the Radiological Emergency Response Independent Study course objectives. Using a soft lead (#2) pencil, record the best answer for each of the following questions on the attached answer sheet. There is only one correct answer for each question. When you have finished, prepare the answer sheet as directed and mail to the address provided. Your examination will be evaluated and the results returned to you as quickly as possible.

1. 10 CFR 20, Standards for Protection against Radiation, is an example of

   a. a regulation.
   b. an ICRP report.
   c. a license.
   d. a guidance document.

2. Molybdenum-99 (Mo-99) has a half-life of 66 hours. After 132 hours, how much of an initial sample of 10 Ci of Mo-99 would remain?

   a. 10 Ci
   b. 5 Ci
   c. 2.5 Ci
   d. 1.25 Ci

3. The measure used to account for biological effect upon tissue is the

   a. roentgen
   b. rad (or gray)
   c. rem (or sievert)
   d. becquerel

4. One terabecquerel (Tbq) equals 10^{12} becquerels. In longhand, one terabecquerel would be written as

   a. 1,000,000,000,000,000 becquerels
   b. 1,000,000,000,000 becquerels
   c. 0.0000000000001 becquerels
   d. 0.000000001 becquerels

5. In scientific notation, one millirem is written as

   a. 10^{-3} rem
   b. 10^{-4} rem
   c. 10^{3} rem
   d. 10^{4} rem

6. An example of a biological variability factor is

   a. the size of the radiation dose received.
   b. the duration of exposure.
   c. the type of radiation.
   d. the exposed person's age.

7. Which are the most radiosensitive cells?

   a. Muscle cells
   b. Blood cells
   c. Nerve cells
   d. Bone cells

8. The factor which determines where in the body an ingested radioisotope will be most likely to concentrate is its

   a. nuclear properties.
   b. physical properties.
   c. chemical properties.
   d. residential properties.

9. For emergency response use in keeping track of radiation exposure during the emergency operation, the appropriate dosimetry would be a

   a. film badge.
   b. pocket ionization chamber.
   c. TLD badge.
   d. survey meter.

10. To maintain a permanent record of radiation exposure, the appropriate dosimetry would be a

   a. film badge.
   b. pocket ionization chamber.
   c. TLD badge.
   d. survey meter.

11. In an emergency situation involving radioactive materials, that is managed under the Incident Command System, the person in charge of the scene is the

   a. radiological response team captain
   b. survey team leader
   c. State Radiological Health Director
   d. Incident Commander.

12. In an incident in which the radiation levels are high but there are no people at risk, time and distance could be incorporated into one protective action strategy by

    a. staying out of the radiation area until a cleanup plan is developed.
    b. building a protective wall around the radiation source.
    c. using shovels to quickly bury the source of radiation.
    d. sending radiological monitors into the radiation area on a rotating schedule.

13. The National Council on Radiation Protection (NCRP) and the International Council on Radiation Protection (ICRP) currently embrace what concept as a cornerstone of radiation protection philosophy?

    a. TED (threshold erythema dose)
    b. ALAP (as low as practicable)
    c. ALARA (as low reasonably achievable)
    d. TDS (time, distance and shielding)

14. A protective action guide (PAG) is

    a. a set of NRC regulations for developing emergency response plans.
    b. an analysis of the economic costs of evacuating versus in-place protection.
    c. the nuclear plant licensee's operating manual.
    d. a projected radiation dose at which a specific protective action is warranted.

15. During the early phase of a nuclear accident, the EPA Protective Action Guide (PAG) for evacuation or sheltering of the public is

    a. .01 - 1.0 rem
    b. 1.0 - 5.0 rem
    c. 5.0 - 10.0 rem
    d. 10.0 - 15.0 rem

16. The Department of Energy establishes a Federal Radiological Monitoring and Assessment Center (FRMAC) in the event of a significant radiological emergency for the purpose of

    a. monitoring the performance of Federal agencies.
    b. monitoring the performance of State and local agencies.
    c. providing technical assistance to the States and the Lead Federal Agency (LFA).
    d. all of the above.

17. During a radiological emergency, offsite authority and responsibility for the health and welfare of the general public rests with

    a. State and local officials.
    b. Department of Energy officials.
    c. Federal Emergency Management Agency officials.
    d. the Lead Federal Agency.

18. While conducting radiological monitoring operations at the scene of an accident, you are tapped on the shoulder and turn to face a reporter with a microphone and a cameraman with his videocamera aimed at your face. In response to the reporter's request for a status report, you

a. point the meter at the reporter and tell her she has 10 seconds to leave or she will die of radiation sickness.
b. stop what you are doing and answer all of the reporter's questions.
c. follow your agency's plan for working with the media and refer the reporter to the Public Information Officer.
d. refer the reporter to the radiological responder who has the most technical background.

19. After an accidental radiation release, short-term environmental monitoring

a. is performed by emergency responders and provides data for determining appropriate action levels and mitigating measures.
b. is performed by supporting or consulting personnel to provide detailed analyses of radiological hazards and accident consequences.
c. is performed only by the Department of Energy's FRMAC.
d. takes precedence over emergency rescue operations.

20. An environmental monitoring program must be in place so that in a nuclear incident, potential dose levels may be projected for

a. whole body external exposure.
b. inhalation of suspended particulate radioactive materials.
c. ingestion of contaminated food and water.
d. all of the above.

21. The role of the radiological response team member in an emergency involving actual or potential radiation releases from a nuclear power plant is defined

a. in State and local radiological emergency response plans.
b. by the nuclear plant operators.
c. by the Environmental Protection Agency's Protective Action Guides.
d. by the Federal Emergency Management Agency.

22. White radioactive labels on packages at an accident scene tell the responder

a. the exposure rate from those packages will be high.
b. the exposure rate from those packages will be low.
c. the packages contain Fissile Class materials.
d. all of the above.

23. A radioactive placard on a vehicle indicates that

a. it is an exclusive use vehicle.
b. it is a non-exclusive use vehicle.
c. it carries one or more packages labeled Radioactive Yellow III and/or LSA material.
d. exposure rates on the surface of the vehicle should not exceed 50 mrem/hr.

24. In defining a radiological problem it is important to consider

a. the external radiation hazard.
b. the internal hazards - ways in which radioactive material may be inhaled, ingested or absorbed.
c. the injury hazards to on-site personnel.
d. all of the above.

25. The control zone in which response actions should be limited to the shortest possible entry time is the

a. hot zone.
b. warm zone.
c. cold zone.
d. decontamination zone.