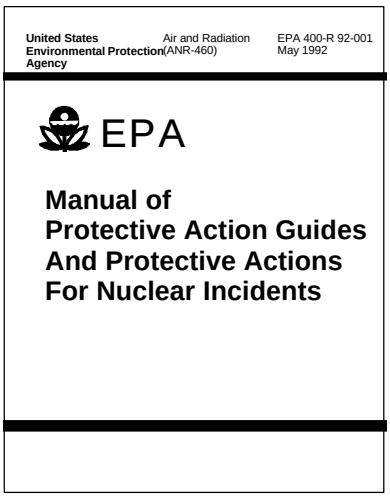
UNIT FIVE

PROTECTIVE ACTIONS AND PROTECTIVE ACTION GUIDES



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.

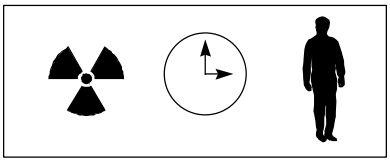
If your answer included all or most of the above points, you should be ready for the Summary Questions at the end of this unit. *Turn to page 5-33.*

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



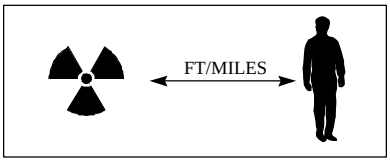
Time is an important factor in limiting exposure to the public and to radiological emergency responders. The shorter the period of time an individual stays in a radiation field, the smaller the dose he or she will receive.

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.

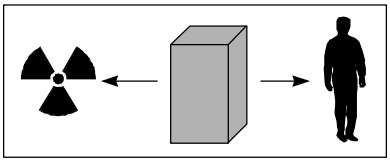
DISTANCE



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.

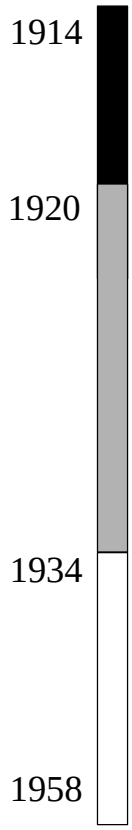
ANSWERS

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

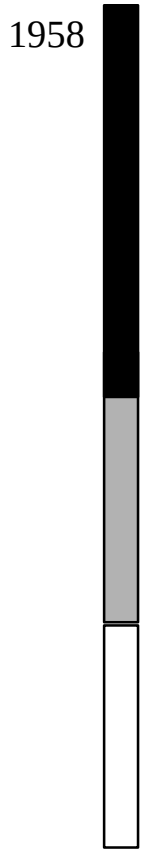
Before 1914, early radiologists determined the quantity of radiation emitted from an x-ray machine by placing a hand in the primary beam until a tingling sensation produced the dose to sufficiently cause reddening of the skin. This was termed "Threshold Erythema Dose" or TED. TED was an inadequate unit 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.

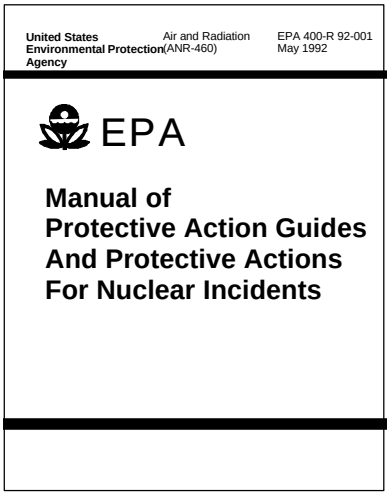
ANSWERS

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.



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.

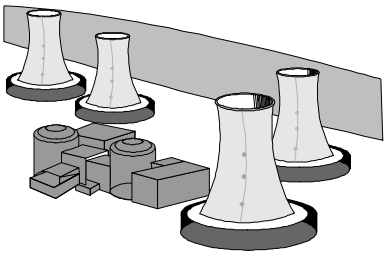
ANSWERS

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

The _____ phase extends until protective actions are completed.

Circle the correct answer

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

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.

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
Administration of stable iodine	25 rem	Requires approval of State medical officials

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.

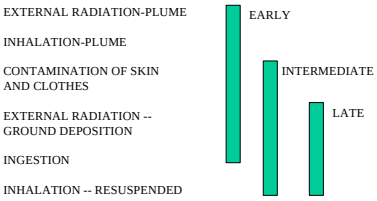
Move on to the next section.

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.

RADIATION EXPOSURE PATHWAYS IN NUCLEAR INCIDENTS

POTENTIAL EXPOSURE PATHWAYS AND INCIDENT PHASES



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

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

Circle the correct answer

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

Circle the correct answer

SUMMARY QUESTIONS

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.