Radiological Worker II Training

Study Guide

March 2007

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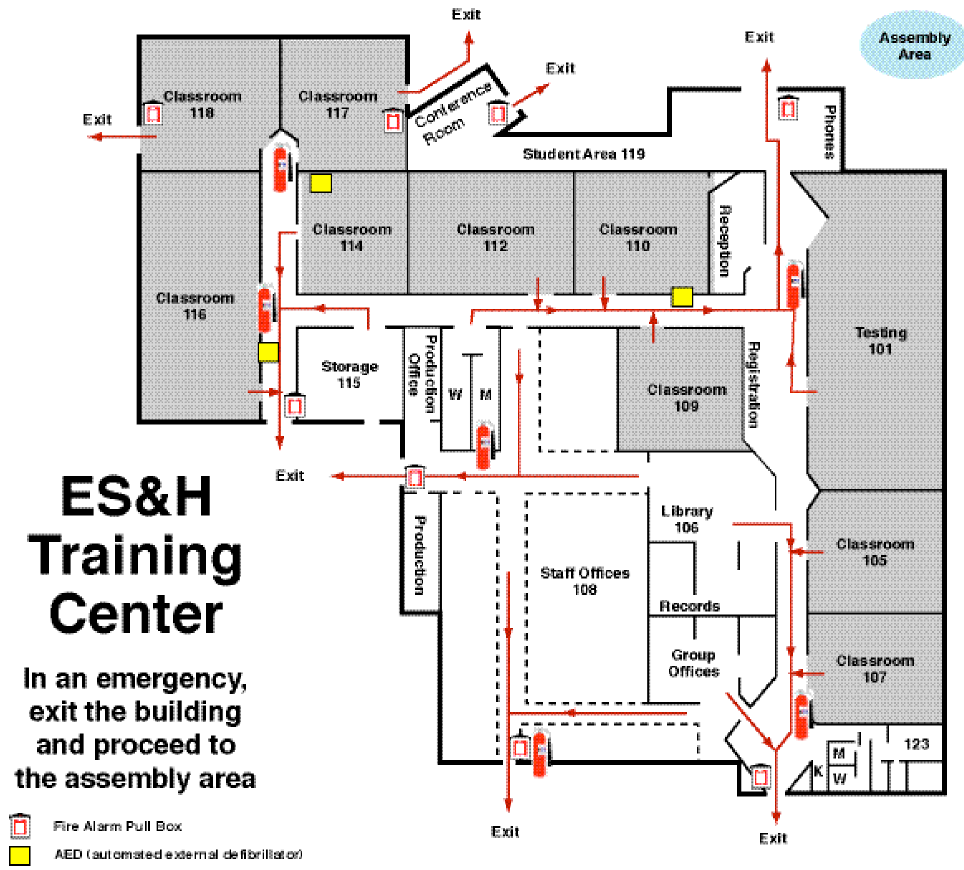

Core course materials were developed by the Department of Energy (May 1994). Information specific to Los Alamos National Laboratory was added by ES&H Training, now designated CT-ITS.

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Introduction

Radiological Safety Policy

Radiological Control Safety

The Department of Energy (DOE), in conjunction with each site, is firmly committed to having a radiological control program of the highest quality. This program, as outlined the in Code of Federal Regulations 10 CFR 835, *Occupational Radiation Protection,* and the Los Alamos National Laboratory (LANL) *Radiation Protection Program* (RPP), requires that managers and supervisors at all levels be involved in the planning, scheduling, and overseeing of radiological work. This directive also requires that radiological safety not be compromised to achieve production or research objectives.

Training Requirements

Radiological Worker training is required if you

- operate radiation-producing devices,
- work with radioactive materials,
- are likely to receive routinely occupational exposure above 100 mrem per year, and/or
- are permitted unescorted access into radiological areas.

At some facilities, radiological worker training is also required for unescorted access to a Controlled Area or a Radiological Buffer Area, depending on the radiological hazards in the area.

This study guide covers Radiological Worker II DOE Core Training. After successful completion of this training, you are permitted unescorted access to all radiological areas, subject to site-specific authorization to work in the radiological area and the need to be working there.

You are required to refresh every two years, either by repeating the initial course or by completing a radiation safety self-study course. In both cases, you must pass an examination to receive the refresher credit

At LANL, “radiological worker training” refers to Radiological Worker II training. LANL does not offer Radiological Worker I training, testing, or evaluation.

Course Overview

Training, Examination, and Practical Evaluation

This study guide for Radiological Worker II Training is used both in the classroom and for self-study.

The Radiological Worker II examination consists of 50 questions and includes material from all units in this study guide. A score of 80% or better is required to pass the examination. In addition, the examination must be refreshed every 24 months (2 years).

You must also pass the practical exercise evaluation, which is a hands-on, real-time demonstration of awareness and understanding of radiological safety concepts and practices for working with or around known sources of ionizing radiation. A score of 80% or better is required to pass the practical exercise evaluation. For LANL operations, this evaluation is required only once; however, line management may require refreshing the practical evaluation as needed for specific work activities at LANL or other DOE sites, such as the Nevada Test Site.

Understanding Hazards, Practices, and Responsibilities

Course Objective

Radiological worker training is the basic building block for any additional radiological training you may receive. Upon completion of radiological worker training, you will have the basic knowledge needed to work safely, using proper radiological practices, in areas where radiological hazards exist. You will also have a better understanding of the hazards and responsibilities associated with radiological work to help prevent the complacency that can occur when working continually with or around radioactive materials.

This course does not qualify you for any specific work involving radioactive materials or sources. You may be required to take additional training at individual facilities to address facility- and job-specific hazards and procedures.

Lessons Learned

The Chernobyl Accident

On April 26, 1986, a nuclear reactor exploded at Chernobyl Nuclear Power Plant in the former Soviet Union. As a result of the radioactive emissions from this accident, six firemen and 22 other workers at the site died of acute radiation sickness. Additionally, the long-term health of millions of people who live near the site has received much publicity. It is likely that some people have died or will die prematurely as a result of radioactive material that was spread for thousands of miles.

Investigations have revealed that the accident resulted from several major violations of procedures, compounded by serious flaws in the design of the nuclear reactor. Worker training was also inadequate. Workers had no way to measure the radioactivity, no way to assess the situation, and inadequate knowledge of how to protect themselves.

Protective equipment was not used. During the first few hours, the workers and firemen had no respirators; in hindsight, even a handkerchief tied over their faces would have helped. Their clothing was permeable to water and to radioactive material, and they had handled extremely radioactive material with their bare hands. As a result, contamination measuring hundreds or even thousands of rem per hour got onto their skin and remained there for many hours. Eventually these workers were taken to the hospital, and the doctors and nurses who treated them received doses up to about 20 rem (rem is a unit for measuring the biological effects of radiation on the human body) from the contamination that was still on their skin. The DOE limit is 5 rem a year.

Most workers at Chernobyl had no dosimeters and no other instruments to measure the dose rates. The radiological control technician (RCT) had only one instrument, which was continuously giving a reading beyond his scale. He concluded it was broken and ignored the readings. There were no other instruments to measure radiation levels, so workers labored for hours in places where the dose rates were between 100 and 1000 rem per hour. The doses received by the 28 people who died were later estimated to be from 600 to 1800 rem. Many of these lives could have been saved if they had received the training provided in this course.

Lessons Learned—continued

Experts agree that a similar accident cannot happen in the United States; however, politicians, scientists, and workers in the former Soviet Union also believed that the Chernobyl accident could not happen. Therefore, no preparations were made. Clearly, appropriate training could have reduced the injuries and fatalities at Chernobyl and will mitigate the hazards in any future incident involving radioactivity at LANL.

Radiological Control Phone Numbers		
Emergencies 911		
EM&R	Emergency Management & Response	7-6211
Health, Safety, and Radiation Protection Division		
RP-1	Health Physics Operations	7-7171
	Chemistry and Metallurgy Research Building	7-4093
	TA-50 and TA-54	7-3097
	TA-53	7-5890
	TA-55	5-0981
	All Other Facilities	5-4926
OM	Occupational Medicine	7-7890
RP-2	Health Physics Measurements	5-6064
	Radiation Information Management	7-5296
IHS-IP	Industrial Hygiene and Safety—Institutional Programs	7-5231
SB-CS	Criticality Safety	7-4789
RP-3	Radiation Protection Technical Support	7-5296
	Dose Assessment	7-5296
HAZMAT	Hazardous Materials Response	5-5237
Other Important Phone Numbers		
CT-ESH	Central Training-Environment, Safety, & Health	5-5605
PTLA	Protection Technology of Los Alamos	7-4437

Unit 1: Radiological Fundamentals

Learning Objectives

Major Objectives

Upon completion of this unit, you will be able to identify the fundamentals of radiation, radioactive material, and radioactive contamination.

Enabling Objectives (EOs)

You will be able to select the correct response from a group of responses, which verifies your ability to

EO1 define radiation, radioactivity, and radioactive half-life;

EO2 define radioactive material and radioactive contamination;

EO3 define ionization;

EO4 distinguish between ionizing radiation and nonionizing radiation;

EO5 state the basic types of ionizing radiation;

EO6 identify the range, shielding, and biological hazards for each of the types of ionizing radiation;

EO7 identify the units used to measure radiation, radioactivity, radioactive contamination; and

EO8 convert rem to millirem and millirem to rem.

Introduction

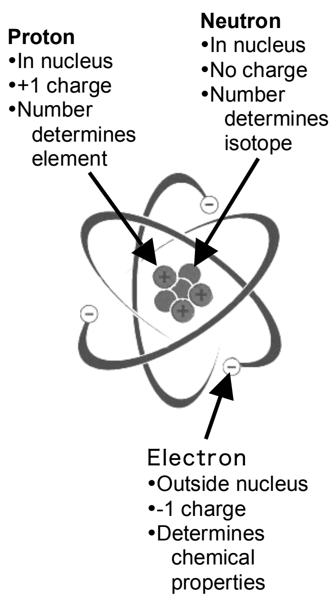
To work safely in and around areas controlled for radiological purposes, you must have a basic knowledge of the fundamental concepts and vocabulary associated with ionizing radiation and radiological protection theory.

Atomic Structure

The Atom

The basic unit of matter is the atom. The atom is made up of three basic particles: *protons, neutrons, and electrons*. Protons and neutrons are found in the nucleus, the central portion of the atom. Electrons surround the nucleus.

Basic Particles of the Atom		
Particle	**Charge**	**Other Properties**
proton	+1	located in the nucleus the number of protons determines the element
neutron	No charge (neutral)	located in the nucleus the number of neutrons determines the isotope
electron	−1	located around the nucleus electrons determine the chemical properties

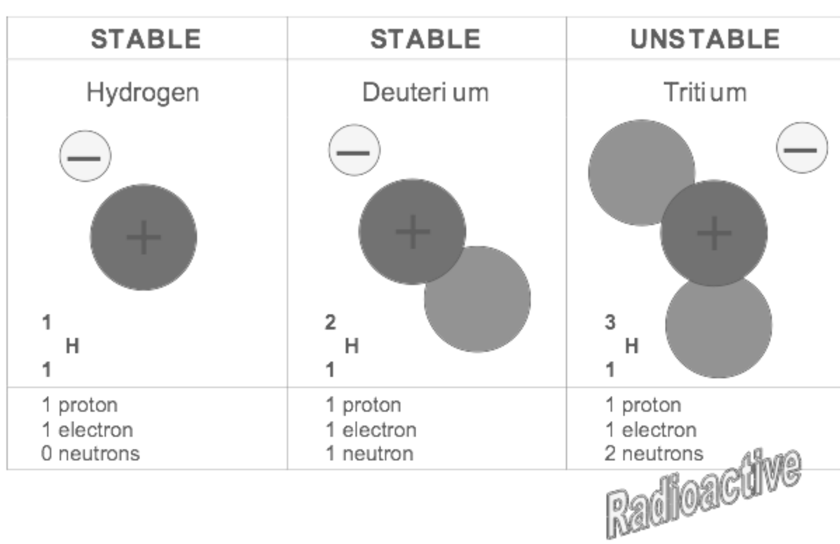


Atomic structure.

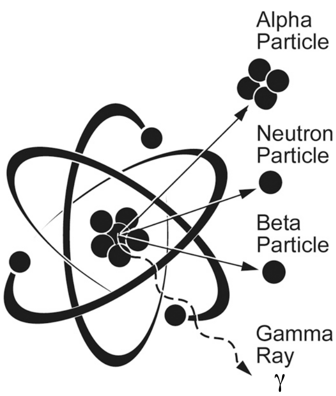
Isotopes

Atoms of the same element have the same number of protons but can have a different number of neutrons. Atoms of the same element that have different numbers of neutrons are called *isotopes*. For example, hydrogen has several isotopes: hydrogen, with one proton; deuterium, with one proton and one neutron; and tritium, with one proton and two neutrons. The number of protons determines the element. If the number of protons changes, the element changes.

The number of neutrons determines the isotope of the element. Isotopes have the same chemical properties but can have quite different nuclear properties. The following diagram illustrates the basic properties of protons, neutrons, and electrons.



Radiation



Ionizing radiation.

Radiation/Ionizing Radiation

Radiation is energy in the form of particles or waves. These particles are like speeding bullets: neither the particle nor the bullet is in itself dangerous; however, the energy resulting from its speed is dangerous. After the particle stops, it becomes harmless.

Some atoms have too many or too few neutrons for a given number of protons. The resulting nuclei in these atoms will have too much energy and will not be stable. These unstable atoms will attempt to become stable by giving off excess energy in the form of particles or waves (radiation). These unstable atoms are also known as radioactive atoms. Radioactive atoms can be either naturally occurring or manmade.

Radioactivity

Radioactivity is the spontaneous decay, or disintegration, of unstable, or radioactive, atoms that emit radiation as they attempt to become stable.

Radioactive Half-Life

Radioactive half-life is the time it takes for one-half of the unstable, or radioactive, atoms present to decay (or disintegrate).

Radioactive Material

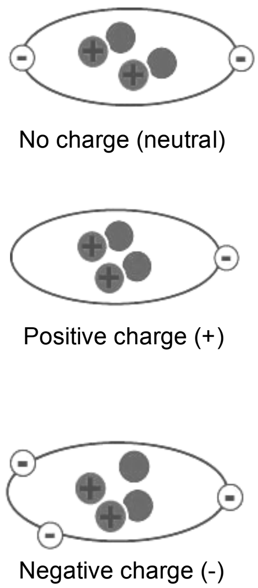
Radioactive material is any material containing radioactive atoms that spontaneously emits ionizing radiation.

Radioactive Contamination

Radioactive contamination is radioactive material in an unwanted location, such as outside the glove box or hood in which it is being handled or stored, in homes or offices where it should never be, on or in your body, or inadvertently released into the environment.

If radiation is like a speeding bullet, contamination is like a live bullet waiting to go off. Contamination is not a hazard if properly controlled. The best policies are not allowing it to occur and being prepared to contain it if it does occur.

Process of Ionization



Charge of the atom.

Ions

To understand how radiation affects matter, one must first understand the process of ionization.

The term *ion* is used to define an atom that has an electrical charge. Normally, atoms have an equal number of protons (+ charge) and electrons (– charge) so the total charge is zero.

Ionization

Ionization is the process of removing electrons from atoms to make charged ions.

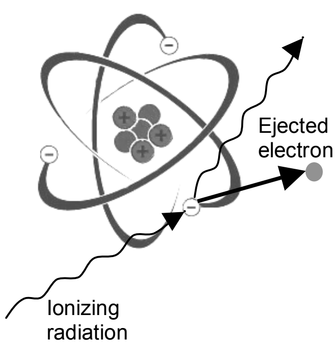
If enough energy is supplied to remove electrons from the atom, the remaining atom has a positive charge. These ions allow radiation to be detected in an ionization chamber. Too many ions in human tissue can cause temporary or long-term damage.

Ionizing Radiation

Radiation that has enough energy to cause ionization is called *ionizing radiation*. Examples of ionizing radiation are alpha particles, beta particles, gamma rays (and x-rays), and neutrons.

Nonionizing Radiation

Radiation that does not have enough energy to cause ionization is called *nonionizing radiation*. Examples of nonionizing radiation include radio waves, radar, microwaves, and visible light.



External Radiation Hazards

Ionizing radiation can be an ***external*** radiation hazard when it comes from outside the body. In this respect, ionizing radiation is like the heat from fire because you can shield yourself from it.

Internal Radiation Hazards

Contamination is an ***internal*** hazard because it is harmful if it gets inside the body. In this sense, contamination is somewhat like smoke.

Types of Ionizing Radiation

Four Basic Types of Radiation

The four basic types of radiation of concern in the nuclear industry are

- alpha particles,
- beta particles,
- gamma rays (and x-rays), and
- neutrons.

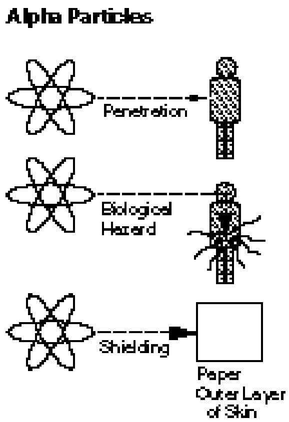
X-rays are very similar to gamma rays, but where gamma rays originate spontaneously in the nucleus, x-rays are generated by man-made devices. Both produce the same biological effects.

The following table shows the types of radiation and their characteristics, hazards, shielding, and sources.

Type of Radiation	Characteristic	Hazard	Shielding	Some Sources at LANL	Some Locations at LANL[a]
alpha particle α	•+2 charge large mass •7200 times larger than electron •very short range: about 1–2 inches in the air	internal	paper outer layer of skin	americium plutonium uranium	TA-3 TA-16 TA-55
beta particle β	•–1 or +1 charge small mass •same as electron short range: 10 feet in air per MeV of energy	external: skin and eyes internal	plastic glass aluminum	phosphorus-32 tritium accelerators instrument calibration sources	TA-3 TA-16 TA-21 TA-43 TA-53
gamma and x-ray γ	•no charge •no mass •long range: several hundred feet in the air	external: whole body internal	lead concrete steel	x-ray machines cobalt-60 accelerators	TA-3 TA-8 TA-53
neutron particle *n*	•no charge •same mass as proton •long range: several hundred feet in the air	external: whole body internal	water plastic concrete with high hydrogen content	americium plutonium uranium accelerators	TA-53 TA-55

[a]*LANL locations may house one or more of the sources listed.*

Types of Ionizing Radiation—continued



Alpha Particles α

Physical Characteristics

The alpha particle has a large mass and consists of two protons, two neutrons, and no electrons (positive charge of +2). It is a highly charged particle that is emitted from the nucleus of an atom. The positive charge causes the alpha particle (+) to strip electrons (–) from nearby atoms as it passes through the material, thus ionizing these atoms.

Range

The alpha particle deposits a large amount of energy in a short distance. This large energy deposit limits the penetrating ability of the alpha particle to a very short distance. This range in air is about 1 to 2 inches.

Shielding

Alpha particles are shielded by less than 1 mm of material, such as a sheet of paper or the outer layer of skin.

Biological Hazard

If ingested or inhaled, an alpha emitter deposits all of its energy in a short distance. It is considered an internal hazard because it deposits all of its energy in a short range within living tissue.

Sources

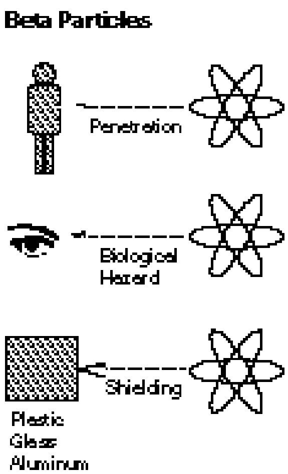
Alpha radiation is emitted during the decay of certain radioactive atoms such as americium, plutonium, and uranium.

Beta Particles β

Physical Characteristics

The beta particle has a small mass and is negatively charged. It is emitted from the nucleus of an atom and has an electrical charge of – 1 or +1. Beta radiation causes ionization by displacing electrons from their orbits. The beta particle is physically identical to the electron. Ionization occurs because of the repulsive force between the beta particle (–) and the electron (–), both of which have a negative charge.

Types of Ionizing Radiation—continued



Range

Because of its negative charge, the beta particle has a limited penetrating ability. The range in air is about 10 feet per MeV (million electron volts) of energy.

Shielding

Beta particles are best shielded by about ½ inch or less of plastic or aluminum.

Biological Hazard

A beta particle poses an internal hazard. A beta emitter deposits all of its energy within a short distance. If ingested or inhaled, this large concentration of beta particles becomes an internal hazard to living tissue.

Externally deposited beta particles can be hazardous to the living layers of skin and to the eyes but not to internal organs.

Sources

Beta radiation is emitted

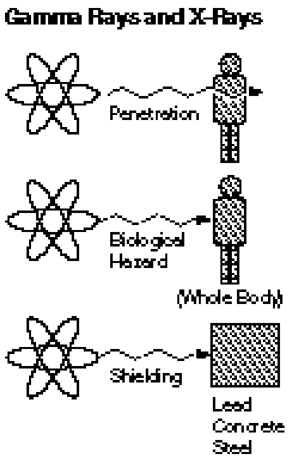
- during the decay of certain radioactive atoms such as tritium and phosphorous-32,
- by activation products from accelerator operations such as Co-60, and
- by sealed sources used for calibration of radiation detection and experimental measurement instruments.

Gamma Rays γ and X-Rays

Physical Characteristics

Gamma and x-ray radiation are electromagnetic waves or photons and have no electrical charge. Gamma rays are very similar to x-rays. The difference is in the place of origin: gamma rays originate in the nucleus; x-rays are generated by man-made devices outside the nucleus. In addition, gamma rays are usually more energetic than x-rays. Gamma and x-ray radiation ionizes by direct interactions with orbital electrons.

Types of Ionizing Radiation—continued



Range

Because gamma rays and x-rays have no charge and no mass, they have a very high penetrating power. The range in air is very long; gamma rays and x-rays will easily go several hundred feet.

Shielding

Gamma rays and x-rays are best shielded by very dense materials, such as lead, concrete, or steel.

Biological Hazard

Gamma rays and x-rays can reach internal organs and result in radiation exposure to the whole body; therefore, both are external and internal hazards to the entire body.

Sources

Gamma and x-ray radiation is emitted by

- x-ray machines;
- the decay of certain radioactive atoms such as cobalt-60, which is used for radiography and instrument calibration; and
- accelerator products from accelerator operations.

Neutrons *n*

Physical Characteristics

Neutron radiation consists of neutrons that are ejected from the nucleus. A neutron has no electrical charge. Neutrons interact with matter by collisions with the nucleus. These collisions result in secondary charged particles that cause ionization.

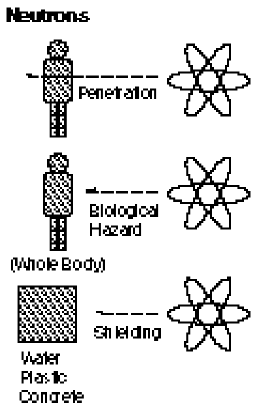
Range

Because neutrons have no charge, they have a relatively high penetrating ability and are difficult to stop. The range in air is very long, and like gamma rays, they can easily travel several hundred feet in the air.

Shielding

Neutrons are best shielded by materials that have a high hydrogen content, such as water, plastic, or concrete.

Types of Ionizing Radiation—continued



Biological Hazard

Neutrons are a whole body, internal and external hazard because of their high penetrating ability to all tissues.

Sources

Neutron radiation is emitted

- when certain radioactive atoms, such americium, plutonium, and uranium, interact with other elements;
- by accelerator operations; and
- by criticality experiments.

Units of Measure

Measuring Radiation

Radiation is measured in units of roentgen, rad, or rem.

Roentgen I

The *roentgen* is a unit for measuring ionization caused by gamma and x-rays in air. Therefore, it does not relate to the biological effects of radiation on the human body. It is a *measurement of exposure* and was named for Wilhelm Roentgen, who discovered x-rays.

1 roentgen (R) = 1000 milliroentgen (mR)

Radiation Absorbed Dose (rad)

The *rad* is a unit for measuring energy absorbed in any material. Absorbed dose results from energy being deposited by the radiation. This unit is defined for any material and applies to all types of radiation. It is a *measurement of absorbed dose* but does not take into account the potential biological effects that different types of radiation have on the human body.

1 rad = 1000 millirad (mrad)

Roentgen Equivalent Man (rem)

The rem is a unit for measuring the biological effects of radiation on the human body. It is the most commonly used unit for dose reporting. The rem takes into account the absorbed dose and the biological effects of different types of radiation. It is *a measurement of biological dose equivalence.* This unit applies to both internal and external doses.

Units of Measure—continued

Curie

The radioactivity, or amount of radioactive material present, is measured by the number of disintegrations in a given period. The *curie* (Ci) is a unit for measuring the amount of radioactive material present. The curie was named for Marie Curie, who discovered radium.

Derived Air Concentration (DAC)

DAC is a unit of measure for the amount of radioactive material present per unit volume in air. It can be used by RCTs (radiological control technicians) to track dose (indirectly) as an indicator of potential internal exposure from airborne radioactivity.

Contamination (cpm and dpm)

Contamination is measured in counts per minute (cpm) and recorded in disintegrations per minute (dpm). Contamination is measured in a specific area (100 cm^2) and reported in dpm divided by the area (dpm/100 cm^2). Contamination is radioactive material, usually too small to see, located in an undesirable place such as on the floor where one may contaminate shoes and thus spread it even more.

The presence of contamination is usually an indication of poor work practices rather than an immediate health hazard. Contamination is normally measured by an RCT using an extremely sensitive detector. The units measured (cpm and dpm) are usually very small.

Converting rem to mrem and mrem to rem

1 rem = 1000 millirem (mrem)

To convert rem to mrem, multiply by 1000.

0.2 rem	=	200 mrem
5 rem	=	5000 mrem
100 rem	=	100,000 mrem

To convert millirem to rem, divide by 1000.

360 mrem	=	0.36 rem
25,000 mrem	=	25 rem
800,000 mrem	=	800 rem

Student Self-Assessment

Answer the following questions to test your mastery of this unit. Strive for a score of 80% or better. (EO#) indicates the enabling objective corresponding to the question.

1. Match the term to the correct definition. (EO1 and EO2)

____ ionizing radiation	a. the spontaneous decay, or disintegration, of unstable atoms that emit radiation as they attempt to become stable
____ radioactive material	b. the time it takes for one-half of the radioactive atoms present to decay
____ radioactive contamination	c. any material that contains unstable, or radioactive, atoms
____ radioactivity	d. radiation that has enough energy to remove an electron from its orbit around an atom
____ radioactive half-life	e. radioactive material in an unwanted location

2. Which of the following correctly distinguish between radiation and contamination? (EO1 and EO2)
   a. radiation is energy; contamination is matter
   b. radiation is measured in rad or rem; contamination is measured in cpm and reported in dpm
   c. radiation ceases to harm you after you leave the area, but you might take contamination with you if it gets on you or into your body
   d. all of the above

3. Ionization is the process of removing ____ from atoms. (EO3)

4. Which of the following is not a form of ionizing radiation? (EO4)
   a. alpha particles
   b. gamma rays
   c. microwaves
   d. beta particles

Student Self-Assessment—continued

5. Four basic types ionizing radiation are____________, ____________, ____________, and ____________. (EO5)

6. Match the shielding to the type of ionizing radiation for which it is typically used. (EO6)

_____ water	a. alpha particles
_____ lead	b. beta particles
_____ paper	c. gamma and x-rays
_____ ½ inch of plastic	d. neutrons

7. Match the term to the correct definition. (EO7)

___ roentgen	a. the unit used to measure radioactive contamination
___ rad	b. the unit used to measure biological dose equivalence
___ rem	c. the unit used to measure ionization in air caused by gamma and x-rays
___ curie	d. the unit used to measure energy absorbed in any material from any type of ionizing radiation
___ dpm	e. the unit used to measure the amount of radioactive material

8. How many mrem equal 5 rem? (EO8)
   a. 50
   b. 500
   c. 5000
   d. 50,000

9. How many rem equal 200 mrem? (EO8)
   a. 2
   b. 0.2
   c. 20
   d. 0.02

10. 3.7 rem is equal to ________ mrem?

Student Self-Assessment—continued

11. 500 mrem is equal to ________ rem?
12. 7000 mrem is equal to ________ rem?
13. 0.09 rem is equal to ________ mrem?
14. 60 mrem is equal to ________ rem?
15. 0.003 rem is equal to ________ mrem?

Answers

1. d,c,e,a,b
2. d
3. electrons
4. c
5. alpha, beta, gamma and x-ray, neutron
6. d,c,a,b
7. c,d,b,e,a
8. c
9. b
10. 3700
11. 0.5
12. 7
13. 90
14. 0.06
15. 3

Unit 2: Biological Effects

Learning Objectives

Major Objectives

Upon completion of this unit, you will be able to determine the biological risks to the exposed population.

Enabling Objectives (EOs)

You will be able to select the correct response from a group of responses, which verifies your ability to

EO1 describe the major sources of natural background and manmade radiation;

EO2 state the method by which radiation causes damage to cells;

EO3 identify the possible effects of radiation on cells;

EO4 define somatic effect and heritable effect;

EO5 define acute radiation dose and chronic radiation dose;

EO6 state examples of chronic radiation dose;

EO7 state the potential effects associated with pregnant worker radiation doses;

EO8 identify the DOE radiation dose limits;

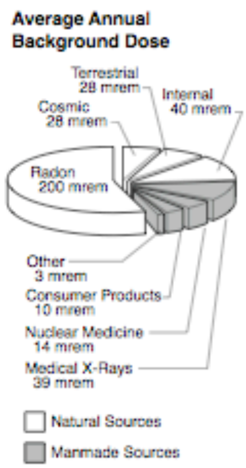
EO9 identify your responsibilities concerning radiation dose limits; and

EO10 compare the biological risks from chronic radiation doses with the health risks workers are subjected to in industry, in radiation-related occupations, and in other activities.

Sources of Radiation

A Radioactive Planet

The earth has always been a radioactive planet. Human beings have always lived in the presence of natural background radiation. In fact, the majority of the earth's population will be exposed to more ionizing radiation from natural background radiation than from occupational exposures.



The average annual radiation dose equivalent to a member of the general population from both natural and manmade background sources is about 360 mrem.

In Los Alamos, background dose averages about 400 mrem per year because of the higher altitude and radon levels. ["Environmental Surveillance and Compliance at Los Alamos during 1996," Los Alamos National Laboratory report LA-13343-ENV (September 1997)].

Natural Radiation Sources

Several sources of radiation occur naturally. The radiation emitted from these sources is identical to the radiation emitted from manmade sources.

The four major sources of naturally occurring radiation are

- cosmic radiation;
- sources in the earth's crust, known as terrestrial radiation;
- sources in the human body, known as internal sources; and
- radon.

Cosmic Radiation (the Sun and Outer Space)

Cosmic radiation comes from the sun and outer space and consists of charged particles as well as gamma radiation. At sea level, the average annual cosmic radiation dose equivalent is about 26 mrem. At higher elevations, the amount of atmosphere-shielding cosmic rays decreases; thus, the dose equivalent increases. In Los Alamos, the annual dose equivalent is about 65 mrem. The total average annual dose equivalent to the general population from cosmic radiation is about 28 mrem.

Sources of Radiation—continued

Terrestrial Radiation (Earth)

Natural sources of radiation exist in the ground, rocks, and drinking water supplies. The major contributors to the terrestrial sources are the natural radioactive elements radium, uranium, and thorium. Many areas have elevated levels of terrestrial radiation because of increased concentrations of uranium and thorium in the soil. On the Pajarito Plateau, the annual dose equivalent is about 50–100 mrem. The total average annual dose equivalent to the general population from terrestrial radiation is 28 mrem.

Internal Radiation (Human Body)

Sources of radiation within the body come from food and water, which contain trace amounts of natural radioactive materials. Potassium-40 is the most abundant radioactive source in the body. The total average annual dose equivalent to the general population from internal sources is 40 mrem.

Radon

Radon comes from the radioactive decay of uranium and thorium, which are naturally present in the soil. Because radon is a gas, it can travel through the soil and collect in basements or other areas of a home. Radon emits alpha radiation. When inhaled, radon and its decay products can cause a dose equivalent to the lungs of approximately 2400 mrem per year, which is equal to a whole body dose equivalent of 200 mrem.

Manmade Radiation Sources

The difference between manmade radiation and naturally occurring radiation is the form of the radiation source.

The four major sources of manmade radiation are

- medical x-rays,
- nuclear medicine,
- consumer products, and
- industrial radiation uses.

Sources of Radiation—continued

Medical Radiation

X-rays are used for medical diagnosis. A typical radiation dose equivalent from a single chest x-ray is about 10 mrem. The total average annual dose equivalent to the general population from medical x-rays is 39 mrem.

Nuclear medicines are used in medical procedures for diagnosis and therapy. The total average annual dose equivalent to the general population from these sources is 14 mrem.

Consumer Products

Some consumer products such as televisions, older luminous dial watches, and some smoke detectors are sources of radiation. Most of the dose from consumer products comes from building materials that contain natural uranium or thorium. The average annual dose equivalent from consumer products is 10 mrem.

Other Sources of Radiation

Industrial uses of radiation include x-ray machines (radiography) for testing pipe welds and boreholes and for atmospheric testing. The average annual dose equivalent from industrial radiation uses is less than 2 mrem.

Biological Effects

Information about the biological effects of radiation is available not only from animal studies but also from studies of human exposures.

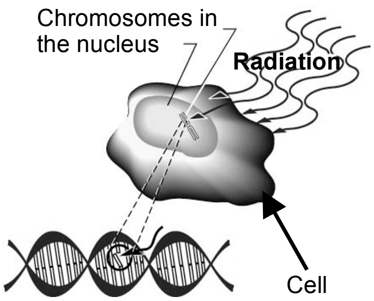
Four major groups of people have been exposed to significant levels of radiation:

- some early workers, such as radiologists who received large doses of radiation before the biological effects were recognized or standards were developed to protect workers;
- the more than 80,000 survivors of the atomic bombs dropped at Hiroshima and Nagasaki who received estimated dose equivalents in excess of 30,000 mrem (30 rem);
- individuals who have been involved in radiation accidents, the most notable being the Chernobyl accident; and
- patients who have undergone therapeutic radiation treatments.

Effects of Radiation on Cells

How Radiation Damages Cells

Radiation causes damage to any material by ionization of atoms in the material. Atoms make up the cells that make up the tissues of the body. Tissues make up the organs of the body. Any potential radiation damage to the body begins with ionization of the atoms. Therefore, radiation causes damage to humans by ionization of atoms in the cells. This ionization changes the properties of vital cell chemicals and causes undesirable secondary chemical reactions to occur.



Possible Effects of Radiation on Cells

Radiation may strike a vital part of the cell (such as the nucleus), a less-vital part (such as the body of the cell), or a cell molecule (such as water). When radiation strikes a cell, the following effects can occur:

- some cells are damaged;
- most cells repair the damage;
- some cells die as a result of the damage; and
- some cells will undergo a damaging alteration.

At any given moment, thousands of cells are dying and being replaced by normal cells. Most cells die naturally; a few cells die from damage caused by a variety of external sources including exposure to chemicals, trauma, and radiation.

As long as the number of cell deaths from external sources is small compared with the natural deaths, the body is programmed to handle this cell loss. However, when the damage is extensive, the body may take some time to repair the damage, and radiation sickness may result. Radiation sickness usually occurs only after an acute whole body dose of more than 100,000 mrem (100 rem).

Types of Effects

Somatic and Heritable Effects

The effects of chromosome damage in a cell resulting from exposure to radiation can be

- somatic (bodily), or
- heritable.

Types of Effects—continued

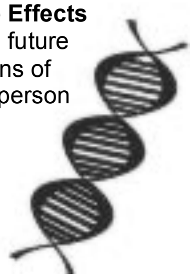
Somatic Effects

Somatic Effects
Appear in exposed person

A *somatic* effect is one that occurs only in the body of the individual exposed to radiation. Somatic effects depend on many factors (discussed later in this unit). Somatic effects such as hair loss, diarrhea, vomiting, coma, or even death occur at doses many times greater than occupational dose limits allow.

One somatic effect of concern is cancer. An individual exposed to radiation can experience chromosome damage that could eventually cause the cell to become a cancer cell. However, the probability of cancer resulting from occupational doses of radiation (discussed later in this unit) is very low compared with the natural probability (20%) of having a fatal cancer.

Heritable Effects



Heritable Effects
Appear in future generations of exposed person

A *heritable* effect is an effect that is inherited or passed on to an offspring. Damage that occurs to chromosomes in the sperm or ovum and then is passed on to future generations but does not affect the exposed individual is a heritable effect.

Heritable effects from radiation have been observed in studies of plants and animals but have never been observed in humans. Studies have included 77,000 Japanese children born to the survivors of Hiroshima and Nagasaki (conceived *after* explosion of the atomic bombs). These studies have followed their children and grandchildren. No effects have been observed in those children who were conceived and born after the atomic bombs.

Factors Affecting Biological Damage

Contributing Factors

Several factors contribute to the biological effects of radiation exposure. These factors include

- type of radiation,
- total radiation dose,
- radiation dose rate,
- cell sensitivity,
- individual sensitivity (dose rate, cell repair rate, and physical condition of the individual), and
- area of body exposed.

Factors Affecting Biological Damage—continued

Type of Radiation

Different types of radiation affect the body differently. For the same energy deposited, alpha and neutron radiation are more damaging than beta or gamma radiation.

Total Radiation Dose

Biological effects depend on how fast a radiation dose is received. In general, the biological effects will increase when the dose is increased.

Radiation Dose Rate: Acute and Chronic

The faster the dose is delivered, the less time the cell has to repair the damage. Radiation doses can be grouped into two categories:

- acute dose—a dose of radiation, typically a large amount, received in a short period; and
- chronic dose—a dose of radiation, typically a small amount, received over a long period.

Acute Dose

Probability of an Acute Dose

It takes a massive dose of radiation for damaging effects to occur. The possibility of a radiological worker's receiving an acute dose on the job is extremely remote. In many areas where radioactive materials are handled, the quantities are small enough to prevent emissions of large amounts of radiation. Where a potential exists for larger exposures, safety features are in place to prevent such exposures.

Acute Dose to Only Part of the Body

Radiation exposure may be limited to only a part of the body such as the hand. In accidents involving x-ray machines, individuals have exposed their fingers to part of the x-ray beam. In some cases individuals have received dose equivalents of millions of millirem, resulting in the loss of finger(s) or other exposed body parts.

Radiation therapy patients receive high doses of radiation in short periods, generally to only a small portion of the body. Some of the effects of radiation therapy are hair loss, nausea, and tiredness.

Factors Affecting Biological Damage—continued

The following table describes acute effects of radiation doses at specific dose rates.

Effects of Radiation Dose (Whole Body)		
Dose (rad)	**Dose (mrad)**	**Effect**
≈0–50	≈0–50,000	nondetectable
≈50–100	≈50,000–100,000	transient changes in the blood but no symptoms of radiation sickness
≈100–200	≈100,000–200,000	possible radiation sickness, including nausea, diarrhea, and vomiting from damage to intestinal lining
≈200–300	≈200,000–300,000	probable radiation sickness ***Note:*** *Radiation therapy patients often receive doses in this range to their whole body, although doses to the tumor region might be many times higher. After such an acute dose, new cells will replace damaged cells, and the body will repair itself. This process may take many months.*
≈300–600	≈300,000–600,000	possible death
≈600–1000	≈600,000–1,000,000	probable death ***Example:*** *Twenty-eight people involved in the Chernobyl accident died following doses in excess of 800,000 mrad (800 rad), compounded by other injuries.*
>1000	>1,000,000	death

Chronic Dose

When an individual receives a small amount of radiation over a long period, such as the dose received from natural background radiation or the dose received from occupational exposure, the body is better equipped to tolerate the dose. The body has time to repair damage because a smaller percentage of cells needs repair at any given time. The body also has time to replace dead or nonfunctioning cells with new, healthy cells.

A chronic dose of radiation does not result in physical changes to the body such as those seen with acute doses. Because of cell repair, even sophisticated analyses of the blood do not reveal any biological effects.

The biological effects of concern from a chronic dose are latent effects such as cancer, cataracts, and LLE (lost life expectancy) that appear later in life. The probability of cancer resulting from typical occupational doses of radiation (44 mrem per year for DOE radiological workers) is very low.

Factors Affecting Biological Damage—continued

Risk of Cancer

The natural incidence of cancer is approximately 20%. Extensive studies of approximately 100,000 radiation workers have shown no increase in the natural incidence of cancer in workers exposed to radiation at LANL or at similar places worldwide. In other words, radiological workers at LANL and at other laboratories throughout the world do not have a higher incidence of cancer than the rest of the population. These studies do not prove that radiation does not cause cancer; rather, they suggest that the radiation normally received by radiological workers at LANL is too small for any effect to be observed.

However, increased incidence of cancer has been observed in those survivors who received acute doses of 35,000 mrem (35 rem) or more from the Hiroshima and Nagasaki atomic bombs. Survivors who received 35 rem have a 3% higher incidence of cancer than unexposed individuals, which means 20.6% rather than the 20.0% natural probability rate.

The report from the National Research Council's Fifth Committee on the biological effects of ionizing radiation (*Health Effects of Exposure to Low Levels of Ionizing Radiation: BEIR V*, National Academy Press, Washington, D.C., 1990) estimated an assumed risk of 4×10^{-4} per rem chronic dose, or four cancer deaths per 10,000 persons, above the normal expectation of 2220 cancer deaths per 10,000 persons (*Cancer Facts and Figures 1995,* American Cancer Society, January 1995). Although risk estimates are less certain when applied to low doses, they do provide a reasonable basis for public health policy.

Cell Sensitivity

Radiation damage to cells depends on how sensitive the cells are to radiation.

Actively Dividing Cells (Nonspecialized Cells)

Cells that are actively dividing are more sensitive to radiation. When a cell is in the process of dividing, it is less able to repair any damage. Actively dividing cells (nonspecialized) include blood-forming cells, hair follicles, cells that line the intestinal tract, and cells that form sperm. Cancer cells are also actively dividing, which makes them receptive to radiation therapy.

Factors Affecting Biological Damage—continued

Less Actively Dividing Cells (More Specialized Cells)

Cells that divide less actively or are more specialized are not as sensitive to radiation. Less actively dividing cells include brain cells and muscle cells.

Pregnant Worker Radiation Exposure

Sensitivity of the Embryo/Fetus

Cells of the embryo/fetus are rapidly dividing, which makes them sensitive to radiation. Many chemical and physical factors, such as alcohol consumption and exposure to lead, are also suspected or known to cause damage to the embryo/fetus.

Effects Associated with Pregnant Worker Exposure

Prenatal Exposure
The fetus is especially sensitive to radiation.

Although no effects were observed in Japanese children who were conceived after the atomic bombs at Hiroshima and Nagasaki, effects were observed in some children who were exposed to the radiation of the atomic bomb while in the womb. Some of these children were born with low birth weight, small head size, and mental retardation. Radiation exposures to the embryo/fetus are suspected, but not proven, to also increase the chance of childhood cancer. Only when dose equivalents exceed 15,000 mrem (15 rem) is there a significant increase in risk.

Limits are established to protect the embryo/fetus from any potential effects that may occur from a significant amount of exposure to radiation from either external or internal sources. At current occupational dose limits, the actual risk to the embryo/fetus is negligible when compared with the normal risks of pregnancy.

Individual Sensitivity

Some individuals are more sensitive to radiation than others. Children are more sensitive than adults. The developing embryo/fetus is the most sensitive of all. In general, the human body becomes relatively less sensitive to radiation with increasing age. The elderly, who are more sensitive than middle-aged adults, are the exception, because they are less able to repair damage as quickly because of their less efficient cell repair mechanisms.

Radiation Dose Limits

To minimize the risks of biological effects associated with exposure to radiation, dose limits have been established for DOE sites. The LANL radiation dose policy is more conservative than the DOE limits. The LANL policy was established to ensure that the DOE limits are not exceeded and to help reduce individual and total worker population radiation dose (collective dose).

The DOE has established radiation dose limits based on guidance from the Environmental Protection Agency, the National Council on Radiation Protection & Measurements, and the International Commission on Radiological Protection.

Specific Dose Limits and Control Levels

Area of the Body Exposed

The larger the area of the body that is exposed to radiation, the greater the biological effects. Extremities are less sensitive than internal organs. Therefore, the annual dose limit for extremities is higher than for a whole body exposure that irradiates the internal organs.

Whole Body

The whole body extends from the top of the head down to just below the elbow and just below the knee. This mid-area is the location of most of the blood-producing and vital organs.

Controls are established to limit both external exposure to radiation and internal exposure from the intake of radioisotopes. Radiation dose limits are based on the sum of internal and external exposure.

During routine conditions, the DOE whole body radiation dose limit is 5 rem/year.

Extremities

Extremities include the hands and arms below the elbow and the feet and legs below the knees. Extremities are less sensitive to radiation than the whole body and can tolerate a larger dose. During routine conditions, the DOE radiation dose limit for extremities is 50 rem/year.

Skin or Internal Organs

The skin and individual internal organs are less sensitive to radiation than the whole body. During routine conditions, the DOE radiation dose limit for skin or internal organs is 50 rem/year.

Specific Dose Limits and Control Levels—continued

Lens of the Eye

The lens of the eye is sensitive to beta radiation. An acute dose of 600–900 rem to the lens of the eye can result in the formation of a cataract or opaque area on the lens, which prevents light from reaching the retina within the eye. Safety glasses can shield the lens of the eye from radiation. During routine conditions, the DOE radiation dose limit for the lens of the eye is 15 rem/year.

Visitors and the Public

For visitors and the public, the DOE radiation dose limit is 100 mrem/year from the sum of internal and external sources. (The dose limits, which do not include background dose, are listed in the following table.)

Radiation Dose Limits

Affected Personnel	DOE Dose Limits	
worker: whole body	5 rem/yr	5000 mrem/yr
worker: extremity	50 rem/yr	50,000 mrem/yr
worker: skin	50 rem/yr	50,000 mrem/yr
worker: internal organ	50 rem/yr	50,000 mrem/yr
worker: lens of the eye	15 rem/yr	15,000 mrem/yr
visitors and public	0.1 rem/yr	100 mrem/yr
pregnant worker embryo/fetus	0.5 rem during entire pregnancy (not more than 0.05 rem per month allowed)	500 mrem during pregnancy (not more than 0.05 rem per month allowed)

Your Responsibilities

Workers' Responsibilities Regarding Dose Limits

You are responsible for complying with the DOE radiation dose limits. If you suspect that a dose limit is being approached or exceeded, you should notify your supervisor immediately.

You must comply with posted radiological control rules when accessing radiological work areas. Recognize that your actions directly affect radiation exposure, contamination control, and the overall radiological work environment.

Note*: Information about dosimetry for personnel monitoring and about obtaining radiation dose records is discussed in Unit 3.*

Risks in Perspective

Risks and Life Expectancy

Life expectancy is dependent on many risk factors. Occupation is just one of these factors.

Because it is not possible to measure the effects of low levels of radiation, risk estimates have been assumed from the studies of individuals exposed to high levels of radiation.

Acceptance of a risk is a highly personal matter and requires a good deal of informed judgment. One way of evaluating risk is to compare lost life expectancy (LLE) of a variety of occupations. The following table compares the estimated LLE for a variety of occupations over a 50-year period.

Comparison of Risks—Lost Life Expectancy

Occupation or Activity over a 50-Year Span	LLE (in days)
demolition	1500
coal or uranium mining	1100
fire fighting	800
railroad	500
agriculture	300
construction	200
transportation/public utilities	160
average of all occupations	60
government	55
radiation worker with a dose of 1000 mrem/year	50
service	45
trade	30
single radiation dose of 1000 mrem	1.5

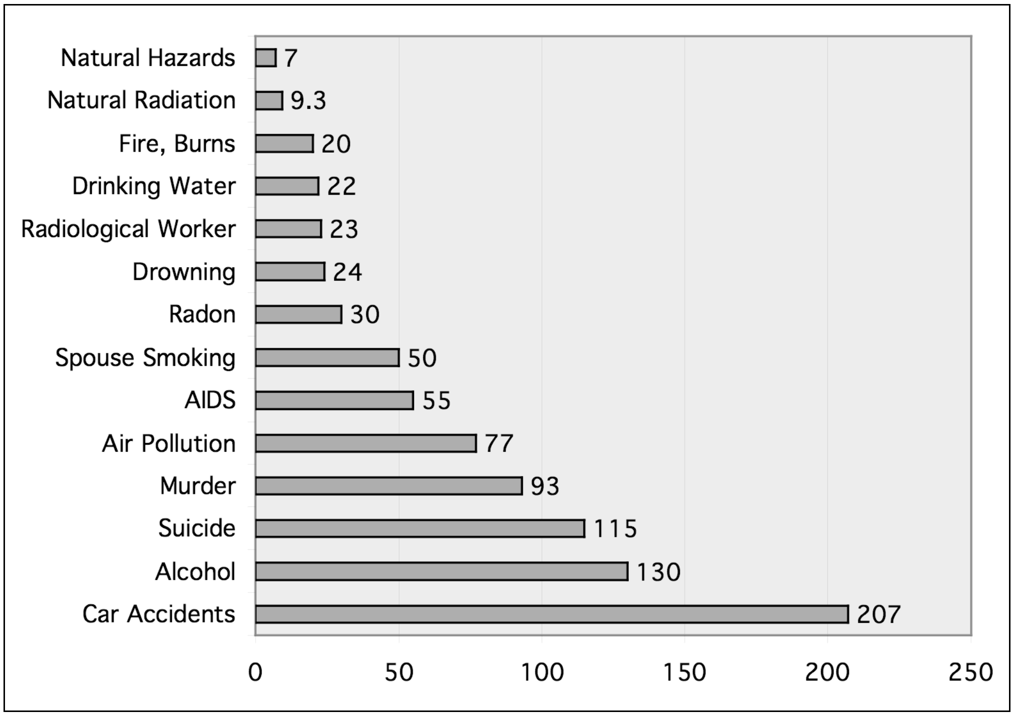
Comparing Occupational Doses

Another way of evaluating risk is to compare occupational radiation doses. The following table compares the radiation dose received by workers in various occupations with the average dose received by DOE employees and site workers.

Comparison of Occupational Doses

Occupation	mrem per year
DOE employees and site workers (radiological work activities)	44
medical personnel (patient diagnosis/treatment)	70
Grand Central Station workers (building materials)	120
nuclear power plant workers (radiological work activities)	700
airline flight crew members (cosmic radiation)	1000

Risks in Perspective—continued



Expected days lost of average life span for various activities or conditions.

Assessing Your Risk

In assessing your risk of radiation exposure, you can assume the following:

- If close to the source, an individual exposed to an acute whole body dose such as that at Chernobyl can be killed.
- Small doses of radiation are far less harmful than routine activities such as driving a car.

Before entering a situation in which you might be receiving doses of radiation between these two extremes, you should be well informed about the doses to be expected and how to minimize them.

Student Self-Assessment

Answer the following questions to test your mastery of this unit. Strive for a score of 80% or better. (EO#) indicates the enabling objective corresponding to the question.

1. The four major sources of naturally occurring ionizing radiation are _____, _____, _____, and_____. (EO1)

2. The four major sources of manmade ionizing radiation are _____, _____, _____, and _____. (EO1)

3. Radiation damages human cells by ______ of the atoms that make up the cells. (EO2)

4. Which of the following statements is true about cells that have been damaged by ionizing radiation? (EO3)
   a. cells may repair the damage
   b. cells may be damaged
   c. cells may die as a result of the damage
   d. all of the above

5. Radiation sickness generally occurs following an acute whole body dose of more than _____. (EO3)
   a. 5 rem
   b. 50 rem
   c. 200 mrem
   d. 100 rem

6. Children who were conceived and born in Hiroshima and Nagasaki after the atomic bombs suffer ______. (EO3 and EO7)
   a. heritable effects as a result of damage to the sperm or ovum of the parent
   b. somatic effects such as radiation sickness
   c. chronic effects such as increased cancer
   d. no measurable effects

Student Self-Assessment—continued

7. Match the term to the correct definition. (EO5 and EO6)

___acute dose	a. an effect that occurs in the individual exposed to radiation
___chronic dose	b. typically a large dose received in a short period
___somatic effect	c. an effect that occurs in the offspring of the affected individual
___heritable effect	d. typically a small dose received over a long period

8. The dose received from natural background radiation is considered a(an) (EO6)
   a. somatic effect
   b. chronic dose
   c. genetic effect
   d. acute dose

9. Example(s) of potential effect(s) of pregnant worker exposure of the unborn child (embryo/fetus) to radiation include (EO7)
   a. small head size
   b. mental retardation
   c. low birth weight
   d. all of the above

10. Match the area of the body to the correct DOE dose limit. (EO8)

____whole body	
____extremity	a. 0.5 rem/pregnancy
____skin	b. 5 rem/year
____internal organ	c. 15 rem/year
____lens of the eye	d. 50 rem/year
____embryo/fetus	

Student Self-Assessment—continued

11. The responsibility of complying with the radiation dose limits belongs to ______. (EO9)
    a. you
    b. visitors
    c. the general public
    d. all of the above

12. If you suspect that you are approaching your radiation dose limit, you should immediately notify _______. (EO9)
    a. security personnel
    b. medical personnel
    c. your supervisor
    d. RP-3

13. According to the risk comparison table in this unit, which of the following occupations has the lowest risk associated with it? (EO10)
    a. radiological work at a DOE site
    b. construction
    c. transportation
    d. agriculture

Answers

1. cosmic, terrestrial, internal, radon
2. medical x-rays, nuclear medicine, consumer products, and industrial radiation uses
3. ionization
4. d
5. d
6. d
7. b, d, a, c
8. b
9. d
10. b, d, d, c, a
11. a
12. c
13. a

Unit 3: Personnel Monitoring Programs

Learning Objectives

Major Objectives

Upon completion of this unit, you will be able to discuss the personnel monitoring programs used in terms of types, purpose, and your responsibilities.

Enabling Objectives (Eos)

You will be able to select the correct response from a group of responses, which verifies your ability to

EO1 state the purpose of each of the external dosimeter devices used at the Laboratory;

EO2 identify the correct use of each of the external dosimeters used;

EO3 identify the correct response for lost, damaged, or off-scale dosimeters;

EO4 discuss internal dosimetry methods;

EO5 identify your responsibilities concerning internal dosimetry programs;

EO6 identify the requirements for declaring a pregnancy;

EO7 identify your responsibilities for reporting radiation dose received from other sites and from medical applications; and

EO8 state the method for obtaining radiation dose records.

Introduction

An important part of ensuring that workers (and visitors) keep their doses as low as reasonably achievable (ALARA) is to

- assess the potential for personal radiation exposure before performing work;
- monitor the doses of individuals through the use of dosimetry (the measurement of external radiation by specialized devices called dosimeters); and
- monitor individuals routinely for evidence of accidental intake of radioactive materials through the use of bioassay, which involves the direct measurement and analysis of samples, such as blood or urine, taken from the body.

To ensure that the appropriate levels of dosimetry and bioassay are established, all visitors, newly hired workers (LANS or contractor), and rehired workers (with the assistance of their supervisors) must request enrollment in these programs by completing the dosimetry enrollment process online at the following Web location:

http://int.lanl.gov/safety/radiation/dosimetry_eval.shtml

In addition, individuals and their supervisors must provide updated information through the dosimetry enrollment process upon change of job assignment, job location, or when deemed necessary by a re-evaluation of the individual’s dosimetry and bioassay results.

Special requirements also exist when an individual enrolled in any routine bioassay program wishes to be terminated from these programs. Health Physics Measurements (RP-2) must be notified at 667-6275 *three days in advance of termination*. Termination samples will be collected at the time of termination from the Laboratory or at the time the individual is removed from the program. For more information, contact RP-2.

External Dosimetry

Types of External Dosimeters

Various types of external dosimeters are used to assess personnel dose from external sources of radiation. The dosimeters used at the Laboratory are the

- thermoluminescent dosimeter (TLD),
- wrist dosimeter,
- track etch dosimeter,
- nuclear accident dosimeter, and
- electronic dosimeter.

External Dosimetry—continued

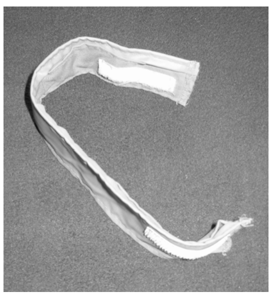
Thermoluminescent dosimeter

Thermoluminescent Dosimeters (Dual Card)

A thermoluminescent dosimeter (TLD) is used to assess the legal dose-of-record because it is the most accurate indicator of dose equivalence. TLDs are used to assess beta, gamma, x-ray, and low- to mid-energy neutron radiation dose.

TLDs contain lithium fluoride chips. Ionizing radiation transfers energy to electrons in the atoms of the chips. When the chips are heated to approximately 300˚C, light is emitted in proportion to the radiation energy absorbed by the chip. The light is measured, and the actual dose equivalent is calculated.

TLDs are issued by RP-2 through various group offices and are processed monthly, quarterly, or as needed.



Wrist dosimeter

Wrist Dosimeters

Wrist dosimeters are used to assess high-energy beta, gamma, and x-ray radiation dose and to provide an estimate of neutron radiation exposure to the extremities during certain jobs. The wrist dosimeter contains a lithium fluoride chip similar to that in the TLD.

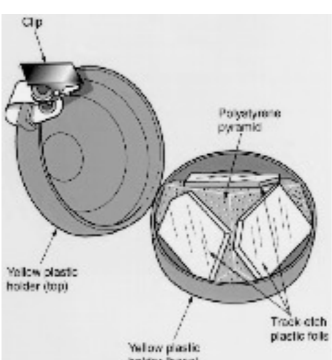
Wrist dosimeters are issued by RP-2, through RP-1 in the field. They are processed monthly or at the end of a job, whichever comes first.

Track etch dosimeter

Track Etch Dosimeters

Track etch dosimeters are used to assess dose from neutron radiation when energies are greater than 5MeV (million electron volts).

These dosimeters are issued by RP-2 to workers only at certain technical areas (Tas) at the Laboratory and are processed quarterly or as needed.



Pocket ionization chamber

Pocket Ionization Chambers

Pocket ionization chambers, such as pencil dosimeters or bubble dosimeters and similar electronic dosimeters, are used at certain areas to provide supplemental dosimetry during some jobs with a potential for exposure to ionizing radiation. These supplemental dosimeters are used only as ALARA (as low as reasonably achievable) tools, not to assess the dose of record.

External Dosimetry—continued

Pencil dosimeters are used to assess gamma and x-ray radiation exposure. Pencil dosimeters are manufactured with scales in different ranges; the 0–500-mR range, marked in increments of 20 mR, is most often used. The scale is crossed with a hairline that moves upscale in proportion to exposure.

Electronic Personal Dosimeters (EPDs)

Electronic pocket dosimeter

Electronic personal dosimeters (EPDs) are replacing pencil dosimeters in most areas of the Laboratory. The one notable exception is in areas where personnel may be exposed to pulsed photons such as pulsed x-rays. One of the primary advantages of these new dosimeters is the ability to set them to alarm at a specified accumulated dose or dose rate. Another advantage is the EPD digital readout.

Bubble dosimeters are used to assess neutron radiation doses and are read by counting the number of bubbles formed in the chamber.

Pocket ionization chambers and electronic dosimeters are issued by RP-2, through RP-1 in the field. They should be read before entry into and after exit from a radiological area, at a minimum, and they should be reset daily.

Nuclear Accident Dosimeters

Nuclear accident dosimeter

Nuclear accident dosimeters are used when sufficient quantities and kinds of fissile materials (materials that can be split apart by nuclear reaction) are present to potentially constitute a critical mass. These dosimeters are used in situations where personnel can be exposed to a criticality accident or a sustained nuclear fission chain reaction. They are used to assess high-level neutron radiation doses over the whole energy range.

These dosimeters are issued by RP-2 only at certain technical areas at LANL, such as TA-55, and are processed as needed.

External Dosimetry—continued

Correct Use of Dosimeters

- Dosimeters must be worn at all times in areas that are controlled for radiological purposes when required by signs, work permits, or radiological control personnel.
- Dosimeters for declared pregnant workers should be worn between the neck and waist for the term of the pregnancy. The frequency of exchange is determined by the Fetal Radiation Protection Specialist as part of the Reproductive Health Assistance Program.
- Other whole body dosimeters must be worn on the chest area between the waist and neck.
- TLDs are worn with the LANL emblem facing outward.
- Pocket or electronic dosimeters, when required, should be worn within three inches of the TLD to provide consistent dose measurement.
- Dosimeters should be kept clean, not be opened, and not be contaminated with any foreign material such as chemicals, oils, detergents, or colognes.
- Dosimeters are sensitive to shock, temperature, and sunlight and should not be left in the car on the dashboard, or in direct sunlight for long periods.
- Dosimeters should not be exposed to sources of radiation that do not relate to your work activities, such as medical, dental, or security x-rays. You should notify RP-2 of any nonwork-related exposures when dosimeters are returned. Dosimeters must be returned for processing as required.
- Never put TLDs in checked or carry-on luggage. LANL TLDs should not be taken on travel without first contacting RP-2.
- Dosimeters issued by LANL must not be worn outside LANL. It is important to know where the dose was received. If you visit another DOE site and radiation exposure is anticipated, you will be issued a temporary dosimeter at that site. That site is required to send you a report of your exposure within 30 days.
- Dosimeter storage procedures are specific to each facility. (This information is provided in facility-specific training.)

External Dosimetry—continued

Lost, Damaged, Off-Scale, Alarming, or Contaminated Dosimeters

While in an area controlled for radiological purposes, you must take proper actions if a dosimeter is lost, off-scale, alarming, damaged, or contaminated. These actions are as follows:

- stop work activities;
- place work activities in a safe condition;
- alert others, as appropriate (request other workers to read their pocket dosimeters);
- immediately exit the area; and
- notify an RCT.

If your TLD is lost, contact your local RCT. Your line manager should complete a Lost Dosimeter form (Form 1325) and submit it to RP-2.

If the TLD is found later, both the lost and the replacement TLD should be brought to the RP-1 representative in the workplace for a determination as to which TLD should continue to be worn.

Internal Dosimetry

Internal Dosimetry Methods

Accidental intake of radioactive material can cause additional dose to the whole body or individual organs.

To measure the amount of radioactive material present inside the body, *in vivo* monitoring (direct measurement from outside the body) and/or *in vitro* monitoring (measurement by the analysis of body fluids or other body material) are used. From these measurements, an internal dose can be calculated.

In Vivo Monitoring (Direct Bioassay)

In vivo monitoring measures the amount of internally deposited radioactive material by direct measurement from outside of the body. Whole body counting, chest counting, thyroid counting, and wound counting are examples of *in vivo* monitoring.

Whole body counters measure gamma radiation emitted from radioactive materials throughout the body. Chest counters measure gamma and x-ray radiation emitted from materials such as uranium or plutonium daughter products that have been inhaled.

Internal Dosimetry—continued

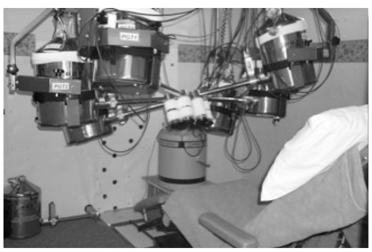
In Vitro Monitoring (Indirect Bioassay)

In vitro monitoring measures the amount of internally deposited radioactive material by the analysis and evaluation of body fluid or other material excreted or removed from the human body. *In vitro* samples include urine, fecal, blood, and saliva sampling; nasal swipes; and tissue counting.

In vitro sampling measures alpha or beta radiation. At LANL, routine urinalysis is conducted to detect the presence of plutonium, tritium, uranium, and americium. RP-2 schedules and tracks all *in vitro* procedures.

Tracking Derived Air Concentration Hours (Workplace Air Monitoring)

Derived air concentration (DAC) hours indirectly track internal dose from airborne contamination. Workplace air monitoring is used as an indicator only.



Whole body counter

Internal Dosimetry Responsibilities

If you are required to have routine whole body counts, you should have an initial baseline whole body count. Routine whole body counts may be required once a year for workers in certain areas. If you are instructed by an RP-3 primary (or RP-1) representative to have a nonroutine whole body count, you must do so. If you are in the whole body count program, you will be required to have a final whole body count upon termination of your job.

If your routine duties may involve exposure to surface or airborne contamination or to radioisotopes readily absorbed through the skin, you are required to submit *in vitro* samples at the frequency specified by your particular bioassay program. A baseline procedure should be completed, as required.

Pregnant Worker Radiation Exposure

Special Monitoring Program for Declared Pregnant Workers

A female radiological worker is encouraged to voluntarily notify OM to begin the process for a family planning, pregnancy, or nursing consultation. No appointment is needed. A nurse will initiate the Reproductive Health Assurance Program evaluation process, including a workplace evaluation. All medical information obtained during this process is confidential. Male radiological workers may also contact OM about reproductive concerns.

Pregnant Worker Radiation Exposure—continued

Remember: *A female worker is encouraged to voluntarily notify Occupational Medicine in writing of her pregnancy and limit exposure during the remainder of her pregnancy.*

The employee will be asked to obtain a supervisor's signature on the Declaration of Pregnancy form. If the worker signs the form, she is considered a declared pregnant worker. If the worker does not want to declare her pregnancy, she may still have a workplace evaluation done. The declaration may be revoked at any time by the worker. If the workplace evaluation identifies the need for workplace restrictions, the supervisor will need to be notified. The work restrictions can be implemented only after the worker has signed the Declaration of Pregnancy. The supervisor should provide the option of a mutually agreeable assignment of work tasks, with no loss of pay or promotional opportunity, so that further occupational radiation exposure is unlikely.

For a declared pregnant worker who chooses to continue working as a radiological worker, the DOE radiation dose limit for the embryo/fetus during the entire pregnancy is 500 mrem, with a recommended monthly limit of 50 mrem.

Radiation dose is measured by the worker's TLD, which is worn between the neck and waist. If the dose is determined to have already exceeded 500 mrem when a radiological worker declares her pregnancy, the worker will not be assigned to tasks in which additional occupational radiation exposure is likely during the remainder of the pregnancy.

The declared pregnant worker should make every reasonable effort to minimize her exposure to radiation fields and radioactive materials during the pregnancy.

Radiation Doses Received Outside LANL

When traveling to another DOE site, including the Nevada Test Site, or a non-DOE site where dosimeters are issued, you should *not* wear a LANL-issued dosimeter. You should provide the sites visited with the address of the RP-3 Radiation Information Management Team, MS E-546. The sites visited should notify RP-3 that a dosimeter was issued. If notification is not possible, then you are responsible for informing RP-3 of this occupational exposure.

Radiation Doses from Medical Procedures

If you have been administered radioisotopes for diagnostic or therapeutic medical purposes, you must report your medical procedure to Health Physics Operations (RP-1) before returning to work. (Routine medical or dental x-rays do not have to be reported unless a TLD has been exposed to them.)

Remember: *Report exposures from other work sites and from medical procedures.*

Radioisotope injections or ingestions for medical purposes will sound the security alarm on special nuclear material (SNM) portal monitors and other radiation detection instruments. If you receive such treatments and work in a Protected Area or in a Material Access Area, including TA-48, TA-55, or the CMR Building, the following procedure must be followed:

- Before the planned treatment, and as far in advance as possible, your group leader must inform RP-1 and Material Control & Accountability (SAFE-MCAS4), MS G735 (5-1744), of the planned treatment and justify why you cannot be assigned to a non-SNM area during the affected period.
- Following SAFE-MCAS4 approval, the Protective Force of Los Alamos (PTLA) will issue supplemental station orders, which detail limitations and conditions for allowing you to enter and exit through the appropriate guard stations or security posts.

Radiation Dose Records

Radiation dose reports are maintained by RP-3 and are provided as follows:

- You may access your monthly dose reports online at

  http://int.lanl.gov/safety/radiation/dosimetry.shtml .

  All reports require smartcard or CryptoCard authentication. Some have additional requirements.
- You may request access from RP-3.
- Hard copy reports of occupational dose are sent to individual workers on an annual basis only.
- Termination reports of the dose received at LANL are sent to all terminated workers as soon as the data are available or within 90 days of termination.
- Reports of visitor dose for non-DOE or DOE contract workers are sent to the visitor and/or the visitor’s employer within 30 days of the visit or within 30 days after the dose has been determined.

Student Self-Assessment

Answer the following questions to test your mastery of this unit. Strive for a score of 80%. (EO#) indicates the enabling objective corresponding to the question.

1. Dosimeters such as TLDs and nuclear accident dosimeters are used to monitor exposure from _________ radiation sources. (EO1)

2. Whole body dosimeters should be worn between the _______ and the ________. (EO2)

3. Supplemental dosimeters such as electronic dosimeters should be worn (EO2)
   a. far from the TLD
   b. near the TLD
   c. on your belt
   d. on your wrist

4. Dosimeters for declared pregnant workers should be worn (EO2)
   a. over the abdomen near the waist
   b. at the corner of the chest
   c. one at the chest and one on the wrist
   d. wherever the worker wants to wear it

5. Your TLD must be worn (EO2)
   a. with the LANL emblem facing inward
   b. in your pocket
   c. behind your training badge
   d. with the LANL emblem facing outward

6. *In vivo* and *in vitro* monitoring are used to detect radioactive material (EO3)
   a. on your skin
   b. on your clothing
   c. inside your body
   d. all of the above

Student Self-Assessment—continued

7. If participating in an *in vitro* monitoring program, you must (EO4)
   a. not wear external dosimetry
   b. submit samples as required
   c. not eat or drink 12 hours before samples are collected
   d. all of the above

8. If you have been administered radioisotopes for medical purposes, you must report the procedure to which group before returning to work? (EO5)
   a. RP-3
   b. RP-2
   c. RP-1
   d. IHS-IP

9. To be considered a declared pregnant worker, a female worker is encouraged to notify her _______, _______, or ______, in writing when she becomes pregnant. (EO6)

10. A pregnant worker (EO4)
    a. is never allowed to receive any radiation dose
    b. must take a leave of absence from LANL
    c. must notify her supervisor, OM, and/or RP-3
    d. is encouraged to notify her supervisor, OM, and RP-3

11. Dose records are available from (EO8)
    a. RP-3
    b. SB-CS
    c. RP-1
    d. RP-2

Answers

1. external
2. waist, neck,
3. b
4. a
5. d
6. c
7. b
8. a
9. supervisor, OM, and/or RP-3
10. d
11. a

Unit 4: ALARA

Learning Objectives

Major Objective

Upon completion of this unit, you will be able to explain the methods used to implement the ALARA—*as low as reasonably achievable*—program.

Enabling Objectives (Eos)

You will be able to select the correct response from a group of responses, which verifies your ability to

EO1 state the DOE and LANL management policies for the ALARA program;

EO2 identify the LANL policy on lifetime dose;

EO3 identify your responsibilities as a radiological worker in the ALARA program;

EO4 identify the basic protective measures of time, distance, and shielding for reducing external radiation dose;

EO5 state examples of the use of time, distance, and shielding;

EO6 state the routes through which radioactive material can enter the body;

EO7 identify the methods for minimizing (reducing) intake of radioactive materials;

EO8 identify the methods you can use to minimize (reduce) radioactive waste;

EO9 identify the requirements for removal of waste from a Radiological Controlled Area (RCA) that is controlled for contamination; and

E10 identify the requirements for shipping, receiving, labeling, and working with radioactive materials.

Introduction

ALARA stands for “as low as reasonably achievable.” The goal of the ALARA Program is to keep radiation dose well below dose limits and the appropriate action level. You should always try to maintain your radiation dose ALARA by using protective measures and methods to reduce exposure to radiation.

Note*: An action level is a notification “flag” that is used to notify the worker, line management, the RP-1 team leader, and the Radiation Protection Program manager (RPPM) that the worker has exceeded a predetermined external dose level and is possibly approaching dose limit.*

ALARA Program

ALARA Principles

The principles of ALARA include minimizing (reducing) both external and internal doses from radiation and radioactive material. These principles are an integral part of all Laboratory activities that involve the use of radioactive materials or radiation-producing machines. You are responsible for implementing the principles of ALARA.

DOE Management Policy

The DOE ALARA policy states that radiation exposures to workers and the public must be

- maintained ALARA;
- kept well below regulatory limits; and
- controlled so that there is no exposure without commensurate (equal) benefit, based on sound economic principles.

Laboratory Management Policy

Each line organization with radiological workers must have a documented ALARA program with a scope that fits the organization’s potential for radiation exposure. The ALARA Steering Committee reviews the LANL-wide and the facility-specific ALARA programs. In addition, ALARA committees are formed in large organizations that have a greater potential for exposure.

Laboratory Policy on Lifetime Dose (Whole Body)

The Laboratory policy requires that you keep the amount of your lifetime dose (in rem) equal to or less than your age in years. If your lifetime dose exceeds your age, a special dose management plan will be established to realign your dose with your age.

ALARA Program Responsibilities

Action Levels

Action levels are established to keep doses well below the regulatory limits listed in Table 4-3 of ISD 121-1.0, *Radiation Protection.* When an action level is exceeded during the calendar year, RP-2 provides notification to the following personnel:

- the individual with the reported dose,
- the individual's group leader,
- the RP-3 team leader assigned to the individual's technical area, and
- the Radiation Protection Program manager (RPPM).

The following table lists the established action levels.

Action Levels	
Dose Being Reported	**Notification Action Level**
whole body dose	1 rem
lens of the eye	3 rem
extremity/organ/tissue	10 rem
embryo/fetus	100 mrem
***Note**: These action levels are based on yearly cumulative doses.*	

Radiological Control Technicians' Responsibilities

RP-1 RCTs who serve as an interface between the radiological control organization and the workers play a key role in the LANL ALARA program. RCTs

- conduct radiological surveys,
- provide information on current radiological conditions in an area,
- identify protective requirements for radiological work assignments,
- identify methods for dose reduction and the control of radiation exposure and contamination,
- address radiological questions and concerns,
- stop work when conditions or practices are unsafe,
- respond to CAM alarms,
- respond to PCM alarms,
- provide continuous and intermittent radiological coverage for radiation work, and
- respond to medical emergencies involving radiation in radiological areas.

ALARA Program Responsibilities—continued

You, the Radiological Worker

You are expected to demonstrate responsibility and accountability through an informed, disciplined, and cautious attitude toward radiation and radioactive materials. You must

- maintain radiation dose ALARA by using dose reduction techniques discussed in this unit;
- know the dose limits and the remaining dose available for the job;
- know the radiological condition in the work area;
- obey the posted, written, and oral radiological control instructions and procedures;
- take part in prejob and postjob briefings;
- report radiological problems to an RCT and/or a supervisor; and
- stop work when conditions or practices are unsafe.

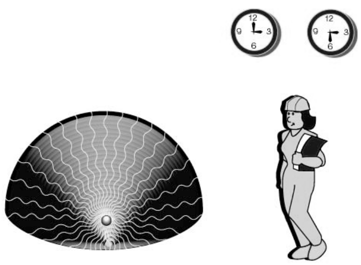
External Radiation Dose Reduction

Basic Protective Measures to Reduce External Radiation Dose

Basic protective measures used to reduce external radiation dose are

- minimizing time in a field of radiation,
- maximizing distance from a source of radiation,
- using shielding whenever practicable, and
- using source reduction whenever practicable.

External Radiation Dose Reduction—continued

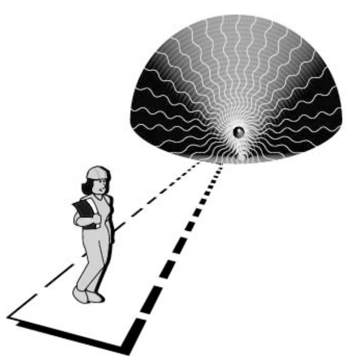


Minimize time.

Methods for Minimizing Time

Reducing the amount of time you spend in a field of radiation will lower the dose you receive. You should

- plan and discuss the task thoroughly before entering the work area (You should be in the work area only if you are required to do the job.);
- have all the necessary tools before entering the work area;
- use mockups and practice runs that duplicate work conditions;
- exit a radiological area as soon as work is completed;
- work efficiently but swiftly;
- do the job right the first time;
- perform as much work as possible outside the area, or when practicable, move parts or components outside the area to perform work; and
- observe stay time if a time has been assigned. [An RCT may limit the amount of time you may stay in an area. This concept is known as stay time (stay time = allowable dose/area dose rate). Stay time may be assigned in areas where standard dose reduction techniques are not practical.]



Maximize distance.

Methods for Maximizing Distance

Maximizing your distance from a source of radiation will lower the dose you receive. You should

- stay as far away as practicable from the source of radiation (For point sources, the dose rate follows the inverse square law. If the distance is doubled, the dose rate falls to one-fourth of the original dose rate. If the distance is tripled, the dose rate falls to one-ninth of the original dose rate.);
- be familiar with the radiological conditions and the sources of radiation in the work area;
- during work delays or when on standby, move to lower dose rate areas;
- carry radioactive materials at a distance from your body or use remote handling devices when practicable; and
- whenever possible and with a supervisor's permission, move the work to an area with a lower dose rate.

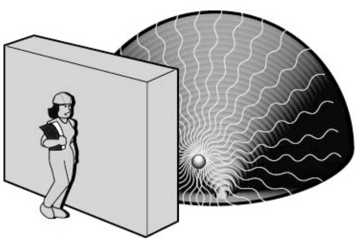
External Radiation Dose Reduction—continued

Note: Inverse Square Law: If the distance from the source is doubled, the exposure will drop to one-fourth of the previous value.

at 1 foot – 100 mrem per hour . . .

at 2 feet – 25 mrem per hour . . .

Proper Use of Shielding



Use shielding.

Shielding reduces the amount of radiation dose you receive. Different materials shield you from different types of radiation. You should

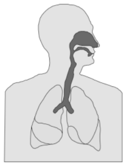
- take advantage of permanent fixtures such as nonradiological equipment and structures, which may provide some shielding;
- use available shielded containment such as glove boxes;
- wear safety glasses or goggles when applicable to protect your eyes; and
- use temporary shielding such as lead or concrete blocks only with proper authorization from your supervisor and RP-1. The placement of shielding could actually increase the total dose because of the man-hours involved in the placement.

Methods of Source Reduction

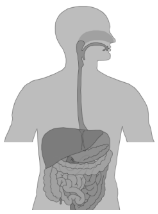
Source reduction involves procedures such as flushing radioactive systems, moving radioactive materials, or decontaminating to reduce the amount of radioactive materials present that contribute to radiation levels in an area. With supervisory approval, you should

- flush components or piping systems with clean water before performing maintenance activities;
- drain pipes, tanks, or components that contain residual contaminated liquid; and
- remove packaged radioactive materials (waste or other storage containers) from the work area.

Internal Radiation Dose Reduction

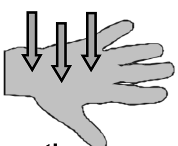


Inhalation
Breathing
Smoking



Ingestion
Eating
Drinking
Chewing

Absorption
through
wounds



Absorption
through skin

Routes of Entry

Internal exposure results when radioactive material is taken into the body. Radioactive material can enter the body through one or more of the following pathways:

- inhalation (breathing, smoking),
- ingestion (eating, drinking, chewing, applying cosmetics and lip balms),
- absorption (passing) through the skin (e.g., tritium and radioiodine), and
- absorption (passing) through wounds.

Methods to Reduce Internal Radiation Dose

Reducing the potential for radioactive materials to enter the body is important. You should

- wear protective clothing, as required;
- wear respirators properly, as required;
- report all wounds, cuts, scabs, or rashes before entering areas controlled for radiological purposes;
- comply with the requirements of work documents;
- do not eat, drink, smoke, apply cosmetics or lip balms, or chew in areas controlled for contamination; and
- use extra caution with sharp tools, and use proper controls when grinding and sanding.

Working with Radioactive Material

Radioactive material exists in many forms. It may be solid (metal, powder, etc.), liquid, gases, or vapors. It may be used or stored in many different containers or exist as a radioactive sealed source, where it is enclosed in a protective container or firmly fixed to a support surface.

No matter what form the material or container, steps must be taken to control the use and movement of radioactive material.

Working with Radioactive Material—continued

Required Labeling of Radioactive Material

- Individual containers of radioactive material and/or radioactive items must be labeled.
- Packaging of items having removable surface contamination in excess of Radiation Protection ISD 121-1.0, Table 14-2 values, must be labeled when used, handled, or stored in areas other than Contamination Areas, High Contamination Areas, or Airborne Radioactivity Areas.
- If a label is applied to packaged radioactive material, it must be applied to the outside of the package or be visible through the package.
- Labels must include the standard radiological warning trefoil and the words CAUTION or DANGER and RADIOACTIVE MATERIAL.
- A tag may be used to meet the labeling requirements described in this chapter. In addition to required information, a tag is subject to additional requirements:
  - must be used only temporarily (for removal, transport, or short-term holding of items);
  - must be completed by RP-1; and
  - may not be used in environments that could degrade the tag or its legibility.

Packaging and Storing Radioactive Material

- Radioactive materials may be stored in radiological areas, radiological buffer areas, RCAs, or uncontrolled areas as long as the above labeling requirements are met, and posting requirements for radiological hazards are met.
- For radioactive material used or stored in uncontrolled areas, the material and its intact packaging must not present the potential for 100 mrem/yr external dose or contamination above the values in Radiation Protection ISD 121-1.0 Table 14-2. If radioactive material will be used or stored in an uncontrolled area, an RP SME must evaluate the conditions to ensure these criteria are met.
- Radioactive material must be packaged and stored so that the package integrity is maintained to prevent the release of contamination; higher risk materials require more robust packaging.

Working with Radioactive Material—continued

- As an ALARA measure, package contents should be readily identifiable. Use of transparent packaging material for items with removable contamination is one method to address this issue.
- As another ALARA measure, items with loose surface contamination that are located within Contamination Areas, High Contamination Areas, or Airborne Radioactivity Areas should be wrapped, bagged, or otherwise controlled.

Shipping and Receiving Radioactive Material from Transportation

The requirements in this section are supplemental to those of the packaging and transportation program maintained by OS-PT and defined in IPP 525.2, "Hazardous Material (Hazmat) Packaging and Transportation."

RCTs perform surveys and provide results in support of packaging and transportation processes, providing information to characterize hazards associated with items, their packaging, and their shipping containers.

- An RCT must perform receipt surveys of radioactive material shipments when received at the central shipping and receiving warehouse (or other facility used as a depot and the container is moved or handled) as soon as practicable but not later than 8 hours after the beginning of the working day following receipt of the package.
- An RCT must perform receipt surveys of radioactive material shipments when received at the final destination facility before the shipping vehicle leaves that facility.
- When outer transport containers of radioactive material are initially opened following receipt, an RCT must be present to perform surveys to ensure no unanticipated conditions exist (i.e., contamination on inner packaging).
- Receipt surveys are required for
  - waste shipments;
  - accountable sealed sources or radioactive materials required to be labeled;
  - any 10 CFR 835 threshold that requires receipt survey;
  - large items having the potential for contamination;
  - a package containing radioactive material of any type or quantity that arrives damaged (e.g., crushed or wet); or
  - other radioactive material (except for limited exceptions).

When in doubt, consult with your RCT.

Radioactive Sealed Sources and Radioactive Material

Control of Radioactive Sealed Sources

Sealed Sources

Sealed sources that have not been properly controlled can be hazardous to both workers and the public. At the Laboratory, radioactive sealed sources are tracked from the time that they are ordered to the time of their disposal (cradle to grave).

You should contact your sealed source custodian if

- you are planning to order a new radioactive sealed source,
- you discover a radioactive sealed source in your work area that is not accounted for, or
- you have questions about procedures for controlling radioactive sealed sources.

The sealed source custodian will contact line management and the Radioactive Sealed Source Office (RP-3).

Control of Radioactive Material

Immediately contact your RCT or facility manager if radioactive material is unaccounted for. Radiation safety, public protection, and national security are important reasons for control of radioactive material and radioactive sealed sources.

Radioactive Waste Minimization

Generation of Radioactive Waste

Working in and around radioactive materials generates radioactive waste, which ultimately must be disposed of. Some examples of radioactive waste are contaminated

- paper,
- gloves,
- glassware,
- tissues, and
- mops.

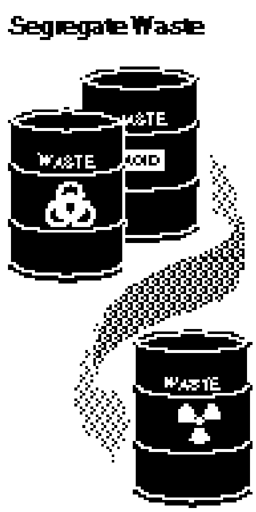
Radioactive Waste Minimization–continued

Minimize the Materials Used for Radiological Work

To minimize exposure and reduce costs associated with the handling, packaging, and disposal of radioactive waste, you must minimize the amount of radioactive waste generated. Minimizing the materials used for radiological work minimizes the amount of radioactive waste generated. You should

- take only the tools and materials needed for the job into areas that are controlled for radiological purposes, especially contamination areas;
- unpack equipment and tools in a clean area to avoid bringing excess clean material to the work area;
- whenever possible, use equipment identified for radiological work; and
- use only the materials required to clean the area. (An excessive amount of bags, rags, and solvent adds to radioactive waste.)

Segregate (Separate) Radioactive from Nonradioactive Waste



Segregating radioactive from nonradioactive waste minimizes the amount of radioactive waste generated. You should

- place radioactive waste in the receptacles identified for radioactive waste, not in receptacles for nonradioactive waste; and
- do not throw nonradioactive waste or radioactive material that may be reused into radioactive waste containers.

Segregate Compactible Waste from Noncompactible Waste

Segregating compactible from noncompactible materials contributes to waste minimization. You should dispose of

- small solid materials such as paper, plastic, rubber, glassware, conduit, and chips of wood or sheet metals as compactible waste; and
- large or bulky materials such as heavy pipes, angle iron, equipment, lumber, and soil as noncompactible waste.

Radioactive Waste Minimization–continued

Minimize the Amount of Mixed Waste Generated

Mixed waste is radioactive waste mixed with hazardous waste. Hazardous materials such as lead, oil, or solvents identified as being radioactive may not be disposed of in the same manner as radioactive waste. Storage and disposal of mixed wastes such as these require additional cost and space. You should

- consider the use of nonhazardous materials;
- determine the type of waste to be generated and the proper disposal procedure for the waste before performing a job;
- place mixed waste in receptacles identified for mixed waste;
- not dispose of chemicals, solvents, or oils in floor drains;
- contact your waste management coordinator before disposing of any mixed waste material or other hazardous materials; and
- contact your waste manager when in doubt about hazardous materials or if you have any questions about waste disposal.

Good Housekeeping Techniques

Good housekeeping techniques contribute to waste minimization. You should

- keep the work area neat by promptly placing drop cloths and catch bags under the work area and by properly segregating and removing all items and waste;
- prevent spills of radioactive liquids (promptly notify an RCT or a supervisor of all spills); and
- place all protective clothing, respiratory equipment, and tools in proper containers (not in radioactive waste containers, unless told to do so by an RCT).

Radiological Controlled Areas

Removing Waste from Radiological Controlled Areas (RCAs)

Two types of RCAs where radioactive waste is likely to exist are

- RCA for surface contamination: an area where a reasonable potential exists for surface contamination in excess of those amounts specified in ISD 121-1.0, Table 14-2, or that could lead to an exposure in excess of 0.1 rem/year from intake of radioactive material; or
- RCA for volume contamination: an area where a reasonable potential exists for contamination to be dispersed throughout material or waste that is not individually labeled.

Waste Segregation (Separation)

Waste should be segregated before leaving an RCA. The primary methods used to segregate waste are

- acceptable knowledge (see glossary for more information),
- surface contamination measurement,
- volume contamination measurement, or
- any combination of the three.

Any waste from RCAs must be removed only in accordance with a procedure approved by line or facility management. You should address any questions regarding this procedure to the area waste management coordinator or a designated alternate.

Student Self-Assessment

Answer the following questions to test your mastery of this unit. Strive for a score of 80% or better. (EO#) indicates the enabling objective corresponding to the question.

1. The DOE/LANL management policy for ALARA states that radiation exposures to workers and the public must ____ (EO1)
   a. be maintained ALARA
   b. be kept well below regulatory limits
   c. have commensurate benefits
   d. all of the above

2. According to the LANL policy, a 40-year-old worker's lifetime dose should be equal to or less than (EO2)
   a. 40 rem/year
   b. 40 rem
   c. 5 rem
   d. 50 rem/year

3. Which of the following is the responsibility of the individual radiological worker? (Choose all that apply.) (EO3)
   a. conducting radiological surveys
   b. obeying posted, written, and oral radiological control
   c. following instructions and procedures
   d. identifying contamination control requirements
   e. maintaining dose ALARA
   e. reporting problems
   f. stopping work when conditions are unsafe

4. Exposure to ionizing radiation can be kept ALARA by following the three basic protective measures of minimizing __________ maximizing ________, and using ________, where practicable. (EO4)

Student Self-Assessment—continued

5. Radioactive material can enter the body by which of the following pathways? (EO4)
   a. ingestion
   b. absorption
   c. inhalation
   d. all of the above

6. Choose one of the two exposure control methods (I or e) for each type of exposure control. (EO4 and EO6)

(i) internal exposure control **(e) external exposure control**

___ minimizing time

___ using respirators

___ using shielding

___ keeping wounds covered

___ using latex gloves

___ maximizing distance

___ using anti-C coveralls

___ not eating in contamination areas

Student Self-Assessment—continued

7. When working with radiation and contamination, which of the following should be minimized (a) and which should be maximized (b)? (EO4–EO6)

(a) minimize (reduce) **(b) maximize (increase)**

_____ time

_____ distance

_____ shielding

_____ sources of radiation

_____ radioactive waste

_____ internal exposure to radioactive material

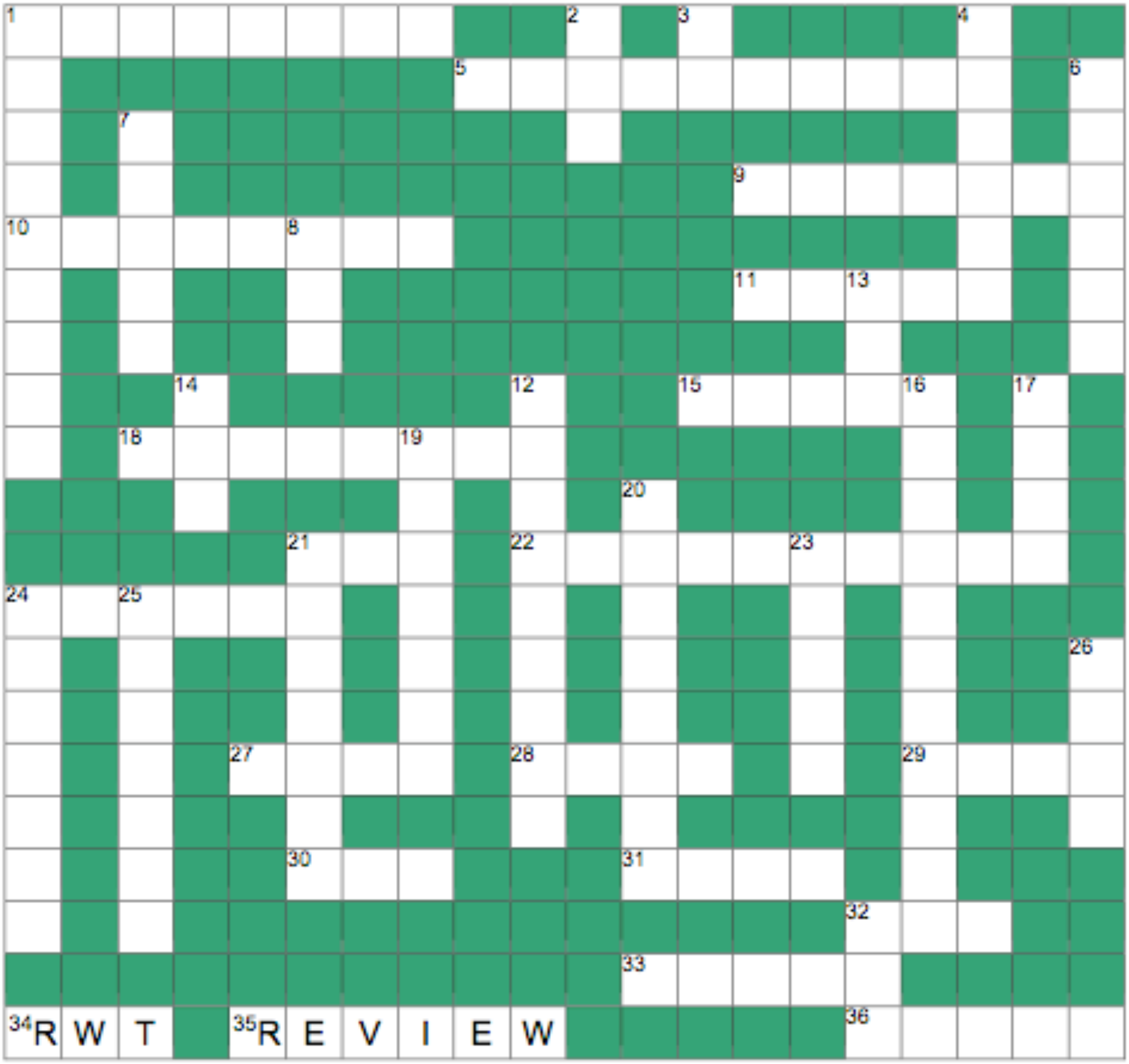
_____ external exposure to radiation

8. All of the following are ways you can minimize radioactive waste except (EO7)
   a. minimizing the material used for radiological work
   b. minimizing the amount of mixed waste
   c. mixing radioactive waste with nonradioactive waste
   d. unpackaging new tools in an uncontrolled area

Crossword Review Units 1–4

Across	Down
1. Unit for gamma exposure	1. Energy in the form of rays or particles
5. Notified, if pregnant	2. Contamination unit
9. A half-inch of ___ shields betas.	3. milliroentgen
10. Respirators protect from ___________ radioactive material.	4. Positively charged particle(s)
11. Natural radioactive gas	6. Alphas can travel 1 to 2 _________ in air.
15. Stops alpha particles	7. _______, Ci for short
18. Time required for half of the atoms to decay	8. Radiation absorbed dose
21. Average dose from radon is _____ hundred mrem/year	12. Effects that could be passed to offspring
22. Process of removing electrons from an atom	13. Sets radiation dose limits
24. Possible effect of chronic radiation exposure	14. Gamma _______
27. Whole body dose limit is _____ rem/year	16. Contamination is ____________ material in an unwanted location
28. 15 rem/year is the dose limit for the _______ of the eye	17. Alpha shield
29. Big three for ALARA: ________, distance, and shielding	19. Same number of protons; different number of neutrons
30. rem: roentgen equivalent _____	20. Alpha biological hazard
31. Maximize distance: use ____-handled tools	21. Hydrogen's radioactive brother
32. 1200 mrem = 1.2 _____	23. Four types of radiation: _________, beta, gamma, neutron
33. Radiation exposure should be kept _______.	24. RCT means radiological __________ technician
34. Radiological worker training	25. Uncharged particle in nucleus
35. Review	26. 1.25 rem = 1250 _____
36. Radioactivity: spontaneous ________ of unstable atoms	32. Unit for energy deposited in any type of material

Crossword Review Units 1–4—continued



Answers

1. d
2. b
3. b, d, e, f
4. time, distance, shielding
5. d
6. e, l, e, l , l ,e, l , i
7. a, b, b, a, a, a, a
8. c

Notes . . .

Unit 5: Radioactive Contamination Control

Learning Objectives

Major Objectives

Upon completion of this unit, you will be able to discuss the methods used to control the spread of radioactive contamination.

Enabling Objectives

You will be able to select the correct response from a group of responses, which verifies your ability to

EO1 define fixed, removable, and airborne contamination;

EO2 state sources of radioactive contamination;

EO3 state the appropriate response to indicators of potential area contamination;

EO4 state the appropriate response to indicators of personnel contamination;

EO5 identify the methods used to control radioactive contamination;

EO6 identify the proper use of protective clothing;

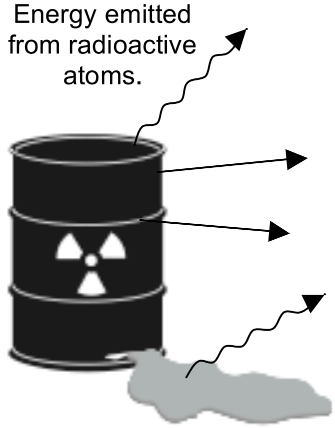
EO7 explain the purpose and use of hand-held personnel contamination monitors (PCMs); and

EO8 identify the normal methods used for decontamination.

Introduction

Contamination control is one of the most important aspects of radiological protection. Using proper contamination control practices will help ensure a safe working environment. You should recognize potential sources of radioactive contamination and use appropriate contamination prevention methods.

Radioactive Contamination



Comparison of Radiation and Radioactive Contamination

The following define radioactivity and radioactive contamination:

- Radiation is the spontaneous emission from unstable atomic nuclei. It is a stream of particles, such as electrons, neutrons, protons, alpha particles, or high-energy photons, or a mixture of these particles.
- Radioactive material is material that contains radioactive atoms.
- Ionizing radiation is energy emitted from radioactive atoms.
- Radioactive contamination is radioactive material in an unwanted location.

Types of Radioactive Contamination

Radioactive contamination can be fixed, removable, or airborne.

Fixed Contamination

Contamination that cannot be readily removed from surfaces is *fixed contamination.* Fixed contamination cannot be removed by casual contact (wiping, brushing, or washing). It may be released when the surface is disturbed (buffing, grinding, or cleaning with acids). Over time it may weep, leach (drain), or otherwise become removable.

Removable Contamination

Contamination that can be readily removed from surfaces is *removable contamination.* It is also known as loose or transferable contamination. It may be transferred by casual contact: wiping, brushing, or washing. Air movement across removable contamination can cause airborne contamination. An object that comes in contact with removable contamination may in turn become contaminated. This concept is known as cross-contamination.

Airborne Contamination

Contamination dispersed in the air in the form of dust, particles, vapors, or gases is *airborne contamination*. Operations that include cutting, grinding, machining, or sanding of radioactive materials or contaminated equipment can generate airborne contamination. Contamination in this form spreads readily with the flow of air. One very important concern is breathing the contaminated air. Careful monitoring and the use of respiratory protection are methods to control internal dose caused by airborne contamination.

Sources of Possible Contamination

Radioactive material can be spread to unwanted locations through lack of awareness or failure to follow procedures. You may encounter radioactive contamination in the form of a solid, liquid, or gas/vapor.

The following are some sources of possible contamination:

- leaks or tears in radiological containers such as barrels, plastic bags, glove boxes, or glove box gloves;
- repackaging radioactive materials;
- airborne contamination depositing on surfaces;
- excessive motion or movement in areas of high contamination;
- uncovering buried radioactive material;
- leaks or breaks in radioactive systems;
- opening radioactive systems without proper controls;
- opening shipping containers that contain radioactive material;
- small, sometimes microscopic pieces of highly radioactive material that may be present when contaminated systems are opened;
- machining, cutting, or grinding highly radioactive or contaminated materials;
- fragments of activated materials that have escaped containment;
- poor housekeeping in contaminated areas;
- sloppy work practices (such as cross-contamination of tools, equipment, or workers) resulting from walking on, touching, brushing against, or laying tools and equipment on contaminated surfaces; and
- not following procedures and work documents that cover all types of radiological work.

Indicators of Radioactive Contamination

Indicators of Possible Contamination

Indicators of contamination can be

- leaks, spills, and standing water;
- damaged radiological containers;
- airborne contamination monitor alarms;
- unexplained personnel contamination; and
- higher-than-normal background readings on personnel contamination survey devices.

Your Response to Suspected Contamination

If you discover contamination, you should

- stop work,
- notify an RCT and your appropriate supervisor, and
- work with the RCT to decontaminate the work area.

In response to airborne contamination or to a continuous air monitor (CAM) alarm (if you are not wearing a respirator), you should

- leave the area immediately, alerting others;
- contact an RCT and your appropriate supervisor;
- proceed to the predetermined safe location until both the workers and the area are surveyed; and
- alert others as you leave.

If you are wearing respiratory protection, you should

- stop the operation safely,
- alert others in the area,
- proceed to the predetermined safe location,
- contact an RCT and follow instructions, and
- do not remove your respirator until surveyed for contamination.

In response to a personnel contamination monitor (PCM) alarm, you should

- remain in the immediate area (as close as practicable to the PCM);
- notify an RCT (by telephone or intercom, or with help from a coworker);
- take available actions to minimize cross-contamination such as putting a glove on a contaminated hand if practicable; and
- follow RCT instructions for decontamination.

Control of Radioactive Contamination

Contamination Control

Control of radioactive contamination can be achieved by the use of source reduction, engineered controls, administrative controls, proper radiological practices, personal protective equipment (PPE) and decontamination.

Proper controls help prevent the spread of contamination to other areas and can decrease personnel contamination. Personnel contamination can result in

- radioactive material on the skin or inside the body, which could cause a dose to the skin or a whole body dose; and/or
- radioactive material spreading beyond established boundaries, which could present a hazard to the public.

Source Reduction

Source reduction is the safe removal of unneeded radioactive sources or the removal of radioactive material from the immediate work area, work processes, or radiological systems.

Contamination Control Methods

HEPA vacuums

Engineered Control Methods

Engineered controls are included in the building's construction and/or into the planning of radiological work. Engineered controls designed to prevent the spread of contamination include

- ventilation that maintains airflow from areas of least contamination to areas of most contamination (clean from contaminated to highly contaminated areas) and that maintains a slight negative pressure on buildings or rooms with a potential for contamination;
- high-efficiency particulate air (HEPA) filters that remove radioactive particles from the air;
- building and shielding materials selected for ease of decontamination;
- remote handling equipment for remote operations;
- containment such as vessels, glove boxes, tents, or plastic coverings that control contamination;
- corridors to establish traffic patterns; and
- walls or doors that act as barriers.

Note: HEPA filters are not effective with gases such as tritium.

Contamination Control Methods—continued

Administrative Control Methods

Administrative controls include access restrictions, exit requirements, procedures, postings, work documents, work permits, and briefings.

Access Restrictions

To control contamination, access to contaminated areas is limited by

- postings (yellow with a black or magenta radiation symbol) that list hazard information, and
- control points at locations with an increased potential for contamination and/or exposure.

Exit Requirements

Continued strict requirements and procedures apply when a person or item leaves an area that has a potential for contamination. These requirements include

- surveying for contamination and
- documenting equipment and item removal.

Procedures, Work Documents, Work Permits, and Briefings

Operating and maintenance procedures, work permits, and briefings should incorporate contamination control measures. Preventive measures used to control contamination include

- establishing adequate work controls before starting jobs; and
- discussing (during prejob briefings) measures that will help prevent the spread of contamination.

Contamination Control Methods—continued

Proper Radiological Practices

Good Housekeeping

Good housekeeping is an important part of an effective contamination control program. It involves the interactions of all groups within the facility. You should

- keep your work area neat;
- try to confine radioactive materials to a small area;
- control and minimize all material taken into or out of contaminated areas;
- keep your work area neat to prevent spills of radioactive liquids;
- identify and report leaks before they become serious problems;
- use sound preventive maintenance practices to minimize the likelihood of radioactive material releases; and
- recognize that, despite precautions, radioactive materials will occasionally escape and contaminate an area.

Good Work Practices

Good work practices are essential to contamination control. You should be alert for violations of the principles of contamination control, such as improper work methods, poor work practices, or procedure violations. You must

- prepare work areas to prevent the spread of contamination, such as covering piping or equipment below a work area to prevent dripping contamination onto clean(er) areas and covering or taping tools or equipment to minimize decontamination after the job;
- comply with procedures, work permits, postings, or instructions from radiological control personnel;
- wear protective clothing and respiratory equipment whenever required, and follow donning and doffing procedures;
- avoid contact of skin, clothing, and respiratory equipment with contaminated surfaces;
- change out gloves or other PPE as needed to prevent cross-contamination of equipment;
- not eat, drink, smoke, chew, or apply cosmetics or lip balms in areas that have a potential for contamination; and

Contamination Control Methods—continued

- take the following special precautions when containing radioactive material in plastic bags:
  - use PPE as applicable;
  - roll the sides of the bag over to protect the outside of the bag as well as the hands;
  - do not force excess air out of the bag, which may cause radioactive materials to become airborne (In some cases, pointing the open portion of the bag away from the face and gently squeezing the bag may be appropriate, with approval of an RCT);
  - tape the ends of any sharp items to prevent the bag from being punctured;
  - tape the ends of the bag securely to prevent leakage; and
  - place an approved absorbent material into the bag to absorb free-standing liquid.

Personal Protective Equipment

PPE, such as protective clothing and respiratory equipment, is used to supplement engineering and administrative controls.

Protective Clothing


Protective clothing

Workers must wear PPE, such as protective clothing (anti-C or anticontamination clothing), to enter contamination areas to prevent contamination of skin or personal clothing. The degree of protective clothing required depends on the work area radiological conditions and the nature of the job.

Protective clothing generally consists of

- coveralls (white or yellow),
- two pair of surgeon’s gloves (cotton glove liners may be worn inside surgeon’s gloves for comfort but not for protection),
- shoe covers, and
- hood or skull cap.

Contamination Control Methods—continued

Prescribed anti-Cs are listed on work permits and/or postings or are specified by an RCT. Specific procedures for donning and doffing anti-Cs may be posted in the vicinity of step-off pads. When using protective clothing, you should

- inspect all protective clothing for rips, tears, or holes before use;
- avoid wearing personal effects such as jewelry in known contamination situations;
- after donning protective clothing, proceed directly from the dress-out area to the work area;
- after exiting the work area, proceed directly to the doffing area;
- avoid getting nonplastic coveralls wet (wet coveralls allow contamination to reach the skin or personal clothing);
- contact an RCT if protective clothing becomes torn or ripped; and
- avoid touching uncovered portions of the body (such as wiping the face or pushing up glasses) with gloves or sleeves of anti-Cs.

Respiratory Protective Equipment

Respiratory protective equipment is used to prevent the inhalation of radioactive materials. Respiratory protective equipment is used when engineered controls may not be able to maintain airborne contamination at acceptable levels. Minimum requirements are stated in operating procedures and work permits.

Respirator

Respiratory protection should be considered under the following conditions:

- when entering a posted Airborne Radioactivity Area;
- during operations that breach contaminated systems; and
- when cutting, grinding, or welding contaminated surfaces.

Radiological Worker Training *does not* qualify you to wear respiratory protective equipment**.** You must meet the following requirements for wearing respiratory protective equipment:

- pass a physical exam,
- receive specific training,
- perform a respiratory fit test,
- be clean shaven as required by respirator type, and
- have a current respirator card issued by IHS-IP.

Decontamination

When the presence of removable contamination is discovered, decontamination is a valuable means of control. However, decontamination of the area is not always possible because of

- economical conditions—the cost of time and labor to decontaminate the location outweighs the hazards of the contamination present, or
- radiological conditions—the radiation dose rates or other conditions present hazards that far exceed the benefits of decontamination.

When decontamination is not possible, other means of control such as engineered controls, administrative controls, proper radiological practices, and PPE must be used.

Decontamination is the removal of radioactive material from a location where it is not wanted. This process does not result in the disappearance of the radioactive material but involves the removal of the radioactive material to another location.

Material Decontamination

Material decontamination involves the removal of radioactive material from tools, equipment, floors, and other surfaces in the work area. When material decontamination is necessary, you should

- notify an RCT before beginning any decontamination and follow the RCT's instructions,
- obtain prior approval before using any chemical solvents or cleaners that will generate mixed waste, and
- follow RCT instructions for the decontamination process.

Material decontamination is accomplished by

- using masking tape,
- mopping or wiping with soap and water,
- scrubbing or wiping with damp rags or pads,
- scrubbing with wire brushes, or
- using chemical solvents or cleaners.

Decontamination—continued

Personnel Decontamination

Internal Decontamination

Radioactive materials deposited inside the body are a continuous source of internal exposure until they are removed or decay. The reduction of radioactive materials inside the body depends on

- the radioactive half-life of the particular isotope, and
- the normal biological elimination process (exhalation, perspiration, urination, and defecation).

In some cases the biological elimination process may be enhanced by the use of chelating agents, under medical advice and supervision.

Note: *A chelating agent is a substance that attaches to heavy metals (plutonium, uranium, mercury, and lead), some of which may be radioactive, and is used to speed their removal from the bloodstream.*

Skin and Clothing Decontamination

Personnel decontamination involves the removal of radioactive material from skin or personal clothing. If you detect contamination on skin or personal clothing, you must notify an RCT and your line manager to ensure accurate occurrence reporting and to initiate appropriate bioassay sampling.

Contaminated wounds may require emergency medical care, which takes precedence over radiological considerations.

The decontamination process should always avoid skin abrasions, which may lead from external contamination to internal contamination.

Skin and clothing decontamination is normally accomplished by

- using a dry decontamination material such as masking tape on clothing; and
- washing with mild soap and lukewarm water, if necessary.

If more intense skin decontamination is required, OM medical personnel must be contacted. Washing too vigorously or with harsh chemicals could increase the intake of radioactive material.

Detection and Measurement of Contamination

Methods of Detection and Measurement

Different methods are used to detect different types of radioactive contamination. Once detected, the amount of contamination present is recorded on work documents, survey maps, and status boards.

Fixed Contamination

Fixed contamination is detected and measured by direct frisking of the area. An RCT passes a survey instrument directly over the area, measuring the amount of radioactivity present. This measurement is reported in units of dpm/100 cm^2.

Removable Contamination

Removable contamination is detected by smearing or swiping surface areas. (This technique is not appropriate for detecting contamination on personnel because it could spread or embed contamination.)

- Smear (used for smaller surface areas such as 100cm^2 or smaller)—a small filter paper is used to smear a 4 x 4 inch area (100cm^2). Radiological control personnel count the smear using counting equipment and report the amount of radioactivity in units of dpm/100cm^2.
- Swipe (used for larger surface areas)—a highly absorbent cotton mesh pad is used to swipe an area larger than 100cm^2.

Airborne Contamination

Airborne contamination is detected and measured using either portable or stationary air samplers. Contamination levels are typically reported in units of μCi/cm^3, μCi/ml, or μCi /m^3 of air.

Radioactive Material Suspended in a Liquid

Radioactive liquids are detected and measured by taking samples of the liquid. Radiological control personnel count the samples and report the contamination levels in units of μCi/ml or μCi/l.

Detection and Measurement of Contamination—continued

Hot particles are small, sometimes microscopic pieces of highly radioactive material that may be released and spread when contaminated systems are opened.

Hot Particles

Highly radioactive hot particles can cause a high, localized dose if they remain in direct contact with skin or extremities. They are very difficult to detect because of their small, sometimes microscopic size.

RP-1 personnel may touch an area using adhesive tape to remove hot particles, and then slowly move a survey instrument over the tape to verify removal of the particles.

Caution must be used when performing a whole body frisk to prevent accidentally knocking the particles off and losing track of them.

Personnel Contamination Monitoring (PCM) Equipment

PCMs are considered to be more accurate and thorough in detecting contamination than hand-held instruments.

Using a Hand-Held Contamination Monitor

Only personnel who have been specifically trained at their work site to perform contamination monitoring will be authorized to perform that monitoring. The training will be site specific, instrument specific, and will be conducted by an authorized person.

Contamination monitoring equipment is used to detect radioactive contamination on personnel. To use a hand-held contamination monitor, you must do the following:

- Be properly trained on an instrument before using it.
- Verify that the instrument is in calibration (by checking the calibration void date).
- Check for any physical damage such as torn Mylar™ or a damaged case.
- Verify that the battery is in operable condition.
- Verify that the instrument is on and set to the proper scale and that the audio can be heard.
- Source-check the instrument. If the response is more or less than expected, do not use the instrument. Contact an RCT for a replacement instrument.
- Hold the probe approximately ½ inch or less from the surface for beta and gamma radiation and ¼ inch or less for alpha radiation.
- Move the probe slowly over the surface, about 1–2 inches per second.

Personnel Contamination Monitoring Equipment—continued

- Proceed with the whole body frisk in the following order:
  - head (start at the mouth and nose area and pause about 5 seconds);
  - neck and shoulders;
  - arms (pause at each elbow):
  - hands (be sure hands are dry);
  - chest and abdomen;
  - back, hips, and seat of pants;
  - legs (pause at each knee);
  - shoe tops; and
  - shoe bottoms (pause at sole and heel).

Take a minimum of 2–3 minutes to complete a whole body frisk:

- If the count increases during frisking, pause 5–10 seconds over the area to provide adequate time for instrument response.
- If contamination is indicated by an increased count rate that is repeated or by an alarm, remain in the area and notify an RCT or a supervisor.
- Minimize cross-contamination while waiting for an RCT to arrive and do not attempt personnel decontamination.

Student Self-Assessment

Answer the following questions to test your mastery of this unit. Strive for a score of 80% or better. (EO#) indicates the enabling objective corresponding to the question. More than one response may be correct.

1. Match the term to the correct definition. (EO1)

___ fixed contamination	a. contamination suspended in air
___ removable contamination	b. contamination that cannot be easily removed by wiping the surface
___ airborne contamination	c. contamination that can be easily removed by wiping the surface

2. Which of the following is a possible source of contamination? Choose **all** that apply. (EO2)
   a. sloppy work practices
   b. following posted procedures
   c. good housekeeping practices
   d. grinding on radioactive material
   e. leaking radioactive systems
   f. leaking radiological containers
   g. opening radioactive systems with proper controls

3. If an instrument is being used for self-monitoring and it indicates higher-than-background readings but does not set off an alarm, you should (EO3)
   a. decontaminate the affected area
   b. pause, reset the instrument, and resurvey the area
   c. ignore the alarm if you believe it is a false alarm
   d. contact medical personnel immediately

4. If an instrument is being used for self-monitoring alarms, you should (EO3)
   a. decontaminate the affected area
   b. remain in the immediate area and contact an RCT
   c. ignore the alarm, if you believe it is a false alarm
   d. contact medical personnel immediately

Student Self-Assessment—continued

5. If an airborne contamination monitor alarms in the work area and you are not wearing a respirator, you should (EO3)
   a. remain in the area until help arrives
   b. contact a personal physician
   c. immediately leave the room and wait in a designated safe area
   d. contact a supervisor and continue working until that person arrives

6. When monitoring for alpha contamination, hold the probe less than ____ from the surface and move about ____ per second. (EO3)
   a. ¼ inch, ¼ inch
   b. ¼ inch, 1 to 2 inches
   c. 1 to 2 inches, ¼ inch
   d. 1 to 2 inches, 1 to 2 inches

7. Match the contamination control method to the correct contamination control category (a, b, or c). (EO4)

____anticontamination gloves	
____prejob briefings	
____ corridors to establish traffic patterns in radiological areas	a. engineered controls
____access restrictions	b. administrative controls
____ HEPA filters in ventilation systems	c. personal protective equipment
____respirators	
____negative air pressure	

Student Self-Assessment—continued

8. The first step in donning protective clothing is to (EO5)
   a. put on coveralls
   b. inspect protective clothing for rips or tears
   c. put on cotton liners
   d. place jewelry in coverall pockets and tape pockets closed

9. Who must be present during personnel decontamination? (EO7)
   a. RCT
   b. supervisor
   c. group leader
   d. medical personnel

10. ______ soap and _________ water are used for personnel decontamination. (EO7)

Answers

1. b, c, a
2. a, d, e, f
3. b
4. b
5. d
6. b
7. c, b, a, b, a, c, a
8. b
9. a
10. mild, lukewarm

Unit 6: Radiological Emergencies

Learning Objectives

Major Objectives

Upon completion of this unit, you will be able to identify the radiological emergencies and alarms and the appropriate response to each.

Enabling Objectives

EO1 state the purpose of and identify the two primary types of radiological emergency alarms used at the Laboratory,

EO2 recognize that alarms and responses vary from one facility to another,

EO3 state the correct response to a continuous air monitor (CAM) alarm,

EO4 state the correct response to an area radiation monitor (ARM) alarm,

EO5 state the correct response to a personnel contamination monitor (PCM) alarm,

EO6 identify responses to personnel injuries, and

EO7 state the possible consequences of disregarding radiological alarms.

Introduction

Various radiological monitoring systems are used to warn you of abnormal radiological conditions. You must become familiar with these alarms to prevent unnecessary exposure to radiation and/or contamination.

Emergency Alarms and Responses

Alarms and Responses at LANL Facilities

Equipment that monitors for abnormal radiation exposure levels and airborne contamination levels is placed in strategic locations throughout the facilities. You must be able to identify the equipment and alarms and respond appropriately to each.

Emergency alarms and responses differ from one facility to another at the Laboratory, although some basic principles apply in all emergency situations. Additional emergency response training will be provided in facility-specific training.

The primary types of radiological emergency alarms are

- area radiation monitors (ARMs), and
- continuous air monitors (CAMs).

Although not a true emergency alarm, the correct response to personnel contamination monitors (PCMs) is important.

Area Radiation Monitors

Area Radiation Monitor

An ARM is an instrument that measures the radiation exposure level. The types of ARMs are specific to each facility and will be discussed during the facility orientation.

ARMS are installed in frequently occupied locations where the potential for unexpected increases in dose rates exists. They are also installed in remote locations where there is a need for local indication of dose rates before personnel enter the work area.

ARMs are not a substitute for radiation exposure surveys in characterizing the work area.

ARMs will alarm when area radiation levels exceed a set level. When an ARM alarms, you should

- leave the area immediately, alerting others; and
- contact an RCT.

Emergency Alarms and Responses—continued

Continuous Air Monitors

A CAM is an instrument that continuously samples and measures the level of airborne radioactivity on a real-time basis. The three types of CAMs are alpha, beta/gamma, and tritium.

Continuous Air Monitor

CAMs will alarm when airborne radioactivity levels exceed a set level. If you do not have respiratory protection when a CAM alarms, you should

- leave the area immediately, alerting others;
- contact an RCT; and
- proceed to the predetermined safe location until both the workers and the area are surveyed.

If you have respiratory protection, you should

- stop the operation safely,
- alert others in the area,
- contact an RCT and follow instructions, and
- do not remove your respirator until surveyed for contamination by an RCT.

Personnel Contamination Monitor

PCMs are placed at the exit from a posted area. You must monitor yourself for contamination whenever you leave the area.

If a PCM alarms, you must

- remain in the immediate area,
- notify an RCT,
- minimize cross-contamination, and
- do not attempt personnel decontamination.

If you have to go somewhere, for example to use a phone to notify an RCT if one is not on hand, you must inform the RCT of all of the places you have been. Cross-contamination can be cleaned up, but only if the RCT knows about it.

Disregard for Radiological Alarms

Consequences of Disregarding Alarms

Disregarding or tampering with any radiological alarms may

- jeopardize both your safety and your coworkers' safety,
- cause excessive personnel exposure,
- result in the unnecessary spread of contamination, and
- lead to disciplinary action.

Radiological Emergency Situations

Emergencies in Radiological Areas

Performing work in a radiological environment requires more precautionary measures than performing the same work in a nonradiological setting. An emergency in a radiological area requires additional precautionary measures.

Situations Requiring Immediate Exit

Situations that require immediate exit from an area that is controlled for radiological purposes are

- ARM alarm,
- CAM alarm (unless the worker is wearing a respirator),
- criticality alarm,
- evacuation alarm set off by a release of radioactive materials,
- stop work and evacuation order,
- lost or damaged dosimeter,
- irregular or off-scale reading of any supplemental dosimetry, and
- torn protective clothing.

Radiological Emergency Situations—continued

Response to Personnel Injuries

In response to personnel injuries in areas that are controlled for radiological purposes, you should follow these guidelines:

- For serious injuries, first aid takes priority over radiological concerns: call 911, administer first aid, and contact an RCT. The immediate health of the individual, rather than the radiological protection procedure, is the primary consideration.
- The following are considered serious injuries that have the potential to cause loss of life, disability, or serious pain (this list is not a complete list):
  - head or neck injury;
  - penetrating injury (except for a minor puncture wound to an extremity);
  - loss of consciousness;
  - disorientation;
  - convulsion;
  - loss of motor function;
  - limbs at abnormal angles (breaks or dislocations);
  - amputations;
  - burns of the face, hands, feet, or genitals;
  - burns larger than the palm of the hand;
  - inhalation of any abnormal substance;
  - extensive bleeding; and
  - abnormal breathing patterns;
- For minor injuries, contamination control takes priority:
  - contact an RCT immediately,
  - follow RCT instructions,
  - have the wound surveyed by an RCT for contamination,
  - contact your supervisor, and
  - administer first aid after decontamination.

Radiological Emergency Situations—continued

Accidental Breach, Leak, or Spill

An accidental breach of or leak from a radioactive system or a spill of radioactive material or radioactive liquid require immediate response. Contact the RCT and follow the SWIMS (Stop, Warn, Isolate, Minimize, Secure) or facility-specific procedure:

- **S**top and evaluate the situation.
  - Stop work that is in progress.
  - Evaluate what supplemental actions are needed.
  - If a leak is from a valve or piping system, do not close the valve (only qualified personnel should close valves).
  - Do not attempt to collect leaking liquids unless told to do so by an RCT.
  - Cover the spill with spill pads, if practicable and if criticality or other safety concerns are not an issue.
- **W**arn others of the hazard and evacuate the area.
  - Inform an RCT, RP-1, and others in the area of the situation.
  - Recruit available coworkers to help make emergency notifications or to respond to the incident.
  - Pass on to others information about the type, quantity, and location of the spill; information on any contaminated personnel; and any other pertinent information.
- **I**solate the area.
  - Place personnel, rope, or tape at entry points to the area.
  - Limit access to the area to minimize the spread of contamination, and assist cleanup personnel in determining the extent of the spill.
- **M**inimize exposure to both contamination and radiation.
  - Move upwind and away from the spill.
  - Use protective clothing, if available.
  - Do not touch areas suspected of being contaminated.
  - Prevent tracking contamination to other areas.
- **S**ecure unfiltered ventilation, as appropriate.

Rescue and Recovery Operations

Considerations in Rescue and Recovery Operations

In extremely rare cases, emergency exposure to high levels of radiation may be necessary to rescue personnel or to protect major property. Rescue and recovery operations that involve radiological hazards can be a very complex issue with regard to the control of personnel exposure.

The type of response to these operations is generally left up to the officials in charge of the emergency situation. The officials' judgment is guided by many variables, which include determining the risk versus the benefit of the action, as well as how to involve other personnel in the operation.

If the situation involves a substantial personal risk, volunteers will be used. The use of volunteers will be based on various factors such as age, experience, and previous exposure.

Emergency Dose Limits

The DOE guidance on emergency doses for these personnel is as follows:

- Protecting major property where the lower dose limit of 5 rem is not practicable.
  - The DOE emergency level is 10 rem.
- Lifesaving or protecting a large population where the lower dose limit is not practicable.
  - The DOE emergency level is 25 rem.
- Lifesaving or protecting a large population—only on a voluntary basis to personnel fully aware of the risks involved.
  - The DOE emergency level is greater than 25 rem (no upper limit).

Note: *Response to these types of situations usually involves emergency response personnel who have received Emergency Responder Radiological Training*.

Student Self-Assessment

Answer the following questions to test your mastery of this unit. Strive for a score of 80% or better. (EO#) indicates the enabling objective corresponding to the question.

1. An ARM warns personnel of sudden increases in external _____ levels. (EO1)

2. A CAM warns personnel of the presence of airborne _____. (EO1)

3. All of the following are emergency alarms except (EO1)
   a. CAM
   b. TLD
   c. ARM
   d. criticality

4. If a CAM alarms and you do not have respiratory protection, you should (EO3)
   a. stay in the area to prevent spreading contamination
   b. leave the area immediately, notify an RCT, and be on standby outside the area
   c. continue working until an RCT gives instructions to leave
   d. ignore the alarm

5. Which one of the following situations requires immediate exit from a radiological area? (EO3 and EO4)
   a. ARM alarm
   b. CAM alarm
   c. criticality alarm
   d. all of the above

Student Self-Assessment—continued

6. In general, the best response to most alarms is to exit immediately. The exception is (EO5)
   a. CAM alarm
   b. ARM alarm
   c. criticality alarm
   d. PCM alarm

7. The correct response to a serious personnel injury is to (EO6)
   a. move the injured person to another area
   b. immediately decontaminate the injured person
   c. administer first aid to the injured person
   d. evacuate the area and wait for help

8. In which of the following situations is radiological control a low priority? (EO6)
   a. a minor skin wound
   b. life-threatening injury in a contamination area
   c. PCM alarm
   d. CAM alarm

9. Disregarding a radiological alarm could result in ____ (EO7)
   a. personnel contamination
   b. unnecessary radiation exposure
   c. release of contamination to the environment
   d. all of the above

Answers

1. radiation
2. radioactivity
3. b
4. b
5. d
6. d
7. c
8. b
9. d

Unit 7: Radiological Postings and Controls

Learning Objectives

Major Objectives

Upon completion of this unit, you will be able to identify radiological postings as well as general and job-specific radiological work permits (RWPs).

Enabling Objectives (Eos)

You will be able to select the correct response from a group of responses, which verifies your ability to

EO1 identify the colors and symbols used on radiological postings, signs, and labels;

EO2 define the types of radiological areas;

EO3 state the entry and exit requirements for each area controlled for radiological purposes;

EO4 state the radiological and disciplinary consequences of disregarding, altering, removing, or relocating radiological postings, signs, and labels;

EO5 state the purpose of and information found on RWPs;

EO6 identify your responsibilities in using RWPs;

EO7 state the correct response if the RWP is incorrect or if you do not understand the information; and

E08 identify information found in a sample RWP and on an associated survey map.

Introduction

Radiological postings and work permits inform you of radiological hazards and required controls for radiological work.

Radiological Postings

Purpose of Radiological Postings

Radiological postings are used to alert personnel to the presence of radiation and radioactive materials. Postings also identify areas that are controlled for radiological purposes based on radiation dose rates and/or contamination levels.

Postings Colors and Symbols

Trefoil

Areas controlled for radiological purposes must be posted with a black or magenta standard three-bladed radiological warning symbol, or trefoil, on a yellow background. Radioactive materials must be identified with black or magenta print on yellow labels or tags. At LANL, black on yellow is used for most postings and labels.

Additionally, yellow and magenta ropes, tapes, chains, or other barriers must be used to mark the boundaries. These barriers must be clearly visible from all directions.

Posting Information

A radiological posting contains the following information from top to bottom:

- a warning word such as "CAUTION" or "NOTICE" that indicates the level of hazard,
- the area designation such as Radiation Area or Contamination Area,
- airborne radioactive concentration as applicable, and
- the normal entry requirements.

Because radiological conditions may change, the information on the postings is also changed to reflect the new conditions. Therefore, a posting seen on one day may be replaced with a new posting the next day.

Note: *RCTs are responsible for the placement and/or removal of all radiological postings.*

Radiological Postings—continued

Hazard Level

The following table lists the first word(s) of the radiological posting, indicating its hazard level and the appropriate responses:

Hazard Levels of Radiological Postings

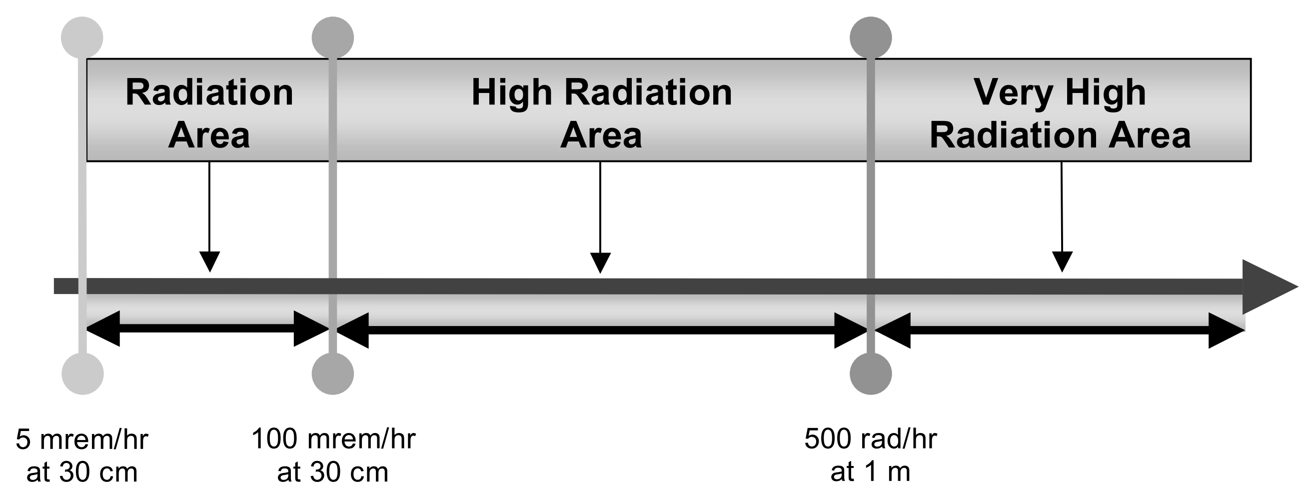
The word(s) . . .	is like . . .	and means . . .	You should . . .
NOTICE	the road sign "traffic signal ahead"	hazards may exist.	proceed.
CAUTION	a flashing yellow traffic light	hazards do exist.	proceed with caution, accompanied by an RCT or other appropriate personnel.
DANGER	a flashing red traffic light	significant dangers do exist.	pause to evaluate the danger, with the help of an RCT or other appropriate personnel.
GRAVE DANGER	a red light	a very great danger exists.	STOP. Do not proceed until the conditions have been evaluated by an RCT and a senior manager. Only volunteers who are fully aware of the risks may proceed.

Types of Radiological Areas

The three primary types of radiological areas found at LANL are

- Radiation Areas,
- Contamination Areas, and
- Airborne Radioactivity Areas.

The words "High" or "Very High" may also appear on the radiological posting. For example, you may encounter postings containing the wording "CAUTION: Radiation Area" or "Grave Danger: Very High Radiation Area."



Radiological Postings—continued

Criteria for Radiological Postings: Radiation Areas

Posting	Defining Conditions	Minimum Entry Requirements	Exit Requirements	Working Requirements
Controlled Area	Not expected to receive a dose exceeding 100 mrem/yr; contamination unlikely	General Employee Radiological Training	Monitor personnel and equipment as required	Follow job-authorized procedures and protection requirements Practice ALARA Do not loiter during work delays Follow no eating, drinking, smoking, or chewing policy except in RCA for legacy contamination Report controls that are not adequate or are not being followed Obey posted, written, or oral requirements Be aware of changing radiological conditions Report any unusual conditions
Radiological Buffer Area	Where individuals are likely to receive >100 mrem/yr or potential contamination levels greater than Table 14-2 values (ISD 121-1.0). May be used for areas containing hoods, glove boxes, and rooms with radiation-producing machines	Radiological Worker I and TLD as required by facility Radiological Worker I no longer meets requirements for working in any radiological controlled area	Monitor personnel and equipment as required	
Radiation Area	>5 mrem/hr at 30 cm from source up to 100 mrem/hr	Radiological Worker I, TLD, and written authorization to enter and perform work in area	Obey posted requirements	
High Radiation Area	>100 mrem/hr at 30 cm from source up to 500 rad/hr @ 1 m	Radiological Worker I, TLD, supplemental dosimetry, radiation survey, RWP, and written authorization to enter and perform work in area Read and sign that you understand job radiological conditions and protection requirements written in the RWP and will abide by them	none	
Very High Radiation Area	>500 rad/hr at 1 m from the source	No entry allowed during normal operations	none	
Hot Spot	≥5 times area dose rate and >100 mrem/hr or ≥5 times surface contamination level	N/A	N/A	
Radioactive Material	Accessible areas where items or containers of radioactive material in quantities greater than Appendix 16A values (ISD 121-1.0) are used, handled, and stored	N/A	N/A	
Hot Job Exclusion Area	as posted	as posted	as posted	

Radiological Postings—continued

Controlled Area

A Controlled Area, also called a Radiological Controlled Area (RCA), is an area of relatively low radiological risk around other areas controlled for radiological purposes. The area is established to control potential external exposure and/or contamination. In areas controlled for external exposure, there is a potential for annual dose equivalents of ≥100 mrem per year. In areas controlled for contamination, there is a potential for contamination at levels higher than the limits specified in the RPP (Radiation Protection Program). In areas controlled for depleted uranium (DU), fragments of DU may exist on the ground and also may be embedded in trees and on the walls of buildings in the area.

Areas Controlled for Legacy Contamination

In these areas, no potential for contamination in normal (routine) activities may exist. Possible contamination may exist in some systems of the facility, and controls must be in place for work on these systems. No restrictions exist on eating or drinking, and there are no exit requirements.

Controlled Area Posting

Entry Requirements for a Controlled Area

Entry requirements include

- General Employee Radiological Training (GERT);
- additional facility- or operation-specific training, as required; and
- protective clothing, as required at specific facilities.

Exit Requirements for a Controlled Area

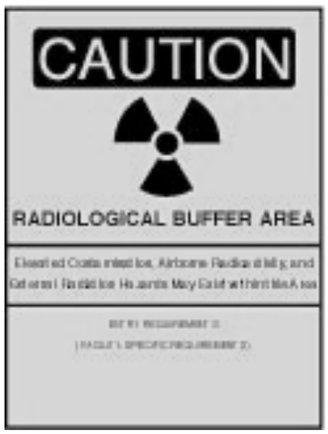
LANL has no exit requirements for areas controlled for potential external exposure. In areas controlled for potential contamination or for DU, personnel and equipment monitoring may be required at exit points.

Radiological Postings—continued

Radiological Buffer Area

A Radiological Buffer Area is a secondary boundary area around other radiological areas containing greater radiological hazards. It is established to control potential external exposure or contamination.

Radiological Buffer Area Posting



Minimum Entry Requirements for a Radiological Buffer Area

Entry requirements are facility-specific and usually include

- Radiological Worker Training,
- facility-specific training, and
- appropriate external and internal dosimetry.

Exit Requirements for a Radiological Buffer Area

Monitoring requirements for exiting are facility specific. In Radiological Buffer Areas so designated for potential contamination, you must

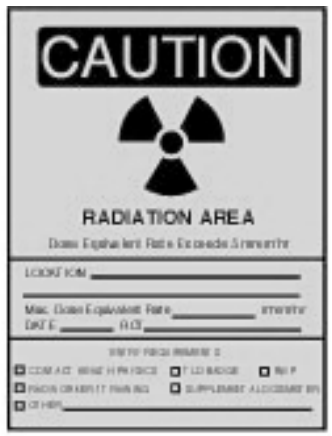
- monitor personnel and equipment for contamination as instructed on the posting at the area exit; and
- monitor personal items such as notebooks, papers, or flashlights as well as equipment used or stored in the area.

Radiological Postings—continued

Radiation Area

A Radiation Area is an area in which the whole body radiation dose rate is greater than 5 mrem at 30 cm from the source in one hour up to 100 mrem at 30 cm in one hour from the source.

Radiation Area Posting



Minimum Entry Requirements for a Radiation Area

Entry requirements include

- Radiological Worker Training,
- facility-specific training,
- a TLD and other appropriate supplemental external dosimetry, and
- written authorization to enter and/or perform work in the area using a required work control document.

Exit Requirements for a Radiation Area

The Laboratory has no exit requirements for Radiation Areas, High Radiation Areas, or Very High Radiation Areas when no other radiological hazards are present.

Radiological Postings—continued

High Radiation Area

A High Radiation Area is an area in which the whole body radiation dose rate is greater than 100 mrem in one hour at 30 cm from the source up to 500 rad in one hour at 30 cm from the source.

High Radiation Area Posting

Entry Requirements for a High Radiation Area

Entry requirements include

- Radiological Worker Training,
- facility-specific training,
- a worker's signature on a job-specific RWP,
- a TLD and supplemental dosimetry,
- written authorization to enter and/or perform work in the area using a required work control document, and
- a radiation survey before entry.

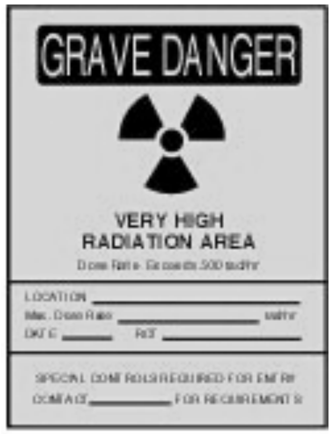
Where dose rates are greater than 1 rem/hour, additional requirements are specified in ISD 121-1.0, Chapter 9, *Access Control.*

Radiological Postings—continued

Very High Radiation Area

A Very High Radiation Area is an area in which the whole body radiation dose rate is greater than 500 rad in one hour at 100 cm from the source.

Very High Radiation Area Posting



Entry Requirements for a Very High Radiation Area

Very high radiation areas are kept locked, and entry is normally controlled. When entry is required, the dose rate usually can be reduced below the limits for a Very High Radiation Area by removing or shielding the source of radiation.

General Considerations for High or Very High Radiation Areas

Dose rates in a High Radiation Area range from 0.1 to 500 rad/hour. In some Very High Radiation areas at LANL, dose rates can exceed a million rad/second. Because of the very wide range of hazards, each entry into a High or Very High Radiation Area is evaluated individually, beginning with a job-specific RWP. Access is controlled by physical barriers,* and actual entry may be controlled by full-time RCTs. Dose rates are continuously monitored by dosimeters. In other words, entry into a High or Very High Radiation Area is very strictly controlled.

***Note:** *Physical controls and other measures are required at >1 rem in 1 hour.*

Radiological Postings—continued

Requirements for Working in All Radiological Areas

While working in radiological areas, you must

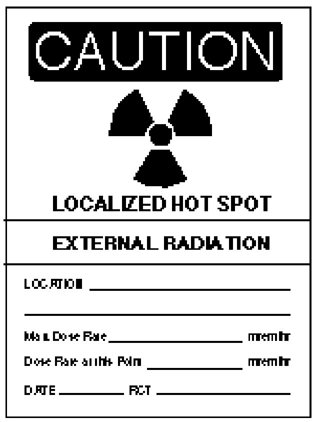
- practice ALARA;
- move to lower dose areas;
- not loiter during work delays;
- follow the no eating, drinking, smoking, or chewing policy;
- obey any posted, written, or oral requirements, including evacuate, hold-point, or stop-work orders from an RCT. (Hold points are specific times, as noted in a procedure or work permit, that work must stop for radiological control evaluations. Stop-work orders usually result from inadequate radiological controls, radiological controls not being implemented, and/or not being observed.);
- report to an RCT if radiological controls are not adequate or are not being followed;
- be aware of changing radiological conditions;
- make sure that your activities do not create radiological problems for others;
- be alert that others' activities may change the radiological conditions in the area; and
- report to an RCT any unusual conditions such as leaks, spills, or radiological control instrumentation alarms.

Radiological Postings—continued

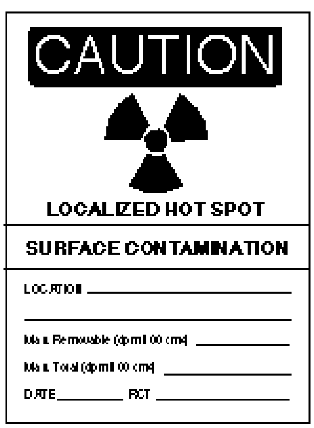
Hot Spot

There are two types of hot spots. One type is categorized as external radiation and the other as surface contamination. A hot spot is a localized source of radiation or radioactive contamination that is sometimes found in equipment or piping. The radiation level at a hot spot (external radiation) is at least five times the level in the surrounding area and greater than 100 mrem/hour. You should avoid these spots.

Hot Spot Posting: External Radiation



Hot Spot Posting: Surface Contamination



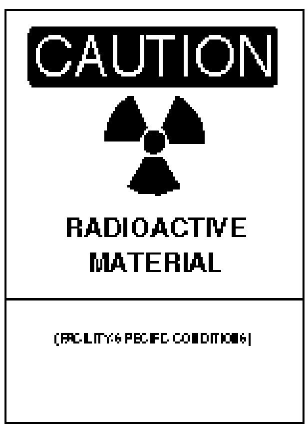
Radiological Postings—continued

Radioactive Material

A Radioactive Material posting indicates a location where radioactive material is used, handled, or stored. This posting is not required when radioactive materials are inside Contamination or Airborne Radioactivity Areas but may be used to provide more information.

For posting purposes, radioactive material includes equipment, components, and materials that have been exposed to contamination or have been made radioactive by activation. Radioactive material also includes sealed or unsealed radioactive sources. A radioactive sealed source is radioactive material encapsulated or bonded to prevent loss and dispersal of the material during continued or repetitive use as a source of test radiation. Examples include radioactive material that is contained in a sealed capsule (sealed between two layers of nonradioactive material) or firmly fixed to a nonradioactive surface. See p. 58; definition should be there first?

Radioactive Material Posting



Note: *Postings that designate equipment or components with actual or potential contamination will contain wording such as "CAUTION: Internal Contamination" or "CAUTION: Potential Internal Contamination."*

Entry/Exit Requirements for Radioactive Material

The Laboratory has no requirements, unless specified by other radiological postings.

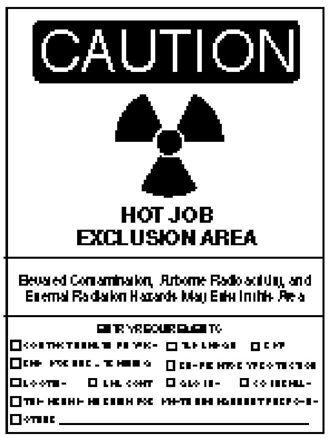
Radiological Postings—continued

Hot Job Exclusion Area

A Hot Job Exclusion Area posting is a temporary sign used only while a job is in progress. It cannot be used for more than eight hours. If the job is not complete after eight hours, the posting must be replaced by another posting such as Contamination Area or Radiation Area.

The RWP is posted at the job site. In an emergency, contact the RCT assigned to the job.

Hot Job Exclusion Area Posting



Entry/Exit Requirements for Hot Job Exclusion Area

Entry is restricted to workers and RCTs who have signed the RWP acknowledgment log. Entry and exit requirements are specific to the job and are listed on the posting and the RWP.

Criteria for Radiological Postings and Entry/Exit Requirements

Posting	Defining Conditions	Minimum Entry Requirements	Exit Requirements	Working Requirements
Contamination Area	Levels (dpm/100 cm^2) that are greater than (or likely to exceed) Table 14-2 values but do not exceed 100 x Table 14-2 values (ISD 121-1.0)	Radiological Worker II, TLD, anti-Cs, and authorization by way of work control documents as required and appropriate internal dosimetry programs	Exit only at step-off pad(s) Remove anti-Cs carefully Monitor personnel via a whole body frisk Monitor personal items and equipment	Follow all of the requirements for working in radiological areas Avoid unnecessary contact with contaminated surfaces Avoid stirring up contamination Secure hoses and cables Wrap or sleeve materials, equipment, and hoses
High Contamination Area	Levels (dpm/100 cm^2) that are greater than (or likely to exceed) 100 x Table 14-2 values (ISD 121-1.0)	Radiological Worker II, TLD, anti-Cs, RWP, and authorization by way of work control documents as required and appropriate internal dosimetry programs Read and sign that you understand the job, radiological conditions, and protection requirements as written in the RWP and will abide by them		
Airborne Radioactivity Area	Concentrations ($\mu Ci/cm^3$) above backgrounds that are greater than the derived air concentration (DAC) values or that would result in an individual's being exposed to greater than 12 DAC-hours in a week	Radiological Worker II, TLD, anti-Cs, RWP, respirator, and authorization by way of work control documents as required and appropriate internal dosimetry programs		
Soil Contamination Area	Contaminated soil not releasable in accordance with DOE Order 5400.5	Radiological Worker II, facility/ job-specific requirements	Facility/job-specific requirements may apply	
Fixed Contamination	No removable contamination and total contamination levels that are greater than Table 14-2 values (ISD 121-1.0)	N/A	N/A	Bag contaminated tools Avoid touchig exposed skin. Exit area immediately if wound occurs or if anti-Cs tear

Radiological Postings—continued

Contamination Area

A Contamination Area is an area in which the removable contamination level is greater than one time but less than 100 times the limits specified in Table 14-2 of ISD 121-1.0.

Contamination Area Posting

Entry Requirements for a Contamination Area

Entry requirements include

- Radiological Worker Training;
- facility-specific training;
- a TLD;
- your signature on the RWP;
- protective clothing, as required by the RWP, posting, or RCT;
- appropriate internal dosimetry programs; and
- written authorization to enter and perform the work.

Exit Requirements for a Contamination Area

When exiting a Contamination Area, you must follow the exit requirements listed on page 110 of this manual.

Radiological Postings—continued

High Contamination Area

A High Contamination Area is an area in which the removable contamination level is greater than 100 times the limits specified in Table 14-2 of ISD 121-1.0.

High Contamination Area Posting

Entry Requirements for a High Contamination Area

Entry requirements include

- Radiological Worker Training;
- facility-specific training;
- a TLD;
- your signature on the RWP;
- protective clothing, as required by the RWP, posting, or RCT;
- a prejob briefing;
- appropriate internal dosimetry programs; and
- written authorization to enter and perform the work.

Exit Requirements for a High Contamination Area

When exiting High Contamination Areas, you must follow the exit requirements listed on page 110 of this manual.

Radiological Postings—continued

Airborne Radioactivity Area

An Airborne Radioactivity Area is an area in which the airborne radioactivity concentration is greater than any derived air concentration (DAC) values or that would result in a worker's being exposed to greater than 12 DAC-hours. These values vary by nuclide identity.

Airborne Radioactivity Area Posting

Entry Requirements for an Airborne Radioactivity Area

Entry requirements include

- Radiological Worker Training;
- a TLD;
- your signature on the RWP;
- protective clothing and respiratory equipment, as required by the RWP, posting, or an RCT;
- a prejob briefing;
- appropriate internal dosimetry; and
- written authorization to enter and perform the work.

Exit Requirements for an Airborne Radioactivity Area

When exiting Airborne Radioactivity Areas, you must follow the exit requirements listed on page 110 of this manual.

Radiological Postings—continued

Soil Contamination Area

A Soil Contamination Area is as area in which the surface or subsurface contamination level exceeds the limits specified in DOE Order 5400.5.

Soil Contamination Area Posting

***Note**: Postings may also contain warnings such as “Consult with Radiological Control before Digging” or “Subsurface Contamination Exists.”*

Entry Requirements for a Soil Contamination Area

Entry requirements include

- Radiological Worker Training, and
- facility- or job-specific requirements.

Exit Requirements for a Soil Contamination Area

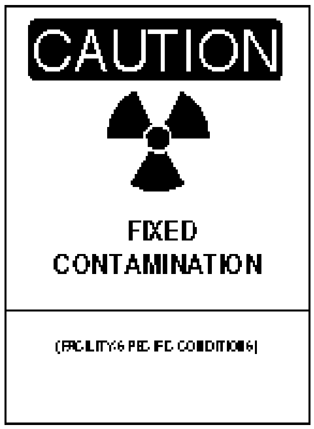
Exit requirements for Soil Contamination Area are facility- and job-specific.

Radiological Postings—continued

Fixed Contamination

A Fixed Contamination posting indicates a location or equipment with no removable contamination and with a fixed contamination level that exceeds the limits specified in Table 14-2 of ISD 121-1.0.

Fixed Contamination Posting



Entry/Exit Requirements for Fixed Contamination

LANL has no requirements, unless specified by other radiological postings.

Requirements for Working in Contamination and Airborne Radioactivity Areas

While working in Contamination and Airborne Radioactivity Areas, you must follow the requirements for working in radiological areas (listed on page 110 of this manual) and also

- avoid unnecessary contact with contaminated surfaces;
- avoid stirring up contamination because it could become airborne;
- secure hoses and cables to prevent them from crossing in and out of a Contamination Area;
- when possible, wrap or sleeve materials, equipment, and hoses;
- place contaminated tools and equipment inside plastic bags when work is finished;
- avoid touching exposed skin surfaces; and
- exit immediately if a wound occurs or protective clothing tears.

Radiological Postings—continued

Fixed Contamination locations have no exit requirements. Soil Contamination Areas have facility-specific requirements. When exiting from other Contamination and Airborne Radioactivity Areas, you must

- exit only at a designated exit point with a step-off pad, which provides a barrier between contaminated and other areas to prevent or control the spread of contamination between areas. (If more than one step-off-pad is used, the final step-off pad is clean, located outside the exit point, and adjacent to the boundary.);
- remove protective clothing carefully, following doffing procedures;
- perform a whole body frisk (If contamination is indicated, stay in the area, notify an RCT, and take actions to minimize cross-contamination.);
- monitor personal items and equipment, following indicated monitoring requirements; and
- after exiting and monitoring, wash hands as a precautionary measure before eating, drinking, chewing, or applying cosmetics.

Your Responsibilities

Your Responsibilities Regarding Postings, Signs, and Labels

You are responsible for reading and complying with all the information on radiological postings, signs, and labels. Radiological conditions may change, and more than one radiological hazard may be identified on a posting, sign, or label. Therefore, it is important to **read daily** all of the information on postings, signs, and labels.

Disregarding any postings, signs, or labels or removing or relocating them without permission can lead to

- unnecessary or excessive radiation exposure,
- personnel contamination, and
- release of contamination or radioactive materials to the environment or the general public.

Your Responsibilities—continued

Deliberately disregarding, relocating, or removing radiological postings, signs, and labels are considered extremely serious misconduct and could result in disciplinary action, up to and including immediate termination.

***Note**: Any type of radiological hazard identification sign found outside an area that is controlled for radiological purposes should be reported immediately to radiological control personnel.*

Your Responsibilities Regarding Escorting

If you perform escort duties for your organization, you must ensure that you have received the required training for unescorted entry into a work area. When you escort someone, you must ensure that the person being escorted complies with the requirements of the LANL Radiation Protection Program and has received training in

- the risks of exposure to radiation and radioactive material,
- the risks of pregnant worker radiation exposure, and
- the methods for requesting their individual exposure records.

Radiological Work Permits

Purpose of Radiological Permits

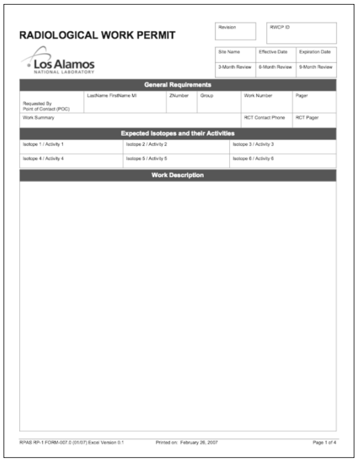
RWPs are used to establish radiological controls for entry into radiological areas. They inform you of area radiological conditions and entry requirements and inform supervisors of radiation doses received from specific work activities.

Types of Radiological Work Permits

Two types of RWPs are used, depending on the radiological conditions:

- A general RWP is used to control routine or repetitive activities, such as tours and inspections, in areas with historically stable radiological conditions. It is valid only for up to one calendar year (with 3-month reviews).
- A job-specific RWP is used to control nonroutine operations or work in areas with changing radiological conditions. It is valid only for the duration of a particular job (subject to 3-month reviews, should the job last that long).

Radiological Work Permits—continued


RADIOLOGICAL WORK PERMIT

Los Alamos NATIONAL LABORATORY

Revision | RWCP ID

Site Name	Effective Date	Expiration Date
3-Month Review	6-Month Review	9-Month Review

General Requirements

Requested By Point of Contact (POC)	LastName FirstName MI	ZNumber	Group	Work Number	Pager
Work Summary				RCT Contact Phone	RCT Pager

Expected Isotopes and their Activities

Isotope 1 / Activity 1	Isotope 2 / Activity 2	Isotope 3 / Activity 3
Isotope 4 / Activity 4	Isotope 5 / Activity 5	Isotope 6 / Activity 6

Work Description

RPAS RP-1 FORM-007.0 (01/07) Excel Version 0.1 Printed on: February 26, 2007 Page 1 of 4

Radiological Work Permits include the following sections:

- **General Requirements:** provides contact information and a summary of work to be performed.
- **Expected Isotopes and Their Activities:** identifies the radioisotopes involved in the work and the amounts.
- **Work Description:** gives a scope of the work to be performed and identifies other potential hazards that may be present (chemical, trips and falls, electrical, etc.)
- **Radiological Control Requirements:** lists the required safety essentials per task, which include
  - expected radiological conditions;
  - maximum radiological conditions allowed before stopping job;
  - protective clothing and equipment;
  - dosimetry;
  - ALARA requirements (containments, ventilation, remote handling tools, etc.); and
  - Task-specific hold points and special instructions.
- **Existing Prejob Conditions:** lists potential radiological issues, such as penetrating a surface with fixed contamination.
- **Job-Specific Hold Points and Special Instructions:** lists hold points and instructions that apply to overall work activity.
- **Monitoring Instructions:** provides requirements for workers.
- **Instrumentation Requirements:** identifies any special instrumentation needs.
- **Bioassay Requirements:** identifies any required special bioassay needs.
- **Completed by RP-1 SME:** identifies who prepared the RWP.
- **Approvals:** requires appropriate signatures from RP-1 and line management.

Radiological Work Permits—continued

Your Responsibilities Regarding Radiological Work Permits

You are responsible for ensuring that you have been authorized by your management to perform the activities covered by the RWP.

You are responsible for signing the RWP acknowledgment log to indicate that you have read, understand, and will comply with requirements of the permit before entering the radiological area.

If you do not think that the RWP is correct or do not understand any part of the information, you should not start the job and should contact an RCT or your supervisor.

Any changes to the RWP must be made by an RP-1 SME and approved by a line manager before you start the job. You must obey any instructions written on the permit and must never make substitutions for specified requirements.

Student Self-Assessment

Answer the following questions to test your mastery of this unit. Strive for a score of 80% or better. (EO#) indicates the enabling objective corresponding to the question.

1. A general or job-specific RWP (EO1)
   a. keeps track of your yearly exposure
   b. lists step-by-step procedures for the job
   c. informs you of area radiological conditions
   d. all of the above

2. If you are working under an RWP, you are responsible for _______, _______, and _______ with the requirements of the RWP. (EO2)

3. The typical colors used to identify radiological hazards are (EO3)
   a. magenta on yellow
   b. white on yellow
   c. black on yellow (with trefoil)
   d. both a and c above

4. Match the posting to the correct definition. (EO4)

____ Radiation Area

____ Contamination Area

____ Airborne Radioactivity Area

____ Radioactive Material Area

____ High Radiation Area

a. any accessible area where the concentration of airborne radioactivity exceeds the derived air concentration (DAC), or where an individual without respiratory protection could receive an intake exceeding 12 DAC hours in a week
b. an area where radioactive material is used, handled, or stored
c. an area where the radiation level is between 5 mrem/hr at 30 cm from any source up to 100 mrem/hr
d. an area where the surface contamination level is between 1 and 100 times
e. an area where the radiation level is between 100 mrem/hour at 30 cm and 500 rad/hour

Student Self-Assessment—continued

5. Match the radiological area to the correct minimum training requirements. (EO5)

____ Radiation Area	
____ Contamination Area	a. General Employee Radiological Training
____ Controlled Area	b. Radiological Worker I
____ Airborne Radioactivity Area	c. Radiological Worker II
____ High Radiation Area	

6. The use of time, distance, and shielding is most appropriate in a/an (EO5)
   a. Contamination Area
   b. Radiation Area
   c. Airborne Radioactive Area
   d. Fixed Contamination Area

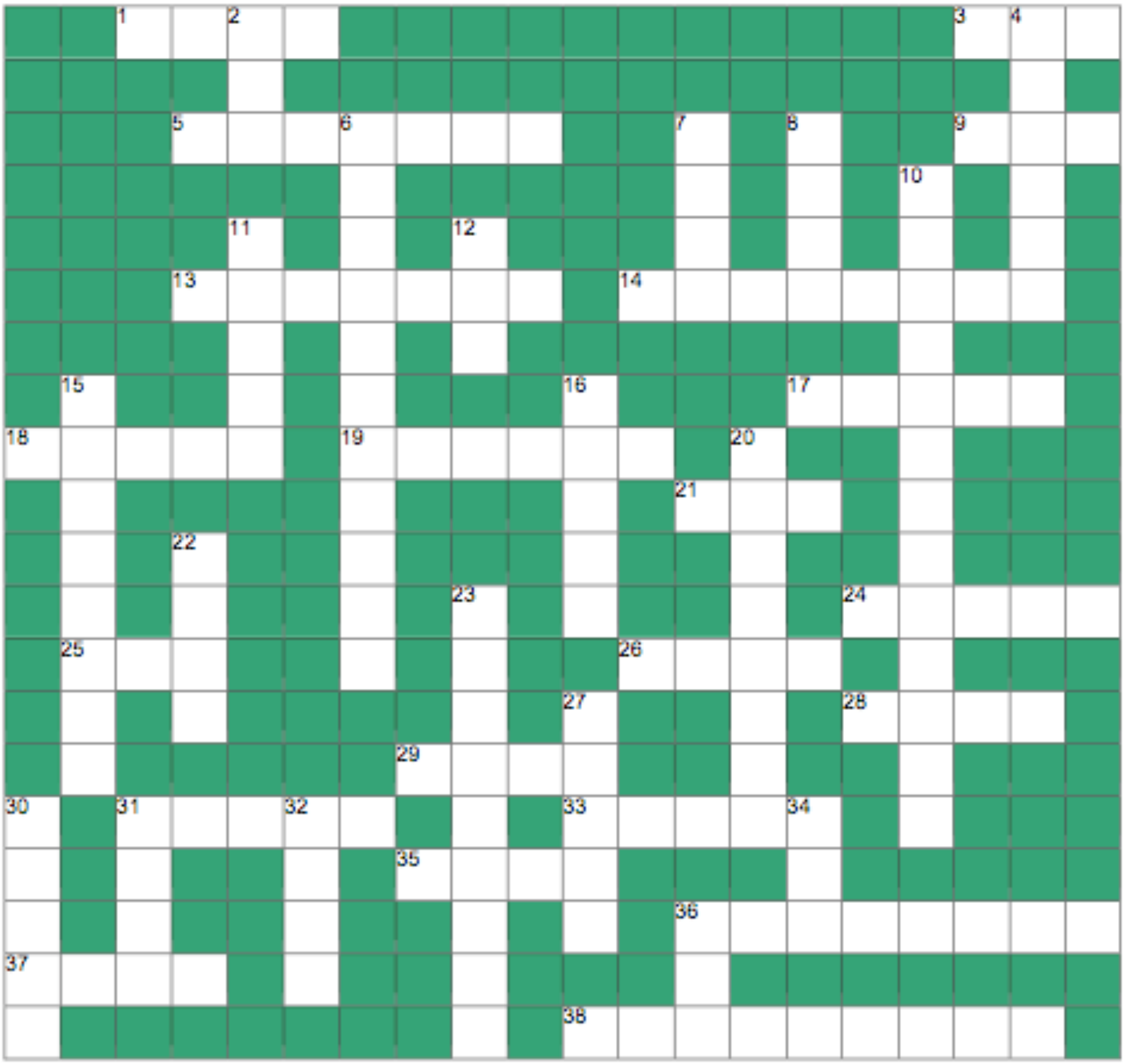
7. Anti-C coveralls are required in a (EO5)
   a. Radiation Area
   b. High Radiation Area
   c. Contamination Area
   d. Fixed Contamination Area

8. Disregarding or removing radiological signs without permission could result in (EO6 and EO7)
   a. personnel contamination
   b. unnecessary radiation exposure
   c. release of contamination to the environment
   d. disciplinary action
   e. all of the above

Crossword Review Units 5–7

Across	Down
1. SWIMS: stop, _____, isolate, minimize, secure	2. Radiological work permit
3. Unit for reporting contamination	4. ____ monitors detect personnel contamination.
5. Supplemental dosimeters serve ________ purposes.	6. Nuclear accident dosimeters are used for ________ accidents.
9. Area radiation monitor	7. Do not touch unprotected _______ while wearing protective clothing.
13. TLD exchange interval	8. _______ warm water is used for skin decontamination.
14. Respirators are worn to prevent ________ exposure.	10. Protective clothing is worn to prevent skin ________.
17. _______ from radioactive systems are a source of contamination	11. Pathway through which radioactive material enters the body
18. Contamination that is not easily removed	12. Official dose recorder
19. ____ limit is 5 rem	15. CAMS measure ______ contamination.
21. High Radiation Area: greater than 0.1 ___/hr	16. TLD location: above the ______
24. A pencil dosimeter measures ____ radiation.	20. Track etch dosimeters detect ________.
25. Radiological control technician	22. ______-C clothing
26. ________ High Radiation Area: greater than 500 rad/hr	23. Term used for all types of TLDS, pocket chambers, etc.
28. A room with 220 mr/hr should be posted as a ________ radiation area.	27. ***In vitro*** sample (type)
29. No limiting radiation value to save a ________	30. An area is _________ after it has been decontaminated.
31. Whole body survey (slang)	31. _________rem/yr: DOE annual limit for whole body exposure
33. TLD location: on _______	32. ______ time
35. Shielded by a half-inch of plastic	34. Move the alpha probe at 1 to _____ inches per second
36. Protective ______ consists of coveralls, gloves, booties, etc.	36. Continuous air monitor
37. Radiation ______: between 5 and 100 mrem/hr	
38. Opposite of fixed	

Crossword Review Units 5–7—continued



Answers

1. c
2. reading, understanding, complying
3. d
4. c, d, a, b, e
5. b, c, a, c, c
6. b
7. c
8. e

Appendix A

Personal, Offsite Contamination Discovered

FOR DETAILS: Occurrence Report: ALO-LA-LANL-SIGMA-2005-0007

The Department of Energy's National Nuclear Safety Administration (NNSA) Los Alamos Site Office has appointed a Type B Investigation Board to investigate a radiological contamination event that was discovered on July 25, 2005.

A Laboratory technical staff member (TSM) received contamination to his skin, and contamination was spread to sites in three other states. The TSM was evaluated and has been placed on special bioassay sampling to determine any internal exposure to the material, americium-241. Additional workers who may have been exposed to americium-241 contamination were also placed on special bioassay programs.

A radiological control technician supervisor first discovered the contamination at Technical Area 3, Building SM-66 (Sigma Complex) after she found a radiological material tag inside a trashcan located in an uncontrolled area. Upon discovering the radiological material tag, the RCT supervisor discussed the tag with the TSM, who is a member of the Materials Technology Metallurgy Group (MST-6) in charge of the operation. The RCT supervisor learned that the TSM had received and unpacked a shipment of radioactive material from TA-55 on July 14, 2005. The RCT supervisor surveyed the local area and found unexpected surface contamination in several areas near the glovebox. The RCT also detected contamination on the TSM's skin and personal items. Subsequent surveys discovered contamination in his office, personal vehicle, and home.

MST Division took immediate actions upon discovery of this contamination, including convening a critique to understand the scope of the issue, evacuating the facility, and monitoring all 160 or so residents for contamination (none detected), and commissioning a comprehensive survey of the facility. Based on survey results and continuing discussion with facility staff, additional workers and areas of the facility were considered potentially affected by this contamination. These workers were placed on special bioassay programs, and the offices and associated spaces were surveyed. Additional controls were temporarily placed at the exit of the facility, and additional surveys of high-traffic areas were initiated to ensure any contamination would be detected and mitigated. Areas found contaminated or considered "suspect contaminated" were cordoned off and are being decontaminated as necessary and released systematically.

Personal, Offsite Contamination Discovered—continued

Based on information from the TSM and evaluation of coworkers' spaces, the Radiological Assistance Program (RAP) deployed a series of teams to offsite locations, including the TSM's home and the homes of several coworkers. Contamination was discovered on a number of items in the TSM's home and one low-level spot in one coworker's home. Based on information from the TSM, a RAP team was deployed to his wife's home in Colorado, his mother's home in Kansas, and a hotel room in Kansas; low-level contamination was found and mitigated in each of these locations.

Additionally, the TSM had prepared two weld test samples for offsite shipment in one package to Bechtel Bettis in Pennsylvania. Bettis evaluated the samples and confirmed the shipment had unexpected, low-level contamination. Further investigation revealed that an Actinide and Fuel Cycle Technologies Group (NMT-11) worker had picked up the package from the TSM on July 20, 2005, transported the package in his privately owned vehicle, and delivered it to the SM-30 warehouse for shipment as a non-hazardous, domestic unclassified shipment. Surveys of the NMT-11 worker's vehicle and office only found contamination on a towel where this package had been placed in his vehicle. Surveys of the SM-30 warehouse area and personnel did not detect any contamination.

TYPE B INVESTIGATIVE PROCESS

The NNSA Los Alamos Area Site Office subsequently concluded that a Type B accident investigation was necessary because of public concern and widespread media attention. A Type B Accident Investigation Board was appointed and began an investigation August 16, 2005.

Appendix B

Web Links

Rule 10 CFR 835 and Amendments

http://www.eh.doe.gov/radiation/rule.html

DOE-HDBK-1130-98 (October 1998, May 2004)

Change Notice No. 1 (February 2005)

http://www.eh.doe.gov/techstds/standard/hdbk1130/hdbk-1130-98_ch1.pdf

LANL ISD 121-1.0 Radiation Protection

http://policy.lanl.gov/pods/policies.nsf/MainFrameset?ReadForm&DocNum=ISD121-1&FileName=ISD1211.pdf

Unit 2

Harry K. Daghlian, Jr.

http://members.tripod.com/~Arnold_Dion/Daghlian/index.html

The Radium Dial Girls

http://www.runet.edu/~wkovarik/hist/radium.html

Background Radiation Calculator

http://newnet.lanl.gov/main.htm

Unit 3

Dosimetry at LANL

http://int.lanl.gov/safety/radiation/dosimetry_eval.shtml

Unit 4

ALARA Center

http://int.lanl.gov/safety/radiation/alara_center.shtml

RP-1 (Health Physics Operations) “So You . . . “ Educational Pamphlets

http://int.lanl.gov/safety/radiation/

Web Links—continued

Specific Radiological Hazards

http://eshtraining.lanl.gov/pls/gencouraxs/cour_by_topic?Cat=Radiation&course_topic=Specific+Hazards

Other

Museum of Atomic Permutation

http://www.nukes.org/Map/museum.html

Technologically Enhanced Naturally Occurring Radioactive Material (TENORM)

http://tenorm.com/

Radiation and Health Physics page

http://www.umich.edu/~radinfo/

The Radiation Information Network

http://www.physics.isu.edu/radinf/index.html

Health Physics Historical Instrumentation Museum Directory

http://www.orau.org/ptp/museumdirectory.htm

The Health Physics Society

http://www.hps.org/

How Stuff Works

http://www.howstuffworks.com/index.htm

Note: *References to Web sites outside of LANL are provided for information use only and do not imply any endorsement by LANL or Los Alamos National Security, LLC.*

Key Acronyms

ALARA	as low as reasonable achievable
ARM	area radiation monitor
CAM	continuous air monitor
cpm	counts per minute
DAC	derived air concentration
DOE	Department of Energy
dpm	disintegrations per minute
DU	depleted uranium
EM&R	Emergency Management and Response
EPD	electronic personal dosimeter
ES&H	Environment, Safety & Health
HEPA	high-efficiency particulate air (filter)
LANL	Los Alamos National Laboratory
LLE	lost life expectancy
PCM	personnel contamination monitor
PPE	personal protective equipment
RAM	radioactive material
RCA	Radiological Controlled Area
RCT	radiological control technician
RP	radiation protection
RPP	Radiation Protection Program
RPPM	Radiation Protection Program Manager
RSS	radioactive sealed source
RWP	radiological work permit
SCBA	self-contained breathing apparatus
SNM	special nuclear material
TA	technical area
TLD	thermoluminescent dosimeter

Notes . . .

Glossary

absorbed dose. Expressed in rad, it is the amount of energy deposited by any type of radiation in any material (one rad equals 100 ergs deposited per gram of material).

acceptable knowledge. A method used in lieu of or in conjunction with sampling and analysis to characterize materials and items through knowledge of (1) origin, (2) processes involved, (3) storage, (4) use of materials, (5) segregation. The method may include supplemental waste analysis data, and facility records or analysis as applied to waste characterization.

action level. Radiation dose limit established by the Laboratory to keep radiation dose below regulatory limit.

activation. The process in which nonradioactive atoms are changed into radioactive atoms by bombardment with neutrons, protons, or other nuclear particles.

acute exposure (dose). The exposure to a relatively large amount of radiation (or intake of radioactive material) over a short period of time such as an hour or a day.

airborne contamination, airborne radioactive material, or airborne radioactivity. Radioactive material dispersed in the air in the form of dusts, fumes, particulates, mists, vapors, or gases.

airborne radioactivity area. Any accessible area where (1) the concentration of airborne radioactivity (above the natural background) exceeds or is likely to exceed the derived air concentration (DAC) values listed in Appendix A or Appendix C of 10 CFR 835, November 4, 1998; or (2) an individual without respiratory protection could receive an intake exceeding 12 DAC hours in a week.

alpha particle. A positively charged particle emitted from the nucleus of an unstable atom, with a range of about 1–2 inches in the air. An alpha particle can be stopped by a sheet of paper or the layer of dead skin. Considered an internal hazard.

annual limit on intake (ALI). Derived limit for the amount of radioactive material taken into the body of an adult worker by inhalation or ingestion in a year. ALI is the smaller value of intake of a given radioisotope in a year that would result in a committed effective dose equivalent of 5 rem or a committed dose equivalent of 50 rem to any individual organ or tissue.

Area Radiation Monitor (ARM). An instrument that measures the external radiation exposure level and alarms when the level exceeds the set point.

area. For purposes of radiological control, a space is considered an area (and would be posted as an *area*) if it is accessible to an individual and that individual could receive a whole body exposure (extremities are not considered whole body). However, containment devices such as glove boxes, hoods, or open-front boxes would not be posted as *areas* for radiological purposes unless an individual were to enter them.

as low as reasonably achievable (ALARA). A radiological control concept to manage and keep exposures to the work force and the general public as low as is reasonable, taking into account social, technical, economic, practical, and public factors.

atom. The smallest part of an element that still retains the chemical properties of that element. The atom is made up of three subatomic particles: protons, neutrons, and electrons.

barrier. An obstruction that prevents access to an area where high dose rates may exist.

beta particle. A negatively or positively charged particle emitted from the nucleus of an unstable atom. Physically identical to an electron, its range is about 10 feet.

bioassay. Determining the kinds, quantities, or concentrations and (in some cases) locations of radioactive material in the human body, whether by direct measurement or by analysis and evaluation of radioactive materials excreted or removed from the body.

calibration. Adjusting and/or determining either one of the following: (1) responding to or reading of an instrument relative to a standard or to a series of conventionally true values; or (2) the strength of a radiation source relative to a standard or conventionally true value.

cell. The smallest structural unit of an organism that is capable of independent functioning.

certification. Formally documented, auditable, quality assurance process by which LANL management is assured that employees have the requisite skills, knowledge, and abilities to perform their assigned duties.

check source. A radioactive source, not necessarily calibrated, that is used to confirm the continuous satisfactory operation of an instrument.

chelating. Removing a heavy metal such as lead or mercury from the bloodstream through a medical process.

chronic exposure (dose). Typically a small dose of radiation received over a long period (months or years) and better tolerated by the body than an acute dose.

compactible waste. Solid waste that consists of trash-type material such as paper, plastic, rubber, small items of glassware (up to 1 gallon) or pipe conduit (up to 12 inches) and small chips of wood or sheet metal.

containment device. A barrier such as a glove bag, glove box, or tent that is used for stopping or slowing the release of radioactive material from a specific location.

Contamination Area. An area in which the contamination level is greater than one time but less than 100 times the limits specified in Table 14-2 of ISD 121-1.0.

contamination survey. Use of smears, swipes, or direct instrument surveys to identify and quantify radioactive material on personnel, on equipment, or in areas.

contamination. *See* radioactive contamination.

continuous air monitor (CAM). An instrument that continuously measures the level of airborne radioactivity and alarms when the level exceeds the set point.

controlled area (same as radiological controlled area). Any area to which access is managed by or for DOE to protect individuals from exposure to radiation and/or radioactive materials.

counts per minute (cpm). The number of disintegrations measured by a radioactive source as detected by an instrument.

critical mass. The smallest of fissionable material that will support a self-sustaining chain reaction under specified conditions.

criticality. A sustained nuclear fission chain reaction.

curie (Ci). The unit of measurement for radioactivity (2.22×10^{12} dpm).

declared pregnant worker. A female worker who has voluntarily notified OM, her supervisor, and/or RP-3, in writing, that she is pregnant.

decontamination. The process of removing radioactive material from personnel, equipment, and areas.

depleted uranium (DU). Uranium that is almost exclusively U-238 because the naturally occurring isotope U-235 has been extracted.

derived air concentration (DAC). The concentration of a single radioisotope in air, such that a person who were to breathe that air for one year (2000 hrs) would received an internal dose of 5 rem., or 50 rem to any one organ.

detector. A device that indicates an electronically measurable quantity of ionizing radiation.

direct survey. Quantitative survey for detecting the presence of both removable and fixed contamination (total contamination) on a surface. ***Note:*** *This test is usually performed by either holding or slowly moving a portable survey instrument detector over a surface and counting the radioactive emissions from the total contamination residing on the surface*.

disintegrations per minute (dpm). The number of atoms that decay (disintegrate) per minute in a radioactive source.

DOE activity. An activity taken for or by DOE in a DOE operation or facility that has the potential to result in the occupational exposure of an individual to radiation or radioactive material.

doffing. The process of taking off protective clothing.

donning. The process of putting on protective clothing.

dose equivalent. Expressed in rem, the product of the absorbed dose and a quality factor based on the type of radiation.

dose rate. The amount of radiation (dose) received per unit of time.

dose. The amount of energy deposited in the body from radiation exposure.

dosimeter. A device used to assess radiation dose.

electron. A negatively charged particle that orbits the nucleus of the atom and determines the chemical properties of an atom.

embryo. The developing human from the time of conception through the eighth week of pregnancy.

engineered controls. Components and systems used to reduce dose and airborne radioactivity and the spread of contamination by using piping, contamination devices, ventilation, filtration, or shielding.

entrance or access point. Any location through which an individual could gain access to areas controlled for the purposes of radiation protection.

exposure. Expressed in roentgens, it measures of the amount of ionizations caused by gamma rays and x-rays in air.

external radiation. Radiation emitted from a source outside the body.

extremities. Below the elbow (hands and arms), below the knee (legs and feet).

fetus. The developing human from the ninth week after conception through birth.

fissile waste. Waste that contains nuclides that can undergo nuclear fission. For waste generated by Laboratory operations, fissile materials are plutonium, americium, uranium-233, and uranium-235.

Fixed Contamination (posting). An area or equipment with no removable contamination but with a fixed contamination level that exceeds the limits specified in the RPP, Table 14-2 of ISD 121-1.0.

fixed contamination. Contamination that cannot easily be removed from surfaces by casual contact such as wiping, brushing, or washing.

frisk/frisking. The process of monitoring personnel for radioactive contamination.

gamma ray. A highly penetrating, chargeless electromagnetic wave or photon emitted from the nucleus of an unstable atom. It has a long range in air; can be shielded by dense materials such as lead, concrete, or steel; and is considered an external hazard.

half-life. See radioactive half-life.

hazard control plan (HCP). A document that, at a minimum, defines the work, identifies the hazards associated with the work, identifies the hazards of the work, and describes controls needed to reduce risk to an acceptable level.

heritable effect. An effect caused by chromosome damage that is passed on to the children of the individual exposed to radiation.

High Contamination Area. An area where removable surface contamination levels exceed or are likely to exceed 100 times the removable surface contamination values specified in Table 14-2 of ISD 121-1.0.

High Radiation Area. Any accessible area where radiation levels could result in an individual's receiving a deep dose equivalent in excess of 0.1 rem (100 mrem) in an hour at 30 centimeters from the radiation source or from any surface that the radiation penetrates.

high-efficiency particulate air (HEPA) filter. A pleated medium-dry-type filter with (1) a rigid casing enclosing the full depth of the pleats, (2) a minimum particle removal efficiency of 99.9 % for a standard challenge particulate, and (3) a maximum pressure drop 1.0-inch water gauge (w.g.) when clean and operated in its rated airflow capacity.

high-level waste. Highly radioactive waste material that results from the reprocessing of spent nuclear fuel, including liquid waste produced directly during reprocessing and any solid waste derived from that liquid, and that contains a combination of transuranic waste and fission products in concentrations requiring permanent isolation. (No high-level waste is generated at the Laboratory at this time.)

hot job exclusion area. Temporary area established around an unknown condition in the event of a radiological incident or an operation that is expected to increase the potential for contamination and/or personnel exposure because of the nature of the hot job.

hot particle. A small, loose, highly radioactive particle with an activity greater than 15,000 disintegrations per minute (dpm) and/or the capability of producing a shallow dose equivalent greater than 100 mrem in one hour.

hot spot. A localized source of radiation or radioactive contamination sometimes found in equipment or piping. The radiation level at a hot spot is at least five times the level in the surrounding area and greater than 100 mrem/per hour.

infrequent or first-time activities. Radiological work activities or operations that require special management attention and consideration of new or novel radiological controls. The designation of infrequent or first-time activities applies specifically to facilities that conduct routine and recurring process operations and does not apply to facilities that routinely conduct first-time activities such as experimental or research facilities.

instrument. A complete system designed to quantify one or more particular types of ionizing radiation.

interlock. A device for preventing access to a radiation hazard area, either by preventing entry or by automatically removing the hazard when the device is actuated.

internal radiation. Radiation emitted from a source that has been taken into the body.

ion. An atom or a group of atoms that has a positive or negative electrical charge.

ionization. The process of removing an electron from an atom.

ionizing radiation. Radiation that has enough energy to cause ionization of an atom with which it interacts. It is energy emitted from radioactive atoms.

ion pair. A positively charged atom and a negatively charged electron removed from an atom.

isotope. One of two or more atoms of the same element that has the same number of protons but a different number of neutrons.

large-area swipe area. Qualitative survey for detecting the presence of removable contamination by wiping Masslin (or an equivalent material such as cheesecloth) over at least 1000 cm of the surface and counting the residual activity on the Masslin with an appropriate portable radiation survey instrument.

lead RCT. The RCT who is assigned the primary responsibility for radiological control at a facility.

level I clothing. One pair of coveralls, two pair of anti-C gloves (inner pair taped), one pair of booties, and a hood.

level II clothing. Two pair of coveralls, two pair of anti-C gloves, (inner pair taped), two pair of booties, and a hood.

lifetime dose. Total occupational exposure over a worker’s lifetime, including external and committed internal dose.

likely. Having a greater than 50% probability of occurrence within a period of time, typically a year.

low-level radioactive solid waste. Waste material that has been contaminated or activated in excess of established limits and has not been classified as high-level waste, transuranic waste, spent fuel, or mixed waste.

manmade background radiation. Radiation that has been generated or produced by humans. Examples include medical x-rays or treatments, consumer products, atmospheric testing of nuclear weapons, and industrial radiography.

millirad (mrad). The absorbed dose term that equals $^{1}/_{1000}$ rad.

millirem (mrem). The dose equivalent term that equals $^{1}/_{1000}$ rem.

milliroentgen (mR). The exposure in air that equals $^{1}/_{1000}$ roentgen.

minor. An individual who is under 18 years of age.

mixed waste. Waste containing both radioactive and hazardous components as defined by the Atomic Energy Act and Resource Conservation and Recovery Act.

monitoring. Measuring radiation levels, airborne radioactivity concentrations, radioactive contamination levels, quantities of radioactive material, and individual doses and using the results of these measurements to evaluate radiological hazards or potential and actual doses resulting from exposures to ionizing radiation.

natural background radiation. Radiation that comes from naturally occurring radioactive materials in the rocks and soil of the earth, from food and water, from radon, and from cosmic rays from the sun and other sources in space.

neutron. A particle with no electrical charge that is located in the nucleus of the atom. The number of neutrons determines the isotope of an element.

neutron particle (as a form of radiation). A highly penetrating particle with no electrical charge that is emitted from the nucleus of an unstable atom. A neutron has a long range in air, can be shielded by materials that are rich in hydrogen (such as water or plastic), and is considered an external hazard.

noncompactible waste. Large or bulky waste exceeding maximum dimensions of compactible packages or other obviously noncompactible common waste such as heavy pipe, angle iron, equipment, lumber, building rubble, and soil. Tritium waste in concentrations greater than 20 mCi/m^3 is also considered noncompactible waste.

nonionizing radiation. Radiation that does not have enough energy to cause ionization to an atom with which it interacts.

nucleus. The central portion of the atom, which contains protons and neutrons.

nuclide. A general term referring to all atomic forms of all the elements.

occupational radiation dose. The radiation dose received by a worker whose assigned duties involve exposure to radiation and/or radioactive material. Occupational dose does not include dose received from natural or man-made background radiation.**operational check.** A test of an instrument to determine if that instrument is operating acceptably.

operation-specific training. Training required for a worker to perform a particular aspect of a job or unique operation.

performance check (or performance test). A test of an instrument to determine if (1) its response is within a stated acceptable range, (2) any alarms associated with the instrument work correctly, and(3) the instrument is otherwise operating acceptably.

personal protective equipment (PPE). Equipment such as booties, anti-C overalls, gloves, respirators, face shields, and safety glasses used to protect workers from excessive exposure to radioactive or hazardous materials.

personnel contamination monitor (PCM). Used to detect radioactive contamination on personnel.

personnel dosimetry. Devices designed to be worn by a single person to assess dose equivalence. Such devices include film bandages, thermoluminescent dosimeters (TLDs), and pocket ionization chambers.

personnel monitoring. Systematic and periodic estimate of radiation received by personnel during working hours; the monitoring of personnel and their excretions, skin, or any part of their clothing to determine the amount of radioactivity present.

planned special exposure. Preplanned, authorized exposure to radiation, separate from and in addition to the annual dose limits.

pregnant worker radiation exposure. Radiation exposure to the unborn child.

protective clothing. Clothing provided to workers to minimize the potential for contamination to skin or personal clothing. Also referred to as anticontamination clothing, or anti-Cs.

proton. A positively charged particle located in the nucleus of the atom. The number of protons determines the element.

quality factor. A modifying number, multiplied by the number of rad to determine the number of rem, which accounts for the different levels of biological damage associated with each type of radiation.

rad (radiation absorbed dose). The unit used to measure the absorbed dose in any material from all types of radiation.

radiation. Radiation is the spontaneous emission of unstable atomic nuclei. It is a stream of particles, such as electrons, neutrons, alpha particles, or high-energy photons, or a mixture of these.

Radiation Area. An area in which the whole body dose rate is more than 5 mrem/hour but less than or equal to 100 mrem/hr at 30 cm from the source.

radioactive contamination. Radioactive material in an unwanted location.

radioactive decay. The transformation of a nuclide into a different energy or into a different nuclide, which results in the emission of radiation and a decrease, over time, of the original radioactive atoms. Also known as disintegration.

radioactive half-life. The time it takes for one-half of the radioactive atoms present to decay.

radioactive liquid waste. Liquid waste contaminated or potentially contaminated with radioisotopes.

Radioactive Material (posting). An area in which radioactive materials are used, handled, or stored in quantities exceeding the values shown in Appendix 16A of ISD 121-1.0.

radioactive material (RAM). Any material containing unstable (radioactive) atoms that emits radiation; material that contains radioactive atoms.

radioactive sealed source (RSS). An item manufactured, obtained, or retained for the purpose of using the emitted radiation. The sealed radioactive source consists of a known or estimated quantity of radioactive material contained in a nonradioactive sealed capsule, sealed between layers of nonradioactive material or firmly fixed to a nonradioactive surface by electroplating or other means intended to prevent leakage or escape of the radioactive material.

radioactivity. The spontaneous decay of unstable, or radioactive, atoms that emit radiation as they attempt to become stable.

radioisotope. An isotope that exhibits radioactivity.

radiological area. A general term referring to any area containing radiological hazards, within (but not including) a Controlled Area.

Radiological Buffer Area. A secondary boundary area around other radiological areas containing greater radiological hazards, established to control potential external exposure or contamination.

Radiological Controlled Area (RCA). An area controlled for surface contamination that could lead to an exposure in excess of 0.1 rem/year (100 mrem/year) or for volume contamination where reasonable potential exists for contamination to be dispersed throughout the material or waste.

radiological control hold point. Cautionary step in an RWP, hazard control plan, or technical work document in which work is stopped and the RCT or health physics technician performs some action or verification.

radiological control personnel. Individuals within the radiation protection organization**.**

radiological control technician (RCT). A person who has been trained in the RCT training program at the Laboratory, whose RCT certification is current, and who is assigned to or authorized by the RP-1 Health Physics Operations group to provide radiological safety support. Also called radiological worker or radiation worker.

radiological posting. Sign, label, or tag that indicates the presence or potential presence of radiation or radioactive materials.

radiological work. Any work that requires the handling of radioactive material or radiation-producing equipment or that requires access to Radiation Areas, High Radiation Areas, Very High Radiation Areas, Contamination Areas, High Contamination Areas, or Airborne Radioactive Areas.

radiological worker. A general worker whose job involves operating radiation-producing devices or working with radioactive materials or who is likely to be routinely occupationally exposed above 0.1 rem (100 mrem) per year total effective dose equivalent.

radiological (or radiation) work permit (RWP). The permit that identifies radiological conditions, establishes worker protection and monitoring requirements, and contains specific approvals for radiological work activities. The radiological work permit serves as an administrative process for planning and controlling radiological work and informing the worker of the radiological conditions.

radiological work permit (RWP) (general). The permit used to control routine operations or work in areas with stable radiological conditions, valid for up to one year.

radiological work permit (RWP) (job-specific). The permit used to control nonroutine operations or work in areas with changing radiological conditions, valid only for the duration of a particular job.

rem (roentgen equivalent man). The unit of dose equivalence used for human exposures, which considers the biological effects of different types of radiation on the body.

removable contamination. Contamination that can be readily removed from surfaces by casual contact such as wiping, brushing, or washing. Also referred to as loose or transferable radiation.

roentgen. The unit of exposure used to measure ionizations caused by gamma rays or x-rays in the air.

routine radiological work. Work that is performed repetitively on a recurring process, or an operation that incorporates standard radiation protection requirements and practices based on experiences with the existing radiological conditions.

self-contained breathing apparatus (SCBA). A full-faced respirator that supplies air from a compressed air cylinder that is worn on the worker's back.

shield or shielding. Material that is used to reduce exposure of personnel to radiation.

smear survey. Quantitative test for detecting the presence of removable contamination. The test is usually performed by wiping a filter paper over 100 cm of the surface and counting the residual activity.

Soil Contamination Area. An area where the soil is contaminated and is not releasable, in accordance with DOE Order 5400.**somatic effect.** An effect from radiation exposure that appears only in the individual exposed to radiation.

source control office. An office in RP-3 that is responsible for maintaining the Laboratory's centralized database of all accountable radioactive sealed sources and Geiger counters containing radioactive material/machine neutron generators so that the Laboratory can document and demonstrate compliance to federal law (10 CFR 835).

special protective equipment. Protective clothing (such as an ice vest, leather gloves, or a lead apron) that provides protection against specific hazards expected during work activities.

special radioactive waste. Radioactive waste that is not mixed waste, but because of various properties, must be specially packaged and handled. Examples include radioactive asbestos and biological waste.

step-off pad. An area established at access points to Radiological Controlled Areas, Radiological Buffer Areas, Contamination Areas, High Contamination Areas, Airborne Radioactivity Areas, or Hot Job Exclusion Areas and used for donning and doffing protective clothing.

supplemental dosimetry (or secondary dosimetry). Dosimetry used in addition to whole body TLDs.

supplied-air suit or bubble suit. A suit that covers the entire body and supplies air to the wearer from an independent air supply.

survey. Evaluating the radiological conditions and potential hazards incidental to the production, use, transfer, release, disposal, or presence of radioactive material or other sources of radiation.

suspect radioactive waste. Waste that is generated in an area where radioactive materials may be present but cannot be verified as being radioactive or nonradioactive.

swipe survey. Qualitative test for detecting the presence of removable contamination. This test is normally performed by wiping Masslin or its equivalent over at least 1000 cm of the surface and counting the residual activity with a radiation survey instrument.

temporary shielding. Shielding that is constructed for (1) one run cycle (such as at an accelerator facility), (2) the duration of an experiment, or (3) a job that lasts less than one year. It is also shielding that is reconfigured to accommodate a new or existing experiment.

thermoluminescent dosimeter (TLD). A radiation monitoring device used to assess the legal dose-of-record from high-energy beta, gamma, x-ray, and neutron radiation.

transuranic mixed waste. Waste that is contaminated with alpha-emitting radioisotopes with an atomic number greater than 92, and has half-lives greater than 20 years and concentrations greater than 100 nCi/g at the time of measurement.

tritium waste. Solid waste that is contaminated with tritium.

uncontrolled area. An area to which access is not controlled for radiological purposes. The surrounding radiological conditions are essentially natural background.

underground radioactive material area. Underground areas, such as pipelines; radioactive cribs; covered ponds, covered ditches; catch tanks; inactive burial grounds; or sites of known, covered, or unplanned spills that contain radioactive material.

urinalysis. Analysis of a urine sample; commonly used to detect alpha- or beta-emitting nuclides to determine internal dose.

Very High Radiation Area (posting). An area in which the whole body radiation dose rate is greater than 500 rad/hr at 100 cm from the source.

volume-contaminated material. Any item or material that contains radioactivity within its volume due to either activation (e.g., neutron activity) of the atoms within the item or material or by the incorporation of radioactive material into the volume of the item or material (e.g., mixing of radioactive material into pulverized concrete).

whole body. The body extending from the top of the head down to just below the elbow and just below the knee.

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