Radiological Worker II

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LIUNA INNOVATION AT WORK

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LEARNING OBJECTIVES

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

The participant will be able to SELECT the correct response from a group of responses which verifies his/her ability to:

E01 IDENTIFY the three basic particles of an atom.

E02 DEFINE ionization.

E03 DEFINE ionizing radiation, radioactive material, and radioactive contamination.

E04 DISTINGUISH between ionizing radiation and non-ionizing radiation.

E05 DEFINE radioactivity and radioactive half-life.

E06 STATE the four basic types of ionizing radiation.

E07 IDENTIFY the following for each of the four types of ionizing radiation:

a. Physical Characteristics
b. Range/Shielding
c. Biological Hazard(s)

E08 IDENTIFY the units used to measure radiation, contamination, and radioactivity.

E09 CONVERT rem to millirem and millirem to rem.

SECTION 301

RADIOLOGICAL FUNDAMENTALS

ATOMIC STRUCTURE

The basic unit of matter is the atom. The three basic particles of the atom are protons, neutrons, and electrons. The central portion of the atom is the nucleus. The nucleus consists of protons and neutrons. Electrons orbit the nucleus similar to the way planets orbit our sun.

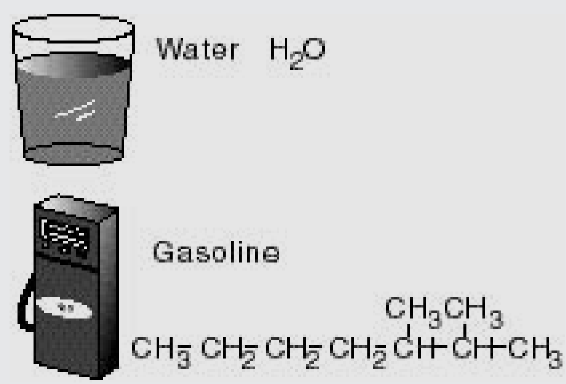
About Atoms

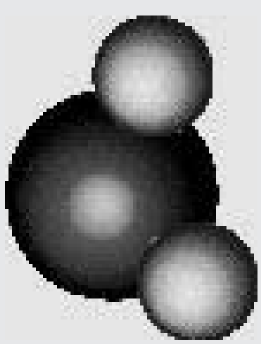
Historically, scientists believed that all substances were made of fundamental particles called *atoms*. Different types of atoms can combine in different patterns to form specific substances. This is the reason atoms are called the basic building blocks of matter.

There are 108 different kinds of atoms, which are known as chemical elements. Atoms of the same element or different elements can combine to form molecules or compounds. Examples of chemical elements are:

- Hydrogen
- Carbon
- Oxygen
- Chlorine

When these chemical elements combine together, they form compounds. Water is a compound made up of two hydrogen atoms and one oxygen atom. Gasoline is made up of many carbon and hydrogen atoms. The illustration pictured to the right, shows the chemical structure of water and gasoline.





Atoms are held together like magnets by chemical bonds. If a water molecule is magnified, it would look like the molecule pictured to the left.

Protons

- Located in the nucleus of the atom.
- Positive electrical charge.
- Number of protons determines the element.

Neutrons

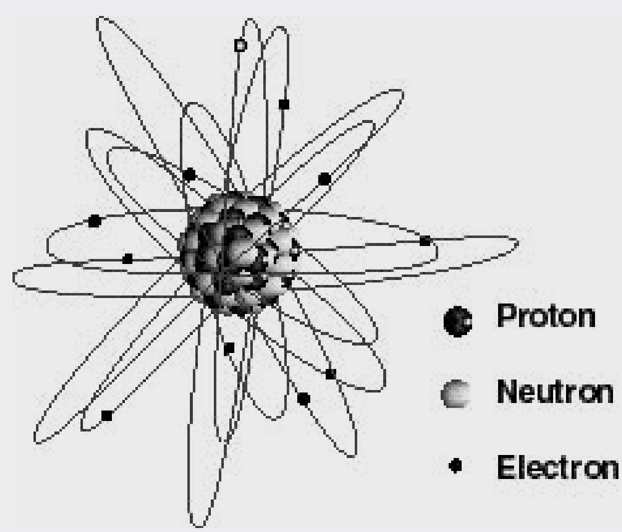
- Located in the nucleus of the atom.
- No electrical charge.
- Atoms of the same element have the same number of protons, but can have a different number of neutrons.
- Atoms which have the same number of protons but different numbers of neutrons are called *isotopes*.
- Isotopes have the same chemical properties; however, the nuclear properties can be quite different.

Electrons

- Orbit the nucleus.
- Negative electrical charge.
- Electrons determine the chemical properties of an atom.

Atomic Structure

If we magnified an atom, its nucleus and electron cloud would resemble the following illustration. The *nucleus* contains most of the atom's weight because of the size of the neutrons and protons. The electron cloud consists of electrons which are negatively charged. In comparison to neutrons and protons, electrons have virtually no weight. Electrons are held in orbit around the nucleus by their electromagnetic attraction to the positively charged protons.



Stable and unstable atoms – Only certain combinations of neutrons and protons result in stable atoms.

- If there are too many or too few neutrons for a given number of protons, the resulting nucleus will have too much energy. This atom will not be stable.

- The unstable atom will try to become stable. It does this by giving off excess energy in the form of particles or waves (radiation). These unstable atoms are also known as radioactive atoms.

Charge of the atom – The number of electrons and protons determines the overall electrical charge of the atom. The term ion is used to define atoms or groups of atoms that have a positive or negative electrical charge.

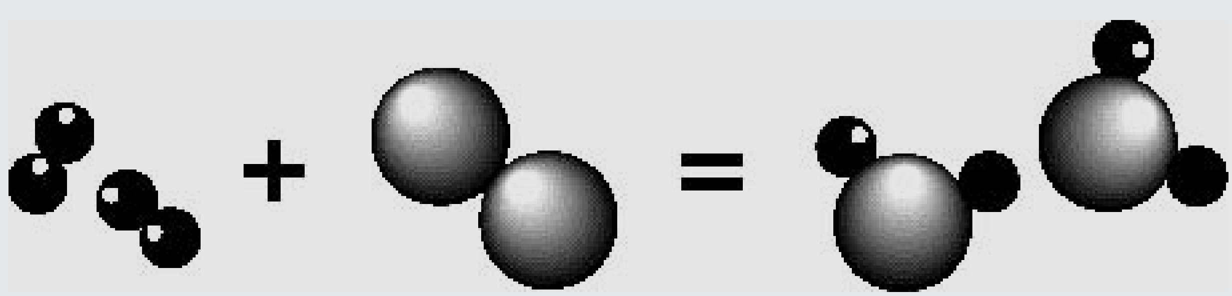
- No charge (neutral) – If the number of electrons equals the number of protons, the atom is electrically neutral and does not have an electrical charge.

- Positive charge (+) – More protons than electrons.

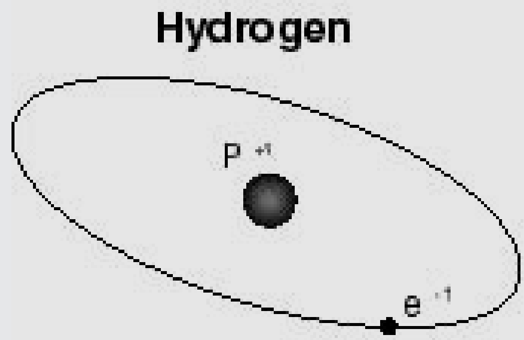
- Negative charge (-) – More electrons than protons.

Charged Atoms

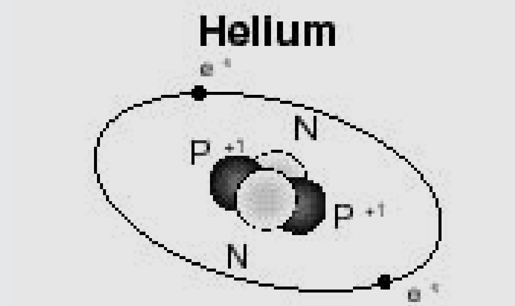
Atoms that have lost or gained electrons are called *ions*. When atoms or groups of atoms (molecules) lose electrons, they become chemically active and are no longer electrically stable. These ions have the ability to react with other atoms and molecules by breaking bonds and making new compounds. Substances that have a large number of ions include acids and bases. For example, when hydrogen gas is combined with oxygen, and an ignition source is introduced, water vapor is the end result. What actually happens? The heat from the ignition source frees electrons from the hydrogen gas, which produces hydrogen ions. These ions then break the chemical bond holding the oxygen together and recombine producing water vapor.



Understanding Chemistry

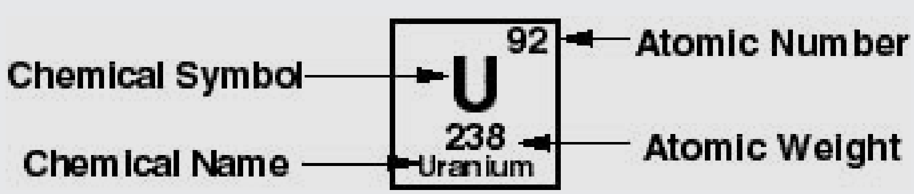


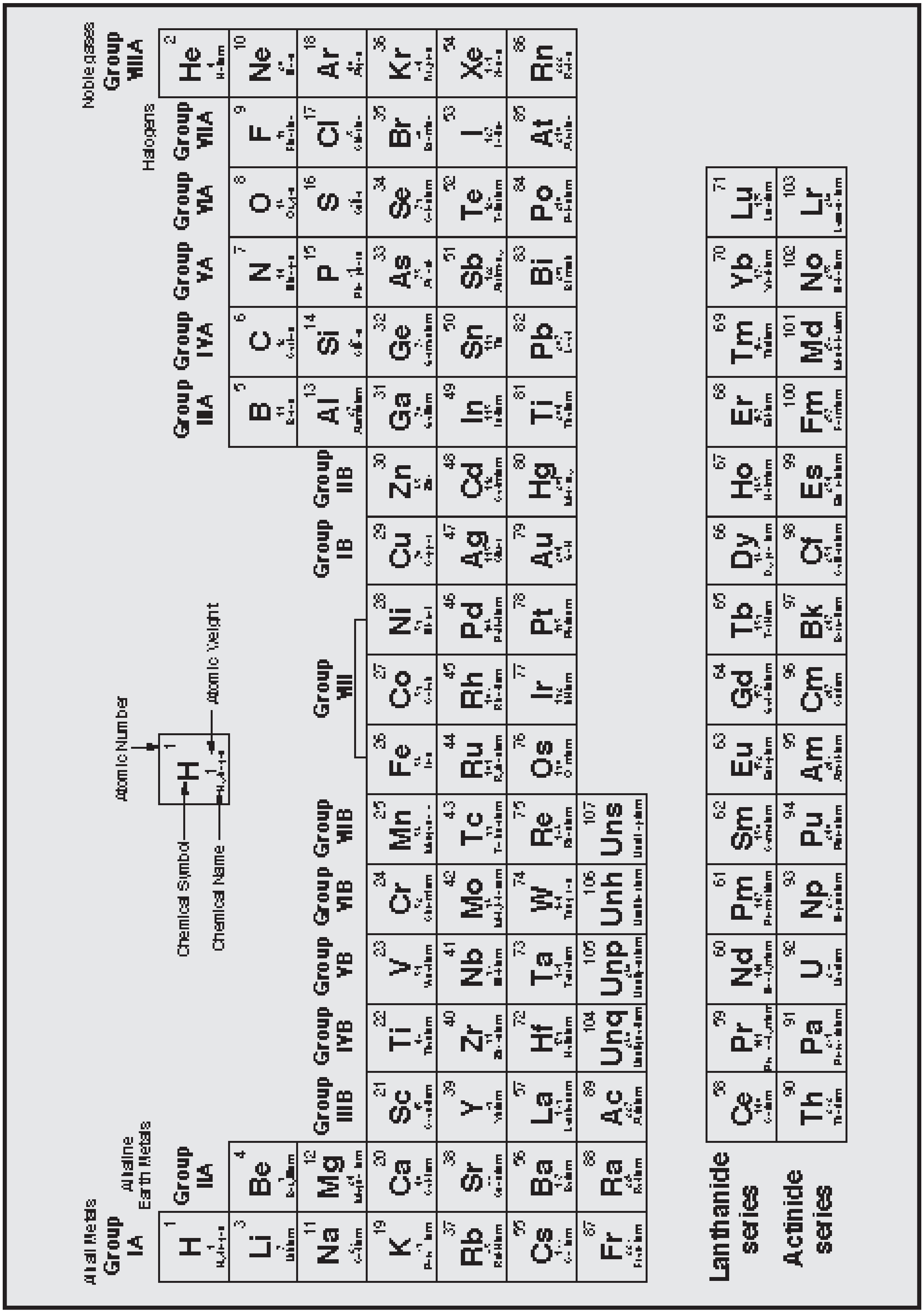
Before radiation is discussed in detail, it is helpful to have a basic understanding of chemistry. Chemistry is the science that deals with the composition, structure, and properties (color, liquid, odor, etc.) of substances, as well as what happens when they interact with other substances. Chemistry deals with the entire material universe; and therefore, it's important to understand chemistry in order to understand other sciences.



The Periodic Table (page 7) is a system for classifying the different chemical elements or atoms according to their atomic number or number of protons. Each atom is unique and contains a different number of protons. In other words, the number of protons in the nucleus determines the element. If the number of protons in the element changes, the element changes. The two simplest atoms are hydrogen and helium. The hydrogen atom contains one proton and one electron. The helium atom contains two protons, two neutrons, and two electrons. In both cases, the atoms have the same number of electrons as protons to make them electrically stable.

Hydrogen is listed at the beginning of the Periodic Table because it has only one proton, and it is the lightest atom. The number of protons are referred to as the *atomic number*. The protons and the neutrons added together are called the *atomic weight*. Every element is classified on the Periodic Table according to its atomic number and weight. Each chemical element is identified by using the format shown below, which identifies the chemical symbol, chemical name, atomic number, and atomic weight. Uranium is a naturally radioactive element; its nucleus contains 92 protons and 146 neutrons.




Alkali Metals
Group IA
Alkaline Earth Metals
Group IIA
Chemical Symbol
Chemical Name
Atomic Number
Atomic Weight
Group IIIB
Group IVB
Group VB
Group VIB
Group VIIB
Group VIII
Group IB
Group IIB
Group IIIA
Group IVA
Group VA
Group VIA
Group VIIA
Halogens
Noble gases
Group VIIIA
1 H
2 He
3 Li
4 Be
5 B
6 C
7 N
8 O
9 F
10 Ne
11 Na
12 Mg
13 Al
14 Si
15 P
16 S
17 Cl
18 Ar
19 K
20 Ca
21 Sc
22 Ti
23 V
24 Cr
25 Mn
26 Fe
27 Co
28 Ni
29 Cu
30 Zn
31 Ga
32 Ge
33 As
34 Se
35 Br
36 Kr
37 Rb
38 Sr
39 Y
40 Zr
41 Nb
42 Mo
43 Tc
44 Ru
45 Rh
46 Pd
47 Ag
48 Cd
49 In
50 Sn
51 Sb
52 Te
53 I
54 Xe
55 Cs
56 Ba
57 La
72 Hf
73 Ta
74 W
75 Re
76 Os
77 Ir
78 Pt
79 Au
80 Hg
81 Tl
82 Pb
83 Bi
84 Po
85 At
86 Rn
87 Fr
88 Ra
89 Ac
104 Unq
105 Unp
106 Unh
107 Uns
Lanthanide series
58 Ce
59 Pr
60 Nd
61 Pm
62 Sm
63 Eu
64 Gd
65 Tb
66 Dy
67 Ho
68 Er
69 Tm
70 Yb
71 Lu
Actinide series
90 Th
91 Pa
92 U
93 Np
94 Pu
95 Am
96 Cm
97 Bk
98 Cf
99 Es
100 Fm
101 Md
102 No
103 Lr

DEFINITIONS

- *Ionization* - Ionization is the process of removing electrons from neutral atoms. Electrons will be removed from neutral atoms if enough energy is supplied. The remaining atom has a positive (+) charge. The positively charged atom and the negatively charged electron are called an ion pair. Ionization should not be confused with radiation. Ions (or ion pairs) produced as a result of radiation exposure allow the detection of radiation.

- *Ionizing radiation* – Energy (particles or rays) emitted from radioactive atoms that can cause ionization. The four basic types of ionizing radiation that are of primary concern in the nuclear industry are alpha particles, beta particles, gamma rays, and neutron particles.

- *Non-ionizing radiation* - Radiation that doesn't have enough energy to ionize an atom. Examples of non-ionizing radiation are radar waves, microwaves and visible light.

- *Radioactivity* - Radioactivity is the process of unstable (or radioactive) atoms trying to become stable. This is done by emitting radiation.

- *Radioactive material* – Any material containing (unstable radioactive) atoms that emit radiation.

Radiation is energy emitted in the form of waves or particles. Wave radiation travels at the speed of light and carries different amounts of energy which is distinguished by their wavelengths.

Non-ionizing Radiation

Non-ionizing radiation is energy emitted from atoms in the form of waves that do not have enough energy to ionize another atom. The ionized atom becomes positively charged because it now has one less electron. Non-ionizing radiation can present some health hazards, but not usually to the extent of ionizing radiation. Examples of non-ionizing radiation include:

- Sunlight
- VHF & UHF
- Microwaves
- Lasers
- Television waves
- Welding arcs
- Light bulbs
- Radar
- Power lines

Ionizing Radiation

Ionizing radiation is energy released by heavy elements, or by elements which have a high proton to neutron ratio, in the form of waves or particles that have enough energy to ionize another atom. Ionizing radiation includes the following types of radiation:

- Alpha Particles
- Beta Particles
- Gamma Rays
- Neutron Particles

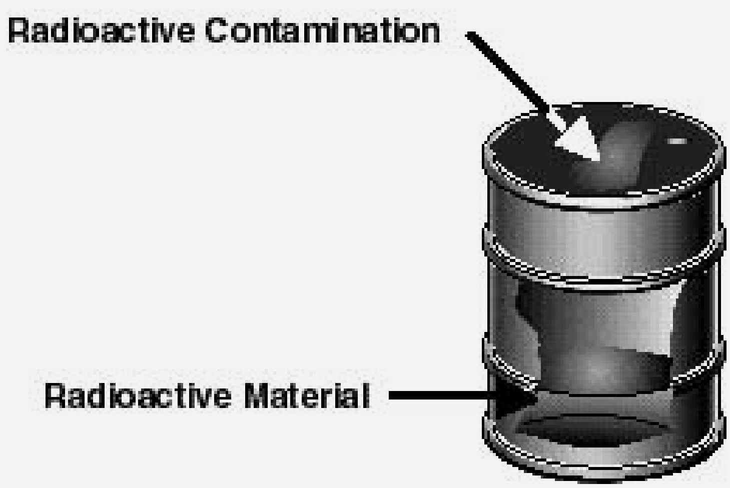
- *Radioactive contamination* - Radioactive contamination is radioactive material in an unwanted place. (There are certain places where radioactive material is beneficial).

  Exposure to radiation does not result in contamination of the worker. Radiation is a type of energy and contamination is material in an unwanted place.

- *Radioactive decay* - Radioactive decay is the process of radioactive atoms releasing radiation over a period of time. This is done to try and become stable (non-radioactive). Radioactive decay is also known as disintegration.

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

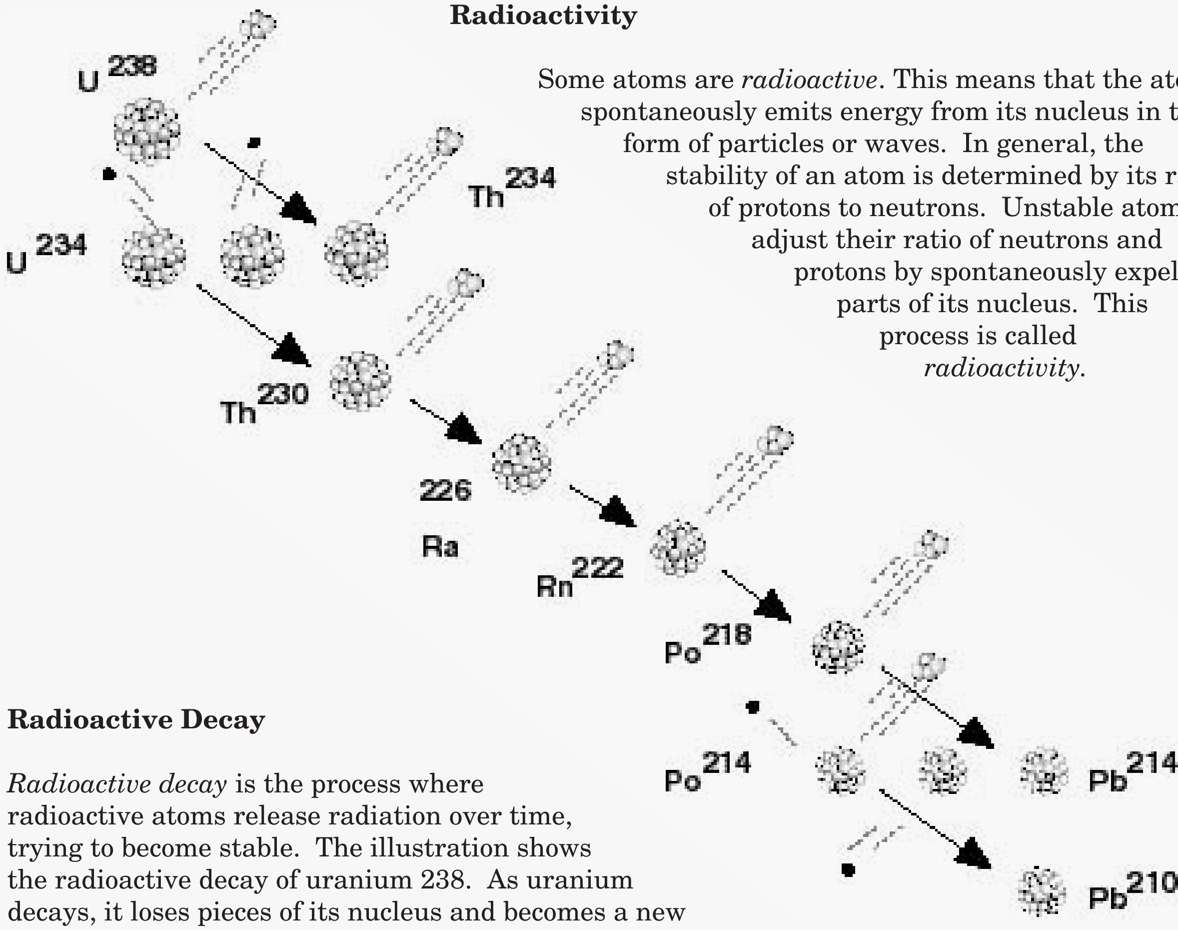
Radioactive Contamination vs. Radioactive Material



Radioactive contamination occurs when a radioactive material is found in an area where it is not wanted. For example, a salvage drum filled with contaminated soil is not considered contaminated if the soil was intentionally placed in the drum. However, if soil residues get on the outside of the drum accidentally during handling, the drum would be considered contaminated. Radioactive contamination may exist as a solid, liquid, or gas.

Radioactivity

Some atoms are *radioactive*. This means that the atom spontaneously emits energy from its nucleus in the form of particles or waves. In general, the stability of an atom is determined by its ratio of protons to neutrons. Unstable atoms adjust their ratio of neutrons and protons by spontaneously expelling parts of its nucleus. This process is called *radioactivity*.

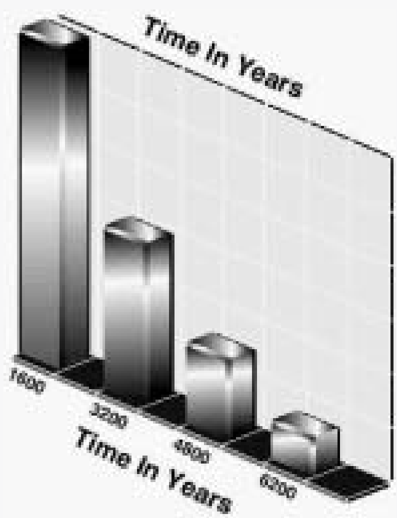


Radioactive Decay

Radioactive decay is the process where radioactive atoms release radiation over time, trying to become stable. The illustration shows the radioactive decay of uranium 238. As uranium decays, it loses pieces of its nucleus and becomes a new atom. As the process continues, the atom decays into new atoms until its nucleus is stable, in this example, stable lead.

Radioactive Half-Life

Radioactive half-life is the length of time it takes for one half of the radioactive atoms to decay. Every radioactive element and isotope has a specific half-life measured in seconds, days, or years. For example, radium has a half-life of 1,600 years. If our sample had 100 atoms, it would take 1,600 years for 50 atoms to decay.



THE FOUR BASIC TYPES OF IONIZING RADIATION

Alpha Particles

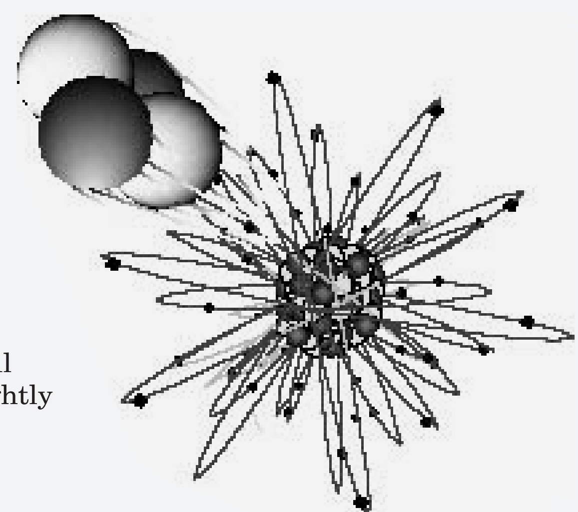
- *Physical characteristics* - The alpha particle has a large mass and consists of two protons, two neutrons and no electrons. It is a charged particle (charge of plus two) that is emitted from the nucleus of an atom. The positive charge causes the alpha particle (+) to strip electrons (-) from nearby 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 of travel. This large energy deposit limits the penetrating ability of the alpha particle to a very short distance. This range in air is about one to two inches.

- *Shielding* – Most alpha particles are stopped by a few inches of air, a sheet of paper, or the dead layer (outer layer) of skin.

- *Biological hazard* – Alpha particles are not considered an external radiation hazard because they are easily stopped by the dead layer of skin. Internally, the source of the alpha radiation is in close contact with body tissue and can deposit large amounts of energy in a small volume of body tissue.

Alpha Radiation



The *alpha particle* is a stable combination of two protons and two neutrons that are ejected from the nucleus of a heavy atom (atomic number greater than 83). Its large mass and high charge forces the particle to interact with, and ionize, thousands of atoms as it travels. Because of these interactions, it quickly loses energy and collects two free electrons to become stable. In gases, such as air, where atoms are separated by mostly empty space, an alpha particle will travel about two inches. In solids, where atoms are tightly bound together, the particle loses all of its energy in a thousand of an inch.

Alpha radiation is easily stopped by the body's outer layer of dead skin. However, if an alpha emitter is ingested or inhaled, the alpha particles will deposit their energy in living tissue causing tissue damage.

Beta Particles

- *Physical characteristics* - The beta particle has a small mass and is usually negatively charged. It is emitted from the nucleus of an atom and has an electrical charge of minus one. Beta radiation causes ionization by displacing electrons from their orbits. Ionization occurs due to the repulsive force between the beta particle (-) and the electron(-), which both have a charge of minus one.

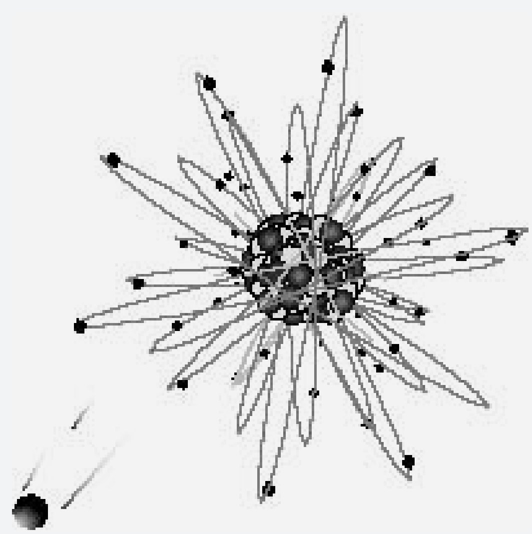
- *Range* - Because of its charge, the beta particle can only penetrate a short distance - Range in air is about 10 feet.

- *Shielding* - Most beta particles can be shielded by plastic, glass, metal foil, or safety glasses.

- *Biological hazard* - If ingested or inhaled, the source of the beta radiation is in close contact with body tissue and can deposit energy in a small volume of body tissue. Externally, beta particles are potentially hazardous to the skin and eyes.

Beta Radiation

A *beta particle* is a small, negatively-charged particle, the size of an electron, ejected from the nucleus of an atom. The stability of an atom is determined by the number of protons and neutrons contained in its nucleus. If the nucleus has an improper balance of neutrons and protons, the element becomes unstable and will decay to a condition of greater stability. When the nucleus is very heavy, the atom will eject alpha particles. However, if the nucleus contains only a few excess neutrons, the atom will eject beta particles. For example, imagine being in a hot air balloon that is descending rapidly, a state of instability. Do you eject the heavy sand bags or the light sand bags to slow descent? To initially stabilize the balloon, heavy bags of sand are ejected first. When the balloon is almost stable, then the light sand bags are dropped.



Gamma Rays/X-rays

- *Physical characteristics* - Gamma/x ray radiation is an electromagnetic wave or photon and has no electrical charge. Gamma rays are very similar to x-rays. The main difference between gamma rays and x-rays is that gamma rays originate inside the nucleus and x rays originate outside the nucleus. Gamma/x-ray radiation can ionize an atom by directly interacting with the electron.

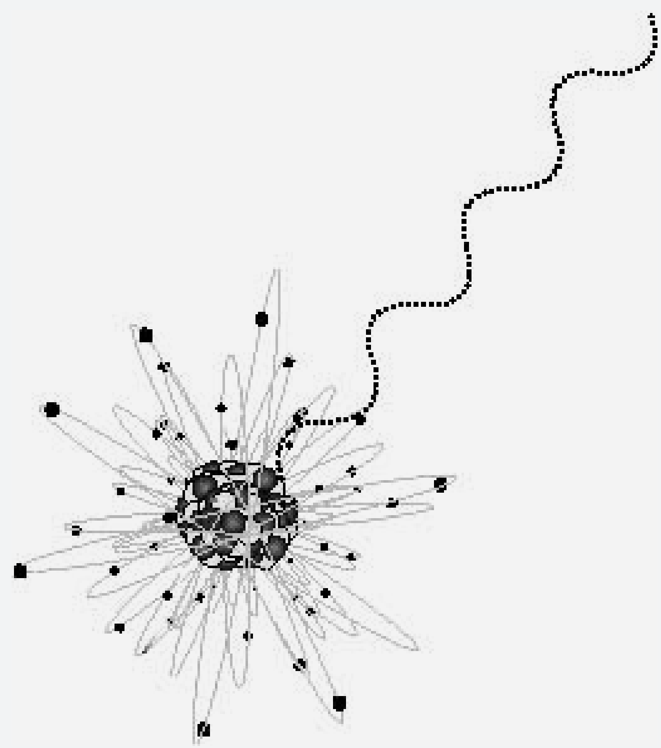
- *Range* - Because gamma/x-ray radiation has no charge and no mass, it has a very high penetrating ability. The range in air is very far. It will easily go several hundred feet.

- *Shielding* - Gamma/x-ray radiation is best shielded by very dense materials, such as concrete, lead or steel.

- *Biological hazard* - Because gamma and x-ray radiation has the ability to penetrate through the body, they are considered a whole body hazard.

Gamma Radiation

Gamma radiation is pure energy in the form of an electromagnetic wave or photon and has no electrical charge. Gamma radiation usually follows the emission of a beta or alpha particle. After a beta or alpha particle is ejected, the atom usually has additional energy which it gives up by emitting a gamma ray. Gamma rays are identical to x-rays. The only difference between them is their place of origin. Gamma rays come from the nucleus, and x-rays come from the electron cloud surrounding the nucleus. Because gamma radiation has no charge and no mass, it has a very high penetrating power.



Neutron Particles

- *Physical characteristics* - Neutron radiation consists of neutrons that are ejected from the nucleus. A neutron has no electrical charge. A direct interaction occurs as the result of a collision between a neutron and a nucleus. A charged particle or other ionizing radiation may be emitted during this direct interaction. The emitted radiation can cause ionization in human cells. This is called "indirect ionization".

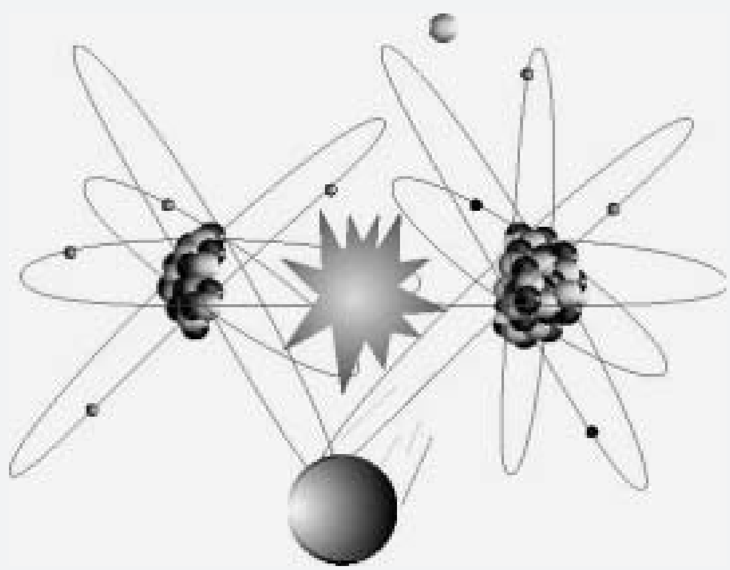
- *Range* - Because of the lack of a charge, neutrons have a relatively high penetrating ability and are difficult to stop. The range in air is very far. Like gamma rays, they can easily travel several hundred feet in air.

- *Shielding* - Neutron radiation is best shielded by materials with a high hydrogen content, such as water, concrete, or plastic.

- *Biological hazard* - Because neutrons have the ability to penetrate through the body, they are considered a whole body hazard.

Neutron Radiation

Neutron radiation consists of neutrons that are ejected from the nucleus of an atom. Neutron radiation is produced during the fission process within an operating nuclear reactor or particle accelerator. Neutrons have no electrical charge; and therefore, have a high penetrating ability. The fission process occurs when a high speed particle collides with a uranium atom and splits it into two different parts. As the uranium atom splits, it also releases two free neutrons. These neutrons are referred to as neutron radiation. Neutron radiation passes easily through body tissue and deposits energy as it travels.



UNITS OF MEASURE

Radiation

- Roentgen (R) – The *roentgen* is a unit for measuring exposure. It is defined only for the effect on air. It applies only to gamma and x-rays. It does not relate biological effects of radiation to the human body.

1 R (Roentgen) = 1000 milliroentgen (mR)

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

1 rad = 1000 millirad (mrad)

- Rem (Roentgen equivalent man) – The *rem* is a unit for measuring dose equivalence. It is the most commonly used unit and pertains to the human body. The rem takes into account the energy absorbed (dose) and the biological effect on the body due to the different types of radiation.

1 rem = 1000 millirem (mrem)

Quality Factors

Quality factors (QFs) exist because each type of radiation has a different potential to release energy; therefore, causing more or less biological damage. Gamma rays and beta particles cause less internal body damage, while alpha particles cause more localized damage. The table illustrates the QFs for the different types of radiation.

Quality Factors

Radiation Type	Quality Factor
Gamma rays	1
Beta particles	1
Neutrons	3 - 10
Alpha Particles	20

REM = RAD X QUALITY FACTOR

Radiation Dose Rate

Dose is the amount of radiation you receive. *Radiation Dose Rate* is the rate at which you receive the dose.

Example:

a. Radiation Dose rate = dose/time
b. Radiation Dose rate = mrem/hr

Contamination/Radioactivity

- Radioactivity is measured in the number of disintegrations radioactive material undergoes in a certain period of time.

Contamination is radioactivity measured per unit area or volume.

1. Disintegration per minute (dpm)
2. Counts per minute (cpm)
3. Curie
   - 2,200,000,000,000 (2.2 x 10^{12}) disintegrations per minute (dpm), or
   - 37,000,000,000 (3.7 x 10^{10}) disintegration per second (dps)

The following example explains how quality factors influence your dose:

A worker receives a .04 rad dose of internal alpha radiation. Alpha radiation has a QF of 20; and therefore, results in a dose of .80 rem.

This was calculated as follows:

Dose = .04 Rad	**QF of Alpha = 20**
Equation:	**Rad x QF = Rem**
Calculation: .04 Rads x 20 = .80 Rems	

Small doses will usually be reported in millirems (mrems), which is equal to one-thousandth of a rem (1/1000).

1 rem = 1,000 mrem

Contamination Units

Contamination is usually measured in the number of disintegrations a radioactive material undergoes in a certain period of time. The two most common units are:

- disintegration per minute (dpm)
- counts per minute (cpm)

Dpm is used to represent the number of atoms disintegrating or decaying every minute.

Cpm is used to represent the number of disintegrations detected by a survey instrument.

For the radioactivity in air and water, the curie (Ci) or microcurie (µCi) is most often used. One curie equals one million microcuries.

- 1 curie = 1,000,000 µCi

Curie

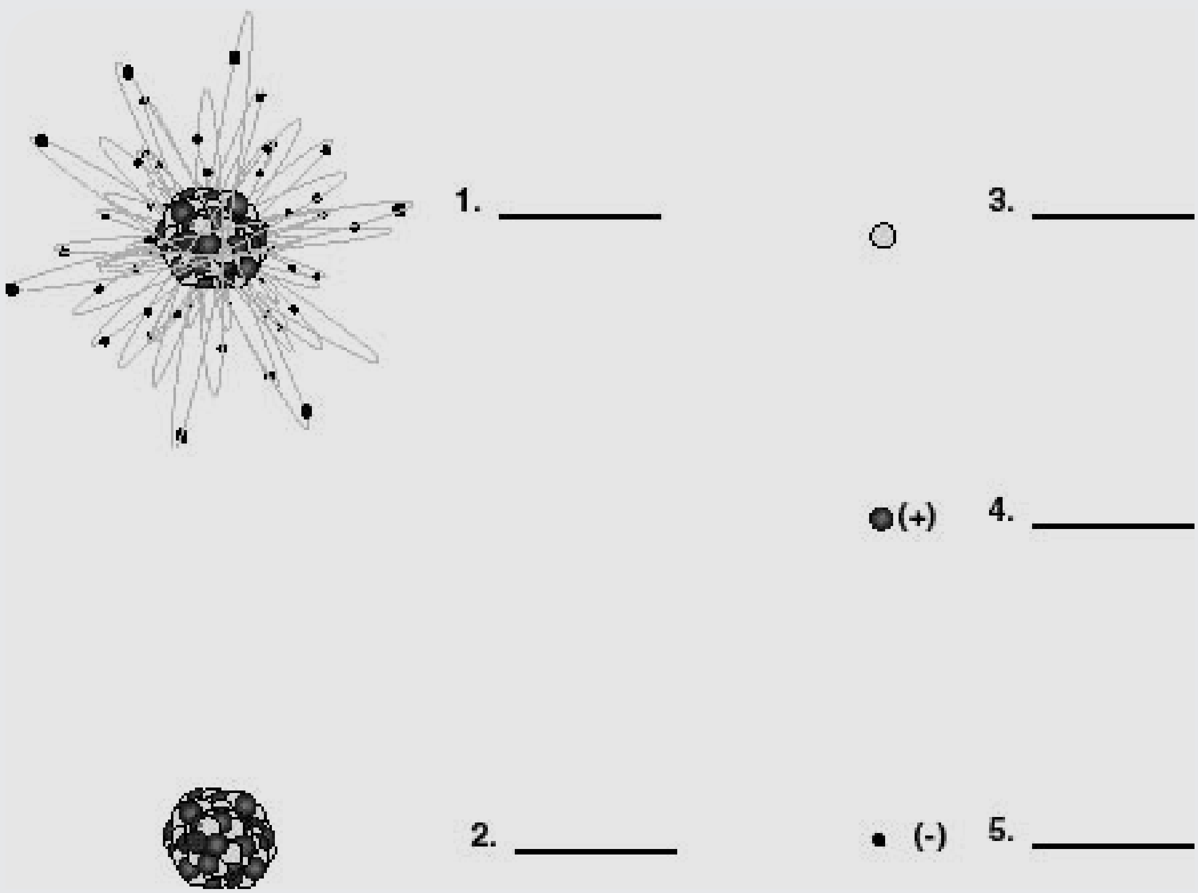
The *curie* (Ci) is a unit used to measure the radioactivity of a material in disintegrations per second (dps) and/or disintegrations per minute (dpm). The curie is the standard unit used to measure how many atoms are disintegrating every second. One curie of any radioactive substance has 37 billion atoms disintegrating every second (2,200,000,000,000 dpm). Each particle or ray emitted can be detected as a result of disintegration occurring. This does not measure strength or intensity. For example, one curie of cobalt weights about one gram, and one curie of uranium weights two metric tons; both have 37 billion atoms disintegrating every second. For radioactivity in air or water, the microcurie (µCi) is commonly used.

(1 curie = 1,000,000 µCi)

SECTION 301 - ASSIGNMENT

1. Identify the basic parts of the atom by matching the following terms to the correct atomic part.

    a. Neutron
    b. Atom
    c. Nucleus
    d. Electron
    e. Proton



SECTION 301 - ASSIGNMENT (CONTINUED)

2. List the four types of ionizing radiation and give their unique characteristics (i.e., composition, penetration, shielding, and hazard).

Radiation Type: ______________________

Composition: ______________________

Penetration: ______________________

Shielding: ______________________

Hazard: ______________________

Radiation Type: ______________________

Composition: ______________________

Penetration: ______________________

Shielding: ______________________

Hazard: ______________________

Radiation Type: ______________________

Composition: ______________________

Penetration: ______________________

Shielding: ______________________

Hazard: ______________________

Radiation Type: ______________________

Composition: ______________________

Penetration: ______________________

Shielding: ______________________

Hazard: ______________________

SECTION 301 - ASSIGNMENT (CONTINUED)

3. Indicate which of the following radiation types are ionizing and non-ionizing.

Alpha	____________	Beta	______________
Radio	____________	Heat	______________
Microwaves	____________	X-rays	______________
Gamma	____________	Artificial light	______________

4. Match the following terms with the appropriate definition.

_______ Ionizing radiation

_______ Radioactive material

_______ Radioactive half-life

_______ Radiation

_______ Radioactive contamination

_______ Ionization

_______ Non-ionizing radiation

_______ Radioactivity

a. The process where radioactive materials emit radiation in an effort to become stable.

b. The time required for a radioactive material to decay to 50% of its original activity.

c. A material that contains unstable atoms which gives off energy in the form of radiation.

d. Energy emitted from a source in the form of rays or particles.

e. Energy from an unstable atom capable of removing an electron from a nearby atom.

f. The process of removing electrons from neutral atoms.

g. Radioactive material in an unwanted place.

h. Energy from an atom that can not remove an electron from a nearby atom.

SECTION 301- ASSIGNMENT (CONTINUED)

5. List the Quality Factor (QF) for each of the following types of radiation.

Alpha	______________
Beta	______________
Gamma	______________
Neutron	______________

6. Convert the following readings from rem to millirem and from millirem to rem.

5 rem =	____________	2.5 rem =	____________
.1 rem =	____________	7250 mrem =	____________
10,000 mrem =	____________	10 mrem =	____________
500 mrem =	____________	1,500 rem =	____________

7. Match the following exposure terms to the appropriate answer.

_______ Rem

_______ mrem

_______ Roentgen

_______ Dose rate

_______ Rad

_______ Curie

_______ cpm

a. Radiation exposure unit that applies only to gamma and x-rays.

b. Radiation unit used for human exposure.

c. Radiation unit used to measure energy deposited in a material from any type of radiation.

d. 1/1000 of a rem.

e. Unit used to measure the radioactivity of a material in disintegrations per minute (dpm) or disintegrations per second (dps).

f. The term used to identify how fast an individual receives a dose (mrem/hr).

g. The unit used to represent the number of disintegrations detected by a survey instrument.

SECTION 302

BIOLOGICAL EFFECTS

LEARNING OBJECTIVES

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

The participant will be able to SELECT the correct response from a group of responses which verifies his/her ability to:

E01 IDENTIFY the average annual dose to the general population from natural background and man-made sources.

E02 IDENTIFY the major sources of natural background and man-made radiation.

E03 STATE the method by which radiation causes damage to cells.

E04 IDENTIFY the possible effects of radiation on cells.

E05 DEFINE the terms “acute dose” and “chronic dose.”

E06 STATE examples of a chronic radiation dose.

E07 DEFINE the terms “somatic effect” and “heritable effect.”

E08 STATE the potential effects associated with prenatal radiation doses.

E09 COMPARE the biological risks from chronic radiation doses to health risks workers are subjected to in industry and daily life.

SECTION 302

BIOLOGICAL EFFECTS

INTRODUCTION

Of all the environmental factors, we know more about the biological effects of ionizing radiation than any other. Rather than just being able to base our information on animal studies we have a large body of information available regarding exposures to humans.

There are 4 major groups of people that have been exposed to significant levels of radiation.

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

2. More than 100,000 survivors of the atomic bombs dropped at Hiroshima and Nagasaki. These survivors received estimated doses in excess of 50,000 mrem.

3. Individuals who have been involved in radiation accidents, the most notable being the Chernobyl accident.

4. The largest group of individuals are patients who have undergone radiation therapy for cancer.

SOURCES OF RADIATION

We live in a radioactive world and always have. In fact, the majority of us will be exposed to more ionizing radiation from natural background radiation than from our jobs.

- The average annual radiation dose to a member of the general population from these sources is about 360 millirem.

Natural Sources

As human beings, we have evolved in the presence of ionizing radiation from naturally occurring sources. There are several sources of radiation that occur naturally. The radiation emitted from these sources is identical to the radiation that results from man-made sources.

The four major sources of naturally occurring radiation exposures are:

- Cosmic radiation
- Sources in the earth's crust, also referred to as terrestrial radiation
- Sources in the human body, also referred to as internal sources
- Radon

Cosmic radiation

Cosmic radiation comes from the sun and outer space. It consists of positively charged particles, as well as gamma radiation. At sea level, the average annual cosmic radiation dose is about 26 mrem. At higher elevations, the amount of atmospheric shielding decreases and thus the dose increases. The total average annual dose to the general population from cosmic radiation is about 28 mrem.

Sources in earth's crust (terrestrial)

There are natural sources of radiation in the ground (i.e., rocks, building materials and drinking water supplies). Some of the contributors to terrestrial sources are the natural radioactive elements radium, uranium and thorium. Many areas have elevated levels of terrestrial radiation due to increased concentrations of uranium or thorium in the soil. The total average annual dose to the general population from terrestrial radiation is 28 mrem.

Internal Sources

The food we eat and the water we drink all contain some trace amounts of natural radioactive materials. These naturally occurring radioactive materials deposit in our bodies and, as a result, cause an internal exposure to radiation. Some naturally occurring radioactive isotopes include Sodium-24 (Na-24), Carbon-14 (C-14), Argon-41 Ar-41) and Potassium-40 (K-40). Most of our internal exposure comes from Potassium-40. Combined exposure from internal sources of natural background radiation account for a radiation dose of about 40 mrem per year.

Radon

Radon comes from the radioactive decay of radium, which is 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. Because alpha radiation cannot penetrate the dead layer of skin on your body, it presents a hazard only if taken in to the body. Radon and its decay products are present in the air, and when inhaled can cause a dose to the lungs. The average annual dose equivalent from radon gas is approximately 200 mrem.

Man-made Radiation Sources

The difference between man-made sources of radiation and naturally occurring sources is the place from which the radiation originates.

The four major sources of man-made radiation exposures are:

- Medical radiation
- Atmospheric testing of nuclear weapons
- Consumer products
- Industrial uses

Medical radiation sources

X-rays – X-rays are similar to gamma rays; however, they originate outside the nucleus. X-rays are an ionizing radiation hazard. A typical radiation dose from a chest x-ray is about 10 mrem. The total average annual dose to the general population from medical x-rays is 40 mrem.

Diagnosis and therapy – In addition to x-rays, radioactive sources are used in medicine for diagnosis and therapy. The total average annual dose to the general population from these sources is 14 mrem.

Atmospheric testing of nuclear weapons

Another man-made source of radiation includes residual fallout from atmospheric nuclear weapons testing in the 1950s and early 1960s. Atmospheric testing is now banned by most nations. The average annual dose from residual fallout is less than one mrem.

Consumer products

Examples include TVs, older luminous dial watches, and some smoke detectors. This dose is relatively small as compared to naturally occurring sources of radiation and averages 10 mrem in a year.

Industrial uses

Industrial uses of radiation include x-ray machines used for baggage inspection, video display terminals, and tungsten welding rods.

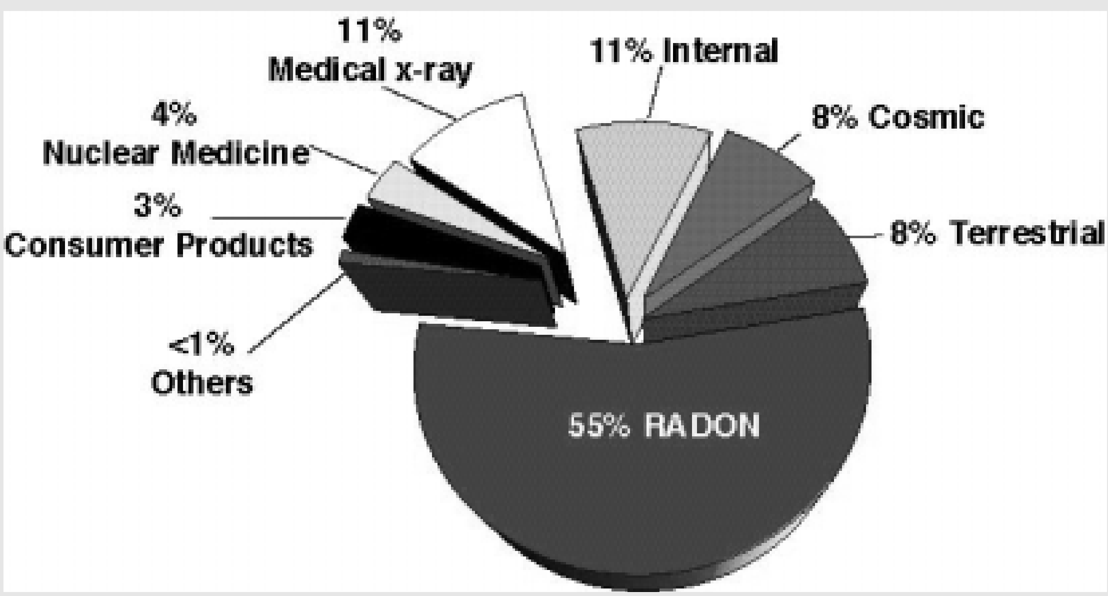
Natural Radiation

Natural radiation comes from natural radioactive sources present in our environment and from outerspace. These sources include:

- Cosmic - originates deep in outer space, and makes up 8% of the exposure.
- Terrestrial - radioactive materials making up the earth's surface.
- Internal - food eaten and air breathed.
- Radon - gas from the decay of radium (a product of the decay of uranium).

Man-made Radiation

Since the discovery of radiation in the late 1800s, man has learned to use the atom in a variety of ways. The largest man-made source of radiation exposure is from medical diagnostics and x-rays, which accounts for about 50 mrem per year. Consumer products, such as smoke detectors, building materials, combustible fuels, some gas mantles, camera lenses, and welding rods, contribute about 10 mrem. Tobacco products containing radioactive forms of lead or polonium are estimated to be the largest contributing factor from consumer products. Nuclear power generation, fallout from nuclear explosive testing, and other sources of nuclear energy contributes less than 1%.



EFFECTS OF RADIATION ON CELLS

The human body is made up of many organs, and each organ of the body is made up of specialized cells. Ionizing radiation can potentially affect the normal operation of these cells.

Biological effects begin with the ionization of atoms:

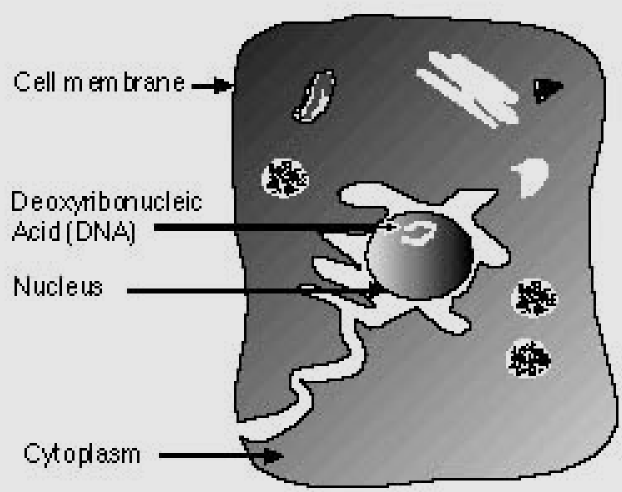
- The method by which radiation causes damage to human cells is by ionization of atoms in the cells. Atoms make up cells that make up the tissues of the body. These tissues make up the organs of which our body consists. Any potential radiation damage to our body begins with damage to atoms.
- A cell is made up of two principle parts, the body of the cell, and the nucleus which is like the brain of the cell.
- The method by which radiation causes damage to any material is by ionization of atoms in the material.
- When ionizing radiation hits a cell, it may strike a vital part of the cell like the nucleus or a less vital part of the cell.

Cell Structure

Cells are tiny living organisms that make up the human body. The human body contains about 50,000 billion cells. Each cell consists of:

- A cell membrane
- Cytoplasm
- A nucleus

The cell consists of an outer membrane which contains an inner watery substance called cytoplasm. *Cytoplasm* contains a variety of substances, such as proteins, sugars, and amino acids. At the center of the cell is the *nucleus*, home of the genetic blueprint "*Deoxyribonucleic Acid*" (DNA). This DNA molecule contains all the information that governs what the cell is and what it does. The nucleus is the brain of the cell.



Cell Sensitivity

Some cells are more sensitive than others to environmental factors such as viruses, toxins and ionizing radiation. Radiation damage to cells may depend on how sensitive the cells are to radiation.

Actively dividing cells and non-specialized cells

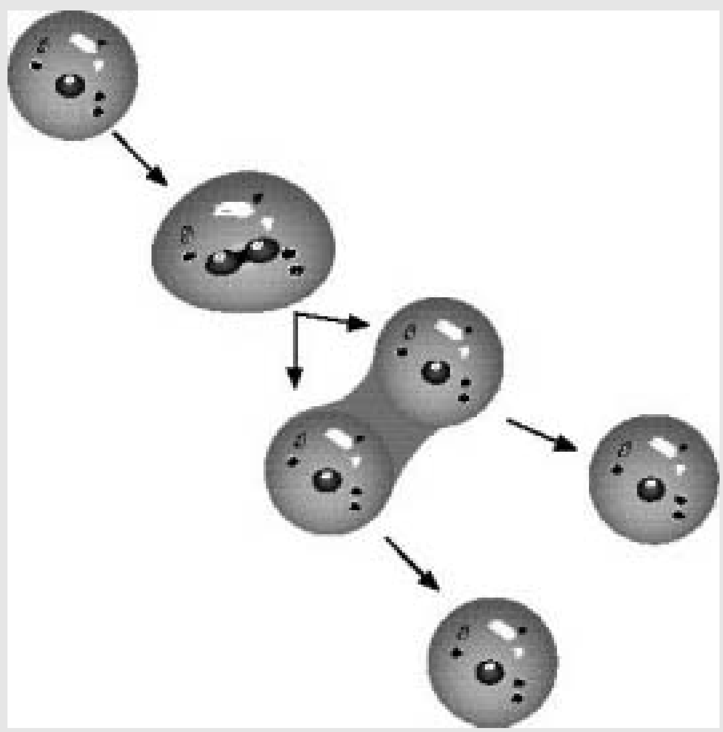
Cells in our bodies that are actively dividing are more sensitive to ionizing radiation. Cells that are rapidly dividing include: blood forming cells, the cells that line our intestinal tract, hair follicles, and cells that form sperm.

Less actively dividing and more specialized cells

Cells which divide at a slower pace or are more specialized (such as brain cells or muscle cells) are not as sensitive to damage by ionizing radiation.

Cell Division

Cell division begins when the cell's chromosomes replicate to form two complete sets. *Chromosomes* are chemical chains which contain DNA. After the chromosomes divide, the cell's nucleus divides, followed by cell division. Each new cell has an identical nucleus both containing identical chromosomes. The result is two identical cells, referred to as daughter cells. This process creates and maintains the body's tissue throughout life. However, during this process cells are more susceptible to radiation damage.



Possible Effects of Radiation on Cells

When a cell is exposed to ionizing radiation, several things can happen. The following are possible effects of radiation on cells.

- There is no damage.
- Cells repair the damage and operate normally.

The body of most cells is made up primarily of water. When ionizing radiation hits a cell, it is most likely to interact with the water in the cell. Often the cell can repair this type of damage. Ionizing radiation can also hit the nucleus of the cell. The nucleus contains the vital parts of the cell such as chromosomes. (The chromosomes determine the cells function.) When chromosomes duplicate themselves, the chromosomes transfer their information to new cells. Damage to chromosomes, although often more difficult, can also be repaired. In fact, the average person repairs 100,000 chromosome breaks per day.

- Cells are damaged and operate abnormally.

Cell damage may not be repaired or may be incompletely repaired. In that case, the cell may not be able to do its function or it may die. It is possible that a chromosome in the cell nucleus could be damaged but not be repaired correctly. This is called a mutation or genetic effect. We will discuss genetic effects when we consider chronic radiation doses.

- Cells die as a result of the damage.

At any given moment thousands of our cells are dying and being replaced by normal cells nearby. It is only when the dose of radiation is very high or is delivered very rapidly that the cell may not be able to repair itself or be replaced.

ACUTE AND CHRONIC RADIATION DOSE

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

We know that radiation therapy patients receive high doses of radiation in a short period of time but generally only to a small portion of the body (not a whole body dose). Ionizing radiation is used to treat cancer in these patients because cancer cells are rapidly dividing and therefore sensitive to ionizing radiation. Some of the side effects of people undergoing radiation therapy are hair loss, nausea and tiredness.

Acute radiation doses

An acute effect is a physical reaction due to massive cell damage. This damage may be caused by a large radiation dose received in a short period of time. Large doses of radiation received in a short period of time are called acute doses. The body can't repair or replace cells fast enough from an acute dose and physical effects such as reduced blood count and hair loss may occur.

Slight blood changes may be seen at acute doses of 10,000-25,000 mrem but an individual would not otherwise be affected.

Radiation sickness

At acute doses greater than 100,000 mrem, about half of the people would experience nausea (due to damage of the intestinal lining). Radiation therapy patients often receive whole body equivalent doses in this range and above, although doses to the region of a tumor are many times higher than this.

If the acute dose to the whole body is very large (on the order of 500,000 mrem or larger) it may cause so much damage that the body cannot recover. An example is the 30 firefighters at Chernobyl who received acute doses in excess of 800,000 mrem. These individuals succumbed to the effects of the burns they received compounded by their radiation dose.

After an acute dose, damaged cells will be replaced by new cells and the body will repair itself, although this may take a number of months. Only in those extreme cases, such as with the Chernobyl firefighters, would the dose be so high as to make recovery unlikely.

Acute doses to only part of the body

It is possible in that radiation exposure may be only to a limited part of the body such as the hands. There have been accidents, particularly with X-ray machines, in which individuals have exposed their fingers to part of the intense radiation beam. In some of these cases individuals have received doses of millions of mrem to their fingers and some individuals have lost their finger or fingers. It is important for individuals who work with x-ray or similar equipment to be trained in the safe use of this equipment.

Probability of an acute dose

What is important to understand is that it takes a large acute dose of radiation before any physical effect is seen. These acute doses have only occurred in Hiroshima/Nagasaki, a few radiation accidents, and Chernobyl. The possibility of a radiological worker receiving an acute dose of ionizing radiation on the job is extremely low. In may areas where radioactive materials are handled, the quantities handled are small enough that they do not produce a large amount of radiation. Where there is a potential for larger exposures, many safety features are in place.

ACUTE DOSE	
(Rems)	**Probable Effect**
0 - 10	No obvious effect. Could be detected by chromosome analysis.
10 - 50	Minor blood changes.
60 - 120	Vomiting and nausea for about one day in 5% to 10% of those exposed. Fatigue, but not serious disability.
130 - 170	Vomiting and nausea for about one day, followed by other symptoms of radiation sickness (increased temperature, blood changes, fatigue) in about 25% of those exposed. No deaths anticipated.
180 - 220	Vomiting and nausea for about one day followed by other symptoms of radiation sickness in about 50% of those exposed.
270 - 330	Vomiting and nausea in nearly all those exposed on the first day, followed by other symptoms of radiation sickness. About 20% of the group will die within 2-6 weeks after exposure; survivors convalesce for about 3 months.
400 - 500	Vomiting and nausea in all those exposed on the first day, followed by other symptoms of radiation sickness. Bone marrow destruction (reversible). Without medical treatment, 50% of the group will die within a month. Survivors convalesce for about 6 months.
550 - 750	Vomiting and nausea to all those exposed within 4 hours, followed by other symptoms of radiation sickness. Irreversible destruction of bone marrow. Deaths in 100% of the group is expected.
1000 to 5000	Vomiting, diarrhea, and nausea in all those exposed within 1 to 2 hours. Damage primarily to the digestive system. First and second degree burns of the skin. Death will occur to whole group in 3-10 days. Note: These are the doses used to treat cancer, but are kept in small areas of the body.
5000 - 10,000	Unconscious minutes after exposure. Death within 48 hours due to nervous system damage.

With proper medical attention, the chances of survival are excellent, even for very high absorbed doses. Radiotherapy treatment for cancer patients often expose the tumor area to protracted doses of several thousand rems over a period of 6 to 8 weeks.

Chronic radiation doses

A chronic radiation dose is typically a small amount of radiation received over a long period of time. An example of a chronic dose is the dose we receive from natural background every day of our lives or the dose we receive from occupational exposure.

Chronic dose versus acute dose

The body is better equipped to handle a chronic dose than an acute dose. The body has time to repair damage because a smaller percentage of the cells need repair at any given time. The body has time to replace dead or non-functioning cells with new healthy cells. It is only when the dose of radiation is high and is received very rapidly that the cellular repair mechanisms are overwhelmed and the cell dies before repair can occur. A chronic dose of radiation does not result in detectable physical changes to the body such as is seen with acute doses. Because of cell repair, even sophisticated analysis of the blood do not reveal any biological effects.

Genetic effects

The biological effects of concern from a chronic dose is changes in the chromosomes of a cell and direct irradiation of a fetus. Genetic effects refer to effects to genetic material in a cell chromosome. Genetic effects can be somatic (cancer, etc.) or heritable (future generations).

- Effects in the exposed individual (*somatic*)

In this case, the individual has experienced damage to some genetic material in the cell that could eventually cause that cell to become a cancer cell. An example of a somatic effect is cancer. The probability of this is very low at occupational doses.

- Heritable effects

A *heritable effect* is a genetic effect that is inherited or passed on to an offspring. In the case of heritable effects, the individual has experienced damage to some genetic material in the reproductive cells. Heritable effects from radiation have never been observed in humans but are considered possible and have been observed in studies of plants and animals. This includes the 77,000 Japanese children born to the survivors of Hiroshima and Nagasaki. (These are children who were conceived after the atom bomb.) Studies have followed these children, their children and their grandchildren.

Factors affecting biological damage due to exposure to radiation

- Total dose - In general, the greater the dose, the greater the potential of biological effects.
- Dose rate (how fast) - The faster the dose is delivered, the less time the cell has to repair itself.
- Type of radiation - Alpha radiation is more damaging than beta or gamma radiation for the same energy deposited.
- Area of the body receiving the dose - In general, the larger the area of the body that is exposed, the greater the biological effect. Extremities are less sensitive than internal organs. That is why the annual dose limit for extremities is higher than for a whole body exposure that irradiates the internal organs.
- Cell sensitivity - The most sensitive cells are those that are rapidly dividing.
- Individual sensitivity - Some individuals are more sensitive to environmental factors such as ionizing radiation. The developing embryo/fetus is the most sensitive, and children are more sensitive than adults. In general, the human body becomes relatively less sensitive to ionizing radiation with increasing age. The exception is that elderly people are more sensitive than middle aged adults due to the inability to repair damage as quickly (less efficient cell repair mechanisms).

PRENATAL RADIATION EXPOSURE

Although no effects were seen in Japanese children conceived after the atomic bomb there were effects seen in some children who were in the womb when exposed to the atomic bomb radiation at Hiroshima and Nagasaki.

Sensitivity of the unborn

Embryo/fetal cells are rapidly dividing which makes them sensitive to any environmental factors such as ionizing radiation.

Potential effects associated with prenatal exposures

Many chemical and physical (environmental) factors are suspected of causing or known to cause damage to an unborn child, especially early in the pregnancy. Alcohol consumption, exposure to lead, and heat from hot tubs are only a few that have been publicized lately. Some children who were exposed while in the womb to the radiation from the atomic bomb were born with a small head size and mental retardation. It has been suggested but is not proven that dose to the unborn may also increase the chance of childhood cancer. Only

when the dose exceeds 15,000 mrem 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 radiation dose. This may be the result of dose from external sources of radiation or internal sources of radioactive material. At present occupational dose limits, the actual risk to the embryo/fetus is negligible when compared to the normal risks of pregnancy.

RISKS IN PERSPECTIVE

Because ionizing radiation can damage the cell's nucleus, it is possible that through incomplete repair a cell could become a cancer cell.

Risk from exposures to ionizing radiation

- No increases in cancer have been observed in individuals exposed to ionizing radiation at occupational levels. The possibility of cancer induction cannot be dismissed even though an increase in cancers has not been observed. Risk estimates have been derived from studies of individuals who have been exposed to high levels of radiation.

Comparison of risks

- Acceptance of a risk is a highly personal matter and requires a good deal of informed judgment.

- The risks associated with occupational radiation doses are considered acceptable as compared to other occupational risks by virtually all scientific groups who have studied them.

- The following information is intended to put the potential risk of radiation into perspective when compared to other occupations and daily activities.

Table 1 compares the estimated days of life expectancy lost as a result of exposure to radiation and other health risks. These estimates indicate that the health risks from occupational radiation dose are smaller than the risks associated with normal day-to-day activities that we have grown to accept.

TABLE 1

Average estimated days lost due to daily activities

HEALTH RISK	DAYS LOST
Unmarried male	3500
Cigarette smoking	2250
Unmarried female	1600
Coal miner	1100
25% overweight	777
Alcohol (U.S. average)	365
Construction worker	227
Driving a motor vehicle	207
100 mrem/year for 70 years	10
Coffee	6

Table 2 addresses the estimated days of life expectancy lost as a result of radiation doses received and common industrial accidents at radiation-related facilities. It compares these numbers to days lost as a result of fatal work-related accidents in other occupations.

TABLE 2

Average estimated days lost in other occupations

INDUSTRY	DAYS LOST
Mining/Quarrying	328
Construction	302
Agriculture	277
Radiation dose of 5,000 rem/yr. for 50 yrs.	250
Transportation/Utilities	164
All industry	74
Government	55
Service	47
Manufacturing	43
Trade	30
Radiation accidents (deaths from exposure)	<1

COMPUTE YOUR OWN RADIATION DOSE

Source	Exposed Group	Body Portion Exposed	Dose mrems/yr	Your Dose
Natural Background				
Cosmic radiation	Total population	Whole body	28	28
Terrestrial radiation	Total population	Whole body	28	28
Internal sources	Total population	Reproductive	40	40
Radon	Total population	Lungs	200	200
Elevation				
Elevation-mrem 1000-2 mrem 2000-5 mrem 3000-9 mrem 4000-15 mrem 5000-21 mrem 6000-29 mrem 7000-40 mrem 8000-53 mrem 9000-70 mrem	Total population	Whole body		______
Medical x-rays				
Chest x-rays	Adult patients	Bone marrow	No. /yr x 40	______
Dental x-rays	Adult patients	Bone marrow	No. /yr x 3	______
Atmospheric weapons test	Total population	Whole body	1	1
Nuclear industry				
Workers at a nuclear commercial power plant	Workers	Whole body	400	______
Residents living near a commercial nuclear power plant	Population within a 10 mile radius	Whole body	10	______
Consumer products				
Building materials, brick masonry, buildings	Total population	Whole body	7	7
Television receivers	Viewing population	Whole body	11	______
Miscellaneous				
Airline travel	Passengers (8 hr flight x the number of flights)	Whole body	4	______
Smoking	Smokers (1 pack/day)	Lungs	Up to 16,000 total	______

SECTION 302 - ASSIGNMENT

1. Match the following items to the appropriate definition.

________ Somatic effect	a. The term used to distinguish how sensitive a cell is to radiation.
________ Cell sensitivity	b. An effect which appears in future generations due to damage at the chromosome level.
________ DNA	c. Radiation effects which appear in the exposed individuals.
________ Genetic effect	d. The blueprint for a cell.

2. Indicate whether the following conditions would most likely result from an acute or chronic exposure.

Vomiting	____________
Leukemia	____________
Hair loss	____________
Reddening of the skin	____________
Low red blood cell count	____________

3. List the four main categories of natural radiation.

   a. ____
   b. ____
   c. ____
   d. ____

SECTION 302 - ASSIGNMENT (CONTINUED)

4. Indicate whether the following sources are natural or man-made.

Radon gas	______________________
X-rays	______________________
Nuclear fallout	______________________
Carbon-14	______________________
Bananas	______________________

5. Indicate the average annual dose the general population receives from the following sources.

Cosmic	______________________
Terrestrial	______________________
Radon	______________________
Medical x-rays	______________________

6. Estimate the sensitivity level for cells of the following body tissues: high, moderate, or low.

Brain	__________
Hair follicles	__________
Bone marrow	__________
Skin	__________
Stomach lining	__________

SECTION 303

RADIATION LIMITS

LEARNING OBJECTIVES

Upon completion of this unit, the participant will be able to IDENTIFY restrictions regarding dose limits and administrative control levels.

The participant will be able to SELECT the correct response from a group of responses which verifies his/her ability to:

E01 STATE the purposes of the Facility administrative control levels.

E02 IDENTIFY the DOE radiation dose limits, DOE administrative control level, and Facility administrative control levels.

E03 STATE the site policy concerning prenatal radiation exposure.

E04 IDENTIFY the employee's responsibility concerning radiation dose limits and administrative control levels.

E05 DESCRIBE the action a worker should take if he/she suspects that dose limits or administrative control levels are being approached or exceeded.

SECTION 303

RADIATION LIMITS

INTRODUCTION

In order to minimize the potential risks of biological effects associated with radiation, dose limits and administrative control levels have been established.

DOE DOSE LIMITS AND FACILITY ADMINISTRATIVE CONTROL LEVELS

The DOE radiation dose limits are set for occupational workers based on guidance from the Environmental Protection Agency (EPA), the National Council on Radiation Protection and Measurements (NCRP), and the International Commission on Radiological Protection (ICRP). These limits are also consistent with the "Radiation Protection Guidance to Federal Agencies for Occupational Exposure" signed by the President of the United States.

The Facility administrative control levels for radiological workers are lower than the DOE limits and are set to ensure the DOE limits and administrative control level are not exceeded. They also help reduce individual and total worker population (collective dose) radiation dose.

Whole body

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

There are limits for external radiation dose and there are limits for internal radiation dose. Internal dose results from radioactive material being inhaled, ingested, or absorbed through the skin or a wound.

Limits are based on the sum of internal and external dose.

The DOE radiation dose limit during routine conditions is 5 rem/year. Since DOE's objective is to maintain personnel radiation doses well below the regulatory limits, a DOE administrative control level has been established. The DOE administrative control level during routine conditions is 2 rem/year. The facility administrative control level during routine conditions is______________.

Extremities

Definition: Extremities include the hands and arms below the elbow and the feet and legs below the knees.

Extremities can withstand a much larger dose than the whole body since there are no major blood-producing organs located there.

The DOE radiation dose limit for extremities during routine conditions is 50 rem/year and the facility administrative control level during routine conditions is____________.

Skin and other organs

The DOE radiation dose limit for skin and other organs during routine conditions is 50 rem/year and the facility administrative control level during routine conditions is______________.

Lens of the eye

The DOE radiation dose limit for lens of the eye during routine conditions is 15 rem/year and the facility administrative control level during routine conditions is______________________.

Declared pregnant worker (embryo/fetus)

DOE policy

A female worker is encouraged to voluntarily notify her employer, in writing, when she is pregnant. When she has done so, the employer must provide the option of a mutually agreeable job, with no loss of pay or promotional opportunity, such that further occupational radiation exposure is unlikely.

- This declaration may be withdrawn, in writing, at any time by the declared pregnant worker.

DOE limit

For a declared pregnant worker who continues working as a radiological worker, the dose limit for the embryo/fetus (during the entire gestation period) is 500 mrem. Efforts should be made to avoid exceeding 50 mrem/month to the pregnant worker. If the dose to the embryo/fetus is determined to have already exceeded 500 mrem, the worker shall not be assigned to tasks where additional occupational radiation exposure is likely during the remainder of the pregnancy.

Visitors and public

The DOE radiation dose limit for visitors and the public is 0.100 rem/year and the facility administrative control the level is_________.

Site Policy

Each Facility may have policies and facility limits, which are more stringent than DOE limits and policy. These additional precautions are taken by the facility to further protect the worker

WORKER RESPONSIBILITIES REGARDING DOSE LIMITS/CONTROL LEVELS

It is each employees responsibility to comply with DOE dose limits, control level and Facility administrative control levels.

If you suspect that dose limits or administrative control levels are being approached or exceeded, you should notify your supervisor immediately.

OCCUPATIONAL RADIATION EXPOSURE LIMITS

Type of Exposure	Administrative Control Level	Annual Limit
Whole body (internal and external)	2 rem	5 rem
Extremity (hands and arms below the elbow; feet and legs below the knees)	NA	50 rem
Any organ or tissue (other than lens of eye and skin)	NA	50 rem
Lens of the eyes	NA	15 rem
Declared pregnant worker: embryo/fetus in 9 months	NA	0.5 rem
Minors & students: whole body (Under age 18)	NA	0.1 rem
Visitors and public: whole body	NA	0.1 rem

SECTION 203 - ASSIGNMENT

1. Indicate the Occupational Exposure Limits for the following:

   Whole body ______________________________
   Skin ______________________________
   Extremities ______________________________
   Declared pregnant worker ______________________________

2. Describe the action a worker should take if he/she suspects that dose limits or administrative control levels are being approached or exceeded.

   ____
   ____
   ____
   ____

3. State the site policy concerning prenatal radiation exposure.

   ____
   ____
   ____
   ____

SECTION 304

ALARA PROGRAM

LEARNING OBJECTIVES

Upon completion of this unit, the participant will be able to EXPLAIN the methods used to implement the site ALARA Program.

The participant will be able to SELECT the correct response from a group of responses which verifies his/her ability to:

E01 STATE the ALARA concept.

E02 STATE the DOE/Site management policy for the ALARA program.

E03 IDENTIFY the responsibilities of management, Radiological Control Organization, and the radiological worker in the ALARA Program.

E04 IDENTIFY the basic protective measures of time, distance, and shielding.

E05 IDENTIFY methods for reducing external and internal radiation dose.

E06 STATE the pathways radioactive material can enter the body.

E07 IDENTIFY methods a radiological worker can use to minimize radioactive waste.

SECTION 304

ALARA PROGRAM

INTRODUCTION

This unit is designed to inform the student of the concept of ALARA (As Low As Reasonably Achievable). While ALARA is a concept that can apply to any biological hazard, just the radiation hazards will be addressed. Methods for reducing both external and internal doses from radiation and radioactive material are also discussed.

Even though there are dose limits and administrative control levels, we strive to keep our radiation dose well below these. Employees should always try to maintain their radiation dose As Low As Reasonably Achievable (ALARA).

ALARA PROGRAM

ALARA Concept

ALARA stands for As Low As Reasonably Achievable.

Since some risk, however small, exists from any radiation dose, all doses should be kept ALARA. ALARA includes reducing both internal and external radiation dose. The ALARA concept is an integral part of all site activities that involve the use of radioactive materials.

DOE Management Policy for the ALARA Program

Personal radiation exposure shall be maintained As Low As Reasonably Achievable. Radiation exposure of the work force and public shall be controlled such that:

- Radiation exposures are well below regulatory limits
- There is no occupational radiation exposure without an expected benefit

Site policy

ALARA is the responsibility of all employees.

RESPONSIBILITIES FOR THE ALARA PROGRAM

Although the individual radiation worker is ultimately responsible for maintaining his/her radiation dose ALARA, management and Radiological Control personnel also play an important role in the ALARA program. The following are some of the responsibilities of the three groups:

Management

Radiological Control Organization

The Radiological Control Organization is responsible for implementing the ALARA program at the Site. It is also responsible for implementing the requirements for the entire Radiological Control program. These requirements are established in DOE Orders, the DOE Radiological Control Manual, and Site Radiological Control documents.

Radiological Control Technicians (RCTs) provide a point of contact for the worker to obtain the most current radiological conditions in an area. RCTs provide assistance when trying to interpret protective requirements or radiological information concerning a work assignment and they address radiological questions/concerns.

Radiological workers

Each person involved in radiological work is expected to demonstrate responsibility and accountability through an informed, disciplined and cautious attitude toward radiation and radioactivity.

EXTERNAL AND INTERNAL RADIATION DOSE REDUCTION

Basic protective measures used to reduce external dose include minimizing time in radiation areas, maximizing the distance from a source of radiation and using shielding whenever possible.

Methods for minimizing time:

Reducing the amount of time spent in a Radiation Area will lower the dose received by the workers.

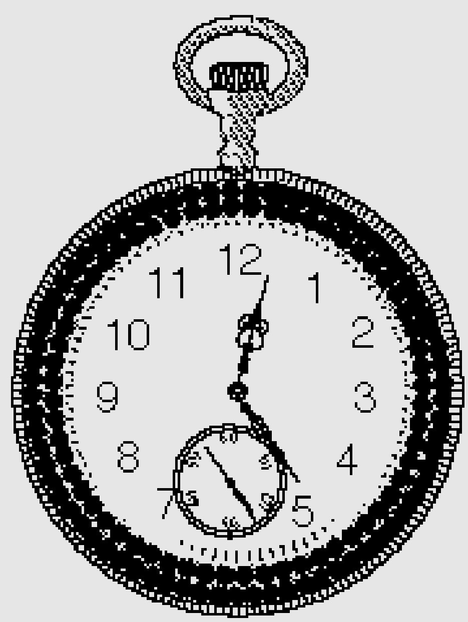
- Plan and discuss the task prior to entering the area. Use only the number of workers actually required to do the job.
- Have all necessary tools present before entering the area.
- Use mock-ups and practice runs that duplicate work conditions.
- Take the most direct route to the job site, if possible and practical.
- Never loiter in an area controlled for radiological purposes.
- Work efficiently and swiftly.
- Do the job right the first time.
- Perform as much work outside the area as possible or, when practical, remove parts or components to areas with lower dose rates to perform work.
- In some cases, the Radiological Control personnel may limit the amount of time a worker may stay in an area due to various reasons. This is known as "*stay time*". If you have been assigned a stay time, do not exceed this time.

TIME

The relationship between *time* and dose is:

Dose = Dose Rate x Time

This means that if you reduce the amount of time you're exposed to ionizing radiation, you also reduce your overall dose. This is called a direct relationship, which means that when you reduce your time by a certain percent, you also reduce your dose by the same percentage. For example, if you reduce your time by half, your dose is also cut in half.



Methods for maximizing distance from sources of radiation:

- The worker should stay as far away from the source of radiation as possible.
- For point sources, such as valves and hot spots, the dose rate follows a principle called the inverse square law.

  This law states that if you double the distance, the dose rate falls to 1/4 of the original dose rate. If you triple the distance, the dose rate falls to 1/9 of the original dose rate.

Maximizing Distance From Point Sources

The second method for reducing exposure is maximizing *distance*. Exposure rates decrease as the distance from the radiation source increases. For small or point sources, radiation exposure decreases rapidly. For example, if a point source emits 1000 millirem per hour (D) at one foot, then at two feet, the radiation level would decrease to 250 millirem per hour (D_2). Using the given equation, D would be 1000 mrem/hr, L would be 2 feet. Therefore, the dose rate at the new distance (D_2) would be 250 mrem/hr.

$$D/(L)^2 = 1000/(2)^2 = 1000/4 = 250$$

Equation:

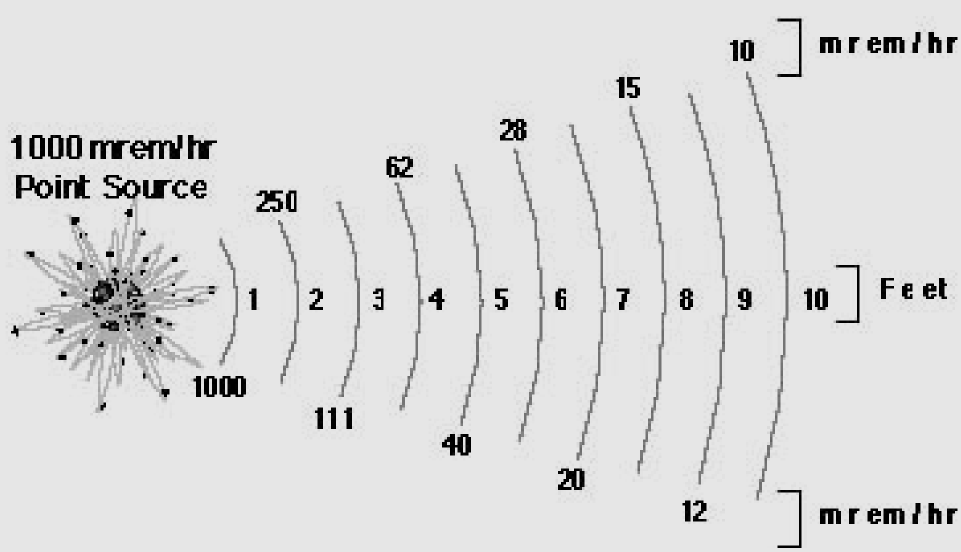
$$D/(L)^2 = D_2$$

D = Dose rate at 1 foot from source
L = Distance from the source
D_2 = Dose rate at new distance

Calculation:

D = 1000 mrem/hr
L = 2 feet
D_2 = ?

Answer: 250 mrem/hr



Methods for maximizing distance from sources of radiation: (continued)

- Be familiar with radiological conditions in the area.
- During work delays, move to lower dose rate areas.
- Use remote handling devices when possible.

Maximizing Distance From Large Sources

For large or grossly contaminated areas, radiation exposure decreases linearly. This means that as you double the distance between you and the source, you cut your exposure in half. For example, if a large source reads 1000 millirem per hour (D) at one foot, then at two feet the radiation level would be one-half or 500 millirem per hour (D_2). Using the equation, D would be 1000 mrem/hr, L would be 2 feet. Therefore, the dose rate at the new distance (D_2) would be 500 mrem/hr.

$D/(L) = 1000/2 = 500$

Equation:

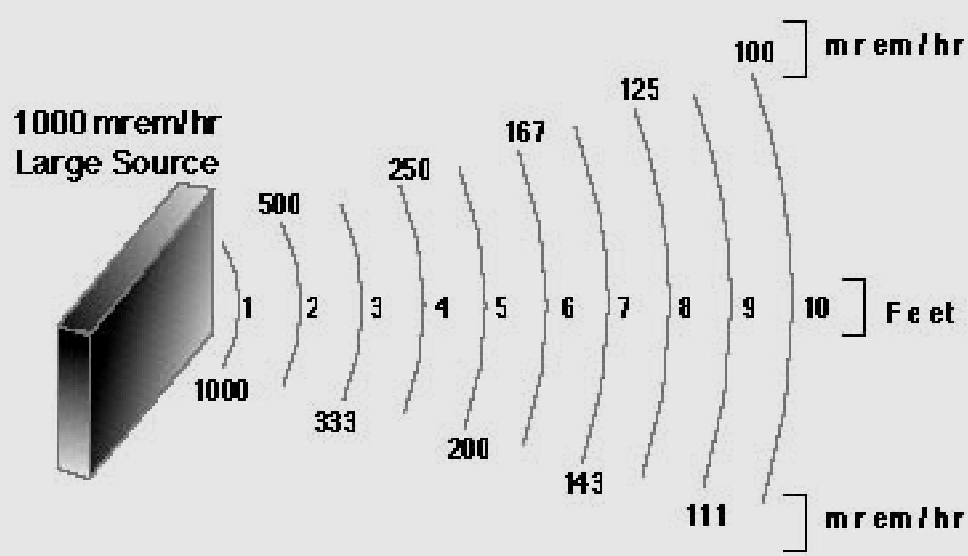
$$D/(L) = D_2$$

D = Dose rate at 1 foot from source
L = Distance from the source
D_2 = Dose rate at new distance

Calculation:

D = 1000 mrem/hr
L = 2 feet
D_2 = ?

Answer: 500 mrem/hr



Proper uses of shielding:

Shielding reduces the amount of radiation dose to the worker. Different materials shield a worker from the different types of radiation.

- Take advantage of permanent shielding including non-radiological equipment/structures.

- Use shielded containments when available.

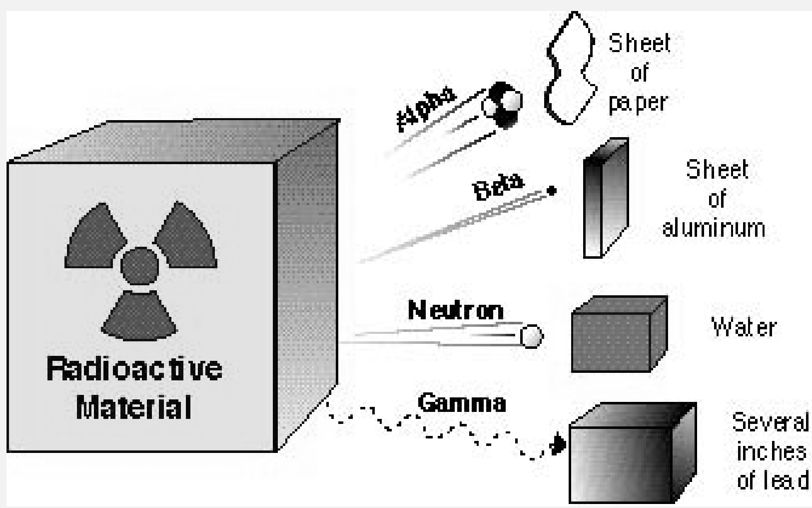
- Wear safety glasses/goggles to protect your eyes from beta radiation, when applicable.

Temporary shielding (e.g., lead or concrete blocks) can only be installed when proper procedures are used. Temporary shielding will be marked or labeled with wording such as, "Temporary Shielding - Do Not Remove Without Permission from Radiological Control." Once temporary shielding is installed, it cannot be removed without proper authorization.

- It should be remembered that the placement of shielding may actually increase the total dose (e.g., person-hours involved in installing and removing shielding).

Shielding

Occasionally, there will be situations where time and distance will not be a practical method for reducing exposure. If this is the case, *shielding* may be necessary. Shielding is one of the most effective means of reducing radiation exposure. Shielding consists of using a material to absorb or scatter all or part of the radiation before it reaches the worker. The illustration shows some materials commonly used to shield or reduce specific types of radiation.



The ability of a material to be a good shield depends on the material's density. Density is defined as the weight of a substance per unit volume. For example, a cubic foot of lead is heavier than a cubic foot of concrete, and therefore, it is also a better shield.

Source Reduction

Source reduction normally involves procedures such as flushing radioactive systems, decontamination, etc. to reduce the amount of radioactive materials present in/on a system that can add to radiation levels in an area.

INTERNAL RADIATION DOSE REDUCTION

Internal dose is a result of radioactive material being taken into the body. Radioactive material can enter the body through one or more of the following pathways:

- Inhalation
- Ingestion
- Absorption through the skin
- Absorption through the wounds

Methods to Reduce Internal Radiation Dose

Reducing the potential for radioactive materials to enter the body is important. The following are methods the worker can use:

- Wear respirators correctly when required (if qualified).

- Report all wounds or cuts (including scratches and scabs) to the appropriate site-specific organization before entering any area controlled for radiological purposes.

- Comply with the requirements of the controlling work documents.

- Do not eat, drink, smoke or chew in areas controlled for radiological purposes.

RADIOACTIVE WASTE MINIMIZATION

One of the consequences of working in and around radioactive materials is that radioactive waste will be generated. This radioactive waste must be disposed of. Examples of radioactive waste include:

- paper
- gloves
- glassware
- rags
- brooms, mops

To reduce personnel dose and reduce costs associated with the handling, packaging and disposal of radioactive waste it is very important for each employee to minimize the amount of radioactive waste generated.

Methods to Minimize Radioactive Waste

Minimize the materials used for radiological work

- Take only the tools and materials you need for the job into areas controlled for radiological purposes especially contamination areas.

- Unpack equipment and tools in a clean area to avoid bringing excess clean material to the job site.

- Whenever possible, use tools and equipment identified for radiological work. If you do not know where to get tools that are to be used for radiological work, ask your supervisor.

- Use only the materials required to clean the area. An excessive amount of bags, rags, and solvent adds to radioactive waste.

Separate radioactive waste from nonradioactive waste

- Place radioactive waste in the containers identified for radioactive waste, not in containers for nonradioactive waste.

- Do not throw nonradioactive waste, or radioactive material that may be reused, into radioactive waste containers.

- Separate compactible material from noncompactible material.

Minimize the amount of mixed waste generated

- Mixed waste is waste that contains both radioactive and hazardous materials.
- Use good housekeeping techniques.

SECTION 304 - ASSIGNMENT

1. Using the equation DOSE = Dose Rate x Time, what would be the dose for the following workers:

   a. A worker dry mopped a floor to prevent dust buildup. The area dose rate was 20 mrem/hr. and the job duration was 4 hours. What would the worker's dose be? ____________

   b. A Radiation Technician performed the following decontamination surveys. Each survey took two hours and was performed in the following areas:

      Zone 1 : Dose rate = 50 mrem/hour
      Zone 2 : Dose rate = 25 mrem/hour
      Zone 3 : Dose rate = 75 mrem/hour

      What would the technicians dose be for the day? ____________

Work Space

SECTION 304 - ASSIGNMENT (CONTINUED)

2. Match the following terms with the appropriate definition.

______ Dose	a. The accumulated exposure to radiation measured in rems or mrem.
______ Time	b. A protection method which uses long handled tools, robots, or other methods to reduce exposure.
______ Dose rate	c. A protection method which uses concrete and lead to reduce exposure.
______ Distance	d. A protection method which stresses pre-planning, pre-paredness, and mockups to reduce exposure.
______ Shielding	e. The term used to define how fast a dose is received.

3. Using the equation $\mathbf{D/(L) = D_2}$ for large sources, and $\mathbf{D/(L)^2 = D_2}$ for point sources, indicate the dose rate at the following distances for a 5000 mrem/hr source:

D = Dose rate at the source
L = Distance from the source
D_2 = Dose rate at new distance

a. What would the dose rate be at the following distances for a large source:

2 feet? ______ 5 feet? ______ 10 feet? ______

b. What would the dose rate be at the following distances for a point source:

2 feet? ______ 5 feet? ______ 10 feet? ______

SECTION 305

PERSONNEL MONITORING PROGRAMS

LEARNING OBJECTIVES

Upon completion of this unit, the participant will be able to DISCUSS the personnel monitoring programs used in terms of purpose, types, and worker responsibilities.

The participant will be able to SELECT the correct response from a group of responses which verifies his/her ability to:

EO1 STATE the purpose of each of the personnel dosimeter devices used at the site.

EO2 IDENTIFY worker responsibilities concerning each of the external personnel dosimeter devices used at the site.

EO3 STATE the purpose of each type of internal monitoring method used.

EO4 IDENTIFY worker responsibilities concerning internal monitoring programs.

EO5 STATE methods for obtaining radiation dose records.

EO6 IDENTIFY worker responsibilities for reporting radiation dose received from other sites and from medical applications.

SECTION 305

PERSONNEL MONITORING PROGRAMS

INTRODUCTION

Each employee's external and internal dose to ionizing radiation is assessed using special types of monitoring equipment. The types used depend on the radiological conditions present.

EXTERNAL DOSIMETRY

A dosimeter is a device that is used to measure radiation dose. Dosimeters used to measure external sources of radiation are called external dosimeters.

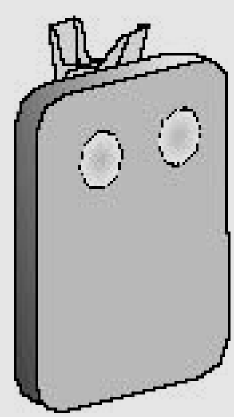
Purpose of each of the external dosimeter devices used (include basic principles of operation of types commonly used at the site).

Worker responsibilities for external dosimetry include the following:

- Wear dosimeters at all times in areas controlled for radiological purposes when required by signs, work permits or Radiological Control personnel. Primary dosimeters are worn on the chest area, between the waist and the neck in a manner directed by radiological control personnel.

Thermoluminescent Dosimeter

Purpose: The *thermoluminescent dosimeter* (TLD) badge provides a means of measuring both shallow and deep radiation doses. It measures beta, gamma, and neutron radiation exposures. The measured dose is then recorded as the worker’s legal occupational exposure.



Principles of Operation: The TLD contains crystalline materials, such as lithium fluoride, calcium fluoride, calcium sulfate, and lithium borate, which upon exposure to ionizing radiation will store electrons in high energy states. A special TLD reader or processor heats the crystals to release these electrons. As the electrons return to their original energy, light is produced in proportion to the dose received. The amount of light emitted from the crystal is used to determine the radiation dose.

Additional special dosimetry is contained within the TLD case to determine neutron dose in the unlikely event of a nuclear criticality accident. This includes a sulphur pellet, an indium foil, a cadmium-coated gold foil, and a bare gold foil. Upon exposure to neutron radiation, these materials become activated and the dose reading from them is used to determine the neutron dose.

TLD Finger Ring

Purpose: A *finger ring* is a TLD encased in a ring-like detection device that can measure beta, gamma, and neutron radiation exposures. It measures the radiation exposure to the extremities. The measured dose is then recorded as the worker's legal occupational extremity exposure.

Principles of Operation: The ring dosimeter operates like the TLD badge, except it contains only one lithium borate crystal.

The finger ring is worn on any finger, except the thumb, with the TLD chip facing the radiation field or source. Usually, the TLD chip is facing the palm of the hand; however, it can face the back of the hand, if the radiation field or source is located above or below the worker's hands.

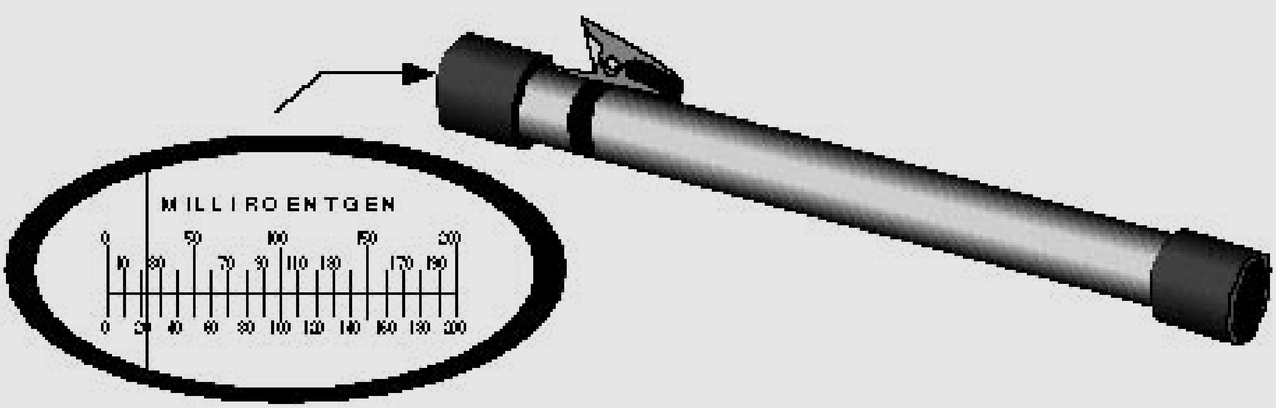
Quartz Fiber Dosimeter

The *quartz fiber dosimeter*, also known as the self-reading gamma pencil, pocket dosimeter, direct reading dosimeter (DRD), and pocket ionization chamber (PIC), provides workers with an estimate of their current radiation dose without leaving the Radiation Area. Usually, quartz fiber dosimeters are required in high (100 mrem/hr) radiation areas, or when a worker is approaching his occupational exposure limit.

The quartz fiber dosimeter is usually worn adjacent to the worker's TLD, usually below the shoulder and above the hips. Protective clothing sometimes has a special pencil-like compartment for the quartz fiber dosimeter.

When the quartz fiber dosimeter is held up to a light source, the workers exposure can be read on a microscopic scale.

When working in high or very high radiation areas, quartz fiber dosimeters must be read periodically. The reading intervals are usually established by the Radiological Control personnel, and are based upon the exposure levels or dose rate of the work area. Normally, the time intervals are every 10 to 15 minutes.

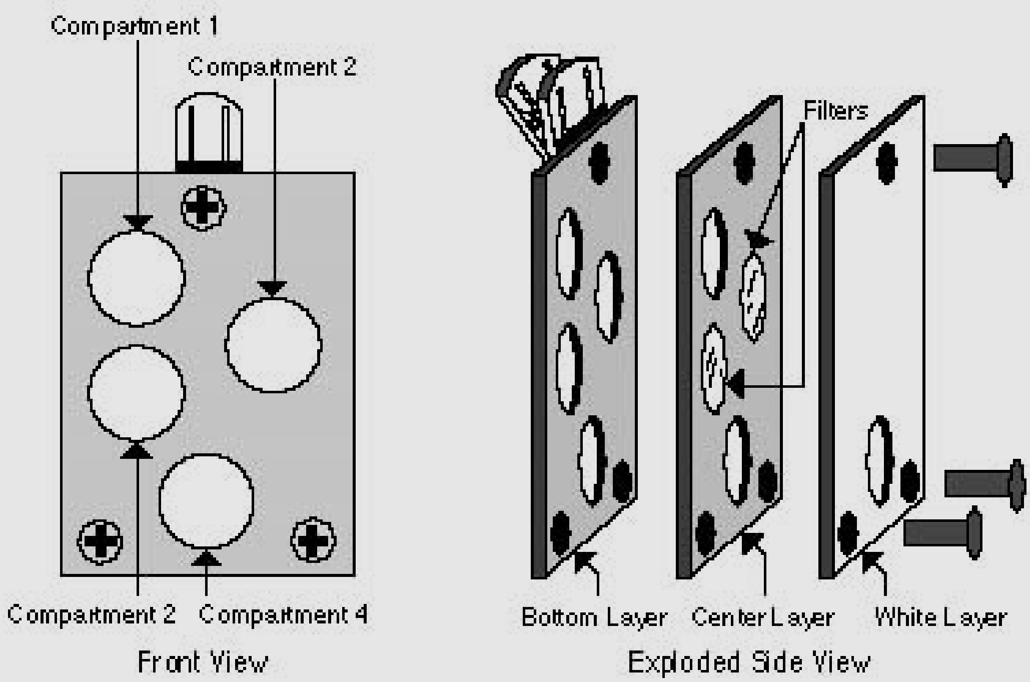


Film Badge

A *film badge* is a relatively simple personal detection device that measures accumulated doses of gamma rays. It contains a small piece of film, similar to the film used in medical x-rays, and some small filters. When the film is exposed to the ionizing radiation, it darkens. The darker the film, the higher the dose. A special device known as a densitometer reads and interprets the actual dose from the film's density.

The filters in the film badge are metal absorbers. They indicate how penetrating the radiation is, and whether the exposure is from low- or high-energy gamma radiation.
Normally, the film badge is attached to the clothing with a clip or pin, in an area between the shoulders and the hips.

Although fairly rugged in construction, film badges can be damaged by heat, light, and moisture. Heat over 125-130°F fogs the film and makes it impossible to determine accurate radiation exposure. If the paper covering on the film is punctured or torn, the film is ruined from the light's exposure. Also, getting the film badge wet (e.g., running it through the laundry) damages the film beyond use.



Wear supplemental dosimeters (e.g., pocket, electronic, neutron) when required, in accordance with site policy.

Take proper actions if dosimeter is lost, off-scale, damaged or contaminated while in an area controlled for radiological purposes. These actions include:

- Place work activities in a safe condition
- Alert others
- Immediately exit the area
- Notify Radiological Control personnel

Know the proper dosimeter storage location.

Return dosimeters for processing periodically. Personnel that fail to return dosimeters will be restricted from continued radiological work.

Dosimeters issued from the permanent work site cannot be worn at another site.

INTERNAL MONITORING

Whole body counters, lung counters, and/or bioassay samples may be used to determine the kinds, quantities or concentrations of radioactive material in the human body. In some cases, locations of radioactive material in the human body may be determined. An internal dose may be calculated from these measurements.

Purpose of each type of internal monitoring

- Whole Body Counter – The *whole body counter* is used to determine the total radioactivity within the whole body and/or lungs regardless of the isotope. The count method will show both natural and occupationally-caused radioactivity.

- Bioassay – Radioactive materials taken into the body through the nose, mouth, or breaks in the skin may be totally or partially eliminated through the urine or feces. If both the quantity of material eliminated and the rate of elimination are measured, the body and the internal dose can be determined. *Bioassay* samples may be requested following certain job assignments. Each individual will be notified when they are scheduled to submit a sample.

Worker responsibilities:

a) Provide bioassay samples for analysis as required or when requested.
b) Appear when requested for whole body count.

RADIATION DOSE RECORDS

Methods for obtaining dose records.

- Personnel (non-visitors) who are monitored with dosimeters will be provided an annual report of their radiation dose.

- Detailed information concerning any individual's exposure shall be made available to the individual upon request of that individual.

- Terminating personnel will receive a report of the radiation dose received at that site.

Reporting radiation dose received from other facilities and medical applications.

Notify Radiological Control personnel, prior to and following, of any radiation dose received at another facility so that dose records can be updated.

Reporting medical applications (this does not include routine medical and dental x rays).

SECTION 305 - ASSIGNMENT (Reading a Dosimeter)

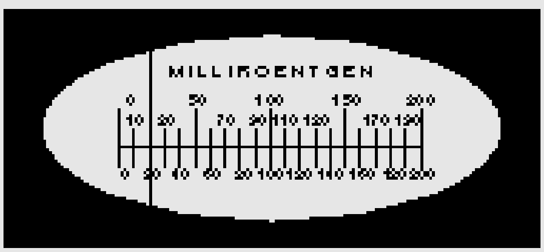
Pocket Dosimeter **Instrument S/N** ________

The *quartz fiber pocket dosimeter* is a precision instrument that measures the cumulative exposure to x-ray and gamma radiation received by the wearer. The instrument consists of an ionization chamber, a quartz fiber electrometer, a precision integrating capacitor, and a microscope, all contained within a sealed barrel. A scale, calibrated in milliroentgens (mR), may be read by looking through the eyepiece toward a source of light. The dosimeter is reset to zero with an auxiliary dosimeter charger.

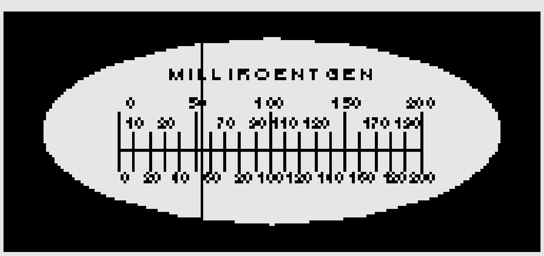
The dosimeter may be worn in a pocket, on a belt, or clipped to a collar. Protective end caps are provided, which should be kept in place to minimize shock transmitted to the instrument. Mechanical abuse can cause the reading to shift, usually in an upscale or fail-safe direction.

Reading the Dosimeter

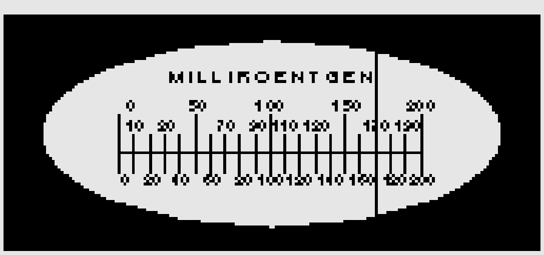
The dosimeter can be read at any time by holding it up to the light and looking through it. It is not necessary to remove either one of the end caps. The exposure in mR received since the last time the unit was charged is read directly on the scale. Increase the accuracy of the reading by holding the dosimeter horizontally with the scale in a natural viewing position. Practice reading the following scales:



1. ______________________



2. ______________________



3. ______________________

SECTION 305 - ASSIGNMENT (Charging and Calibrating the Dosimeter)

Charging the Dosimeter

The charging process is used to reset the dosimeter back to the zero reading. Zeroing the dosimeter is accomplished with a dosimeter charger using the following steps:

1. Remove the protective cap from the charging end of the dosimeter (opposite the alligator clip).
2. Press the dosimeter on the charging pedestal and press down.
3. While the dosimeter is pressed down, look through the eyepiece and adjust the "Upscale/Down scale" control knob until the fiber rests slightly below zero.
4. Remove the dosimeter, slowly allowing it to rest under its own weight on the pedestal for a moment.
5. Look through the eyepiece toward a light. If the fiber has drifted upscale or is off the zero position, repeat the procedure.
6. Replace the protective end cap. If the fiber has been off zero for more than one day, it may be necessary to re-zero the dosimeter after a few hours.

Using the procedures described above, read and zero the following dosimeters.

Dosimeter Number	Initial Reading	Final Reading
1)		
2)		
3)		

SECTION 305 - ASSIGNMENT (CONTINUED)

1. Match the following items with the appropriate definition.

______ PIC

______ TLD

______ Finger ring

______ Whole body counter

______ Bioassay

a. This dosimeter measures the radiation dose to the hands.

b. This supplemental dosimeter is used to measure exposure to gamma radiation.

c. Very sensitive instrument used to detect small amounts of radioactive material inside the body.

d. A method for measuring an internal radiation dose by sampling body fluids for radioactive material.

e. This dosimeter measures the doses from penetrating beta, gamma, and neutron radiation.

2. List a worker's two main responsibilities concerning internal monitoring programs.

1. ____

____

2. ____

____

SECTION 306

RADIOACTIVE CONTAMINATION CONTROL

LEARNING OBJECTIVES

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

The participant will be able to SELECT the correct response from a group of responses which verifies his/her ability to:

E01 DEFINE fixed, removable, and airborne contamination.

E02 STATE sources of radioactive contamination.

E03 STATE the appropriate response to a spill of radioactive material.

E04 IDENTIFY methods used to control radioactive contamination.

E05 IDENTIFY the proper use of protective clothing.

E06 IDENTIFY the purpose and use of personnel contamination monitors.

E07 IDENTIFY the normal methods used for decontamination.

SECTION 306

RADIOACTIVE CONTAMINATION CONTROL

INTRODUCTION

This unit is designed to inform the worker of sources of radioactive contamination. It will also present methods used to control the spread of contamination.

Contamination control is one of the most important aspects of radiological protection. Using proper contamination control practices will help ensure a safe working environment. It is important for all employees to recognize potential sources of contamination, as well as to use appropriate contamination prevention methods.

COMPARISON OF RADIATION AND RADIOACTIVE CONTAMINATION

Ionizing radiation – the energy (particles or rays) emitted from radioactive atoms that can cause ionization.

Radioactive contamination – recall that radioactive material is material that contains radioactive atoms. Even when this radioactive material is properly contained, it may still emit radiation and be an external dose hazard, but it will not be a contamination hazard. When this radioactive material escapes its container, it is then referred to as radioactive contamination.

Radiation is an energy; contamination is a material.

Types of Contamination

Radioactive contamination can be fixed, removable, or airborne.

- *Fixed contamination* – contamination that cannot be readily removed from surfaces. It cannot be removed by casual contact. It may be released when the surface is disturbed (buffing, grinding, using volatile liquids for cleaning, etc.). Over time it may "weep," leach, or otherwise become loose or transferable.

- *Removable/transferable contamination* – contamination that can readily be removed from surfaces. It may be transferred by casual contact, wiping, brushing, or washing. Air movement across removable/transferable contamination could cause airborne contamination.

- *Airborne contamination* – Contamination suspended in air.

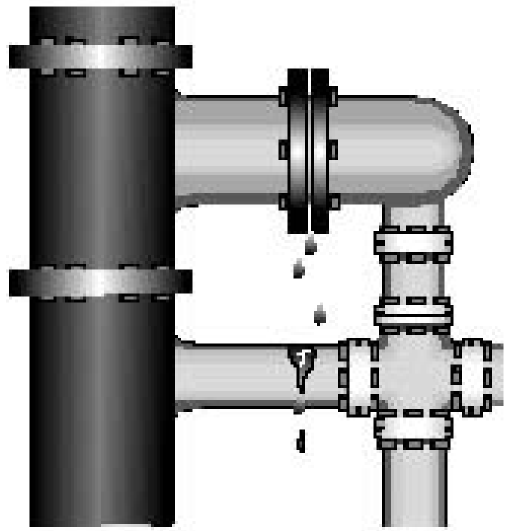
SOURCES OF RADIOACTIVE CONTAMINATION

Regardless of the precautions taken, radioactive material will sometimes escape and contaminate an area. The following are some sources of radioactive contamination:

- Sloppy work practices, that lead to cross-contamination of tools, equipment or workers. Examples include:

  Opening radioactive systems without proper controls.

  Poor housekeeping in contaminated areas.



- Excessive motion or movement in areas of higher contamination.

- Leaks or breaks in radioactive systems

- Small, sometimes microscopic pieces of radioactive material that are highly radioactive may escape. These pieces are known as "hot particles." Hot particles may be present when contaminated systems are opened. These particles may also be present when machining, cutting, or grinding is performed on highly radioactive materials. They can cause a high, localized radiation dose in a short period of time if they remain in contact with skin/tissue.

- Airborne contamination depositing on surfaces.

- Leaks or tears in radiological containers such as barrels, plastic bags or boxes.

Indicators of possible area contamination:

Workers need to be aware of potential radiological problems. Here are some examples of potential radiological problems.

- Leaks, spills, standing water
- Damaged radiological containers

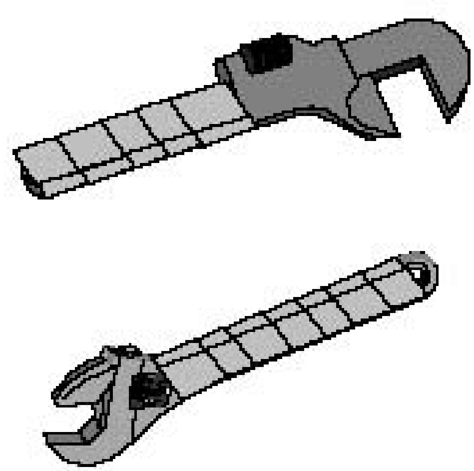
Employee response to a spill of radioactive material.

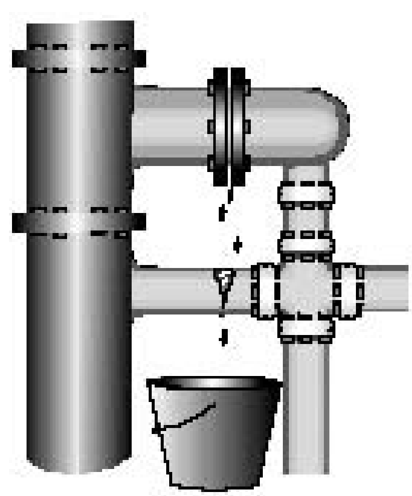
Each of the examples listed above may be considered a spill of radioactive material. Here is the minimum response to a spill of radioactive material:

- Stop or secure the operation causing the spill.
- Warn others in the area.
- Isolate the area.
- Minimize exposure to radiation and contamination.
- Secure unfiltered ventilation.
- Notify Radiological Control personnel.

CONTAMINATION CONTROL METHODS

Every possible effort should be made to confine the spread of radioactive materials to the smallest area possible. By controlling contamination, the potential for internal exposure and personnel contamination can be limited. Here are some methods used to control the spread of radioactive contamination.





Preventative methods

A sound preventative maintenance program can prevent many radioactive material releases. Here are some preventative methods.

- Identify and repair leaks before they become a serious problem.

- Establish adequate work controls before starting jobs.

- Discuss measures that will help reduce or prevent contamination spread. This can be done during pre-job briefs.

- Change out gloves or protective gear as necessary to prevent cross-contamination of equipment.

- Stage areas to prevent contamination spread from work activities.

  Cover piping/equipment below a work area to prevent dripping contamination onto cleaner areas. Another example would be covering/taping tools or equipment used during the job to minimize decontamination after the job (i.e., taping up a screwdriver before use).

  Use good work practices such as good housekeeping and cleaning up after jobs. "Good Housekeeping" is the prime factor in an effective contamination control program. It involves the interaction of all groups within the facility. Each individual should be dedicated to keeping "his house clean" to control the spread of contamination.

- Control and minimize all material taken into or out of contaminated areas.

- Be alert for potential violations to the basic principle of contamination control; such as use of improper contamination control methods, bad work practices, basic rule or procedure violations, radioactive material releases or liquid spills.

- Radiological workers should always ensure that the proper procedures to avoid the spread of contamination are followed or implemented.

Engineering Control Methods

Ventilation - Ventilation is designed to maintain airflow from areas of least contamination to areas of most contamination (e.g., clean to contaminated to highly contaminated areas). A slight negative pressure is maintained on buildings/rooms where potential contamination exists.

High efficiency particulate air (HEPA) filters are used to remove radioactive particles from the air.

Containment - Containment generally means using vessels, pipes, cells, glovebags, gloveboxes, tents, huts, plastic coverings, etc. to control contamination by containing it.

Personnel Protective Measures

If engineering methods are not adequate then personnel protective measures such as protective clothing and respiratory equipment will be used.

Protective clothing - Protective clothing is required to enter areas containing contamination and airborne radioactivity levels above specified limits to prevent contamination of personnel skin and clothing. The degree of clothing required is dependent on the work area radiological conditions and the nature of the job.

Personal effects such as watches, rings, jewelry, etc. should not be worn.

Full protective clothing generally consists of coveralls, cotton liners, gloves, shoe covers, rubber overshoes, and a hood.

NOTE: Cotton glove liners may be worn inside `standard' gloves for comfort, but should not be worn alone or considered as a layer of protection against contamination.

Proper use of protective clothing

- Inspect all protective clothing for rips, tears, holes, etc. prior to use. If you find damaged clothing, discard of it properly.
- Supplemental dosimeters should be worn as prescribed by the Radiological Control Organization.
- After donning protective clothing, proceed directly from the dress-out area to the work area.
- Avoid getting coveralls wet. Wet coveralls provide a means for contamination to reach the skin/clothing.

- Contact Radiological Control personnel if clothing becomes ripped, torn, etc..

Respiratory protection equipment

This equipment is used to prevent the inhalation of radioactive materials. This training does not qualify a worker to wear respiratory protection.

CONTAMINATION MONITORING EQUIPMENT

Contamination monitoring equipment is used to detect radioactive contamination on personnel and equipment.

Frisking Procedure

- Verify the instrument is in service, set to the proper scale, and the audio can be heard. Note background count rate at frisking station.

- Survey hands before picking the probe up.

- Hold probe approximately 1/2 inch from surface being surveyed for beta/gamma and 1/4inch for alpha.

- Move probe slowly over surface, approximately 2 inches per second.

- Proceed to survey in the following typical order:

    head (pause at mouth and nose for approximately 5 seconds)
    neck and shoulders
    arms (pause at each elbow)
    chest and abdomen
    back, hips and seat of pants
    legs (pause at each knee)
    shoe tops
    shoe bottoms
    personal and supplementary dosimeters

- The whole body survey should take at least 2-3 minutes per survey instrument.

- Carefully return the probe to holder. The probe should be placed on the side or face up to allow the next person to monitor.

- If the count rate increases during frisking, pause for 5-10 seconds over the area to provide adequate time for instrument response.

- Take appropriate actions if contamination is indicated; remain in the area and notify Radiological Control personnel. Minimize cross- contamination (such as putting a glove on a contaminated hand).

Geiger-Mueller Counters

Geiger-Mueller counters (GM), also known as geiger counters, are the most widely used and versatile type of portable radiation detection device. The most common Geiger-Mueller counter is the beta-gamma frisker, which is used to conduct contamination surveys of personnel, equipment, and smears. They are inexpensive, easy to operate, sensitive, and reliable. The beta-gamma frisker should not be used in backgrounds greater than 300 cpm.

Scintillation Detectors

Scintillation detectors work on the principle that certain materials produce visible light, when struck by radiation. These materials are referred to as phosphors or scintillators. As radiation enters and passes through a phosphor, it gives up its energy to electrons in the phosphor by both ionization and excitation. Excited electrons move into defects or gaps in the atomic structure of the phosphor called traps. When the electrons escape from the traps to return to lower energy levels, the excess energy releases in the form of visible light. These energy releases produce light which is read by a light meter. Scintillation detectors are one of the oldest instruments used for detecting and measuring ionizing radiation and are still being used today.

DECONTAMINATION

Decontamination is the removal of radioactive materials from locations where it is not wanted. If the presence of removable contamination is discovered, decontamination is a valuable means of control.

Personnel decontamination is normally accomplished using mild soap and lukewarm water.

Material decontamination is the removal of radioactive materials from tools, equipment, floors and other surfaces in the work area.

In some situations, decontamination is not always possible.

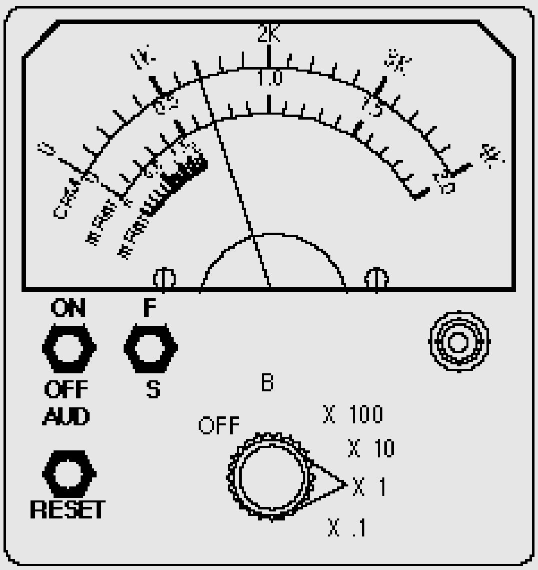
- Economical conditions: Cost of time and labor to decontaminate the location outweigh the hazards of the contamination present.

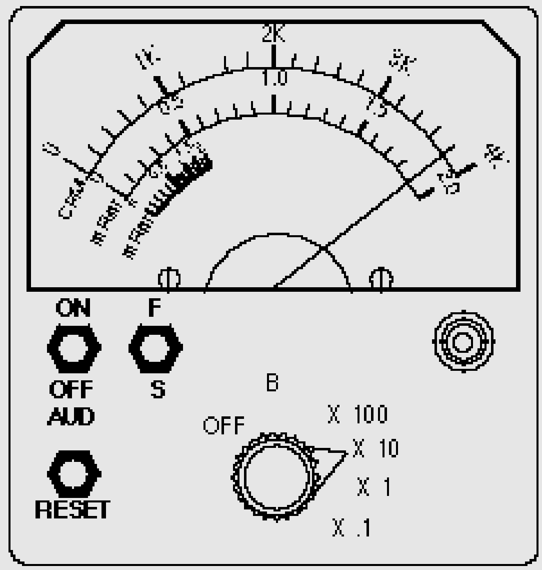
- Radiological conditions: Radiation dose rates or other radiological conditions present hazards which far exceed the benefits of decontamination.

NOTE: Decontamination should be performed by qualified personnel under the direction of the Radiological Control Organization.

SECTION 306 - ASSIGNMENT

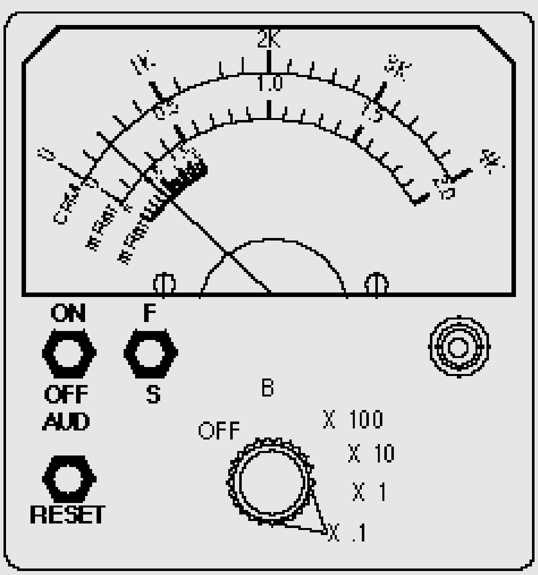
1. Identify the correct readings for the Ludlum model 3 survey meter:

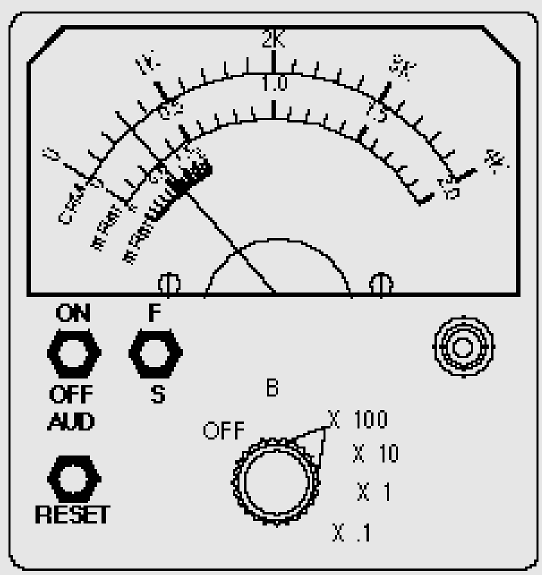




1. ______________ cpm
______________ mR/hr

2. ______________ cpm
______________ mR/hr





3. ______________ cpm
______________ mR/hr

4. ______________ cpm
______________ mR/hr

SECTION 306 - ASSIGNMENT (CONTINUED)

2. Match the following terms with the appropriate definition.

________	Removable contamination	a.	Radioactive material suspended in water.
________	Fixed contamination	b.	Radioactive material attached to a surface, and not easily removed.
________	Airborne contamination	c.	Radioactive material in the form of a loose dust.
________	Waterborne contamination	d.	Radioactive material ingested into the body.
________	Internal contamination	e.	Radioactive material suspended in air.

3. List four sources of radioactive contamination.

____

____

____

____

____

____

SECTION 306 - LABORATORY ASSIGNMENT (CONTINUED)

Station #1

Use the Ludlum model 3 survey meter with pancake probe to obtain the following readings. Indicate readings in counts per minute (cpm).

Distance from Source	cpm
1 inch	
2 inch	
3 inch	
4 inch	
6 inch	
8 inch	

Station #2

Set the survey meter on (Aud-on), and (S-Slow). Hold the detector 4 inches from the source and place the various shields in between. Indicate the activity of the source in counts per minute (cpm). (For best results, use shields that have the same thickness.)

Shielding	cpm
Air	
Water	
Lead	
Concrete	

SECTION 306 - LABORATORY ASSIGNMENT (CONTINUED)

Station #3

Indicate the type of radiation coming from each of the following sources:

SOURCE	ALPHA	BETA	GAMMA
Cesium			
Technetium ^{99}			
Thorium ^{230}			

Work Space

SECTION 306 - LABORATORY ASSIGNMENT (CONTINUED)

Frisking procedures:

1. Have the individual being monitored stand on a step off pad. This reduces the possibility of contaminating the monitoring site.
2. Verify the instrument is on, set to the proper scale (x1 scale), and ensure the audio can be heard.
3. Place the survey meter probe about 1/2 inch from the individual's body, being careful not to make body contact.
4. Instruct the person to stand straight, feet spread slightly, arms extended with palms up and fingers straight out.
5. Monitor hands and arms, then repeat with hands and arms turned over.
6. Starting at the top of the head, cover the entire front of the body, monitoring carefully the head, neckline, trunk, legs, crotch, and armpits.
7. Have the individual turn around and repeat the monitoring on the backside of the body.
8. Monitor the shoes and soles.

Station #4

Instrument S/N __________

Source: Lantern Mantle

Background: ______________

Indicate the contaminated area on the figure.

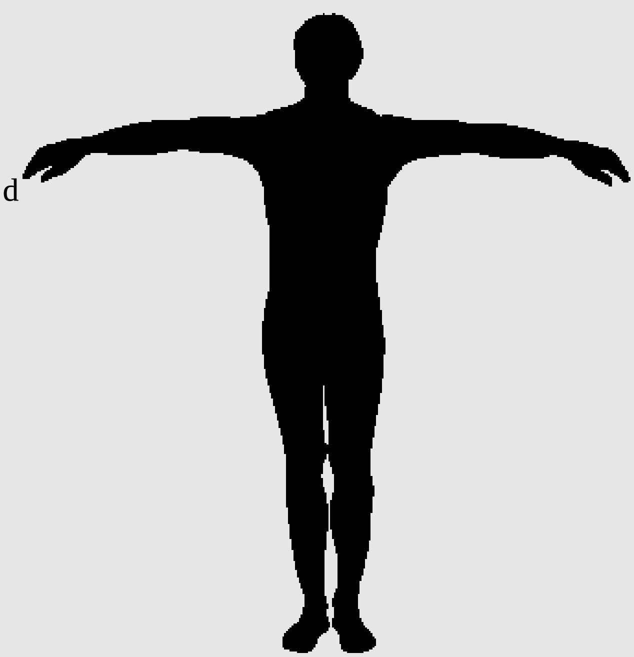
Comments:

____

____

____

____



SECTION 307

RADIOLOGICAL POSTING AND CONTROLS

LEARNING OBJECTIVES

Upon completion of this unit, the participant will be able to DISCUSS radiological postings, and general and job-specific Radiological Work Permits.

The participant will be able to SELECT the correct response from a group of responses which verifies his/her ability to:

E01 STATE the purpose of and information found on Radiological Work Permits (RWPs).

E02 IDENTIFY the individual's responsibilities in using Radiological Work Permits.

E03 IDENTIFY the colors and symbols used on radiological postings.

E04 STATE the radiological and disciplinary consequences of disregarding radiological postings, signs, and labels.

E05 DEFINE the ares controlled for radiological purposes.

E06 IDENTIFY the minimum requirements for entering, working in, and exiting:

a. Radiological Buffer Areas
b. Radiation Areas
c. High Radiation Areas
d. Very High Radiation Areas
e. Contamination Areas
f. High Contamination Areas
g. Airborne Radioactivity Areas
h. Radioactive Material Areas
i. Fixed Contamination Areas
j. Soil Contamination Areas
k. Underground Radioactive Material Areas

SECTION 307

RADIOLOGICAL POSTING AND CONTROLS

INTRODUCTION

Up until now, we have basically discussed some very important background radiological information and radiation dose and contamination control methods. We now take this information and see how it will apply to the actual working environment.

RADIOLOGICAL WORK PERMITS

RWPs are used to establish radiological controls for entry into areas controlled for radiological purposes. They serve to inform workers of area radiological conditions, entry requirements into the areas, and provide a means to relate radiation doses received by workers to specific work activities.

There are two types of Radiological Work Permits:

- A General Radiological Work Permit is used to control routine or repetitive activities such as tours and inspections in areas with historically stable radiological conditions. It is valid for up to one year.

- A Job Specific Radiological Work Permit is used to control non-routine operations or work in areas with changing radiological conditions. It is valid for the duration of a particular job.

The RWP should include the following information:

- Description of work
- Work area radiological conditions (This information may also be determined from area radiological survey maps/diagrams or the radiological posting for that area.)
- Dosimetry requirements
- Pre-job briefings (as applicable). Pre-job briefings generally consist of workers and supervisor(s) discussing various radiological aspects and controls of the job. This is done to minimize radiological exposure and unplanned situations.
- Required level of radiological training for entry
- Protective clothing and protective equipment requirements
- Radiological Control coverage requirements and stay time controls, as applicable
- Limiting radiological conditions which may void the permit
- Special dose or contamination reduction considerations
- Special personnel frisking considerations

RADIOLOGICAL WORKER PERMIT

SECTION I (To be completed by requester) **RWP NUMBER :**	**ISSUE DATE:**	**SHIFT:**	**EXPIRATION DATE:** (Maximum 7 days from issuance.)
RWP JOB DESCRIPTION:			
SYSTEM:	COMPONENT:	LOCATION:	
REQUESTER NAME & PHONE NUMBER:			
ESTIMATED MAN-HOURS IN AREA	TOTAL NUMBER OF WORKERS		

SECTION II (To be completed by requester)

Radiological Training Requirements: Rad Worker I ❑ Rad Worker II ❑	ALARA Requirements: ALARA Review ❑ Air Sampling ❑ Pre-Job Briefing ❑
SURVEY FREQUENCY	HP SIGNATURE / DATE
❑ CONSTANT HP COVERAGE (LINE OF SIGHT)	GENERAL AREA DOSE RATE / DATE/TIME OF SURVEY
❑ PERIODIC HP COVERAGE (SHIFT)	JOB SPECIFIC DOSE RATE / DATE/TIME OF SURVEY
❑ PERIODIC HP COVERAGE (DAILY)	CONTAMINATION LEVEL
❑ PERIODIC HP COVERAGE (4 HOURS)	AIRBORNE ACTIVITY

ANTI-CS	**RESP. PROTECTION**	**MONITORING**	**MISC**
❑ HOOD	❑ FULL FACE	❑ PIC	❑ GOGGLES
❑ COVERALLS	❑ PARTICULATE FILTER	❑ MID-RANGE PIC	❑ BETA SHIELD
❑ COVERALLS 2 PAIR	❑ IODINE FILTER	❑ EXTREMITY TLD	❑ SPECIAL PRECAUTIONS
❑ RUBBER SHOE COVERS	❑ SUPPLIED AIR	❑ MULTI WHOLE BODY	(SPECIFY)
❑ CLOTH BOOT COVERS	❑ SCBA		
❑ SURGICAL GLOVES		(TLD BADGE MANDATORY)	
❑ COTTON WORK GLOVES	Protection Requirements and Special Precautions:		
❑ RUBBER GLOVES			
❑ COTTON GLOVE LINERS			

Actual Total Man Rem:	Actual Total Man Hours:	Actual Total Number of Workers:

SECTION II

H.P. Technician:	Date:
H.P. Supervisor:	Date:
Termination:	Date:
Termination by H.P. Supervisor:	Date:
RWP and Area Reviewed By:	Date:

GENERAL INSTRUCTIONS

1. Enter exposure and total time on the RWP sign-in sheet.
2. Remove personal outer clothes before donning protective clothing as directed by H.P. personnel.
3. Have H.P. monitor tools and equipment before removing them from work area.
4. Return RWP to H.P. Office at the end of each shift.
5. If Job Specific Survey results are not known, H.P. personnel will accompany workers at initial start of job.
6. Briefing required by H.P. personnel.

- Technical work document and other unique identifying numbers
- Date of issue and expiration
- Authorizing signatures

WORKER RWP RESPONSIBILITIES

Workers must read and comply with the RWP requirements. Workers must acknowledge by signature that they have read, understood, and will comply with the RWP prior to entering the radiological area. If you believe the RWP is incorrect or you don't understand any of the information, contact Radiological Control personnel or your supervisor prior to beginning work. Do not make substitutions for specified requirements. The use of protective clothing or equipment beyond that specified by the Radiological Control Organization is not authorized. Report to Radiological Control personnel if radiological controls are not adequate or are not being followed.

RADIOLOGICAL POSTINGS

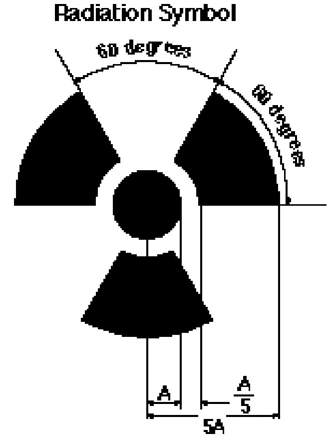
Radiological postings are used to:

- alert personnel to the presence of radiation and radioactive materials.
- aid in minimizing personnel dose.
- prevent the spread of contamination.

POSTING REQUIREMENTS

Areas and materials controlled for radiological purposes will be designated with a magenta (or black) standard three-bladed radiological warning symbol (trefoil) on a yellow background.

Radiation Symbol



Shaded area is to be magenta, purple, or black. Background is to be yellow.

- Fixed barriers such as walls, rope, tape or chain will designate the boundaries of posted areas. Where possible, the barriers will be yellow and magenta in color. The barriers should be placed to clearly mark the boundary of the radiological areas. Controlled Areas may use the buildings as the barrier.

- Entrance points to radiologically controlled areas will have signs (or postings) stating the entry requirements, such as, "Personnel Dosimeters, RWP and Respirator Required." In some cases, more than one radiological hazard may be present in the area. The area will be posted with all radiological hazards that are present.

- In areas of on-going work activities, the dose rate and contamination levels (or ranges of each) may be included if applicable.

- The posting should be placed where it is clearly visible to personnel.

RESPONSIBILITIES OF THE WORKER ASSOCIATED WITH POSTINGS, SIGNS, AND LABELS

Before entering an area controlled for radiological purposes, read all of the signs. Since radiological conditions can change, the signs will also be changed to reflect the new conditions. A sign or posting that you saw one day may be replaced with a new one the next day.

Obey any posted, written or oral requirements including "Exit", "Evacuate", "Hold Point" or "Stop Work Orders", from the Radiological Control personnel.

- Hold points are specific times noted in a procedure, work permit, etc. where work must stop for Radiological Control evaluations.

- Stop Work Orders are usually a result of:

    - inadequate radiological controls,
    - radiological controls not being implemented, or
    - radiological hold point not being observed.

Report unusual conditions to the Radiological Control personnel such as leaks or spills, dusty or hazy air, and alarming area monitors.

Be aware of changing radiological conditions. Be aware that others' activities may change the radiological conditions in your area.

If any type of material used to identify radiological hazards is found outside an area controlled for radiological purposes, it should be reported to Radiological Control personnel immediately.

CONSEQUENCES OF DISREGARDING RADIOLOGICAL POSTINGS, SIGNS AND LABELS

It is each worker's responsibility to read and comply with all the information identified on radiological postings, signs and labels. Disregarding any of these or removing/relocating them without permission can lead to:

- unnecessary or excessive radiation dose
- personnel contamination
- disciplinary actions such as a formal reprimand or suspension

REQUIREMENTS FOR ENTRY, EXIT AND WORKING IN WORKING RADIOLOGICALLY POSTED AREAS

The following are the various areas controlled for radiological purposes.

RADIOLOGICAL AREAS

RADIATION AREAS	CONTAMINATION AREAS
Radiation Area	Contamination Area
High Radiation Area	High Contamination Area
Very High Radiation Area	Fixed Contamination Area
	Airborne Radioactivity Area
	Soil Contamination Area

RADIOLOGICAL BUFFER AREAS

OTHER RADIOLOGICAL AREAS
Radioactive Materials Area
Underground Radioactive Materials Area

Radiological Buffer Area

Radiological Buffer Areas (RBA) provide secondary boundaries to minimize the spread of radioactive contamination and to limit doses to general employees who have not been trained as radiological workers.

Posting Requirements:

"CAUTION, RADIOLOGICAL BUFFER AREA"

Minimum requirements for Unescorted Entry:

- Radiological Worker I Training
- Personnel dosimetry, as appropriate

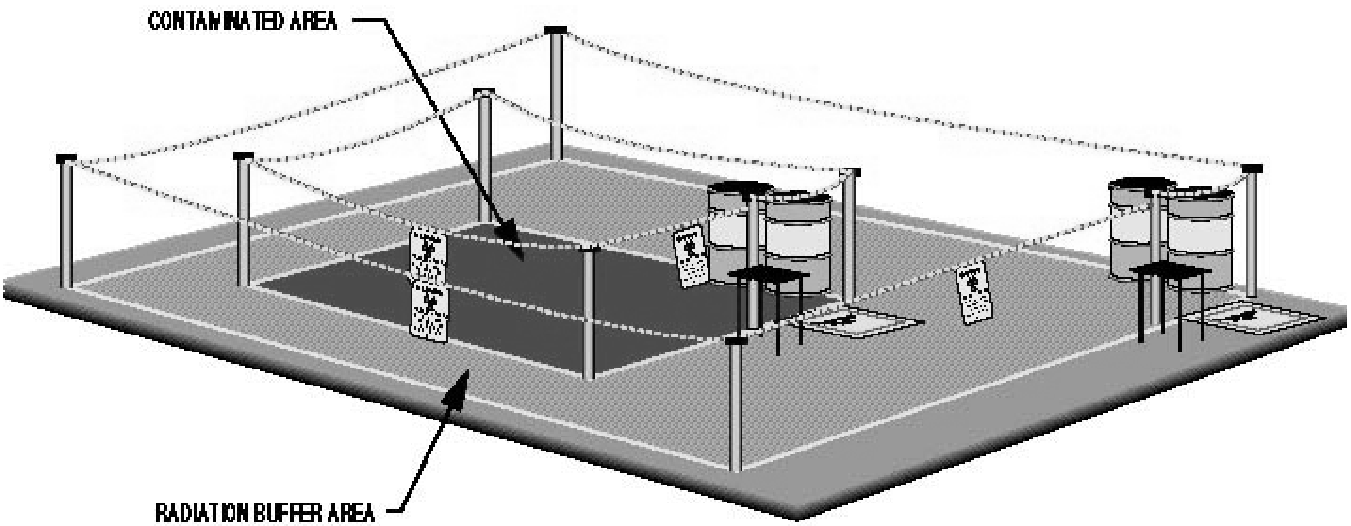
Requirements for Working in the RBA

- Always practice ALARA.
- Obey eating, drinking, smoking, or chewing policy.
- Obey any posted, written, or oral requirements including “Evacuate,” “Hold Point,” or

"Stop Work" orders from Radiological Control personnel.

Requirements for Exit:

Personnel exiting a RBA containing a contamination, high contamination, or airborne radioactivity area should, at a minimum, perform a hand and foot frisk.



Radiation Area

Radiation Area means any area accessible to individuals in which radiation levels could result in an individual receiving a deep dose equivalent in excess of 5 mrem/hr but less than or equal to 100 mrem/hr. This is established based on dose rates at 30 cm from the source of radiation.

Posting Requirements

CAUTION, RADIATION AREA"
"Personnel Dosimetry Required for Entry"

Minimum requirements for Unescorted Entry:

- Radiological Worker I Training
- Personnel dosimetry
- Worker's signature on the RWP, as applicable

Requirements for working in Radiation Areas:

- Don't loiter in the area
- Follow proper emergency response to abnormal situations

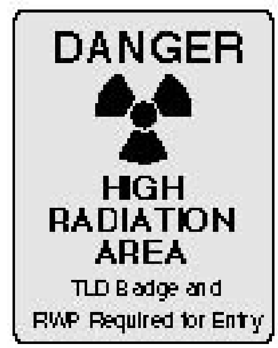
Requirements for Exit:

- Observe posted exit requirements

High Radiation Area

High Radiation Areas means any area accessible to individuals in which radiation levels could result in an individual receiving a deep dose equivalent in excess of 100 mrem/hr at 30 centimeters from the source but less than or equal to an absorbed dose of 500 rad/hr at 1 meter from the source of radiation.

Posting Requirements:



DANGER, HIGH RADIATION AREA"
"Personnel Dosimetry Required for Entry"

Entry Requirements

The requirements for entry into High Radiation Area include:

- Radiological Worker I training plus High Radiation and Very High Radiation Area course or Radiological Worker II training
- worker signature on the appropriate Radiological Work Permit
- personal and supplemental dosimeter(s)
- survey meter(s) or dose rate indicating device(s) must be available at the work area
- access points will be secured by control devices
- a radiation survey prior to the first entry
- notification of operations personnel

Working in Requirements

Additional requirements will be needed where dose rates are >1 rem/hr. Examples would include formal radiological review of non-routine or complex work, pre-job briefing, determination of worker's current dose, and radiological control coverage.

Always practice ALARA when working in High or Very High Radiation Areas. In addition, one should never loiter. Know your job, perform it quickly and efficiently and exit upon completion of the identified task.

The DOE's objective is to maintain personnel radiation exposure well below regulatory dose limits. To accomplish this objective, challenging numerical Administrative Control Levels are established below the regulatory limits. These control levels are multi-tiered with increasing levels of authority required to approve higher Administrative Control Levels (ACLs).

Administrative and physical access controls for high radiation and very high radiation areas are addressed in the DOE Radiological Control Manual. The methods used to control access may vary from facility to facility, depending upon the work environment and site work practices.

Administrative controls could include formal radiological reviews, RWPs, pre-job briefings, postings and procedures. Administrative control levels (ACLs) are set by the individual facilities and are generally well below regulatory dose limits. ACLs are determined by historical dose trends and anticipated future operations.

Interlocks

One or more of the following physical controls should be used for each entrance or access point into a High Radiation Area and are required at the entrance or access point if an individual could exceed a whole body dose of one rem in any one hour:

- a device that energizes a visible or audible alarm
- locked entry ways
- continuous direct or electronic surveillance

Requirements for Exiting

- Monitoring requirements for exiting are site specific.

- Workers must monitor for contamination per instructions posted at the area exit before exiting area.

Very High Radiation Area

Very High Radiation Areas means any area accessible to individuals in which radiation levels could result in an individual receiving an absorbed dose in excess of 500 rad/hr at 1 meter from the source of radiation.

Posting Requirements:

"GRAVE DANGER, VERY HIGH RADIATION AREA"
"SPECIAL CONTROLS REQUIRED FOR ENTRY"

Entry Requirements

The requirements for entry into a Very High Radiation Area include:

- Radiological Worker I training plus High Radiation and Very High Radiation Area course or Radiological Worker II training
- worker signature on the appropriate Radiological Work Permit
- personal and supplemental dosimeter(s)
- survey meter(s) or dose rate indicating device(s) must be available at the work area
- access points will be secured by control devices
- a radiation survey prior to the first entry
- notification of operations personnel

Working in Requirements

Additional requirements will be needed where dose rates are >1 rem/hr. Examples would include formal radiological review of non-routine or complex work, pre-job briefing, determination of worker's current dose, and radiological control coverage.
Always practice ALARA when working in High or Very High Radiation Areas. In addition, one should never loiter. Know your job, perform it quickly and efficiently and exit upon completion of the identified task.

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Administrative controls could include formal radiological reviews, RWPs, pre-job briefings, postings and procedures. Administrative control levels (ACLs) are set by the individual facilities and are generally well below regulatory dose limits. ACLs are determined by historical dose trends and anticipated future operations.

Interlocks

One or more of the following physical controls should be used for each entrance or access point into a High Radiation Area and are required at the entrance or access point if an individual could exceed a whole body dose of one rem in any one hour:

- a device that energizes a visible or audible alarm
- locked entry ways
- continuous direct or electronic surveillance

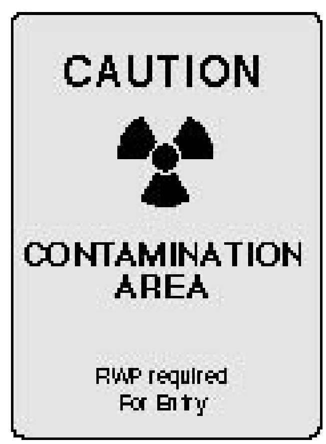
Requirements for Exiting

- Monitoring requirements for exiting are site specific.

- Workers must monitor for contamination per instructions posted at the area exit before exiting area.

Contamination Area

Contamination Area is an area where contamination levels are greater than specified limits.



Posting Requirements:

"CAUTION, CONTAMINATION AREA"

Requirements for entering

- Radiological Worker II Training
- Personnel dosimetry, as appropriate
- Protective clothing and respiratory protection as specified in the RWP
- Worker's signature on the RWP, as applicable
- Pre-job briefings as applicable.

Requirements for working in area

- Avoid unnecessary contact with contaminated surfaces
- Secure equipment (lines, hoses, cables, etc.,) to prevent them from crossing in and out of contamination area
- When possible, wrap or sleeve materials, equipment and hoses
- Place contaminated materials in appropriate containers when finished
- **DO NOT** touch exposed skin surfaces. Highly contaminated material left on the skin for an extended period of time can cause a significant localized dose to the skin.
- Avoid stirring contamination, it could become airborne.
- Do not smoke, eat drink or chew.
- Exit immediately if a wound occurs.

High Contamination Area

High Contamination Area is an area where contamination levels are 100 times greater than the Contamination Area limits.

Posting Requirements:

"DANGER, HIGH CONTAMINATION AREA"
"RWP REQUIRED FOR ENTRY"

Requirements for entering

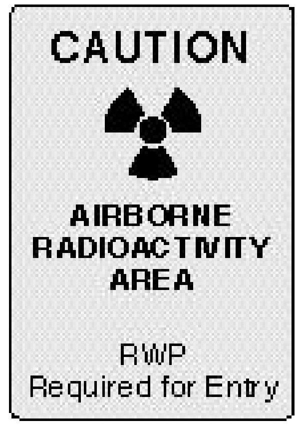
- Radiological Worker II Training
- Personnel dosimetry, as appropriate
- Protective clothing and respiratory protection as specified in the RWP
- Worker's signature on the RWP, as applicable
- Pre-job briefings as applicable.

Requirements for working in area

- Avoid unnecessary contact with contaminated surfaces
- Secure equipment (lines, hoses, cables, etc.,) to prevent them from crossing in and out of contamination area
- When possible, wrap or sleeve materials, equipment and hoses
- Place contaminated materials in appropriate containers when finished
- **DO NOT** touch exposed skin surfaces. Highly contaminated material left on the skin for an extended period of time can cause a significant localized dose to the skin.
- Avoid stirring contamination, it could become airborne.
- Do not smoke, eat drink or chew.
- Exit immediately if a wound occurs.

Airborne Contamination Area

Airborne Radioactivity Areas are those areas where the concentration of airborne radioactivity, above natural background, exceeds or is likely to exceed the specified DOE limits



Posting Requirements:

"CAUTION, AIRBORNE RADIOACTIVITY AREA"
"RWP REQUIRED FOR ENTRY"

Requirements for entering

- Radiological Worker II Training
- Personnel dosimetry, as appropriate
- Protective clothing and respiratory protection as specified in the RWP
- Worker's signature on the RWP, as applicable
- Pre-job briefings as applicable.

Requirements for working in area

- Avoid unnecessary contact with contaminated surfaces
- Secure equipment (lines, hoses, cables, etc.,) to prevent them from crossing in and out of contamination area
- When possible, wrap or sleeve materials, equipment and hoses
- Place contaminated materials in appropriate containers when finished.
- **DO NOT** touch exposed skin surfaces. Highly contaminated material left on the skin for an extended period of time can cause a significant localized dose to the skin.
- Avoid stirring contamination, it could become airborne.
- Do not smoke, eat drink or chew.
- Exit immediately if a wound occurs.

Exit requirements:

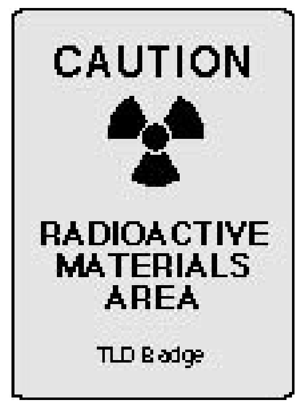
- Exit only at the step-off pad
- Use proper techniques to remove protective clothing.
- Frisk or be frisked for contamination when entering an uncontaminated area. If personal contamination is found, stay in the area, notify the Radiological Control Technician and minimize the potential for cross contamination.
- Survey all tools and equipment prior to removal from the area.
- Observe RWP and control point guidelines.

Radioactive Materials Area

Radioactive Materials Area (RMA) is an area where radioactive materials are used, handled or stored. This posting will not be required when the radioactive materials are located inside Contamination or Airborne Radioactivity Areas.

Radioactive material may consist of equipment, components or materials which have been exposed to contamination or have been activated. Sealed or unsealed radioactive sources are also included. Radioactive materials may be stored in drums, boxes, etc. and will be marked appropriately.

Posting Requirements:



"CAUTION, RADIOACTIVE MATERIAL"

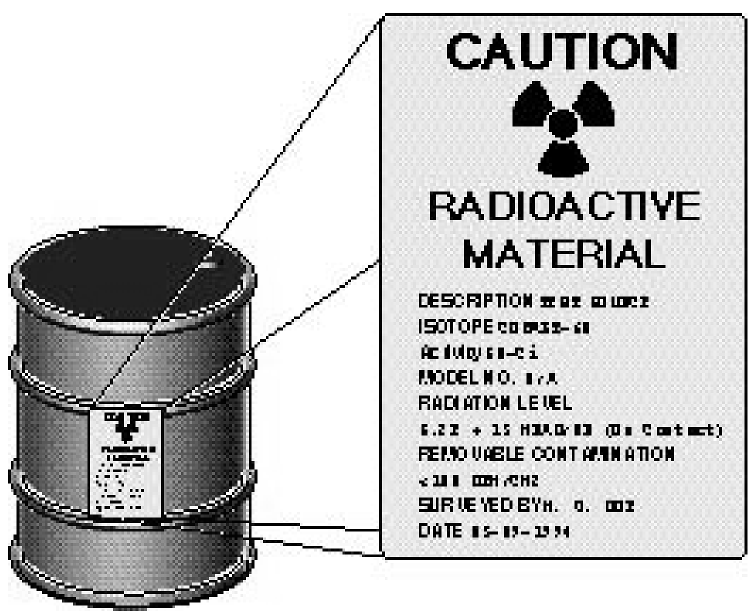
The following posting will be used designate equipment or components with actual or potential contamination:

"CAUTION, INTERNAL CONTAMINATION" or
"CAUTION, POTENTIAL INTERNAL CONTAMINATION"

Minimum requirements for unescorted entry:

- Radiological Worker I

For entry into Radioactive Material Areas where whole body dose rates exceed 5 mrem/hour, the Radiation Area entry requirements will apply.



For entry into Radioactive Material Areas where removable contamination levels exceed the specified DOE limits, the Contamination Area entry requirements will apply.

- Requirements for working in RMAs
- Exit requirements:

Fixed Contamination Areas

Fixed Contamination Areas may be an area or equipment that contains radioactive material that cannot be easily removed from surfaces by nondestructive means, such as wiping, brushing or laundering. Fixed Contamination Areas may be located outside of Controlled Areas.

Posting Requirements:

"CAUTION, FIXED CONTAMINATION"

Contact the Radiological Control Organization for entry requirements.

Soil Contamination Area

Soil Contamination Areas contain surface soil or subsurface contamination levels that exceed the specified DOE limits. A Soil Contamination Area may be located outside an RBA.

Posting Requirements:

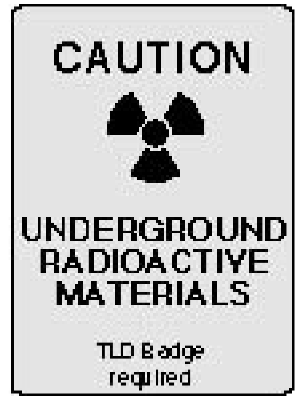
"CAUTION, SOIL CONTAMINATION AREA"

Contact the Radiological Control Organization for entry requirements.

Underground Radioactive Materials Area

Underground Radioactive Materials Areas are established to indicate the presence of underground items that contain radioactive materials such as pipelines, radioactive cribs, covered ponds, inactive burial grounds and covered spills. Such areas may be outside of the Controlled Area.

Posting Requirements:



"UNDERGROUND RADIOACTIVE MATERIALS"

Special instructions such as, "Consult with Radiological Control Organization before Digging" or "Subsurface Contamination Exists" may be included.

Requirements for entry:

- An Underground Radioactive Materials Area is exempt from the general entry and exit requirements if individual doses do not exceed 100 mrem in a year.

- Contact the Radiological Control Organization prior to entry.

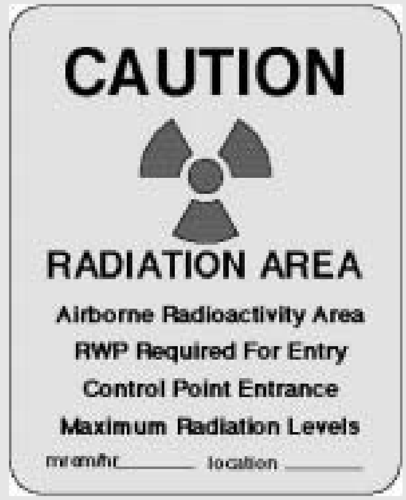
Hot Spots

Hot Spots are localized sources of radiation or radioactive material that are 5 times greater than the general area radiation levels and greater than 100 mrem per hour on contact. Generally, hot spots are found within equipment or piping.

Posting Requirements:

"CAUTION, HOT SPOT"

Hierarchy Posting



Hierarchy posting is a common system used to display information on signs posted at control point entrances and exits, or wherever modifying instructions are required. Information corresponding to the area's radiological conditions is inserted into each of the slots located on the sign. The information required for each hierarchy insert is described below:

- Hazard insert - The first slot identifies the area's classification (e.g., Radiation, High Radiation, etc.) and corresponds to the area's exposure rates.
- Area modifications insert - The second slot is used for secondary postings required in some areas (e.g.,airborne radioactivity, fixed contamination, storage area, etc.)
- Radiological Work Permit (RWP) Requirements insert - The third slot is reserved for the RWP requirements. If a RWP is not required, this slot is used for one of the following inserts: "No Entry," "No Exit," "Emergency Exit Only," or "Control Point Entrance."
- Specific instructions insert - Contains entry or exit requirements for areas with no RWP. For areas with RWPs, reserve this slot for one of the following inserts: "No Entry," "No Exit," "Emergency Exit Only," or "Control Point Entrance.
- Notifications or other postings insert - For areas with no RWP, this slot contains personnel entry requirements. For areas with RWPs, this slot is reserved for extra posting at the discretion of the Health Physics Department.

SECTION 307 - ASSIGNMENT

1. Match the following signs to the correct meaning.

   a. Sign commonly used at control point entrances and exits, to provide additional information about entry requirements.

   b. Dose rates in area are between 5 mrem/hr and 100 mrem/hr.

   c. Respiratory protective equipment is required.

   d. Dose rates in area are in excess of 500 rads/hr.

   e. A label used to designate a point, in which radiation levels are much higher than the surrounding area.

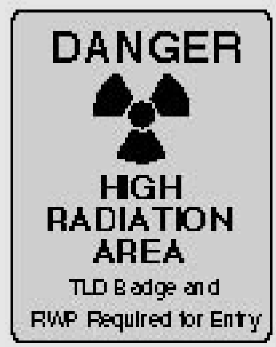
   f. Dose rates in area are between 100 mrem/hr and 500 rads/hr.

1. ______

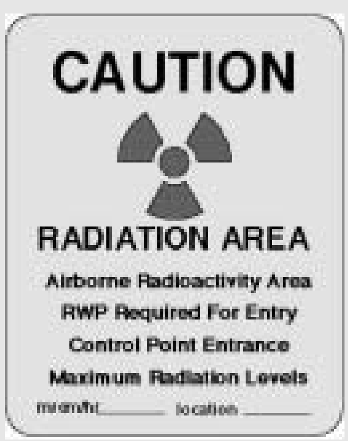
2. ______

3. ______

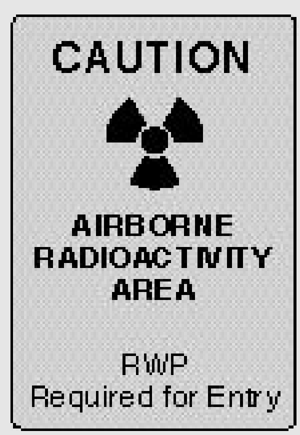
4. ______



5. ______



6. ______



SECTION 307 - ASSIGNMENT

2. List the possible consequences of disregarding, removing, or relocating postings, signs and labels without permission:

   a. ______________________________

   ____

   b. ______________________________

   ____

   c. ______________________________

   ____

3. What is a worker's responsibilities in using Radiological Work Permits.

____

____

____

____

SECTION 308

RADIOLOGICAL EMERGENCIES

LEARNING OBJECTIVES

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

The participant will be able to SELECT the correct response from a group of responses which verifies his/her ability to:

- **E01** STATE the purpose and types of emergency alarms.
- **E02** IDENTIFY the correct responses to emergencies and/or alarms.
- **E03** STATE the possible consequences for disregarding radiological alarms.
- **E04** STATE the DOE and site administrative occupational emergency radiation dose guidelines.

SECTION 308

RADIOLOGICAL EMERGENCIES

INTRODUCTION

Various radiological monitoring systems are used to warn personnel if abnormal radiological conditions exist. It is very important that employees become familiar with these alarms to prevent unnecessary exposure to radiation and contamination.

EMERGENCY ALARMS AND RESPONSES

Equipment that monitors for abnormal radiation dose rates and airborne contamination levels are placed in strategic locations throughout facilities. It is essential for the worker to be able to identify the equipment and alarms and respond appropriately to each.

Each facility is equipped with numerous radiation detection alarms, each of which are designed to provide an audible and/or visual indication of increased radiation or contamination levels. In the event an alarm is initiated, the worker must be aware of, and comply with, the appropriate emergency response. The following examples illustrate some common alarms and emergency response procedures:

Criticality Alarm

Indication: Red flashing or revolving light, and a continuous series of one second blast of an air horn.

Emergency Response Procedure:

1. Stop whatever you are doing and leave the building immediately by the nearest exit.
2. Get to paved roads and follow them to the assembly area assigned for your facility.
3. Walk quickly, but do not run. Do not stop until you reach the assembly area.
4. Once you reach the assembly area you must:

   - Report in to your supervisor or whoever is doing the accountability for your group.
   - Report anything unusual you may have seen.
   - Remain in the assembly area.
   - No eating, drinking, chewing, or smoking.

Continuous Air Monitor (CAM)

Continuous air monitors are used in areas where there is a potential for contamination. CAMs are instruments which continually sample the air for contamination. The sampled air passes through a filter which collects particles. A sensitive detection instrument measures the radioactivity collected on the filter. If the activity exceeds the alarm setpoint, a bell will sound and a red light will flash.

Emergency Response Procedure:

1. Secure your work area.
2. Exit the area, room, or building using proper radiological controls.
3. Notify Radiological Control of the alarm.
4. Stand fast in the general vicinity, but outside of the affected area.

DISREGARD FOR RADIOLOGICAL ALARMS

Disregarding any of these radiological alarms may lead to:

- Possible excessive personnel exposure
- Unnecessary spread of contamination
- Disciplinary action

RADIOLOGICAL EMERGENCY SITUATIONS

Working in a radiological environment requires more precautionary measures than performing the same job in a non-radiological setting. This premise holds true if an emergency arises during radiological work. Emergency situations can involve:

- Personnel injuries in areas controlled for radiological purposes.

- Situations that require immediate exit from an area controlled for radiological purposes.

- Accidental breach of radioactive system or spill of radioactive material.

CONSIDERATIONS IN RESCUE AND RECOVERY OPERATIONS

In extremely rare cases, emergency exposure to high levels of radiation may be necessary to rescue personnel or 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 official's 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.

Controlling exposure to radiation during rescue and recovery actions is extremely complex. Multiple hazards and alternate methods are to be taken into account; prompt, sound judgement and flexibility of action are crucial to the success of any emergency actions. The risk of injury to those persons involved in the rescue and recovery activities should be minimized, to the extent practicable. However, the control of radiation exposures should be consistent with the immediate objectives of saving human life, recovering deceased victims, and/or protection of health and property.

Rescue actions that might involve substantial personal risk shall be performed by volunteers. The use of volunteers will be based on their age, experience, and previous exposure

DOE emergency dose guidelines for rescue and recovery operations are as follows:

- Protecting major property where the lower dose limit of 5 rem is not practicable - 10 rem

- Lifesaving or protection of large populations where the lower dose limit is not practicable - 25 rem

- Lifesaving or protection of large population - only on a voluntary basis to personnel fully aware of risks involved - greater than 25 rem

SECTION 308 - ASSIGNMENT

1. List the correct response to a continuous air monitor.

    ____

    ____

    ____

    ____

2. List three (3) possible consequences for disregarding radiological alarms.

    ____

    ____

    ____

3. List the DOE and site administrative occupational emergency radiation dose limits for:

    Protecting major property: ______________________________

    Lifesaving or protection of large populations: ______________________________

    Lifesaving (voluntary basis): ______________________________

GLOSSARY

Acute dose	A large dose of radiation received in a short period of time.
Acute radiation syndrome	A condition resulting from a large dose of radiation. Symptoms include hair loss, nausea, vomiting, and spasms.
Airborne contamination	Radioactive material suspended in the air.
Airborne radioactivity area	An area where airborne radioactive material exceeds specified limits.
Air monitor detector (portable)	Portable detector which can be located in areas during maintenance operations or where radioactive materials are being used or processed.
ALARA	An acronym for "As Low As Reasonably Achievable" that refers to keeping exposure level as low as possible.
Alpha particles	A charged particle emitted from the nucleus of an atom consisting of two protons and two neutrons.
Alpha radiation	Ionizing radiation that emits alpha particles. Shielding is a few centimeters of air, a sheet of paper, or the dead layer of skin.
Anti-C clothing	The nuclear industry's protective clothing, identified by a canary yellow color.
Area radiation monitor	Monitors mounted in areas where abnormal radiation levels might occur.
Atom	The smallest particle of an element that consists of an inner nucleus surround by a cloud of electrons.
Atomic number	The number of protons an element has in its nucleus.
Atomic weight	The combined number of protons and neutrons in an element.

Background radiation	Radiation from naturally occurring sources.
Beta particles	A charged particle emitted from the nucleus of an atom the size of an electron. It's usually negatively charged.
Beta radiation	Ionizing radiation that emits beta particles. Most beta radiation is shielded by plastic, glass, metal foil, or safety glasses.
Bioassay	Procedure for determining radiation level in the body through tissue and body fluid samples.
Carcinogen	Cancer causing agent.
Cell	The basic structural unit of living organisms.
Cell membrane	The membrane that encloses the cell.
Chromosome	Structure in a cell's nucleus containing DNA that transmits genetic information during cell division.
Chronic dose	A small amount of radiation received over a long period of time.
Contamination area	Area where the removable surface contamination levels are > 1000 dpm per 100 square centimeters of area.
Containment	The means for controlling radioactive contamination by using vessels, pipes, glovebags, tents, etc., to contain it.
Continuous air monitor (CAM)	An instrument that detects airborne radioactivity.
Cosmic radiation	Radiation which originates deep in outer space.
Curie (Ci)	A unit for measuring radioactivity in disintegrations per second (dps).

Cytoplasm	A watery substance surrounding the nucleus of a cell, containing substances, such as proteins, sugars, and amino acids.
Decontamination	Removal of radioactive materials from locations where it isn't wanted.
Distance	Method of reducing radiation exposure by increasing the distance between the radiation source and the worker.
Dose	The accumulated exposure to radiation measured in rems or mrems.
Dose rate	The term used to identify how fast an individual receives a dose. Measured as dose over time (mrem/hr).
Electron	Negatively charged particles which orbit the nucleus of an atom.
External contamination	Radioactive materials outside the body.
External exposure	Exposure resulting from radioactive materials on the outside of the body.
Film badge	A personal monitoring device that uses photographic film inside a badge. The film darkens measurably when exposed to ionizing radiation.
Finger ring	A thermoluminescent dosimeter (TLD) encased in a ring-like detection device and used to measure radiation exposure to the extremities.
Fixed contamination	Contamination embedded into tiny cracks or pores of a material, like an oil stain on a driveway.
Fixed contamination area	An area or equipment with no removable contamination, but contains fixed contamination levels exceeding specified limits.

Gamma radiation	Ionizing radiation that is pure energy in the form of an electromagnetic wave or photon with no electrical charge. Gamma rays originate in the nucleus and have a high penetrating power. The best shielding is dense material, such as concrete, lead, or steel.
Genetic effect	Change to the genetic material in the chromosomes from radiation exposure. Genetic effects can be somatic or heritable.
Heritable effect	Genetic effect that is inherited or passed on to an offspring.
High contamination area	An area where contamination levels are greater than the contamination area.
High radiation area	Area where radiation dose rates are from 100 mrem to 500 rad per hour.
Hot spot	Localized source of radiation or radioactive material that emits radiation in excess of 100 mrem per hour and five times the general area on contact with the surface.
Internal contamination	Radioactive material that has entered the body, by swallowing, breathing, skin absorption or through wounds.
Internal exposure	Exposure resulting from radioactive material being taken into the body.
Internal radiation	Radiation from food we eat and air we breathe.
Ion	Atoms that have lost or gained electrons.
Ionization	The process of removing electrons from, or adding electrons to, a neutral atom.
Ionizing radiation	Particles or rays emitted from radioactive atoms that can cause ionization. The four types are alpha, beta, gamma, and neutron radiation.

Isotopes	Chemical elements that have the same number of protons but a different number of neutrons.
Millirem (mrem)	One-thousandth of a rem (1/1000).
Neutron	Neutral particle (no electrical charge) of an atom located in the nucleus.
Neutron radiation	Ionizing radiation consisting of neutron particles produced during the fission process of a nuclear reactor or particle accelerator. Neutrons have a high penetrating ability and require dense shielding that has a high hydrogen content, such as water or plastic.
Non-ionizing radiation	Particles or rays emitted from radioactive atoms that can't cause ionization.
Nuclear Regulatory Commission	Develops regulations governing emergency planning, preparedness for nuclear power plants.
Nucleus	1. The part of the cell that contains the genetic material DNA. 2. The core of an atom containing the protons and neutrons.
Occupational exposure	Exposure received while employed.
Personal contamination monitor	A monitor that detects radiation emitted from contamination on the body.
Personal monitoring device	Device used to measure personal radiation exposure levels.
Personal protective equipment	Any safety equipment designated to protect the worker against specific hazards. The equipment used varies with the potential for exposure and radiation type.
Pocket alarm dose indicator (PADI)	Small personal monitoring device with a digital display and an audible alarm.
Proton	Positively charged particle located in the nucleus of an atom.

Quality assurance	Refers to all planned systematic actions necessary to provide confidence that all parts of a facility are working properly.
Quality factor (QF)	Number which identifies the amount of energy each type of radiation has the potential to release. A quality factor shows the potential biological damage that can result from radiation exposure.
Quartz fiber (pocket) dosimeter	A direct reading device that provides workers with an estimate of their current radiation dose without leaving the Radiation Area. It is usually required in high (100 mrem/hr) radiation areas or when a worker is approaching his occupational exposure limit. Also known as a pocket ionization chamber (PIC), self-reading gamma pencil, pocket dosimeter, and direct reading dosimeter (DRD).
Radiation	Energy from a source in the form of particles or rays.
Radiation absorbed dose (Rad)	A measurement of the energy deposited when a material is exposed to radiation.
Radiation area	Area where radiation dose rates are greater than 5 mrem per hour but less than 100 mrem per hour.
Radiation dose rate	The rate at which an individual receives a dose of radiation and illustrated as dose/time; for example, mrem/hour.
Radioactive	A term used to describe the state of an atom's nucleus when it's spontaneously emitting energy in the form of waves or particles.
Radioactive contamination	Radioactive material in an unwanted place. Contamination may appear as liquid, solid or gas. There are five subcategories of contamination: removable, fixed, total, airborne and waterborne.

Radioactive decay	The process of radioactive materials losing their radioactivity over time.
Radioactive half-life	Length of time it takes for half of the radioactive atoms to decay.
Radioactive material	A material that contains unstable atoms and gives off energy in the form of radiation.
Radioactive materials area	An area that is established to indicate areas where radioactive materials are used, handled, or stored.
Radioactivity	The process where radioactive materials emit radiation in an effort to become stable.
Radiological buffer area (RBA)	A boundary area around areas of greater radiological hazards.
Radiologically controlled areas	Area where access is restricted due to potential or actual existence of radiological hazards.
Radiological work permit (RWP)	Work documents used to establish radiological controls for entry into areas controlled for radiological purposes. They inform workers of area radiological conditions and entry requirements into the areas. RWPs also provide a means to relate radiation doses received by workers due to specific work activities.
Radiosensitivity	The term used to distinguish how sensitive an organ is to radiation.
Radon	A naturally occurring radioactive gas present in the soil that comes from the decay of radium. Radon emits alpha radiation and can collect in basements and other areas of the home.
Removable contamination	Loose contamination found on a surface that is easily removed by wiping.
Roentgen (R)	A measure of radiation intensity (strength) used to measure gamma rays and x-rays.

Roentgen equivalent man (rem)	The unit used to measure human exposure to radiation.
Shielding	Method of reducing radiation exposure by placing a physical barrier between the source of radiation and the worker.
Soil contamination area	An area where surface or subsurface contamination levels exceed specified limits.
Somatic effect	Radiation effects that appear in exposed individuals.
Stay time	The length of time that it's safe to stay in a high radiation work site. Stay time is calculated by using the actual radiation level in the work area.
Terrestrial radiation	Radiation that comes from radioactive sources in the earth.
Thermoluminescent dosimeter (TLD)	Personal monitoring device. A TLD is a series of radiation sensitive crystals in a plastic case used to measure both shallow and deep radiation doses.
Time	Method of reducing radiation exposure by limiting the time a worker can spend in a radiation area.
Very high radiation area	Area where exposure is greater than 500 rad per hour.
Waterborne contamination	Radioactive material found in water.
Whole body counter	Device used to determine the internal dose from radioactive materials taken into the body.

ABBREVIATIONS AND ACRONYMS

ALARA	As Low As Reasonably Achievable
ARM	Area radiation monitor
Ci	Curie
cpm	Counts per minute
DNA	Dioxyribonucleic acid
DOE	Department of Energy
DRD	Direct reading dosimeter
dpm	Disintegrations per minute
dps	Disintegrations per second
EPA	Environmental Protection Agency
HEPA	High efficiency particulate air
HP	Health physics
ICRP	International Commission on Radiological Protection
mR	Milliroentgen
mrem	Millirem
NCR	Nuclear Regulatory Commission
NCRP	National Council on Radiation Protection and Measurements
OSHA	Occupational Safety and Health Administration
PADI	Pocket alarm dose indicator
PIC	Pocket ionizing chamber
QF	Quality factor
R	Roentgen
rad	Radiation absorbed dose
RBA	Radiological buffer area
rem	Radiation equivalent man
RWP	Radiological work permit
SOP	Standard operating procedure
SRD	Self reading dosimeter
TLD	Thermoluminescent dosimeter
μCi	Microcurie